

**TOWARDS SUSTAINABLE UTILISATION OF THE FISHERY  
RESOURCES OF THE KOWIE ESTUARY, SOUTH AFRICA.**

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## ABSTRACT

The annual biomass of fish caught from estuaries in South Africa is currently estimated at over 24,800 tons. These estuarine fishes are caught by over 73,000 fishers, most of them recreational. Annual income derived from South Africa's total estuarine fishery was worth approximately R430,000,000 in 1997. There is increasing concern that unless our estuarine fisheries are effectively managed, we will not be able to sustain these benefits into the future. Two factors that contribute to inadequate management of the estuarine fisheries in South Africa are a lack of data on which to base management decisions, and the lack of indicators by which to assess trends towards sustainability. The main aims of this study were to provide a description of the Kowie estuary fishery, identify suitable indicators of sustainability for this fishery, and assess its sustainability.

Boat-based and shore-based roving creel surveys were carried out on the Kowie estuary between July 2000 and June 2001; 1,091 interviews were conducted with linefishers, and 277 interviews with bait collectors. In the boat-based interviews, data were collected on fisher demographics, fishing site, fishing method, choice of bait, fishing duration and catch statistics. In the shore-based surveys, additional data were collected from shore-based linefishers and bait collectors on their perceptions, attitudes, and knowledge of fishery regulations.

Total annual fishing effort on the Kowie estuary was estimated at 30,952 angler.hours (SD=154); 84% of it recreational, and the rest subsistence. Most fishing occurred during December and January, and decreased during winter, especially June and July. The annual yield of fish from the estuary was estimated at 16,240 fish (SD=667) or 5.99 tons (SD=0.81). By number, recreational anglers caught 69% of the annual catch. Three species dominated the catch by number: *Rhabdosargus holubi* (62%), *Pomadasys commersonnii* (17%) and *Argyrosomus japonicus* (7%). By mass, the dominant species caught were *Argyrosomus japonicus* (60%) and *Pomadasys commersonnii* (19%). Overall catch rate on the estuary was 0.57 fish.ang.<sup>-1</sup>h<sup>-1</sup> (SD=0.24), or 0.298 kg ang.<sup>-1</sup>h<sup>-1</sup> (SD=0.31). Overall catch rate by number was highest in the subsistence sector at 1.13 fish.ang.<sup>-1</sup>h<sup>-1</sup>(SD=0.70), while the boat-based recreational sector recorded the highest overall catch rate by mass (0.427 kg.ang.<sup>-1</sup>h<sup>-1</sup>, SD=0.625). *Argyrosomus japonicus* had the highest overall catch rate by mass on the estuary (0.496 kg ang.<sup>-1</sup>h<sup>-1</sup>), and *Rhabdosargus holubi* the highest overall catch rate by number (1.233 fish.ang.<sup>-1</sup>h<sup>-1</sup>). Only 19% of the catch of *R. holubi* was above the minimum legal size, while the estimates for *P. commersonnii* and *A. japonicus* were 21% and 25%, respectively.

The annual number of bait collecting outings on the estuary was estimated at 2,889, of which 75% were subsistence. The highest numbers of bait collecting outings were recorded in December and April. The Bay of Biscay was the most popular site for bait collecting. A total of five invertebrate species were collected from the estuary to be used as bait, of which the mud prawn *Upogebia africana* was the dominant species. Total annual number of mud prawns collected from the estuary was estimated at 260,648; of which 41% was collected by subsistence bait collectors.

Thirteen indicators were selected to assess sustainability in three fishery sectors on the Kowie estuary: namely, the shore-based recreational linefishery, the subsistence linefishery and the subsistence bait fishery. Social sustainability was evaluated on the basis of the use fishery resources to fulfil Maslow's basic human needs of food and employment, safety and security, affiliation, self-esteem and self-actualisation. Indicators of ecosystem sustainability assessed the productivity, diversity, disturbance and degree of water quality in the estuary. Institutional sustainability was assessed on the basis that management systems in the fishery should be results-oriented, consent-based, truth-seeking and adaptable. Data on indicator performance was collected during the shore-based roving creel survey, and from published literature. Arbitrarily set reference points were used to assess indicator performance, which was graded on a scale from 1 (indicating minimum probability of sustainability) to 4 (indicating maximum probability of sustainability). Sustainability was illustrated with the aid of amoeba plots.

Overall sustainability was low in all three fishery sectors investigated. Nine of the 13 indicators in the shore-based recreational fishery performed poorly, while 11 of 13 in the subsistence line fishery, and 10 of 13 in the subsistence bait fishery, performed poorly.

In all three fishery sectors all four selected indicators of institutional sustainability performed poorly. The probability of social sustainability was higher in the shore-based recreational line fishery, where the performance of two of the five selected indicators was very good. The probability of ecological sustainability was lowest in the shore-based recreational linefishery, while in the subsistence linefishery only one selected indicator performed very well.

Recommendations made towards assessing sustainability in small-scale estuarine fisheries include the formulation of national policy for assessing sustainability in fisheries, the involvement of fishers in the assessment process, use of fisher perceptions where data gaps exist, and the use of research results to guide future management decisions. Management changes recommended for the Kowie estuary fishery

include the formulation of an effective and integrated management plan, identification of the key stakeholders in the fishery, inclusion of fishers in management, the protection of the estuary's *Zostera capensis* beds, and the establishment of a programme to increase research and monitoring in the fishery.

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## **DEDICATION**

This thesis is dedicated to the memory of my late father, Michael Nangabo Nsubuga, for believing in the education of his daughters.

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# CHAPTER 1

## GENERAL INTRODUCTION

### 1.1 BACKGROUND

Estuaries are among the most threatened ecosystems in South Africa as a result of coastal development and human activities in river catchments (Whitfield 1998). There is increasing concern that unless estuarine management is improved, the supply of estuarine goods and services will be lost to future generations. The White Paper for Sustainable Coastal Development (Department of Environmental Affairs and Tourism 2000), the Marine Living Resource Act 18 (Anon. 1998), and the Eastern Cape Estuaries Programme (Institute of Natural Resources 1999a) are examples of recent actions taken to improve the management of estuaries in South Africa.

A major aim of the Eastern Cape Estuaries Programme is to establish institutions for effective and integrated management of the region's estuaries. The success of this programme will depend on the supply of reliable scientific data on which to base future management actions. Unfortunately, such data are not available for most estuaries, not only in the Eastern Cape but also throughout the country. A key issue to consider in terms of estuary management is the exploitation of estuarine living resources, such as fish and bait. Efforts to improve estuary management in the Eastern Cape risk being frustrated by the general lack of data on the exploitation of the region's living resources.

Since the Earth Summit in Rio in 1992, sustainability has become the guiding principle in natural resource management (Morrisette 1992; Rosenberg *et al.* 1993; Goodland and Daly 1996). The goal of sustainable utilisation offers an opportunity by which the management of Eastern Cape's estuaries can be made more integrated and more effective. To help achieve this, estuary managers need access to a simple yet scientifically valid methodology by which sustainability in the use of estuarine living resources can be assessed.

The overall goal of this study is to contribute to the integrated and effective management of the Kowie estuary through sustainable utilisation of its fishery resources. This is approached in two ways. First, I describe the Kowie estuary fishery in terms of catch statistics, fishing effort and

socio-economics of the fishers. This is done in order to improve the quality and quantity of data available on the fishery. Secondly, I assess the sustainability of the Kowie estuary fishery using a set of simple, locally relevant, yet scientifically valid sustainability indicators.

The Kowie estuary fishery is described in the first part of the study. Chapter 1 introduces the reader to estuaries and estuarine fisheries. The economic importance of estuarine fisheries in South Africa is discussed, together with the threats they face, followed by an overview of past research on estuarine fisheries. Chapter 2 describes the study site (the Kowie estuary) and the socio-economics of Port Alfred. Chapter 3 provides an overview of fishery research methods, and also reports on the results of the fishery surveys carried out on the Kowie estuary. The second part of the study gives an overview of sustainability assessment in fisheries, and also presents the results of sustainability assessment in three fishery sectors on the Kowie estuary (Chapter 4). Finally, Chapter 5 uses the research findings of this study to make recommendations towards improved management of the Kowie estuary fishery, and towards successful assessment of sustainability in South Africa's small-scale estuarine fisheries.

## **1.2 DEFINITION AND FUNCTIONS OF ESTUARIES**

Day (1981a) defined an estuary as:

“A partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with fresh water derived from land drainage.”

There are about 255 functioning estuaries along South Africa's coastline (Lamberth and Turpie 2001), covering an area of 500–600 km<sup>2</sup> (Heydorn 1989). Most of South Africa's estuaries are found along the coast of KwaZulu-Natal Province (KZN). The coastline between Port Elizabeth and East London, in the Eastern Cape Province contains 37 functioning estuaries (Cowley 2000). Estuaries are characterized by high levels of primary and secondary productivity, comparable to those of tropical forests and coral reefs (Day 1981a; Day and Grindley 1981a). This is attributed to rich nutrient influx, sediment accumulation, salinity variations, and shallow sheltered waters (Knox 1986).

South Africa's estuaries are difficult to categorize since they show great variation in time and space. According to the bio-geographical classification system (Whitfield 1992) the estuaries

between Port Elizabeth and East London on the east coast of South Africa fall into the warm temperate category. However, according to another classification system based on mouth condition, river flow, and salinity (Whitfield 1998), eight of the estuaries between Port Elizabeth and East London are classed as permanently open estuaries, while the rest are temporary open/closed estuaries (Cowley 2000). Permanently open estuaries maintain a permanent link with the sea and have large tidal prisms, while temporary open/closed estuaries are cut off from the sea for some time of the year, and have a small tidal prism.

Numerous authors have reviewed the functions of estuaries (see Day and Grindley 1981a; Wallace *et al.* 1984; Breen and McKenzie 2001). These functions can be divided into two major groups: ecological and socio-economic. Like most ecosystem services, the ecological functions of estuaries are not traded in the marketplace, and have often been overlooked in the past. They include serving as nursery areas and refugia for various aquatic biota, and as habitats for wildlife species, supplying and regulating water and sediments, soil formation, and erosion control. Species found in estuaries and nearby coastal waters form part of the coastal biodiversity. Some are endemic and listed in South Africa's Red Data Book for fish, for example *Hippocampus capensis* and *Syngnathus watermeyerii* (Skeleton 1987). South Africa is a signatory to the Convention on Biological Diversity, which promotes the conservation of species, as well the Ramsar Convention, which protects wetlands, of which estuaries are an example.

Because of their high productivity, aesthetic value and sheltered waters, South Africa's estuaries are utilised for many purposes; important examples are production of food and raw materials for industries, provision of water transport as harbour sites, for recreational and educational activities, and for urban development (Day and Grindley 1981b; Breen and McKenzie 2001). Since the economic functions of estuaries are tangible and easier to quantify and express in monetary terms, they have tended to overshadow the ecological functions during formulation of estuarine management policies. Unfortunately, many of the economic functions contribute to estuary degradation unless they are strictly regulated. For example, uncontrolled fishing may result in loss of biodiversity in the estuary; unregulated urban development may lead to loss of critical estuarine habitats and decrease in water quality due to domestic and industrial pollution. Other symptoms of estuary degradation in South Africa include disturbance of the hydrological regime, loss of productivity, increase in siltation, decrease in aesthetic value, and invasion by alien species (Cyrus 1991; Whitfield 1998). Although most of the estuaries between Port

Elizabeth and East London were judged by Whitfield (1995) to be in good or excellent condition, they are under increasing pressure as coastal human populations increase, resulting in higher demand for estuarine space, leisure, and greater reliance on natural resources due to lack of employment opportunities.

## **1.3 OVERVIEW OF SOUTH AFRICA'S ESTUARINE FISHERIES**

### **1.3.1 Economic importance**

Fishery resources, which include fish and bait organisms, are key renewable natural resources associated with estuaries. Fishing and bait collecting are important economic activities in many coastal areas. Although data exist for individual estuaries around the world, nationwide surveys of estuarine fisheries have been conducted in only a few countries, for example in the USA where most of the fish caught are estuary dependent (McHugh 1966; Houde and Rutherford 1993), and in Australia (Anon. 1999). However, Lamberth and Turpie (2001) recently evaluated the economic importance of South Africa's estuary-associated fishery resources.

Estuary-associated fisheries take place within estuaries (estuarine fisheries) and in nearby coastal waters (inshore marine fisheries). Both types of fisheries are important in coastal economies (Lamberth and Turpie 2001). The main contribution of estuary-associated fisheries to coastal economies comes from expenditure by recreational anglers. There are an estimated 72,000 recreational anglers who fish within South Africa's estuaries, compared to the 431,000 in the inshore marine sector (Lamberth and Turpie 2001). Recreational anglers in South Africa's estuary-associated fisheries spent over R2.4 billion on fishing in 1997 (equivalent to R3.34 billion in 2002 terms). This expenditure in turn supported secondary industries such as tourism, the tackle and bait trade, and boat building and servicing. At the same time estuary-associated fisheries are a source of income to commercial, artisanal and subsistence fishers. Commercial linefishing is banned in most of South Africa's estuaries, and the number of commercial fishers operating in estuaries is relatively low (around 1,350), compared to that in the inshore marine component, which is estimated at around 21,000 (Lamberth and Turpie 2001). In 1997 the net cash income made by commercial fishers in South Africa's estuary-associated fisheries was almost R45 million (based on total landings and average fish prices) (equivalent to approximately R56 million in 2001 terms).

The annual artisanal fish catch from estuaries along the coast of Senegal and Sierra Leone in West Africa is in the region of 100 tons.km<sup>-1</sup> (Baran 2000). Although little research has been conducted on the economic importance of subsistence estuary-associated fisheries in South Africa, Cochrane and Payne (1998) observed that this fishery is not as well developed as other fisheries in South Africa. This is partly due to past political policies, which did not recognize access rights of subsistence fishers to the country's marine resources (Anon. 1998). Preliminary investigations by Robertson and Fielding (1997) showed widespread exploitation of estuary-associated fish and invertebrates along the eastern coast of the Eastern Cape. The subsistence fisheries in the estuaries of KZN have received relatively more attention. For example, annual catch of fish from the Kosi system by traditional fish traps was estimated to number 40,000 fish (Kyle 1993). The per capita annual income earned by the estimated 120 traditional fishers operating in estuaries in KZN is R2, 300 in 2001 terms (Lamberth and Turpie 2001).

So far the extent and importance of invertebrate exploitation has been evaluated for only a few of South Africa's estuaries. Cowley (2000), in his report on the utilisation of marine resources between East London and Port Elizabeth, identified nine exploited estuarine species, with mud prawns (*Upogebia africana*), sand prawns (*Callinassa kraussi*), and bloodworms (*Arenicola loveni*) being major targets. Cowley (2000) also noted that subsistence bait collectors collected more bait than recreational anglers. Intensive exploitation of bait organisms also occurs on the Kosi system (Kyle 1993), St Lucia (Forbes and Benfield 1986), and Richards Bay (Schleyer and Tomalin 1994), all in KZN, and Langebaan lagoon on the west coast of South Africa (Wynberg and Branch 1991). Kyle (1993) estimated that 300,000 sand prawns were extracted annually from the Kosi system, while almost  $1.9 \times 10^6$  mud prawns were removed annually from the Knysna estuary on the southern coast (Cretchley 1996). Wynberg and Branch (1991) estimated that more than one million mud and sand prawns per year were removed from the Langebaan lagoon.

Economic evaluations have been conducted for the bait fisheries on the Kosi system (Kyle 1993), on St Lucia (Forbes and Benfield 1986), and on estuaries along the coast of the former Transkei region (Fielding *et al.* 1994; Robertson and Fielding 1997). Bait is sold mainly to tourists and forms the basis of the recreational fishery. The bait fishery in South Africa is regarded as mostly under exploited, and the development of artisanal and even commercial bait

fisheries on some estuaries has been recommended (Robertson and Fielding 1997; Centre for Marine studies 1999; Cowley 2000).

### **1.3.2 Status of estuarine fisheries**

Concerted effort to reduce commercial fishing effort in Australia's estuaries has contributed to a reduction in fishing pressure, and the number of over exploited species has declined (Anon. 1999). Caputi and Lenanton (1999) reported that estuarine fisheries along the coast of Western Australia are well managed and appear to be sustainable. On the other hand, most estuarine fisheries in the tropics are not managed at all, and they are either fully or over exploited (Blaber 1997). Houde and Rutherford (1993) report that most estuarine fisheries in the USA suffer from over fishing, habitat loss or degradation, and pollution. Generally, in South Africa there is a lack of reliable data to substantiate claims of a dramatic decline in South Africa's coastal fisheries (Attwood and Farquhar 1999). Some incidents of declines in catch rate, changes in catch composition, and reduction in body mass have been reported for selected South African estuaries. Examples include: the depletion of spotted grunter (*Pomadasys commersonnii*) and white steenbras (*Lithognathus lithognathus*) in the Swartkops estuary (Marais and Baird 1980a; Baird *et al.* 1996) and Durban Harbour (Gaustella 1994). Catches of some fish species from some estuaries seem to be sustainable despite increases in fishing effort, for example river bream (*Acanthopagrus berda*) on the Kosi estuary system (Kyle and Robertson 1997; Kyle 1999). However, fishery resource stocks for most estuaries and their exploitation rates remain unknown, especially for estuaries outside KZN. The lack of long-term catch data, inadequate baseline information, and differences in fish capture methods and gear makes valid comparisons between different estuarine fisheries difficult.

Lamberth and Turpie (2001) used data on historic and present spawner biomass, compared current and historical catch, and contribution to catch, to place South Africa's 80 exploited estuary-associated fish species in different categories of exploitation. Species such as dusky kob (*Argyrosomus japonicus*) and *L. lithognathus*, whose present spawner biomass is estimated to be less than 10% of their historic value (based on expert opinion), were rated as collapsed. Species whose current biomass falls between 40% and 50% of their historic values were regarded as maximally exploited; these include highly targeted species such as *Pomadasys commersonnii*, freshwater mullet (*Myxus capensis*), southern mullet (*Liza richardsonii*), elf (*Pomatomus saltatrix*) and blacktail (*Diplodus sargus capensis*). A number of species from both categories

were prioritised for research and management by van der Elst and Adkin (1991). Those fish species whose spawner biomass estimates are greater than 50% of their historic values are regarded as under exploited. These are mostly small-sized fishes, such as strepie (*Sarpa salpa*) and striped mullet (*Liza tricuspidens*), and are not favoured by commercial fishers or recreational anglers. A number of species from this category have been recommended for subsistence exploitation (Centre for Marine Studies 1999).

Certain authors have expressed concern about the suitability of the Eastern Cape's estuarine fisheries for human exploitation. Paterson and Whitfield (1996) and Cowley (1998) reported wide annual variations in estuarine fish populations in the Kariega and East Kleinemonde estuaries respectively, which makes it difficult to estimate fish production. Species such as *A. japonicus*, *P. commersonii*, *L. amia* and *L. lithognathus* were found to form a very small proportion of gill and seine net catches from the Kariega (Paterson 1998), East Kleinemonde (Cowley 1998) and the Great Fish and Kowie estuaries (Whitfield *et al.* 1994). This points to low stock levels of these species in those estuaries, yet they continue to be highly targeted by Eastern Cape anglers (Daniel 1994b). Whitfield *et al.* (1994) found most of the gillnet catch from the Kowie estuary below the minimum legal size. This led Cowley (2000) to conclude that most estuarine fishery resources in the Eastern Cape are unsuitable for the development of net or small-scale commercial fisheries.

### **1.3.3 Threats to estuarine fisheries**

The major threats to South Africa's estuarine fisheries are excess water extraction from rivers, loss and degradation of estuarine habitats, and over fishing (Cyrus 1991; Whitfield 1998). The role and contribution of each factor is unknown and complicated by the high ecological variability within estuarine systems.

Dams and weirs have been constructed on most rivers in South Africa, reducing the incidence and amplitude of floods in the estuaries. One result has been high salinities, as has occurred in Lake St Lucia and the Seekoei estuary in the Eastern Cape (Whitfield 1998). This is often followed by mass death of fish. Less freshwater inflow into estuaries results in less nutrient input, which reduces primary production. With reduced river scouring, closure of the estuary mouth is prolonged, which interferes with migration of larval and adult fish between the sea and

the estuary. All these impacts have a negative effect on fish abundance and diversity in the estuary (Whitfield 1998).

It is well known that estuaries support critical habitats such as salt marshes, intertidal mud and sand banks, and eel grass beds, which are used by many species for foraging and as nursery areas. Changes in land use, such as expanding agriculture and human settlement, especially in catchment areas, hydrological manipulations such as canalisation and dredging, cause loss of critical estuarine habitats, while illegal fishing methods such as the use of spades and forks cause sediment disturbance (Whitfield 1998).

The depletion of stocks of major target species such as *A. japonicus* and *L. lithognathus* has been linked directly to over fishing (Whitfield 1998). Lamberth and Turpie (2001) point out that estuarine fisheries are easy to access and exploit even with simple gear, which makes them highly vulnerable to overexploitation. Although commercial fishing is illegal in most of South Africa's estuaries, Lamberth and Turpie (2001) report that the practice is nonetheless widespread. Cowley (2000) reported illegal commercial fishing with the use of gillnets and cast nets in the estuaries of the Eastern Cape. Compliance and enforcement of fishing regulations is reported to be low, especially along the coastline of the former Transkei. As a result, estuarine fisheries are being overexploited, which has resulted in depleted stocks. Although no studies have been carried out, the increase of industrial activity along the coast of South Africa, and the high level of agricultural and domestic pollution in the estuaries of KZN (Morant and Quinn 1998), are likely to have a negative effect on South Africa's estuarine fisheries.

#### **1.3.4 Management of estuarine fisheries in South Africa**

Various factors contribute to the daunting task of managing estuarine fisheries. These resources are part of complex estuarine ecosystems, with great spatial and temporal variations, which makes predictions difficult (Blaber *et al.* 2000). Estuarine fisheries are part of larger ecosystems such as rivers and oceans, and are affected by impacts to those ecosystems. Each estuarine fishery occurs within a unique socio-economic climate, hampering generalisations from other studies. Situated on estuaries that are a focal point of various human activities, estuarine fisheries are exposed to conflicting uses, goals and visions from various user groups. They are also impacted by a variety of regulations, such as those controlling water use, marine resources

utilisation, recreation and coastal development (Smith and Cullinan 2000), which contributes to uncoordinated management.

If estuarine fisheries are to be available to future generations, they must be effectively managed. This requires interdisciplinary research and an integrated management approach. Unfortunately, this has not been accomplished in the past, and ecological and biological data have dominated research output on estuarine fisheries. Investigations into the socio-economics of estuarine fisheries have been neglected, and data on catch composition, exploitation levels, user-group demographics, and fishing behaviour are scant, not only in South Africa but also worldwide. There is an urgent need to supply decision makers with such data, and this necessitates more research on estuarine fisheries that has a bias for social science.

Sustainability is recognized worldwide as the overriding goal of natural resource management (Rosenberg *et al.* 1993; Goodland and Daly 1996). However, relative to forestry and agriculture, research on sustainable fisheries is still in its infancy. Furthermore, research has been biased towards the fisheries of the northern hemisphere, which tend to be highly commercialised, single species, and harvested with high-technology fishing gear. By comparison, estuarine fisheries in South Africa are usually small-scale, multi-species, and operated by a variety of user groups using a variety of gears. There is an urgent need for research into the sustainability of these fisheries within the South African context, and a need to design suitable protocols by which to assess them. This hinges on the identification of appropriate indicators of sustainability that are not only cost effective, but also relevant to local fisheries and acceptable to key stakeholders. This need is made more urgent by the negative impact that increasing human populations are having on South Africa's coastlines and fisheries, and by recent positive attempts by the South African government to broaden access and management responsibility of estuarine living resources to include previously disadvantaged populations (Anon. 1998).

#### **1.4 PREVIOUS RESEARCH ON ESTUARINE FISHERIES**

There are numerous references to estuary-associated fisheries from a perspective of estuary management (Day and Grindley 1981b; Heydorn 1989; Whitfield 1994) or ichthyological research (Whitfield 1998). However, studies that primarily focus on the management or exploitation of estuary-associated fisheries are less common. This is changing, however, since the role that estuary-associated fisheries play in coastal economies has become better appreciated

(Lamberth and Turpie 2001) along with acknowledgement of the threats they face as a result of human activities (Cyrus 1991). Rather than giving detailed overviews of research on individual estuarine fisheries, this chapter takes a theme-based approach to the literature survey, with examples from various estuarine fisheries worldwide.

#### **1.4.1 Reviews of estuarine fisheries**

There are only a few comprehensive published reviews on the world's estuarine fisheries. One of the earliest is that by McHugh (1966). He noted that the management of estuarine fisheries in the USA lagged behind that of marine fisheries and blamed it on the stochastic nature of estuarine resources. In a review of tropical estuarine fisheries, Blaber (1997) reported that those fisheries are usually small-scale, exploited with low-technology gear, and outside the formal economies. In a review of estuarine fisheries in Australia (Anon. 1999a), resource allocation and the threat from eutrophication were identified as major management issues. A review of estuary-associated fisheries in South Africa was made by Lamberth and Turpie (2001). Those authors estimated fisher participation, the economic value of different sectors of estuary-associated fisheries in South Africa, and assessed the stock levels and exploitation rates in different estuaries. In a review of estuarine fisheries between East London and Port Elizabeth, in Eastern Cape, Cowley (2000) reported that there is little data on them, especially those based in the small temporary/closed estuaries. Lamberth and Turpie (2001) and Cowley (2000) concur that, as a result of a stochastic nature, fishery resources in South Africa's small temporary/open estuaries should not be commercially exploited.

#### **1.4.2 Studies on individual fishery sectors**

A common approach to estuarine fisheries research is to study individual sectors of an estuarine fishery. For example, angling and subsistence fishing in various estuaries along the east coast of South Africa have been investigated by Daniel (1994b), Mann *et al.* (1994), Kyle (1995), Pradervand (1998) and James *et al.* (2001). Meanwhile, the integrated human utilisation of fishery resources in the majority of South Africa's estuaries is yet to be investigated.

Research work on the exploitation of estuarine invertebrates (bait fisheries) in South Africa is also scarce. A few investigations have been done on bait stocks, rates of extraction and the resultant impacts (see Wynberg and Branch 1991; Cretchley 1996; Forbes 1998). Such studies have revealed that although South Africa's bait fishery is mostly under exploited, secondary

impacts such as local extinctions, decrease in body size, trampling, sediment disturbance, and increased predation of disturbed fauna could become important in the future.

### **1.4.3 Descriptions of estuarine ichthyofauna**

Descriptions of estuarine ichthyofauna are a basic research need for estuarine fisheries assessment (see Bennett 1989; Plumstead *et al.* 1989; Potter *et al.* 1990; Whitfield 1998; Harrison *et al.* 2001). Approximately 160 fish species occur in South Africa's estuaries, of which about 80 are exploited (Lamberth and Turpie 2001). These are predominately species of the families Sparidae and Mugilidae, and subsequently common in the catch of fishers along the Eastern Cape coast (Daniel 1994b; Pradervand 1998). In the estuaries of West Africa, the dominant fish families are Ariidae, Bagridae, Carangidae and Cichlidae (Baran 2000). Whitfield (1998) observed that while the ichthyofaunal species richness in South Africa's estuaries is low, the abundance of individual taxa is high.

There have been various attempts to classify estuarine fish according to their dependence on estuaries (Wallace *et al.* 1984; Potter *et al.* 1990; Whitfield 1994). The estuarine fish fauna in South Africa, for example, is dominated by euryhaline species, which spawn at sea and then move into estuaries as juveniles. Blaber (1997) recorded similar findings for tropical estuaries.

Comparisons of the fish fauna in different types of estuaries are also popular with researchers (see Bennett 1989; Whitfield *et al.* 1994; Harrison and Whitfield 1995). Bio-geographical position, size of the estuary and its catchment, condition of the estuary's mouth, and salinity are some of the factors that affect fish abundance and diversity in estuaries. Suarez *et al.* (2001) report that in the Pantanal lagoons of Brazil, macrophyte cover, piscivore abundance and water depth determine fish abundance. There is less fish diversity in temperate estuaries than in tropical ones. For example, species diversity in Eastern Cape estuaries between Port Elizabeth and East London is lower than in the estuaries of KZN (Whitfield 1998), due to the lower number of tropical and subtropical species. Cowley (2000) observed that even between relatively similar estuaries, the general fish fauna differ, and thus recommends a different exploitation and management plan for individual estuaries.

#### **1.4.4 Biology and ecology of estuarine fish**

Detailed information on the biology and ecology of estuarine fauna is a prerequisite for effective management of estuarine fisheries. In South Africa, this has been an area of great research output since the late 1960s (Whitfield 1998). Commonly researched areas have included life histories (Lasiak 1983; Whitfield 1990, Whitfield 1994), larval recruitment into the estuary (Melville-Smith and Baird 1980; Harris and Cyrus 1995) and feeding ecology (Smale and Kok 1983; White and Bruton 1983; Blaber 1997). As a result, detailed information is available on the biology and ecology of some of the major estuarine fish species, and has been used to support fishery management recommendations (Hecht 1990b). Nevertheless, our knowledge of the biology and ecology of a large number estuarine fish species is still inadequate, including those under heavy exploitation (Lamberth and Turpie 2001).

#### **1.4.5 Description of catch**

Where long-term catch data are available, they have formed the basis of investigations into trends over time of catch biomass, catch rate, catch composition, and body size of caught species. In South Africa, the National Marine Linefish System as well as records from various angling competitions are examples of such databases. Examples of research works based on long-term catch data are Marais and Baird (1980b), Kyle (1993) and Baird *et al.* (1996). While most investigations of estuarine fisheries point to a decline in fishing success over time, fisheries on the Kosi system appeared to be generally stable (Kyle 1993). Kyle (1993) ascribed this to the continued use of traditional fishing methods instead of modern technology. Unfortunately, for most of South Africa's estuaries no reliable long-term catch data exists. Blaber (1997) noted that while accurate long-term data are available for estuarine fisheries in developed countries, this is not the case with most tropical estuarine fisheries.

#### **1.4.6 Socio-economics**

Effective management of a fishery depends not only on having a sound knowledge of the target species but also on the users carrying out the fishing or bait collecting (Aguero and Lockwood 1986). In South Africa, investigations of fisher demographics, attitudes, expectations, regulation knowledge and participation are a relatively new trend in fisheries research (see McGrath *et al.* 1997; Sauer *et al.* 1997; Brouwer *et al.* 1997). Community management, the role of traditional knowledge systems, and subsistence user rights have become popular social issues to consider, especially in the estuarine fisheries of East Asia (Berkes and Kislalioglu 1991; Agbayani and

Siar 1993; Pomeroy 1995; France and Exel 1999). Economic factors are also gaining prominence in the formulation of fishery management plans. Examples of research into the economics of estuary-related fisheries are McGrath *et al.* (1997), Sauer *et al.* (1997) and Pradervand (1998), Lamberth and Turpie (2001) and Mann *et al.* (2002).

#### **1.4.7 Management of estuarine fisheries**

Blaber *et al.* (2000) identified eight effects from fishing on estuarine ecosystems and recommended integrated management of estuarine fisheries. Sustainability has been adopted as the guiding principle of fishery management worldwide (FAO 1995; Goodland and Daly 1996; Iversen 1996). For example, fisheries management in the USA is based on the Sustainable Fisheries Act of 1996, and in Australia on Ecologically Sustainable Development (ESD). Much of the research work done so far on sustainability in fisheries has been desk-top, for example conceptualisation of sustainability within the context of fisheries, identification of key sustainability principles, design of fisheries sustainability frameworks, and identification of suitable indicators (Charles 1994; Garcia 1997; Staples 1997; Dahl 2000), and more recently devising techniques for assessment (Pajak 2000; Pitcher and Preikshot 2001). Although some progress has been made on sustainability assessment in fisheries, little of the work done so far refers specifically to small-scale estuarine fisheries. Compared to Australia, work on sustainable fisheries in South Africa is in an early phase of development. For example, more than 60 indicators of ecological sustainability have been identified for use in Australia's fisheries (Ward 2000). A preliminary investigation of the Kosi fishery by Kyle (1993) focused on "wise utilisation" of fishery resources. That author regarded information on size and stock availability, and the control and monitoring of utilisation, as essential to determining "wise use" of the resources. However, Phillips *et al.* (1997) and Garcia (1997) take a more holistic view of a sustainable fishery and include not only biological and ecological issues but also political, social, and economic issues. Despite the identification of numerous suitable indicators of sustainable fisheries, examples of fisheries that are actually being assessed within the broad context of sustainability are still rare.

### **1.5 RESEARCH AIMS**

The Kowie estuary is one of the major estuaries along the coast of the Eastern Cape. It is the lifeblood of the town of Port Alfred, helping to attract thousands of tourists to the town annually (Urban Dynamics 1995). Activities on the estuary include boating, water skiing, fishing and bait

collecting. The multi-purpose use of the estuary is a potential source of conflict as the different users compete for limited estuarine space. There is also concern over the effects of siltation, reduced water inflow, and loss of habitat on the estuary's living resources. There is an urgent need for effective and integrated management of the Kowie estuary, to ensure that the supply of goods and services from the estuary, and the well being of the ecosystem, continues on into the future.

To this end, the Institute of Natural Resources, of the University of Natal, Pietermaritzburg, under the Eastern Cape Estuaries Programme, helped to formulate a management plan for the estuary (Institute of Natural Resources 1999a). However, the success of the management plan will depend on the availability of key data concerning the estuary. Examples of existing data gaps include the exploitation of living resources from the estuary, and the socio-economics of the user groups.

This study aims to contribute to more effective and integrated management of the Kowie estuary by:

- Carrying out a comprehensive survey of the estuary fishery, and so contribute data on which to base management decisions.
- Identifying a limited number of indicators suitable for assessing sustainability in the estuary's fishery.
- Assessing the sustainability of various sectors of the estuary's fishery.
- Making recommendations towards assessing sustainability in small-scale estuarine fisheries.
- Making recommendations towards effective management of the Kowie estuary fishery

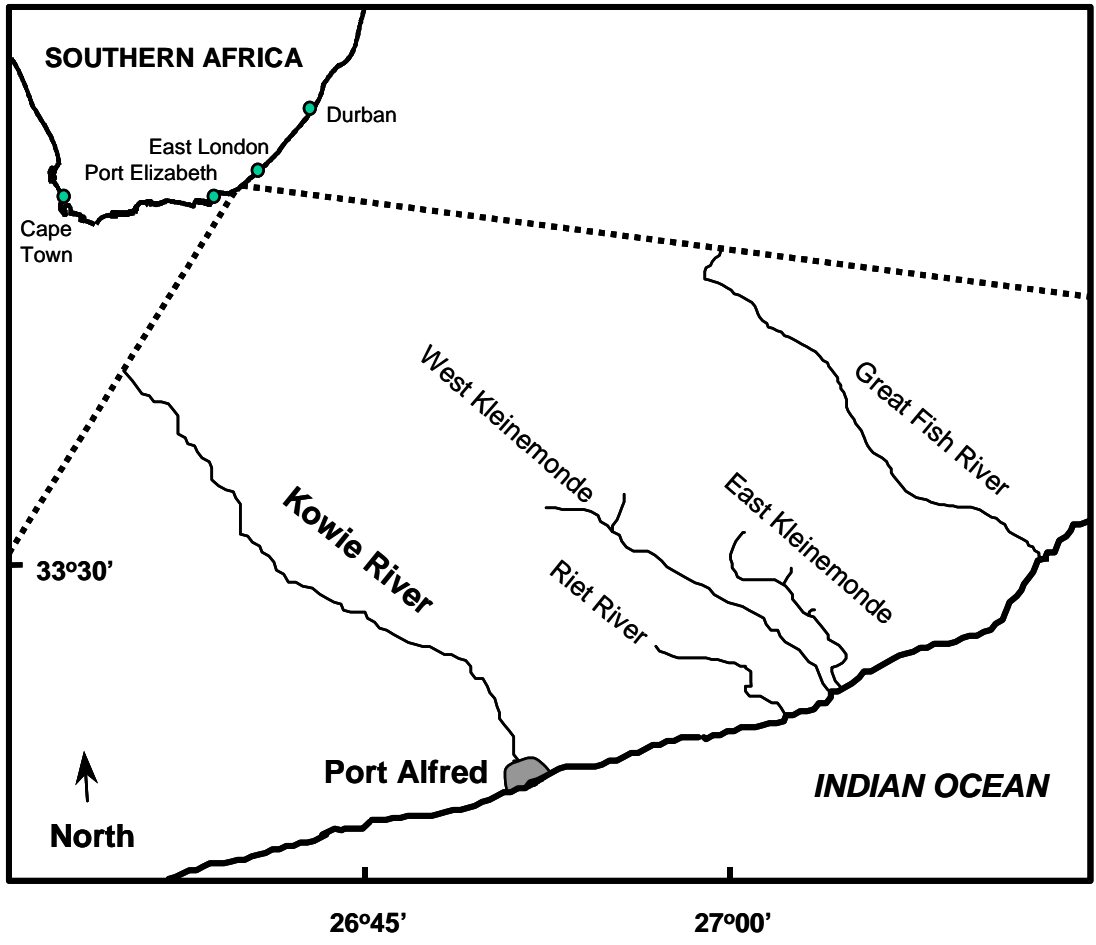
## CHAPTER 2

### STUDY SITE

#### 2.1 PHYSICAL CHARACTERISTICS OF THE KOWIE ESTUARY

From its source in the hills near Grahamstown, the Kowie River flows southward until it enters the Indian Ocean at Port Alfred at 33° 36' S; 26° 54'E (Figure 2.1). The river is 70 km long and its catchment covers 769 km<sup>2</sup>. Average rainfall in the catchment is 638 mm per year, most of it falling in spring and autumn (Day 1981b). Water temperatures show a seasonal range of 11–27°C in the upper reaches of the estuary, and 14–22°C in the mouth region, sometimes dropping below 14°C when cold-water upwelling occurs along the coast (Bok 1983). The river's annual flow is erratic due to frequent droughts and floods in the catchment. Estimates of mean annual run off for the Kowie River range from 17 x 10<sup>6</sup> to 50 x 10<sup>6</sup> m<sup>3</sup> (Heydorn and Grindley 1982).

The river flows mainly through privately owned farmland and indigenous scrub forest of the Valley Bushveld type. The underlying rocks consist mostly of shale and sandstone, and are responsible for the river's low silt load, its high pH (mean 8.2), and its high alkalinity (mean 139–185 ppm CaCO<sub>3</sub>) (Heydorn and Grindley 1982). There is reduced light penetration in the river due to its brown colour, which is caused by a high content of dissolved organic matter and clayey soils (Day 1981b; Bok 1983). Bok (1983) reported that the average salinity of the water is approximately 30 ‰, but may reach 40 ‰ during drought, and 0 ‰ (in the mouth region of the estuary) during prolonged river floods. Bok (1983) also reported a gradual increase in conductivity from the upper to lower reaches of the river. The surface water of the river is normally well oxygenated or supersaturated during the day (Heydorn and Grindley 1982). Heydorn and Grindley (1982) reported that although there are a number of bridges and dams in the upper reaches of the river, only a weir just above the “ebb and flow” (approx. 25 km from the river mouth) restricts fish movement up river. The Kowie estuary is tidal for at least 21 km from the mouth (Heydorn and Grindley 1982).



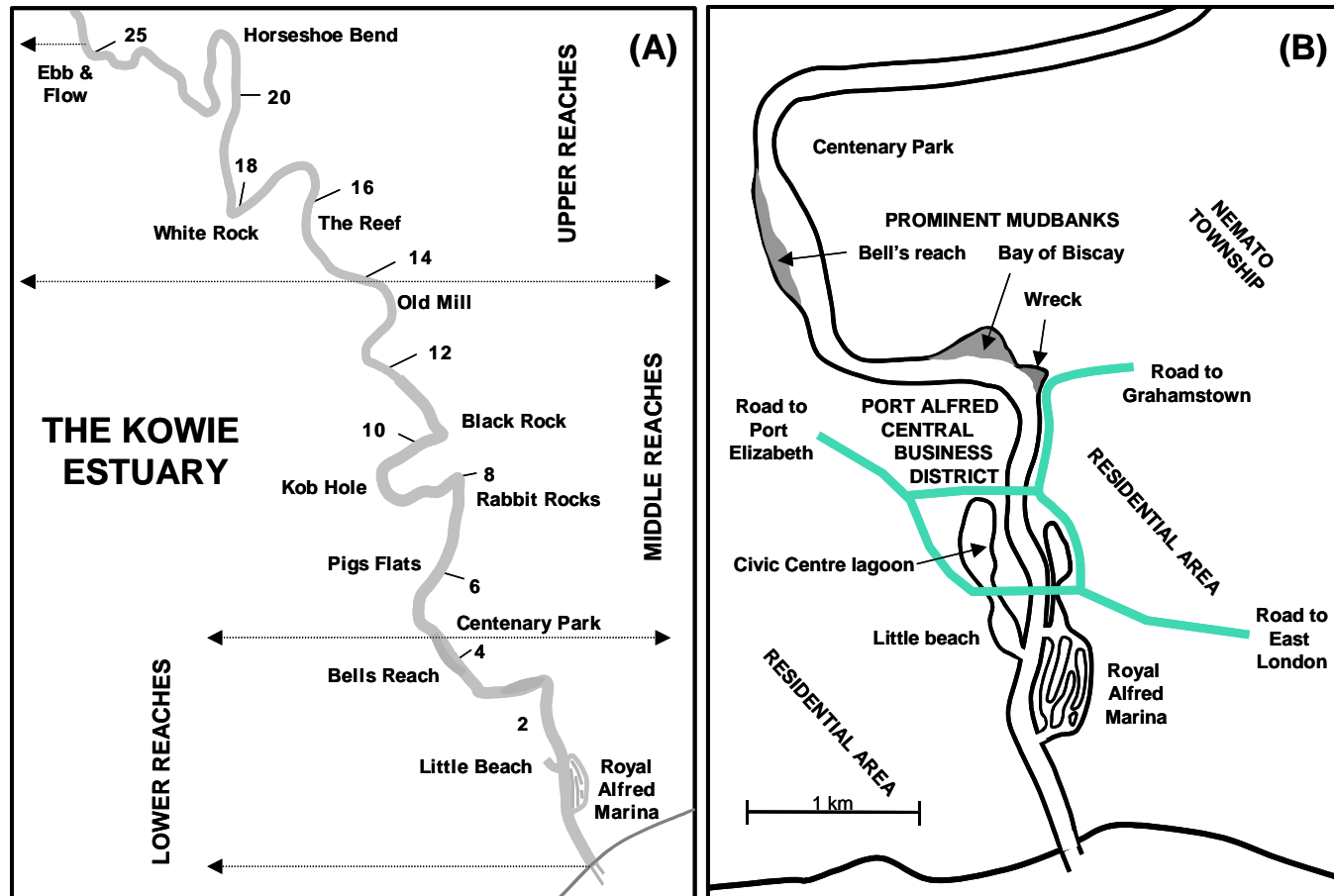
**Figure 2.1:** Location of the Kowie River estuary, Eastern Cape Province, South Africa.

Occupying an estimated area of 118.6 ha (Lamberth and Turpie 2001), the Kowie estuary is one of South Africa's larger estuaries. It falls within the warm temperate bio-geographic region of South Africa's coast, which stretches from Cape Point on the southern coast to the Mendu estuary in the former Transkei region (Whitfield 1998). According to Whitfield's (1992) classification of South Africa's estuaries, the Kowie estuary is classified as permanently open since it maintains a permanent link with the sea. Considerable ecological degradation has occurred in the Kowie estuary as well as in its catchment, although Whitfield (1995) assessed the condition of the estuary as fair. The botanical importance rating of the estuary, based on the condition and diversity of essential estuarine plant communities, is only 45 out of a normalized score of 100, due to considerable destruction of eel grass beds and reeds in the estuary, especially in the lower reaches (Coetzee *et al.* 1997).

The upper reaches of the estuary begin at the "ebb and flow" and extend seawards for 12 km (Figure 2.2). This part of the estuary flows through steep-sided, densely wooded valleys that form part of the Waters Meeting Provincial Nature Reserve (Heydorn and Grindley 1982). The rest of the land is privately owned. The width of the estuary in this region is between 50–90 m, with water depths ranging between 2–6 m, but as much as 10 m at river bends (Day 1981b).

The bottom of the estuary consists mostly of very fine sand and silt. The tidal range at spring tide is 1.1 m (Heydorn and Grindley 1982), and the speed of the outgoing current ranges from 12 to 20 cm.sec<sup>-1</sup> (Day 1981b). Cultivation of maize, pineapple and some vegetables takes place in this region of the estuary, sometimes right up its banks (Heydorn and Grindley 1982). This increases the rate of soil erosion into the estuary, which contributes to its siltation.

The middle reaches of the estuary extend for approximately 9 km, from the Old Mill to Bell's Reach (Figure 2.2A), with a width of 100–150 m (Heydorn and Grindley 1982). Water depth ranges between 2 to 6 m, but may reach 8 m on river bends. Here the substratum of the channel consists of sand. The spring tidal range is approximately 1.5 m and the speed of the outgoing tide may reach 12 cm.sec<sup>-1</sup> (Day 1981b).



**Figure 2.2:** (A) Map showing the different regions of the Kowie River estuary. Numbers indicate distance from river mouth (km). (B) Lower reaches of the Kowie estuary with names of sites mentioned in the text.

Apart from the small Kowie Nature Reserve to the north of the Centenary Park, land in this part of the estuary is privately owned. Some residential development has taken place, especially on the east bank of the estuary.

The lower reaches of the estuary extend seawards for 3 km from the “Wreck” to the river mouth (Figure 2.2B). This region of the estuary lies within the town of Port Alfred and has been greatly modified by residential development and infrastructure (Cowley and Daniel 2001). The mouth of the estuary has been extended by an artificial channel, which reaches into the surf zone. To the east, the channel leads into the privately owned Royal Alfred Marina, which was constructed in the wetlands of the East Flats and the Blue Lagoon. The marina occupies 45 ha; its walls and those of the main channel are man-made and reinforced with granite rocks. On the west bank of the estuary are the Civic Centre Lagoon and the Little Beach Lagoon, which are connected to the main channel by culverts under the main road (R72) between Port Elizabeth and East London. The water depth in the main channel here is 2–6 m, but may be reduced to 0.3 m during drought (Heydorn and Grindley 1982). Silting of the estuary is a major problem and implies serious social and economic consequences for Port Alfred (Institute of Natural Resources 1999a). Siltation here is attributed to reduced scouring of the estuary bed as a result of reduced freshwater inflow into the estuary. The spring tidal range in the lower reaches of the estuary is 1.7 m with the speed of water outflow reaching  $25 \text{ cm}\cdot\text{sec}^{-1}$  if floods coincide with the outgoing spring tide (Day 1981b).

Mud banks are common in the lower reaches of the estuary, the largest being the Bay of Biscay, which measures approximately 100 m wide. Intertidal salt marshes occur north of the Bay of Biscay, near Bell’s Reach and at Berrington Cove, near the road to Grahamstown (Figure 2.2B). Parts of the salt marshes between the Bay of Biscay and Centenary Park have been invaded by *Acacia karroo*, and have become areas used for cattle grazing (Heydorn and Grindley 1982) or as playing fields by children. North of the Bay of Biscay is a municipal picnic area, Centenary Park. Extensive development in the lower reaches has destroyed much of the original salt marshes, *Zostera capensis* beds and reed swamps; the remaining marsh and swamp is mainly restricted to areas around the three remaining lagoons. Although the Civic Centre Lagoon forms part of a bird sanctuary, development pressures have impacted on this region. Most of the estuary banks are occupied by residential and commercial properties and two road bridges cross this section of the estuary (see Figure 2.2B).

## **2.2. BIOLOGICAL CHARACTERISTICS OF THE KOWIE ESTUARY**

The biotic characteristics of the Kowie estuary were described by Day (1981b) and Heydorn and Grindley (1982). Over 286 species of phytoplankton and 39 species of zooplankton have been identified in the estuary. Algal blooms occur in the streams north of the Bay of Biscay. *Ruppia* sp. and *Phragmites australis* are the commonest aquatic macrophytes on the estuary, although *Zostera capensis* is the dominant species near the Bay of Biscay and along Bell's Reach. Remnants of reed swamps can be found at the lower East Bank lagoon, and to the east of the "Wreck". The salt marshes to the north of the Bay of Biscay consists of *Sporobolus virginicus*, *Sarcocornia decumbens*, *Juncus kraussi* and *Sarcocornia perennis* near the water's edge (Cowley and Daniel 2001).

The benthic invertebrate community of the Kowie estuary was described by Day (1981b) as being probably poor in diversity. The commonest species are mud prawn *Upogebia africana*, sand prawn *Callinassa kraussi*, and various species of crab. The ecology of mud prawns in the Kowie estuary was studied by Hill (1967), who recorded densities of up to 600 m<sup>-2</sup> mud prawns in the estuary. The biology and ecology of sand prawns in the estuary were studied by Forbes (1973), while Warren (1964) investigated that of grapsoid crabs.

The ichthyofauna of the Kowie estuary has been described by Whitfield *et al.* (1994). The high diversity of fish species in the seine-net catches (36 species) was attributed to the diversity of habitats in the estuary. Extensive beds of *Zostera capensis* support high densities of the omnivorous *Rhabdosargus holubi*. Juveniles of species such as *Liza dumerilii* and striped mullet *Liza tricuspidens* are common in the estuary because of the dominant marine influence. Fish abundance was reported by Whitfield *et al.* (1994) to be highest in the upper reaches of the estuary. The rest of the vertebrate community recorded on the estuary includes 11 species of frogs, 24 species of reptiles, 93 species of birds, and 31 species of mammals (Heydorn and Grindley 1982).

## **2.3 A SOCIO-ECONOMIC DESCRIPTION OF PORT ALFRED**

The lower reaches of the Kowie estuary fall within the central business district of the town Port Alfred. In the 1850s, Port Alfred was an important harbour for mail ships and cargo carriers (Urban Dynamics 1995). Persistent silting of the estuary mouth made the harbour dangerous for large ships, and only small boats and yachts use it now. Port Alfred has a small economic base

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consisting mostly of tourism and associated industries. Recreational activities on the estuary include fishing, sailing, hiking and bird watching (Cowley and Daniel 2001) and more than 40,000 people visit Port Alfred annually (Urban Dynamics 1995). With the inflow of tourists to Port Alfred reaching 6,000 during the December holiday peak season (Urban Dynamics 1995), the problem of excessive human impact on the estuary has become a major environmental issue.

The population of Port Alfred municipality stands at 47,475 (Statistics South Africa 1998), and more than 80% of residents live in the adjoining township of Nemato. Like most economically deprived areas in the Eastern Cape, Nemato has a high rate of population growth (3–7%), mainly as a result of migration from surrounding farmlands and the former Ciskei homeland (Urban Dynamics 1995). Education and skill levels are low (approx. only 6% of adults have matriculated), while unemployment stands at 34.1%. In the past, the fishery resources of the Kowie have not played a central role in the socio-economic uplifting of the majority of Port Alfred's citizens. In the Marine Living Resources Act 18 of 1998 (Anon. 1998), the rights of subsistence fishers to marine and estuarine resources, and the responsibility for their management, have for the first time been legally recognized. This is likely to have raised expectations of the role the Kowie estuary fishery resources could play in addressing poverty and inequality issues concerning Port Alfred. How to use the fishery resources of the Kowie estuary to improve the living standards of the majority of the town's residents without destroying the integrity of the estuary on which its tourism industry depends, is a major challenge facing decision makers in Port Alfred.

## **2.4 THREATS TO THE KOWIE ESTUARY**

The threats to the Kowie estuary are typical of those to most urban estuaries in South Africa. Primarily, they are:

- Siltation due to catchment mismanagement and as a result of construction of the marina.
- Increased loss of estuarine habitats due to urban development.
- Excessive recreational use of the estuary.
- Uncontrolled exploitation of the estuary's natural resources.
- Increased agricultural, industrial and domestic pollution.
- Ineffective and uncoordinated management.

## **2.5 REGULATION ENFORCEMENT ON THE KOWIE ESTUARY**

Nationally, the Directorate: Marine and Coastal Management (previously Sea Fisheries) is responsible for the management of marine and estuarine living resources in South Africa. At provincial level, the management of estuaries in the Eastern Cape falls under the Department of Economic Affairs, Environment and Tourism. At the local level there are four agencies concerned with managing the Kowie estuary. The catchment and upper reaches of the estuary are managed by the former Western District Council (regional government). The lower reaches of the estuary are under the jurisdiction of the Ndlambe Municipality, formerly Port Alfred Municipality (local government). The Port Alfred police also conduct patrols along the estuary. An Estuary Forum consisting of representatives from concerned agencies and stakeholders has been established to coordinate management activities between different agencies (Institute of Natural Resources 1999a). A management plan for the Kowie estuary was launched in 1999 as part of the Eastern Cape Estuaries Management Programme.

Prior to 1998, the Sea Fisheries Act (No. 12 of 1988), various provincial ordinances, and the laws set up by local authorities controlled the utilisation of South Africa's estuaries. For example, there are various bylaws pertaining to the use of boats on the Kowie estuary, and also a bylaw that prohibits fishing and bait collecting at the Civic Centre Lagoon. Since September 1998, estuarine living resources are considered part of marine living resources, and their utilisation is controlled by the Marine Living Resources Act No.18 of 1998 (Anon. 1998).

## CHAPTER 3

### THE KOWIE ESTUARY FISHERY

#### 3.1 INTRODUCTION

Estuarine fishery resources require effective and integrated management if their benefits to humankind are to be sustained. To achieve this, the management of estuarine fisheries should be based on data that are accurate, reliable, replicable and readily available. This data will contribute to wise decision making during the formulation and evaluation of estuarine fishery policies, management plans and actions. To this end the FAO (1997) recommends setting up structures and mechanisms for routine collection, analysis and verification of fishery data. Griffiths (1997) regards natural history studies a prerequisite to fishery management. However, Matlock (1991) points out that data requirements in fisheries should not focus only on fish, but should include the fisher as well. Socio-economic data are especially useful in anticipating the nature and extent of impacts of management actions on the fishery (FAO 1997).

Information on estuarine fisheries in South Africa has mostly been indirectly derived from surveys such as those on the shore fishery (Clarke and Buxton 1989; Brouwer *et al.* 1997; Lamberth *et al.* 1997), or the linefishery (Mann *et al.* 1997). Published work focusing primarily on estuarine fisheries is relatively scanty and recent (see Kyle 1986, 1993; Daniel 1994b; Gaustella 1994; Baird *et al.* 1996; James *et al.* 2001; Pradervand 1998; Pradervand and Baird 2002; Mann *et al.* 2002)..

There are two main fisheries on the Kowie estuary: the linefishery and the bait fishery. Both fisheries consist of a recreational and a subsistence sector. Anglers in the recreational sector are either shore-based or boat-based. Although the Kowie estuary linefishery was recently investigated by Pradervand (1998), and Pradervand and Baird (2002), data were collected mostly from the recreational sector, and total annual fishing effort and catch levels were not quantified. Less is known about the bait fishery on the Kowie estuary, apart from the work of Hill (1967) and Forbes (1998).

In this study, onsite data collecting methods were used to investigate three fishery sectors on the estuary: the recreational linefishery, the subsistence linefishery, and the bait fishery. The results can contribute to the creation of a more accurate and comprehensive database on which management decisions affecting fishery resource utilisation on the Kowie estuary can be founded, and hence contribute to the sustainability of the fishery, and the assessment of progress made towards achieving sustainability (see Chapter 5).

The aims of this part of the study were to:

- Provide a demographic sketch of the main user groups of fishery resources on the Kowie estuary, together with their attitudes and perceptions about fishery management.
- Estimate monthly and annual subsistence and recreational fishing effort.
- Estimate monthly and annual subsistence and recreational catch of linefish and bait organisms.
- Estimate catch rate of the major linefish and bait species.

### **3.2 OVERVIEW OF FISHERY SURVEY METHODS**

Fishery survey methods have been reviewed by Malvestuto (1983), Robson (1991) and Pollock *et al.* (1994). Survey methods are divided into two groups: offsite methods and onsite methods.

The main characteristics of offsite fishery surveys are:

- The survey usually takes place away from the fishing site.
- The data are reported by the fisher, rather than directly collected by the researcher (Pollock *et al.* 1994).

Offsite methods include mail surveys, telephone surveys, door-to-door surveys, and examinations of fisher's logbooks and/or diaries. These methods are popular because they are relatively time and cost effective, and simple to conduct. Their main disadvantage is that the quality of data depends on the memory, knowledge, and integrity of the fisher (Pollock *et al.* 1994). As a result, offsite methods suffer from significant biases, such as incorrect identification and measurement of catches by the fishers, difficulty in recalling past statistics (recall bias), or inflated catch statistics (prestige bias). Furthermore, some of these methods (for example, mail and telephone surveys) require prior listing of the fishers (such as in a telephone directory or on a

list of licence holders) from which a random sample can be chosen. If a list of fishers to be sampled (the sampling frame) is constructed from such sources, it will be biased towards the more affluent fishers who have telephones, or towards those fishers with fishing licenses (notably, in fisheries where regulation compliance is low). Under-coverage of fishing effort may also occur where the completion of logbooks and diaries is voluntary.

Despite the advantages associated with onsite angler survey methods, voluntary catch cards still form the basis of some of the most recent surveys on estuarine fisheries in South Africa, for example (Gaustella 1994; James *et al.* 2001; Mann *et al.* 2002). Inaccurate data from fishery surveys may result in unwise management decisions, which contributes to unsustainable fisheries. The use of onsite survey methods reduces biases in the data, thus improving their quality. Since there is a need for increased use of onsite direct survey methods during investigations on South Africa's fisheries, all the data in this survey of the Kowie estuary fishery were collected by onsite interviews of fishers and other stakeholders.

Onsite survey methods take place at the fishing site. Onsite methods consist of three types: access-point surveys, roving creel surveys and aerial surveys. The main advantage of onsite surveys is that they allow the researcher to verify the fisher's data, thus reducing biases (with the exception of aerial surveys). In access-point surveys the researcher intercepts the fisher as he/she comes off the fishing site. This method requires that the number of fishing sites be countable and be open to the public (Hyne 1991). For fisheries such as the Kowie estuary fishery, where there are numerous fishing sites, many of them privately owned, Pollock *et al.* (1994) recommend the use of the roving creel method.

During roving angler surveys the researcher conducts interviews with fishers that he/she comes across as he/she moves along the water body. Advantages of the roving creel method are:

- It allows the researcher to inspect the fisher's catch, thus minimizing recall and prestige bias in the data.
- It can provide site-specific data.
- Other relevant information about the fishery can be collected at the same time.
- The researcher seeks out the fisher, thus increasing the size of the sample (Robson 1991; Pollock *et al.* 1994).

However, there are also several disadvantages associated with the roving creel method. According to Pollock *et al.* (1994) the disadvantages are:

- Data obtained are mostly from incomplete fishing trips and assumptions are made about the remainder of trips.
- There is a bias towards respondents who fish for longer (length of stay bias) and those who fish more frequently (avidity bias).
- The interview is conducted during the respondent's fishing time, so it has to be kept as short as possible. This may result in the collection of sketchy data.
- Conducting angler counts and interviews at the same time results in underestimation of fishing effort, since the researcher is unable to simultaneously conduct angler counts and interviews.

The key assumptions relating to a roving creel survey have been discussed by Pollock *et al.* (1994) and Brouwer (1997). The assumptions are that:

- Interviewees answer the questions truthfully.
- Catch per unit effort remains unchanged for the entire fishing trip.
- All fishers are correctly identified and counted.
- The catch rate of interviewed fishers is representative of that of all fishers.

### **3.3 SAMPLING PROTOCOL**

#### **3.3.1 Site selection**

Fishing sites are areas of the estuary from which recreational anglers or subsistence linefishers conduct their fishing, and bait collectors obtain bait species. There are numerous such areas along the lower reaches of the Kowie estuary, many of them accessible to people on foot. They are either low-lying estuary banks or elevated bank platforms with enough space for the fisher. A few are better developed and have jetties, but many of these are privately owned. In some sections of the middle reaches of the estuary, and in most of its upper reaches, access is by boat only, because of the presence of steep estuary banks, large mud flats, or private ownership of adjacent land. It was therefore decided to conduct the roving creel surveys from a boat. For convenience the estuary was divided into four sections (Table 3.1). No surveys were conducted beyond 15 km from the estuary mouth because a feasibility investigation showed that no fishing takes place there.

Fishers identified as recreational were those who said their main reason for fishing was recreation or sports, or those who used motorboats and other high-technology fishing gear. Subsistence fishers were identified as those who said they were fishing mainly for food or as a source of income, and who were using low-technology fishing gear (see Branch *et al.* 2002).

**Table 3.1:** Names and locations of the estuary sections sampled during the survey.

Estuary zone	Description	Distance from estuary mouth
1	River mouth to Pig Flats	0 – 6 km
2	Pig Flats to Rabbit Rocks	6 – 8 km
3	Rabbit Rocks to Black Rock	8 – 10 km
4	Black Rock to the Reef	10 – 15 km

### 3.3.2 Boat patrol

One type of roving creel survey was conducted from a boat. Each boat trip took place from the entrance to the Royal Alfred Marina, up to the Reef, 15 km upstream (see Figure 2.2). Sampling took place between July 2000 and June 2001. Except for July during which only one weekday and one weekend day were sampled, sampling effort was arbitrarily set at two weekdays and one weekend day per month. The dates were randomly selected at the beginning of each month. To cater for within-day variation, two runs (boat trips) of the estuary were made during winter, and three or four during summer (Table 3.2). The surveys were scheduled to ensure that all tidal phases were sampled. However, for security reasons no sampling was carried out at night. Interviewers were equipped with measuring boards and files containing the short questionnaire shown in Appendix 1. The information gathered from the interviewees included:

- Number of fishers encountered.
- Type of fisher (subsistence or recreational).
- Location of fisher on the estuary.
- Fisher demographics (name, age, gender, race, hometown).
- Length of fishing trip (starting time and expected ending time).
- Fishing method, and number of rods/lines used.

- Type of bait.
- Species caught, their number and their body sizes (including those released).

### 3.3.3 Foot patrol

Because of the short duration of the boat-interviews, it was felt not enough socio-economic data were collected. Therefore, a second survey of the fishers was carried out to collect additional socio-economic data. This roving creel survey was conducted on foot, from the estuary mouth up to Centenary Park. The foot patrol took place from July 2000 to January 2001, and involved three randomly selected days of sampling per month. Interviews were conducted between 0700 hrs and 1800 hrs.

Sampling involved walking along the estuary and interviewing fishers who were being encountered for the first time during the foot patrol. The sampling equipment consisted of the long questionnaire shown in Appendix 2. In addition to questions on fisher demographics, fishing effort and catch, this questionnaire includes questions on fishing behaviour, attitudes, perceptions, and regulation knowledge. Only shore-based fishers were interviewed. Where it was necessary, an interpreter was used to change the questions into Xhosa.

## 3.4 DATA ANALYSIS AND CALCULATIONS

The data were entered into computer spreadsheets and analysed for the following trends.

### Fishing effort

Daily fishing effort was calculated using the following formula (after Pollock *et al.*1994):

$$e_i = I_i \cdot T_i$$

where:

$e_i$  is the fishing effort on day  $i$

$I_i$  is the number of fishers recorded on the estuary on day  $i$

$T_i$  is the average duration of a fishing trip (from the time the fisher started fishing to the time he/she expected to stop fishing).

Monthly fishing effort ( $E$ ) was obtained by the expansion method:

$$E = e \cdot x$$

where:

$e$  is the average daily fishing effort, and  $x$  is the number of days in the month. Annual fishing effort was calculated as the summation of monthly effort ( $\sum E$ ). Fishing effort was expressed in angler hours (ang.h).

### **Species and size composition**

Where possible, catch was identified to species level. Using an estimate of the frequency of occurrence in the catch of the interviewed fishers, the percentage contribution of different fish species to the overall catch was calculated. Based on length measurements, length frequency histograms were constructed for the three dominant species in the catch, and the proportion of catch above minimum legal size was estimated.

### **Total annual catch**

Number of fish or bait organisms caught by the fishers during the survey period (including those returned to the water) was obtained directly from the interviews. Respondents were also asked to recall the species, number and body size of their released catch. Daily catch was calculated as:

$$c_i = m_i \cdot I_i$$

where:

$c_i$  is the number of fish/bait organisms collected on day  $i$

$m_i$  is the average number of fish/bait organisms collected per interviewed fisher on day  $i$

$I_i$  is the total number of fishers/bait collectors recorded on the estuary on day  $i$ .

For longer time periods (i.e., monthly totals) the numbers of fish/bait organisms collected were calculated using the mean of ratios method (Pollock *et al.* 1994). Catch data from each fisher on each of the three survey days were pooled and averaged to obtain a monthly estimate. Annual catch estimates were obtained by summing the monthly totals. To estimate the mass of fish caught, standard length/mass regressions were used (Mann 2000).

### **Catch rate**

If the catch size and fishing effort of each interviewed fisher are known, then his/her daily catch rate (catch per unit effort, CPUE) can be calculated as:

$$CPUE = c_i / e_i$$

where:

$c_i$  is the number or mass of fish caught (including those released) by the fisher on day  $i$

$e_i$  is the effort expended by the fisher on day  $i$  (estimated from time started fishing to time of interview).

For species-specific catch rate, the number or mass caught for the species was substituted for  $c_i$  in the above formula. To estimate overall daily catch rate, the next formula was used:

$$CPUE = \sum (C_i / E_i) / N_i$$

where:

$C_i$  is the total number or mass of fish caught by the interviewed fishers on day  $i$

$E_i$  is the total fishing effort of all the fishers interviewed on day  $i$

$N_i$  is the total number of fishers interviewed on day  $i$ .

Monthly and annual catch rates were calculated using the mean of ratios method (Pollock *et al.* 1994).

### **3.5 SURVEY RESULTS**

#### **3.5.1 BOAT PATROL OF THE LINEFISHERY**

A total of 156 boat trips (271 survey hours) on the estuary were carried out over 35 days between July 2000 and June 2001 (Table 3.2). A total of 958 interviews were conducted using the short questionnaire (Appendix 1).

##### **Fisher demographics**

The majority of the linefishers were recreational (87%), of which 40% were boat-based. Of the shore-based linefishers, 86% were recreational and the rest subsistence. The majority of the linefishers on the estuary were male (90%) and white (75%). Among the other racial groups, blacks, coloureds and Asians constituted 19%, 6% and 0.2% of the interviewees, respectively. The majority of the linefishers on the Kowie estuary were aged between 19 and 40 years (37%), and 34% were aged 41 to 65 (Table 3.3).

**Table 3.2:** Distribution of sampling effort during the survey of the Kowie estuary fishery between July 2000 to June 2001.

<b>Months</b>	<b>Number of sampling days</b>	<b>Number of long runs</b>	<b>Number of short runs</b>
July	2	7	0
August	3	12	0
September	3	6	5
October	3	6	6
November	3	6	10
December	3	6	12
January	3	8	10
February	3	6	12
March	3	6	8
April	3	4	8
May	3	4	8
June	3	6	6
<b>Total</b>	<b>35</b>	<b>77</b>	<b>85</b>

**Table 3.3:** The distribution of age groups among linefishers interviewed on the Kowie estuary between July 2000 and June 2001.

<b>Age group (yrs)</b>	<b>Number of linefishers</b>	<b>Percentage of total</b>
< 19	230	24
19 to 40	351	37
41 to 65	322	34
> 65	55	6

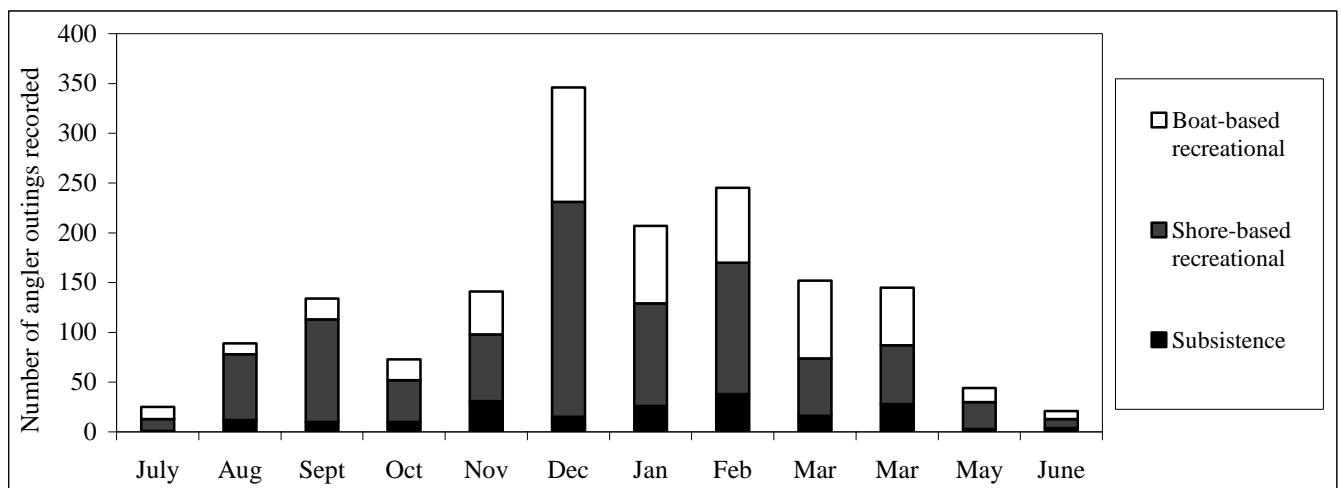
The subsistence sector was dominated by linefishers aged below 19 years (57%), while anglers aged between 19 and 40 years (42%) formed the majority in the shore-based recreational sector. In the boat-based recreational fishery, most anglers were aged between 41 and 65 (41%) (Table 3.4).

**Table 3.4:** Distribution of age groups among linefishers in different fishery sectors on the Kowie estuary between July 2000 and June 2001.

Fishery sector	% Under 19 yrs	% 19– 40 yrs	% 41– 65 yrs	% over 65 yrs
Subsistence	57	33	10	0
Shore-based recreational	21	42	34	3
Boat-based recreational	16	32	41	11

### Temporal distribution of linefishers

The annual number of fishing outings on the estuary was estimated at 1,619. The highest number of fishing outings (all sectors combined) was recorded in December (n=346), while the lowest number occurred in June (n=21) (Figure 3.1). The mean number of fishing outings recorded on the estuary was 4.4 per day. Shore-based recreational anglers dominated the Kowie estuary fishery in all months except March/April. The highest number of both shore-and boat-based recreational angler outings occurred in December, while that for the subsistence sectors was in February. All three sectors registered a decrease in the number of fishing outings during winter, especially from May to July.



**Figure 3.1:** Temporal variation in the numbers of fishing outings recorded on the Kowie estuary between July 2000 and June 2001.

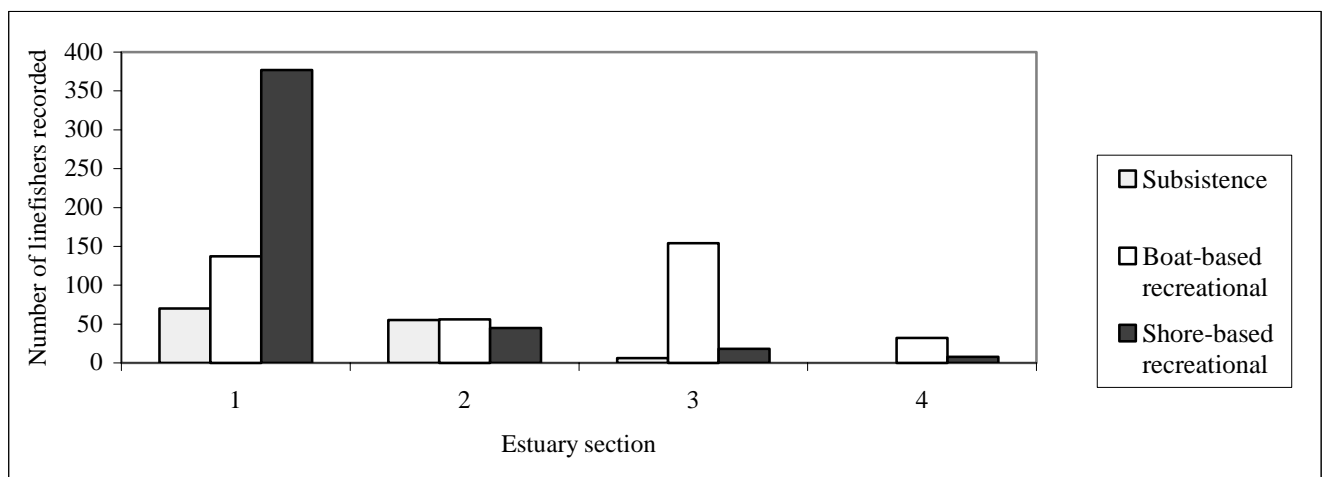
### Spatial distribution of linefishers

Linefishers were unevenly distributed along the estuary (Table 3.5). The highest number was recorded in Section 1 of the estuary (0–6 km from the river mouth), and the lowest was in Section 4 (10–15 km from the river mouth).

**Table 3.5:** Spatial distribution of linefishers recorded on the Kowie estuary between July 2000 and June 2001. (Refer to Table 3.1 regarding estuary sections.)

Estuary section	Number of linefishers outings recorded	Percentage
1	584	61%
2	156	16%
3	178	19%
4	40	4%

Figure 3.2 compares the distribution of different types of linefishers on different sections of the estuary. Shore-based recreational anglers showed a strong preference for section 1. Although most boat-based recreational anglers were found in section 3, they were more evenly spread along the estuary than other types of linefishers. The majority of the subsistence linefishers operated within the first 8 km of the estuary, especially in Section 1, which is closest to Nemato Township.



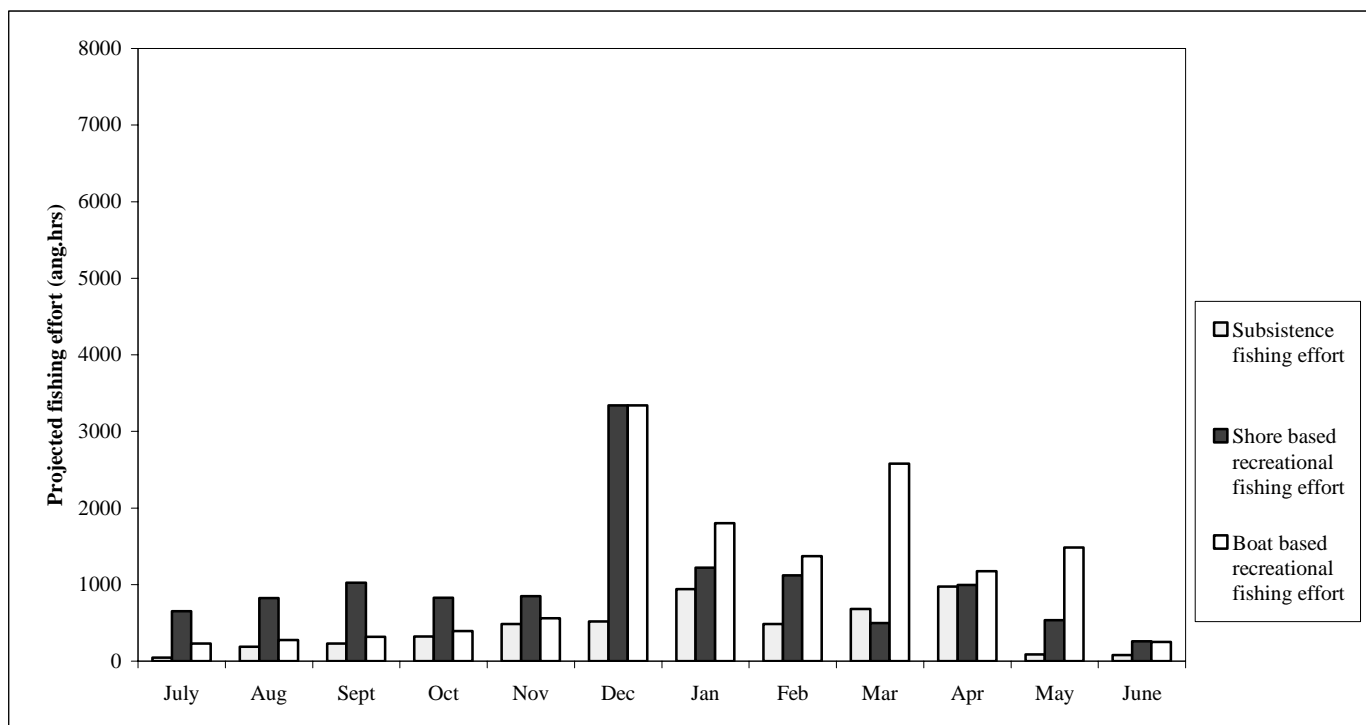
**Figure 3.2:** The spatial distribution of different linefishers recorded on the Kowie estuary during July 2000 to June 2001.

## Fishing effort

Annual fishing effort on the estuary was estimated at 30,952 ang.hrs (SD=154), of which 45% came from the boat-based recreational sector, 39% from the shore-based recreational sector and 16% from the subsistence sector. Recreational fishing alone accounted for 84% of the annual fishing effort on the estuary.

Monthly variation in total fishing effort during the survey period is shown in Figure 3.3. Total fishing effort peaked in summer, with December alone contributing over 25% of the overall annual fishing effort. There was a drop in fishing effort in mid-winter, especially during June/July.

However, when fishing effort was compared across the different fishery sectors, only the recreational fishery (both shore and boat based) showed peak fishing effort in December, while peak fishing effort for the subsistence fishery occurred in April. All the three fishery sectors recorded their lowest fishing effort in mid-winter (June/July).



**Figure 3.3:** Monthly variation in fishing effort (ang.hrs) on the Kowie estuary between July 2000 and June 2001.

### Bait used

The linefishers interviewed used a total of 22 different bait species (Table 3.6). Of these, ten species were caught in the estuary, and the rest purchased from retail outlets. The most commonly used bait species was mud prawn (39%).

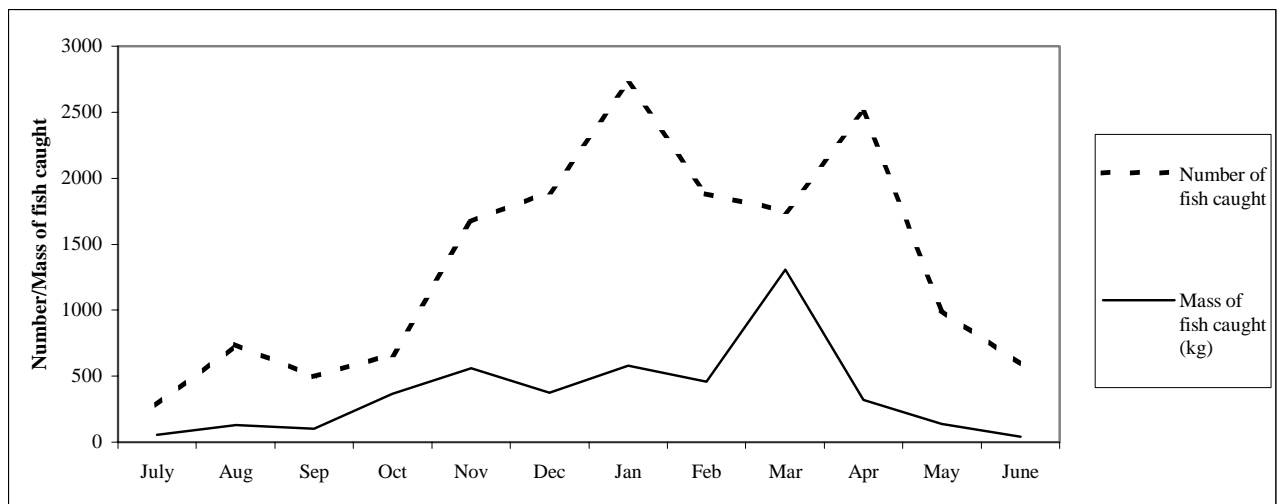
**Table 3.6:** Bait usage among linefishers interviewed on the Kowie estuary between July 2000 and June 2001.

Species	Common name	Frequency of use
<i>Upogebia africana</i>	Mud prawn	39%
<i>Sardinops sagax</i>	Pilchard	30%
<i>Loligo vulgaris reynaudii</i>	Chokka squid	18%
<i>Mugilidae</i> sp.	Mullet	6%
<i>Rhabdosargus holubi</i>	Cape stumpnose	2%
Artificial lures		2%
<i>Penaeus indicus</i>	Swimming prawn	1%
<i>Callinasa kraussi</i>	Sand prawn	1%
Others		1%

### Total catch

Estimates of total catch included fish that were caught, together with those that were put back into the estuary. The annual number of fish caught from the Kowie estuary was estimated at 16,240 (SD=667). Most of the catch by number was caught by boat-based recreational anglers (38%), while subsistence linefishers and shore-based recreational anglers were responsible for 31.3% and 30.9% of the catch numbers, respectively. The highest numbers of fish were caught in December and April.

In terms of mass, the total annual catch from the estuary was estimated at 5.99 tons (SD=0.81). Boat-based recreational anglers were responsible for 67.6% of the catch by mass, while the proportions caught by shore based recreational anglers and subsistence linefishers were almost equal (16.3% and 15.9%, respectively). The highest fish mass was caught during February/March.



**Figure 3.4:** Monthly variation in the projected number and mass of fish caught on the Kowie estuary between July 2000 and June 2001.

### Catch composition

Twenty fish species representing 15 families were identified in the catches of the interviewed linefishers (Table 3.7). The most commonly represented family was Sparidae (six species). The dominant species by number were *R. holubi* (62%) and *P. commersonnii* (17%). In terms of mass, the dominant species were *A. japonicus* (60%) and *P. commersonnii* (19%).

### Catch rate (CPUE)

In terms of fish numbers, overall catch per unit effort (CPUE) for the Kowie estuary linefishery was estimated at 0.570 fish.ang.<sup>-1</sup>h<sup>-1</sup> (SD=0.24). Subsistence linefishers achieved the highest overall catch rate by number (1.13 fish.ang.<sup>-1</sup>h<sup>-1</sup>; SD= 0.70) while estimates for the shore-based and boat-based recreational anglers were almost equal: 0.52 fish.ang.<sup>-1</sup>h<sup>-1</sup> (SD=0.19) and 0.51 fish.ang.<sup>-1</sup>h<sup>-1</sup> (SD=0.32), respectively. Of the four major catch species on the estuary, *R. holubi* had the highest overall catch rate by number (1.23 fish.ang.<sup>-1</sup>h<sup>-1</sup>).

When the catch rates by number are compared across the three fishery sectors (Table 3.8), the boat-based recreational fishery had the highest catch rate for both *P. commersonnii* and for *A. japonicus* (0.133, SD=0.132), and 0.068 fish.ang.<sup>-1</sup>h<sup>-1</sup>, SD=0.093, respectively). For *R. holubi*, the highest catch rate was in the subsistence sector (0.753.ang.<sup>-1</sup>h<sup>-1</sup>, SD= 0.697). The catch rate for *L. lithognathus* was very low in all the three sectors (all < 0.01 ang.<sup>-1</sup>h<sup>-1</sup>).

**Table 3.7:** Species composition by number and mass of the catches of linefishers interviewed on the Kowie estuary between June 2000 and July 2001. (Species arranged in phylogenetic order according to Smith and Heemstra, 1986.)

Family	Species	No.	%	Mass (kg)	%
<b>Chondrichthyes:</b>					
Torpedinidae	<i>Torpedo sinuspersici</i> (marbled electric ray)	4	0.4	14.7	2.6
Rajidae	<i>Raja miraletus</i> (twin-eye skate)	1	< 0.1	0.7	0.1
<b>Ostiechthyes:</b>					
Paralichthyidae	<i>Pseudorhombus arsius</i> (flounder)	1	0.1	0.1	< 0.1
Elopidae	<i>Elops machnata</i> (springer)	3	0.3	4.6	0.8
Ariidae	<i>Galeichthys feliceps</i> (white seabarbel)	27	2.7	9.5	1.7
Platycephalidae	<i>Platycephalus indicus</i> (bartail flathead)	9	0.9	4.1	0.7
Serranidae	<i>Epinephelus andersoni</i> (catface rockcod)	6	0.6	2.4	0.4
Carangidae	<i>Lichia amia</i> (leervis)	4	0.4	8.8	1.5
Potamidae	<i>Pomatomus saltatrix</i> (shad)	6	0.6	6.1	1.1
Sciaenidae	<i>Argyrosomus japonicus</i> (dusky kob)	66	6.6	344.3	59.9
Haemulidae	<i>Pomadasys commersonnii</i> (spotted grunter)	172	17.3	107.5	18.7
	<i>Pomadasys olivaceum</i> (olive grunter)	13	1.3	0.45	0.1
Sparidae	<i>Diplodus sargus capensis</i> (blacktail)	3	0.3	0.8	0.1
	<i>Diplodus cervinus hottentotus</i> (zebra)	20	2.0	2.9	0.5
	<i>Lithognathus lithognathus</i> (white steenbras)	15	1.5	23.1	4.0
	<i>Rhabdosargus holubi</i> (Cape stumpnose)	622	62.4	37.0	6.4
	<i>Sarpa salpa</i> (strepie)	4	0.4	1.7	0.3
Mugilidae	Mullet	20	2.0	6.8	1.1
Gobiidae	Goby	1	0.1	0.05	< 0.1
Tetraodontidae	<i>Amblyrhynchotes honckenii</i> (evileye blaasop)	2	0.2	0.05	0.01

**Table 3.8:** Comparison of catch rate by number for four major caught by linefishers interviewed on the Kowie estuary between July 2000 and June 2001.

	<i>R. holubi</i>	<i>P. commersonnii</i>	<i>A. japonicus</i>	<i>L. lithognathus</i>
Subsistence	0.753 (SD=0.697)	0.068 (SD=0.073)	0.025 (SD=0.063)	0.006 (SD=0.011)
Shore-based recreational	0.311(SD=0.178)	0.041(SD= 0.047)	0.007 (SD=0.083)	0.009 (SD= 0.016)
Boat-based recreational	0.169 (SD=0.238)	0.133 (SD=0.132)	0.068 (SD=0.093)	0.008 (SD=0.0189)
<b>Overall total</b>	<b>1.233</b>	<b>0.242</b>	<b>0.100</b>	<b>0.023</b>

In terms of biomass, overall catch rate per unit effort for the estuary was estimated at 0.298 kg fish.ang.<sup>-1</sup>h<sup>-1</sup> (SD=0.319). The highest catch rate by mass occurred in the boat-based recreational sector 0.427 kg.ang.<sup>-1</sup>h<sup>-1</sup>(SD=0.625), while in the shore-based recreational and subsistence sectors the corresponding figures were 0.284 kg.ang.<sup>-1</sup>h<sup>-1</sup>(SD=0.226) and 0.143 kg.ang.<sup>-1</sup>h<sup>-1</sup>(0.450), respectively.

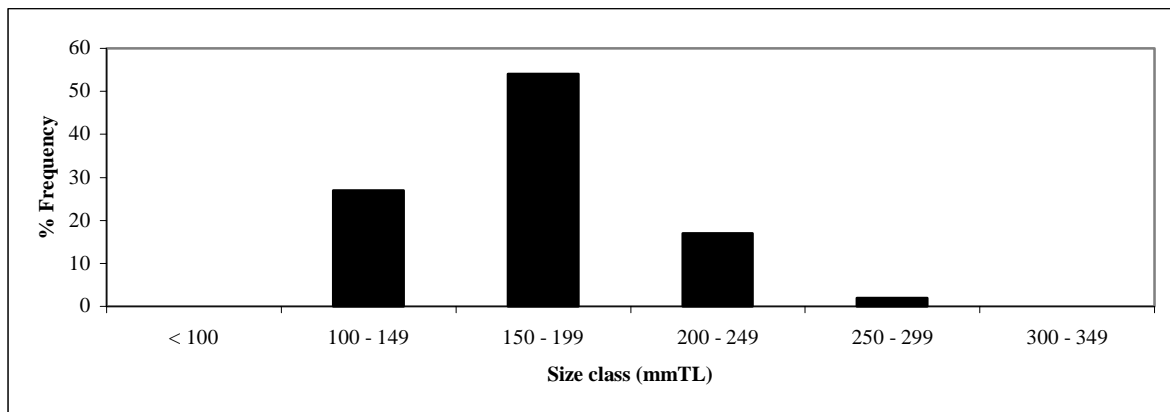
The catch rates by mass of four major species are compared across different fishery sectors in Table 3.10. The highest catch rate by mass for *R. holubi* occurred in the subsistence sector (0.044 kg ang.<sup>-1</sup>h<sup>-1</sup>, SD=0.697). The highest catch rate for both *P. commersonnii* and *A. japonicus* was in the boat-based recreational sector (0.087 kg ang.<sup>-1</sup>h<sup>-1</sup>, SD=0.103) and 0.276 kg ang.<sup>-1</sup>h<sup>-1</sup>, SD=0.518, respectively). *A. japonicus* had the highest overall catch by mass on the estuary (0.496 kg.ang.<sup>-1</sup>h<sup>-1</sup>). The catch rate of *L. lithognathus* was very low in all the three fishery sectors (average 0.011 kg ang.<sup>-1</sup>h<sup>-1</sup>).

**Table 3.9:** Comparison of the catch rate by mass (kg ang.<sup>-1</sup>h<sup>-1</sup>) for four major species caught by linefishers interviewed on the Kowie estuary between July 2000 and June 2001.

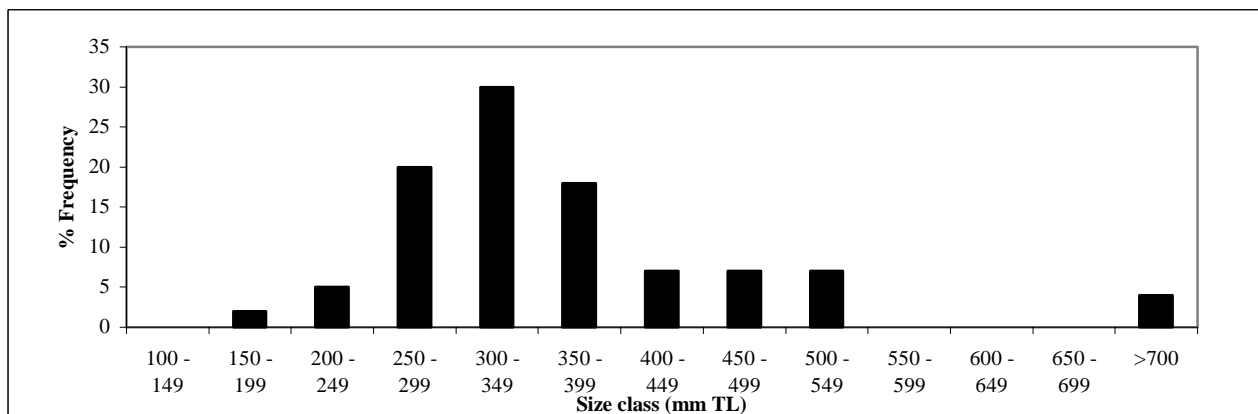
	<i>R. holubi</i>	<i>P. commersonnii</i>	<i>A. japonicus</i>	<i>L. lithognathus</i>
Subsistence	0.044 (SD=0.047)	0.030 (SD=0.051)	0.162 (SD=0.414)	0.009 (SD=0.017)
Shore-based recreational	0.019 (SD=0.013)	0.026 (SD=0.033)	0.058 (SD=0.097)	0.011 (SD=0.021)
Boat-based recreational	0.011 (SD=0.017)	0.087 (SD=0.103)	0.276 (SD=0.519)	0.014 (SD=0.029)
<b>Overall total</b>	<b>0.074</b>	<b>0.143</b>	<b>0.496</b>	<b>0.011</b>

### Size composition

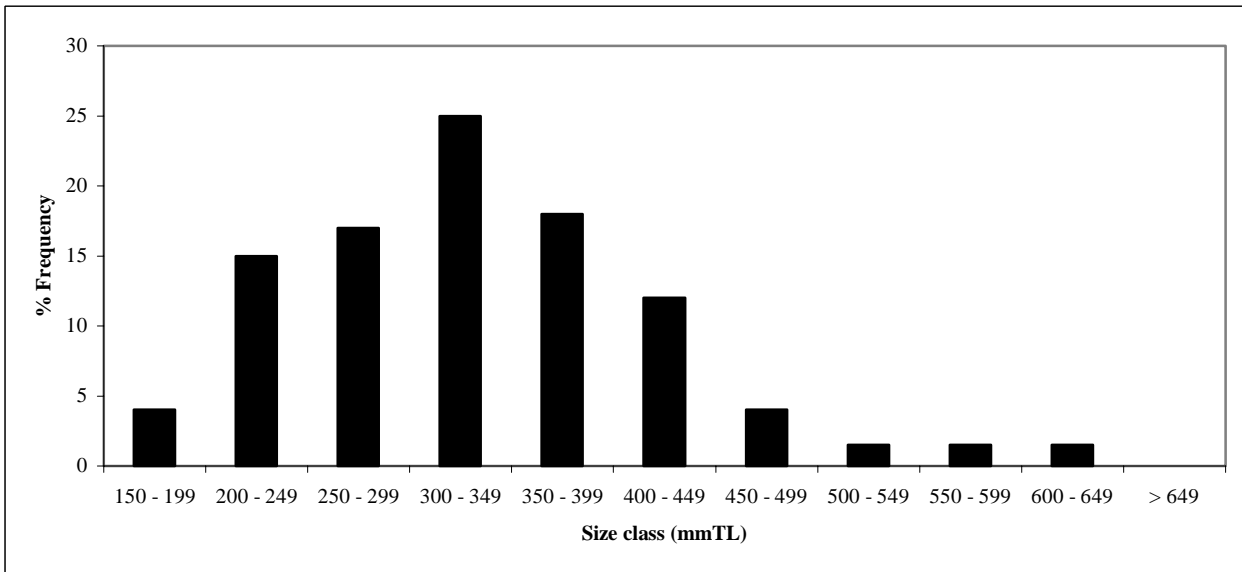
The histograms in Figures 3.5, 3.6 and 3.7 show the frequency distribution of body length for the three major catch species on the estuary. Only 19% of the recorded catch of *R. holubi* was above the minimum legal size (200 mm TL); most of the catch (54%) occurred in the size class 150–199 mm TL. The mean body length for the species was 154.76 mm TL (SD 2.52). The mean body size of *P. commersonii* was 326.44 mm TL (SD 31.68), and the proportion of the catch above the minimum legal size of 400 mm TL was 21%. For *A. japonicus*, the mean body size was 366.58 mm TL (SD= 12.08). Only 25% of the catch of this species was above the minimum legal size of 400 mm TL. Most *P. commersonii* (26%) and *A. japonicus* (25%) caught fell into the 300–349 mm TL size class.



**Figure 3.5:** Length frequency distribution of *Rhabdosargus holubi* in linefishery catches from the Kowie estuary between July 2000 and June 2001 (n = 622).



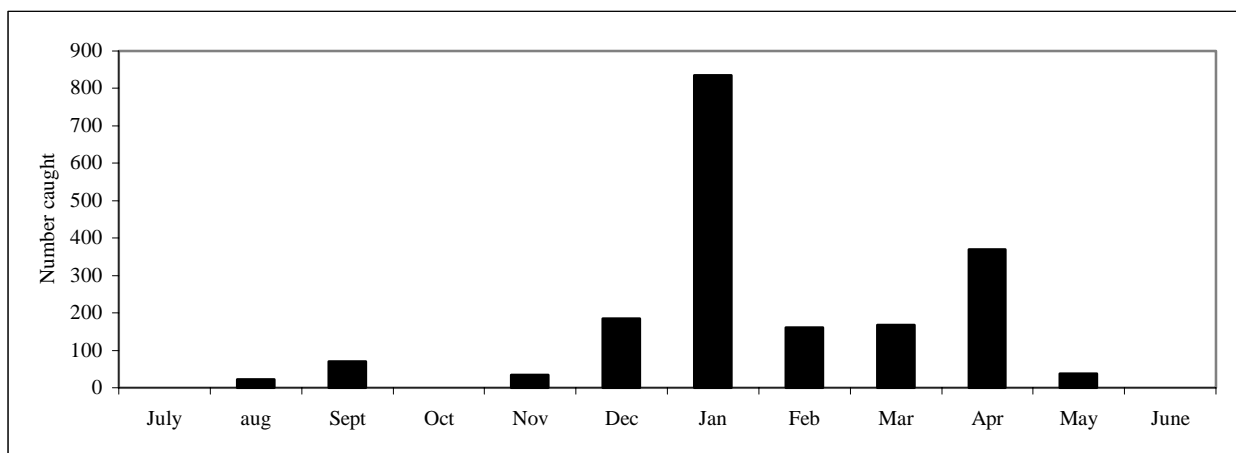
**Figure 3.6:** Length frequency distribution of *Agryrosomus japonicus* in linefishery catches from the Kowie estuary between July 2000 and June 2001. (n = 66)



**Figure 3.7:** Length frequency distribution of *Pomadasys commersonii* in linefishery catches from the Kowie estuary between July 2000 and June 2001 (n = 172)

### Other species caught

The only invertebrate species significant in catches of the linefishery sector was the estuarine mud crab (*Scylla serrata*). The annual number of estuarine mud crabs caught by line from the Kowie estuary was estimated at 1,854 (SD=242). Figure 3.8 shows the monthly variation in the numbers of mud crabs caught during the survey period. The majority of the catch was made in January (44%) and April (20%).



**Figure 3.8:** Monthly variation in the number of mud crab *Scylla serrata* caught from the Kowie estuary between July 2000 and June 2001 (n=1854).

### 3.5.2 BOAT PATROL OF THE BAIT FISHERY

During the survey, 277 bait collecting outings were recorded on the estuary, and 187 interviews were conducted with the bait collectors using the short questionnaire. The findings of the survey are summarised below.

#### Demographics of bait collectors

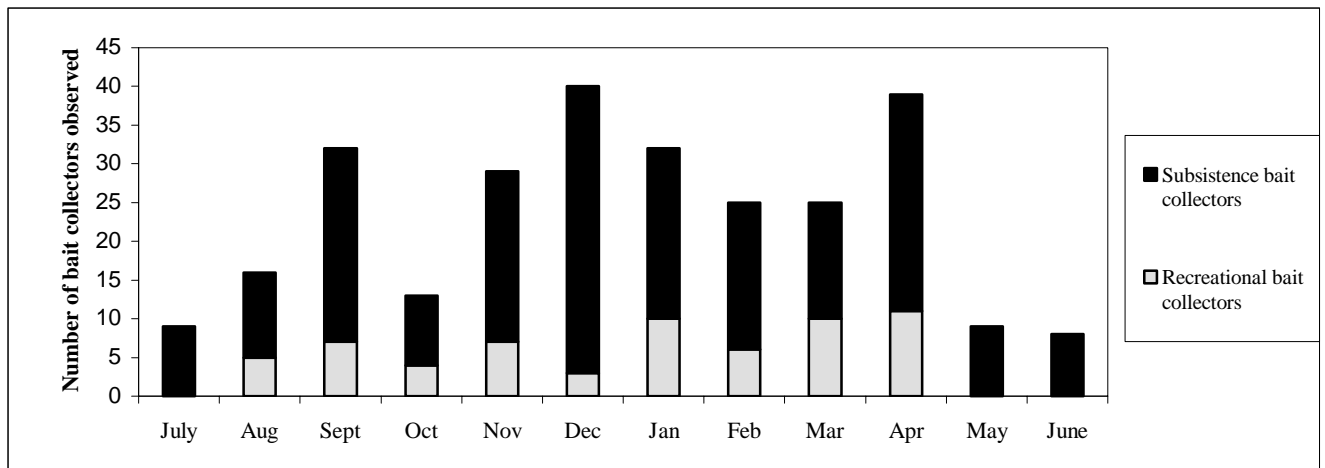
Two main types of bait collectors operated on the estuary: subsistence and recreational. Subsistence bait collectors formed the majority (75%), and consisted of those who collected bait for sale, and those who collected bait for their own subsistence linefishing. The recreational bait collectors were shore-based linefishers who also collected bait for their own recreational linefishing. The majority of the bait collectors on the estuary were male (98%) and black (80%). Whites and coloureds formed 16% and 4% of the interviewed bait collectors, respectively. Table 3.10 presents the age composition of the bait collectors on the Kowie estuary. While youths dominated the subsistence bait fishery (60%), bait collectors in the 19–40 yrs age bracket formed the majority in the recreational sector (55%).

**Table 3.10:** Age distribution among bait collectors interviewed on the Kowie estuary.

Age (years)	% Subsistence bait collectors	% Recreational bait collectors
< 19	60	11
19 to 40	25	55
41 to 65	11	28
> 65	4	6

#### Temporal distribution of bait collectors

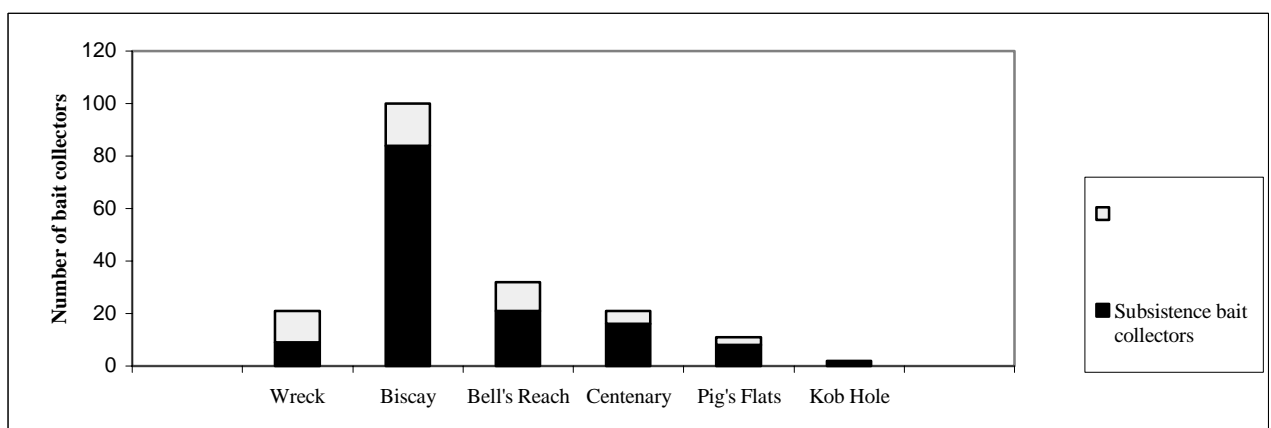
Monthly variation in the number of bait collectors recorded on the estuary during the survey period is shown in Figure 3.10. The highest number of subsistence bait collectors was in December, while that of recreational bait collectors occurred in January and April. In all months, the number of subsistence bait collectors exceeded recreational bait collectors. The mean number of bait collectors on the estuary per day was estimated at 8 (2 recreational and 6 subsistence). The temporal distribution of bait collectors tracked that of the linefishers (cf. Figure 3.1). The projected annual number of bait collecting outings on the estuary was estimated at 2,889.



**Figure 3.9:** Monthly variation in the number of subsistence and recreational bait collectors recorded on the Kowie estuary between July 2000 and June 2001.

### Spatial distribution of bait collectors

In contrast to the linefishery, in which there are numerous and diffuse fishing sites on the Kowie estuary, sites for bait collecting are few and more clearly defined. Bait collecting sites are: the Wreck, Bay of Biscay, Bell's Reach, Centenary Park, Pig's Flats and Kob Hole (see Figure 2.2). The mud flats at the Bay of Biscay and Bell's Reach were the sites most utilised for bait collecting (Figure 3.10).



**Figure 3.10:** The spatial distribution of bait collectors on the Kowie estuary between July 2000 and June 2001.

### Catch composition

In total, five invertebrates and five fish species caught from the Kowie estuary were used as bait

in the linefishery (Table 3.11). Mud prawn was the most frequently used bait (77%).

**Table 3.11:** Frequency of use of bait species caught from the Kowie estuary by linefishers interviewed on the Kowie estuary between July 2000 and June 2001.

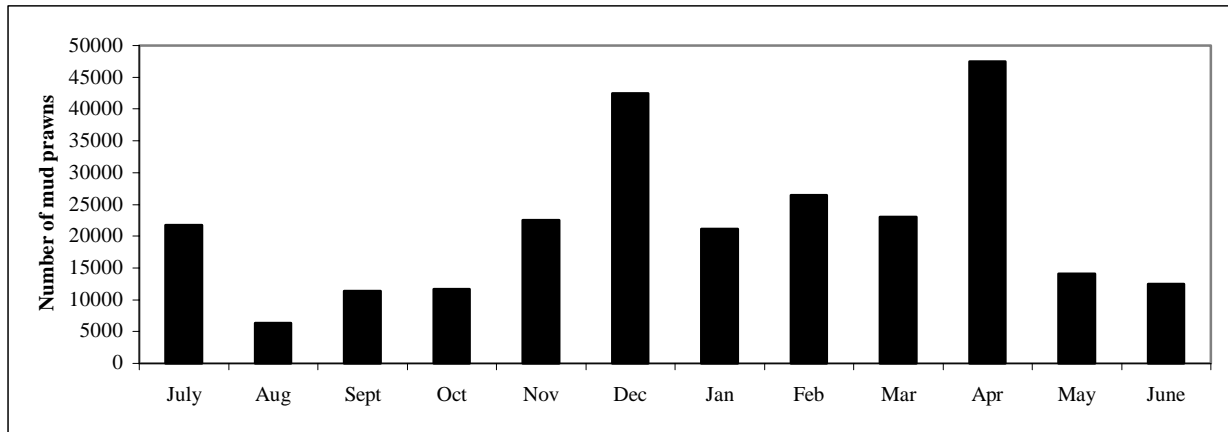
Species	Common name	Frequency of use
<i>Upogebia africana</i>	Mud prawn	77%
<i>Mugilidae</i>	Mullet	11%
<i>Callinasa kraussi</i>	Sand prawn	4%
<i>Rhabdosargus holubi</i>	Cape stumpnose	3%
<i>Penaeus indicus</i>	Swimming prawn	2%
Other		3%

### Number of mud prawns collected

The annual number of mud prawns collected from the Kowie estuary was 260,648. Most of the mud prawns (41%) were collected by subsistence bait collectors (Table 3.12). Most mud prawns were collected in April (18.2%) and December (16.2%), while the fewest were collected in August (2.4%) (Figure 3.11).

**Table 3.12:** Comparison of total number of mud prawns collected by various types of bait collectors interviewed on the Kowie estuary between July 2000 and June 2001.

Type of bait collectors	Number of mud prawns	%
Subsistence bait collectors	108,033	41
Subsistence linefishers	59,387	23
Shore-based recreational anglers	51,003	20
Boat-based recreational anglers	42,225	16



**Figure 3.11:** Monthly variation in the numbers of mud prawns collected from the Kowie estuary between July 2000 and June 2001. (n=260,648).

### 3.5.3 THE FOOT PATROL

During the foot patrol, a total of 133 shore-based linefishers and 84 bait collectors were interviewed. Some fishers were operating in places not accessible to the researcher, while others refused to be interviewed. In addition, no proper spatial or temporal stratification was carried out to match the temporal and spatial distribution of sampling effort with that of fishing effort. It is also unlikely that all the respondents answered all the questions truthfully. Hence there is bias in the data collected during the foot patrol. Only socio-economic data collected during this survey were analysed. Data on recreational bait collectors were not considered for analysis because of the small size of the sample (11).

#### Residence of the fishers

In the recreational shore-based linefishery, local residents made up 20% of the respondents, while 45% came from outside the Eastern Cape Province. In the subsistence bait fishery, 93% of the respondents were Port Alfred residents. All the subsistence linefishers interviewed were Port Alfred residents.

#### Education levels among fishers

Education levels among the recreational anglers were generally high: 50% had matric qualifications, while another 21% had post-matric training. Although 54% of the respondents in the subsistence linefishery said they had some form of primary schooling, only seven of the

interviewees said they had matric qualifications. None of the subsistence bait collectors had matric, although 49% said they had primary schooling.

### **Levels of formal employment among fishers**

In the shore-based recreational linefishery, 85% of the anglers said they had formal jobs, while in the subsistence linefishery and subsistence bait fishery the corresponding figures were 17% and 3%, respectively. Respondents who were still at school were dominant in both the subsistence linefishery (52%) and subsistence bait fishery (56%), but formed only 14% of the shore-based recreational anglers.

### **Motivation for fishing**

In the shore-based linefishery, food was given as the sole reason for fishing on the Kowie estuary by 14% of the respondents, while 43% and 3% gave recreation and income as the sole reason for fishing, respectively. Some linefishers had more than one reason for fishing: food and income (14%), food and recreation (24%), income and recreation (2%). The proportion of subsistence linefishers who said their catch was very important in their diets was 29%; 40% said it was fairly important, while 31% said it was not important.

Respondents who said they collected bait both for sale and for their own fishing formed the majority on the estuary (49%), followed by those who said all their bait was for sale (24%). Another group of respondents consisted said all their bait was for their own linefishing (27%).

### **Fishers' perceptions of the fishery**

The majority of the respondents in the subsistence bait fishery said the fishery resources 'belonged to God' (21%), in the subsistence linefishery 'to the government' (26%), and in the shore-based recreational fishery 'to nobody' (35%). Respondents who believed they 'owned' the fishery resources formed only 5% in the subsistence linefishery, 10% in the shore-based recreational sector, and 9% in the subsistence bait fishery. Respondents who believed the fishery had declined (in terms of catch) formed 66% of the subsistence linefishers, 44% of the subsistence bait collectors and 85% of the shore-based recreational anglers. Subsistence linefishers and shore-based recreational anglers who said they caught fewer species than in the past formed 83% and 74% of respondents, respectively.

Bag limits were seen as effective in protecting the fishery resources by 51% of the subsistence linefishers, 39% of the shore-based recreational anglers, and 66% of the subsistence bait collectors. The proportion of respondents who believe size limits are effective in protecting the fishery resources was 34% in the subsistence linefishery, 35% in the recreational shore fishery, and 16% in the subsistence bait fishery. In the linefishery, respondents with a valid fishing licence formed 74% in the shore-based recreational sector and 36% in the subsistence sector. Only 14% of the subsistence bait collectors were in possession of a bait collecting licence.

Respondents in the bait fishery regarded the main threats to the fishery as over fishing (81%), effects of the marina (80%) and siltation (62%). In the subsistence linefishery, the main threats were considered to be boating (46%), over fishing (15%) and siltation of the estuary (59%). In the shore-based recreational linefishery, over fishing was seen as a threat to the fishery by 74% of the respondents, while 69% and 62% saw the marina and siltation respectively, as major threats.

Only 5% of the respondents in the subsistence linefishery believed fishers should manage the fishery, while in the subsistence bait fishery and shore-based recreational fishery, the proportion was 20% and 9%, respectively. None of the linefishers or bait collectors interviewed was currently involved in the management of the Kowie estuary fishery.

### **Knowledge of fishing regulations**

Ninety seven percent of the subsistence bait collectors knew the correct bag limit for mud prawns. In the subsistence linefishery, 38% and 52% of the respondents knew the correct minimum legal size for *A. japonicus* and *P. commersonni*, respectively. The corresponding figures in the shore-based recreational sector were 57% and 63%, respectively. The proportion of subsistence bait collectors who said they always manage to reach their daily bag limit of mud prawns was 89%. The only fish species for which respondents said they managed to reach the daily bag limit was *R. holubi* (11% and 37% of the linefishers in the subsistence sector and shore-based recreational sector, respectively).

## **Fishing behaviour**

In the shore-based recreational linefishery, *A. japonicus* was the most targeted species (46%) followed by *P. commersonii* (42%), and *L. lithognathus* (7%). *R. holubi* was targeted by only 3% of the respondents in the shore based recreational sector. In the subsistence linefishery, *P. commersonii* the most targeted species (34%) followed by *R. holubi* (32%), and *A. japonicus* (15%). None of the respondents in the subsistence line and bait fisheries were members of fishing clubs, while in the shore-based recreational linefishery, fishing club members formed 13% of the respondents. The majority of the respondents in the subsistence linefishery (77%) and in the subsistence bait fishery (64%) operated on the estuary on a weekly basis, while in the shore-based recreational linefishery those who were annual holidaymakers to the estuary were the majority (41%)

Only 6% of the subsistence bait collectors and 7% of the subsistence linefishers operated in estuaries other than the Kowie, while the corresponding figure in the shore-based recreational linefishery was 63%. Almost 80% of the respondents in the subsistence bait fishery used cans to collect the mud prawns, while the rest used pumps. Only one shore-based recreational angler was recorded using a throw net as fishing gear; the rest used lines and rods. Among subsistence linefishers 92% used rods, and the rest hand lines.

## **3.7 DISCUSSION**

### **3.7.1 The linefishery**

Making valid interpretations and comparisons between different estuarine fishery data sets is beset with problems. First of all, estuarine ichthyofauna shows great spatial and temporal variation (Whitfield 1998), which is likely to have an impact on catch statistics and fishing effort. It is imperative that such statistics be based on long-term data series. Such data are not available for most of South Africa's estuarine fisheries, especially those outside KZN. Second, fishers use different fishing methods that affect the catchability of the fish (Baird *et al.* 1996). Third, there is no standard fishing effort under which the catch statistics are obtained. Fourth, researchers in estuarine fisheries sometimes express the same type of data in different units, for example, number of fishers, annual boat outings and fisher density for fishing effort. Fifth, in South Africa, there has been a bias towards recreational estuarine fisheries research, thus less

data are available on the subsistence sector, resulting in incomplete data on estuarine fishing in the country. Lastly, recreational catch data is subject to recall and prestige bias, while fishing competitions on estuaries tend to exaggerate catches statistics (Gaustella 1994). Despite the above disadvantages, fishery surveys are an essential tool in fisheries evaluation, planning and management (Schneiderm and Merna 2000; Stamatopoulos 2001).

There were numerous possible sources of error to the data collected during this survey. In order to minimise variance in fishery data, Pollock *et al* (1994) recommend stratification of sampling effort according to type of day. This means there should be more sampling on those days on which fishing effort is high than on those days on which it is less. During this survey, sampling was done in the ratio of two weekdays to one weekend day per month. However, Pradervand (1998) showed that weekend angling effort on the Kowie estuary was almost twice that on normal days of the week. Results from this survey are likely to have been biased by the mismatch between the temporal distribution of sampling effort and fishing effort on the estuary.

According to Pollock *et al.* (1994), spatial stratification of sampling effort removes bias in the data in those fisheries where certain sections of the water body are more heavily fished than others. Although during this survey the estuary was divided into sections, it was more for convenience than for the spatial stratification of sampling effort. Sampling effort was equally distributed along the sampling area, although those sections near the estuary mouth were more heavily fished than the rest. Data collected during this survey is likely to have been affected by the failure to match sampling effort with the spatial distribution of fishing effort on the estuary.

One cause of management failure in fisheries is the tendency to focus on the biology and ecology of the fish stocks while ignoring the fishers (Aguero and Lockwood 1986). However, this is slowly changing as fishers become recognised as key components of the fishery ecosystem, and are playing a greater role in fishery management. There is also increasing concern over fairness in the allocation of fishery benefits and the resolution of fishery disputes (Hanna 1997). Clearly, understanding and predicting fisher behaviour under different management options is now a major challenge facing fishery scientists and managers (Ditton and Hunt 2001). This calls for valid scientific data on not only fisher demographics, but also other factors that affect how fishers use the fishery resources, for example their attitudes, opinions, beliefs, perceptions and

fishing habits. Social-economic surveys of South Africa's estuarine fisheries are still relatively rare. Recent examples of socio-economic fishery surveys on the east coast of South Africa include Daniel (1994b) on the Swartkops and Sundays estuaries, Pradervand (1998) on the Kowie estuary, Pradervand *et al.* (in press) on the Mgeni estuary and Durban Harbour (in KZN) and Mann *et al.* (2002) on St Lucia.

Pollock *et al.* (1994) regarded identification of the various sub-groups that make up a fishery as essential to understanding the human component of a fishery. This consideration improves fishery management by helping to formulate specific management actions directed towards particular fisher sub-groups (Ditton 1996). This is especially relevant in the South African situation, where participants in estuarine fisheries operate within different socio-economic contexts, which is likely to affect their attitudes, perceptions, fishing behaviour and motivation. For example, in the Mgeni shore-based fishery, 97% of the linefishers were recreational (Pradervand *et al.* in press), while on the Kowie estuary approximately 75% are shore-based and recreational. Whereas 93% of the anglers on the Mgeni estuary were local residents, according to this study roughly 45% of the anglers in the shore-based recreational sector came from outside the Eastern Cape. This implies that the approaches to fishery management for the Mgeni estuary might not work on the Kowie estuary. Management strategies for South Africa's estuarine fisheries need to reflect the socio-economic climate they are under, and as such need to be estuary specific. For example, educational programmes on the Kowie estuary should probably be geared towards schools because of the considerable student proportion in the subsistence fisheries. Data on the socio-economics of estuarine fisheries in South Africa remains inadequate and more studies need to be conducted as an initial step towards their effective management.

Angler counts or angler outings can be used as a simple tool to indicate fishing pressure. However, they have been conducted on only a few estuaries in South Africa (e.g., Daniel 1994b; Baird *et al.* 1996; Pradervand 1998; Pradervand *et al.*, in press; Mann *et al.* 2002). According to Pradervand (1998), the Kowie estuary is one of the most heavily utilised estuaries in the Eastern Cape, with a mean angler count of 10.8 anglers per weekend day, and 10.0 anglers per weekday. Results from this study, however, reveal a lower angler count on the estuary (i.e., mean 4.4 anglers day<sup>-1</sup>). It is possible that there has been a reduction in fishing effort on the Kowie estuary since Pradervand's study. However, the two studies used different sampling strategies, which

could have contributed to the discrepancy between the two estimates. Whereas this study relied solely on the more accurate roving creel surveys, Pradervand (1998) based his estimate mostly on opportunistic boat patrols. Compared to some other estuaries in South Africa, the number of linefishers on the Kowie estuary is still relatively small. For example, the mean number of anglers per day on the Durban Harbour was 34 on weekdays and 121 on weekends (Pradervand *et al.*, in press); on the Swartkops estuary, Baird *et al.* (1996) recorded an average of 148 linefishers per weekday.

This study found the participation of previously disadvantaged racial groups (black, coloured, Asian) in the Kowie estuary fishery to be low (15%). Previously disadvantaged people were also under represented in surveys on seven other Eastern Cape estuaries, including the Gamtoos, Kromme and Sundays (Pradervand and Baird 2002). In contrast, the shore fisheries on the Mgeni estuary and in Durban Harbour are dominated by Indian males (Pradervand *et al.*, in press). The low participation rate of previously disadvantaged groups in the Kowie fishery may explain the low proportion of subsistence linefishers on the estuary observed during this study (14%). It could also be a sign of the poor state of the Kowie estuary fishery, forcing most of the subsistence linefishers to earn their living elsewhere.

The dominance of the recreational fishery on the estuary underlines the importance of the Kowie estuary fishery resources to the recreation and tourism industries in Port Alfred. Higher numbers of recreational than subsistence linefishers were also recorded on the Swartkops and Sundays estuaries (Daniel 1994b) and Langebaan lagoon (Wynberg and Branch 1991). In contrast, on the Kosi system, where there is a long tradition of subsistence fishing among the Tonga people, recreational anglers are outnumbered (Kyle 1986).

The accessibility of the Kowie estuary to shore-based linefishers is enhanced by the presence of elongated piers in the mouth region of the estuary and artificial embankments on both sides. This explains the concentration of linefishers in the lower reaches of the estuary. Daniel (1994b), Forbes (1998) and Pradervand (1998) also reported high numbers of anglers in the lower reaches of other Eastern Cape estuaries. Away from the mouth, land ownership along the Kowie estuary changes from public to private ownership. Shore-based linefishers enjoy less access to the estuary and so their numbers dwindle. Boat-based anglers on the other hand suffered less

restriction in access, and their distribution is independent of distance from the estuary mouth. Whitfield *et al.* (1994) showed that the upper reaches of the Kowie estuary contained more fish than the lower reaches. Efforts to regulate accessibility to the Kowie estuary fishery resources will need to look at the ownership of the land adjacent to the estuary. Another Eastern Cape estuary to which access is restricted by private land ownership is the Sundays estuary (Daniel 1994b).

There are three possible sources of error in the estimates of fishing effort obtained during this survey. First, interviews were conducted at the same time as the angler counts, which could have resulted in undercounting. This arose because the interviewer was unable to conduct angler counts on other parts of the estuary during the time of the interviews (see Pollock *et al.* 1994). A second possible source of error was the fact that estimation of fishing effort were based on duration of fishing trips, which was calculated from expected finishing times supplied by the respondents. If for some reason the respondents fished for longer or shorter periods than expected, fishing effort was underestimated or overestimated, respectively. Lastly, the exclusion of night sampling during this survey means actual annual fishing effort on the estuary was probably more than the estimate obtained from this study.

This study estimated annual fishing effort on the estuary to be 30,952 ang.hrs, which is far less than what Pradervand (1998) estimated for the recreational sector alone (53,290 ang.hrs). This difference could be due to the different sampling strategies used in the two studies, or to normal inter-annual variation in fishing effort. The use of police patrols during by Pradervand (1998) could have resulted in over sampling in the heavily fished areas of the estuary, resulting in over estimation of fishing effort. However, the difference in estimates could also mean that, despite an increase in the number of linefishers on the estuary, annual fishing effort on the estuary has decreased, possibly due to a decrease in the mean duration of fishing trips on the estuary. Although this was not verified during this study, it highlights the unreliability of angler counts alone to measure fishing pressure.

The high contribution of shore-based anglers to overall fishing effort on the estuary is due to the existence of numerous suitable public and private fishing sites, the absence of dangerous animals such as crocodiles in the estuary, and the fact that shore angling is relatively inexpensive in terms

of equipment and operating costs. The dominance of shore-based fishing effort in the Kowie estuary fishery was also reported by Pradervand (1998), although with a more pronounced difference (81% shore-based fishing effort vs. 19% boat-based fishing effort). Other estuaries that are dominated by the shore fishery include the Durban Harbour and the Mgeni estuary in KZN (Pradervand *et al.*, in press). On the other hand, on the St Lucia lake system 71% of the fishers were found to be boat-based (Mann *et al.* 1994).

The major factors controlling the temporal distribution of fishing effort on the Kowie estuary seem to be the occurrence of school and public holidays, and weather. The extreme increase in fishing effort during December was mainly recreational, as a result of the influx of holidaymakers into Port Alfred for the Christmas holidays. Subsistence fishing on the Kowie estuary peaked during March/April rather than in December/January. The influx of holidaymakers during December could have caused some subsistence linefishers to switch to other forms of livelihood such as casual labouring, or the illegal sale of bait to recreational anglers, resulting in a reduction in subsistence fishing effort. Indeed, the number of subsistence bait collectors was highest in December. The reduction in fishing effort during winter, especially in June, can be ascribed to winter weather and school terms, resulting in fewer visitors to Port Alfred. Forbes (1998) reported a similar temporal distribution of recreational fishing effort on the Kowie, and on other seven Eastern Cape estuaries.

Few fishing competitions are held within the Kowie estuary, so there was no observed increase in fishing effort associated with fishing competitions as reported for the Durban Harbour fishery (Gaustella 1994). The “kob and grunter runs” which occur along the east coast in July, and between November/December, respectively (Mann *et al.* 1994; Pradervand 1998), do not seem to have a major effect on fishing effort on the Kowie estuary. In contrast, windy spring weather and fishing competitions were found to be the main factors controlling fishing effort in the Durban Harbour and the Mgeni estuary fisheries (Pradervand *et al.*, in press).

Estimates of catch and catch rates obtained from this study were subject to three main sources of bias. First, total catch included fish that were retained and those that were released. Data on released catch was subject to memory relapses among the respondents (recall bias) and deliberate over inflation of catch figures (prestige bias). Second, respondents could have misidentified their

released catch. Third, total catch could only be estimated indirectly through catch rate, whose estimator was liable to the same biases outlined above. Fourth, the estimation of catch rates was based on the biased assumption that within a particular fishery sector, all linefishers exerted equal fishing effort on all the species caught.

According to Lamberth and Turpie (2001), estuary size alone accounts for 80% of the difference in fish productivity between South Africa's permanently open estuaries. This partly explains the relatively low annual fish catch for the Kowie linefishery (16,240 fish, SD=667), or 5.99 tons (SD= 0.81), compared to that from the larger estuaries in KZN. For example, in 1992 a total of 383,135 fish weighing 81.6 tons were caught from the Kosi system (Kyle 1993), while in 2000 over 23,000 fish with a mass of 16.9 tons were caught from the Durban Harbour (Pradervand *et al.*, in press). The recreational catch alone from St Lucia was estimated at 64.5 tons in 1993 (Mann *et al.* 2002). The catch estimate from this study was obtained over a one-year period, and should be treated with caution, since there is likely to be yearly temporal variation in fish biomass as well as fishing effort on the estuary. However, the catch estimate is much less than the 10.0 tons estimated for the estuary by Lamberth and Turpie (2001).

Despite the fact that shore-based recreational fishing effort was almost three times the fishing effort in the subsistence sector, the two sectors caught roughly the same number of fish. One probable explanation is that high targeting of *R. holubi* by subsistence linefishers increased the overall catch in that sector. The selective fishing carried out by the recreational anglers could also have resulted in reduced overall catch in that sector. Estuarine fisheries where recreational anglers are responsible for most of the catch include the Durban Harbour and the Mgeni estuary fisheries (Pradervand *et al.*, in press). In contrast, on the Kosi system subsistence linefishers caught most of the catch, both by number and by mass (Kyle 1993).

The absence of tropical and subtropical species from the Kowie estuary resulted in catches that showed less species diversity than those from KZN estuaries. For example angler catches from the Durban Harbour consisted of 85 species (Gaustella 1994), while those from the St Lucia lake system consisted of 55 (Mann *et al.* 2002). In comparison, only 15 and 17 species were recorded in angler catches from the warm temperate Swartkops and Sundays estuaries, respectively (Daniel 1994b).

Estuary dependent marine migrant species dominated most of the catch from the Kowie estuary. These are species which breed at sea and enter the estuary as juveniles to feed and grow. Estuary-dependent migrant fishes also dominated catches from the Durban Harbour (Gaustella 1994; Pradervand *et al.*, in press), St Lucia (Mann *et al.* 2002), the Mgeni estuary (Pradervand *et al.*, in press) and the Kosi system (James *et al.* 2001). Whitfield *et al.* (1994) ascribed the high incidence of marine migrants in the Kowie to the great marine influence in the system. The maintenance of a permanent link between the Kowie estuary and the sea, and the protection of its nursery and feeding areas should therefore be key issues in the management of fishery resources of the Kowie estuary.

Although this study recorded 26 species in the catch, over 60% of the catch by number consisted of *R. holubi*. Domination of the catch by a single species has been reported for a number of estuaries in South Africa, although multi-species domination is more common. For example, on the Great Fish estuary, 62.8% of the recreational catch by number consisted of *P.commersonnii* (Pradervand and Baird 2002), and in the shore fishery on the Mgeni estuary, 68% of the catch by number was *Mugil cephalus* (Pradervand *et al.*, in press). Other Eastern Cape estuaries where *R. holubi* dominated catch by numbers, although at a lesser extent, include the Bushmans and Swartkops (Pradervand and Baird 2002). In the estuaries of KZN, the same species makes minimal contribution to the catch by numbers, for example in the Durban Harbour and Mgeni estuary fisheries (Pradervand *et al.*, in press).

The relatively low biomass of the caught fish as compared to their numbers is due to the presence of a large number of small fish in the catch, especially *R. holubi* (62%). This is to be expected since estuaries act as nurseries for many fish species (Whitfield 1998). Lower catches by biomass as compared to fish numbers were also recorded in the Durban Harbour shore fishery and in the Mgeni estuary (Pradervand *et al.*, in press). Mass and numerical species composition were reported to be similar in the Kosi system gill net fishery (Kyle 1999).

Published data on catch rates are available for a limited number of estuarine fisheries in South Africa, for example the Durban Harbour and the Mgeni estuary (Pradervand *et al.*, in press), some Eastern Cape estuaries such as the Swartkops and the Sundays estuaries (Daniel 1994b; Pradervand and Baird 2002), and the recreational sectors on the St Lucia estuary (Mann *et al.*

2002) and on the Kosi estuary (James *et al.* 2001). The overall catch rate by number estimated for the Kowie estuary in this study (0.57 fish.ang.<sup>-1</sup>h<sup>-1</sup>, SD=0.23) seems very high when compared to that reported by Pradervand (1998) (0.22 fish.ang.<sup>-1</sup>h<sup>-1</sup>) for the recreational sector alone on the same estuary. It is also higher than the estimates from some sub-tropical estuaries of KZN. For example, overall catch rate by number in the Durban Harbour fishery was 0.181 fish.ang.<sup>-1</sup>h<sup>-1</sup>, while that on the Mgeni estuary was estimated at 0.098 fish.ang.<sup>-1</sup>h<sup>-1</sup> (Pradervand *et al.*, in press).

The exceptionally high overall catch rate by number on the Kowie estuary is explained by the high catches of *R. holubi* on the estuary, especially in the subsistence sector. However, overall catch rate by number is relatively low when compared to that on some of the large permanently open estuaries in KZN. For example, in the shore fishery on the St Lucia estuary, Mann *et al.* (1994) recorded a catch rate of 0.86 fish.ang.<sup>-1</sup>h<sup>-1</sup> while Gaustella (1994) estimated a catch rate of 0.60 fish.ang.<sup>-1</sup>h<sup>-1</sup> in the boat-based recreational fishery in Durban Harbour.

While this study estimated overall catch by mass on the Kowie estuary to be 0.298 kg.ang.<sup>-1</sup>h<sup>-1</sup>, (SD=0.319) that recorded on the Swartkops and Sundays estuaries was much higher, 0.6 kg.ang.<sup>-1</sup>h<sup>-1</sup> and 1.5 kg.ang.<sup>-1</sup>h<sup>-1</sup>, respectively (Baird *et al.* 1996). This study found that in terms of mass, it was the recreational sector that was responsible for the highest catch rate by mass on the estuary, especially the boat-based sector (0.43 kg.ang.<sup>-1</sup>h<sup>-1</sup>). These results are comparable to the 0.44 kg.ang.<sup>-1</sup>h<sup>-1</sup> estimated by (Pradervand 1998) for the recreational sector on selected Eastern Cape estuaries. Catch rate by mass was comparatively lower (0.28 kg.ang.<sup>-1</sup>h<sup>-1</sup>) in the recreational fishery on St Lucia system (Mann *et al.* 2002), and on the Kosi system (0.25 kg.ang.<sup>-1</sup>h<sup>-1</sup>, James *et al.* 2001). A similarly low catch rate by mass was recorded by Pradervand *et al.* (in press) for the boat-based recreational sector in the Durban Harbour. (0.15 kg.ang.h-1).

According to Pradervand and Baird (2002), seasonality of major catch species plays an important role in determining catch rates in the eight Eastern Cape estuarine fisheries they studied. Results from this study confirm those findings. The higher catch rate by number during February and April was due to increased catches of *R. holubi*. The higher catch rate by mass that occurred between November and January was due to increased catches of *A. japonicus* and *P. commersonii*. Distinct trends in catch rate caused by seasonal migration of *A. japonicus* and *P.*

*commersonnii* have also been reported in the St Lucia recreational fishery (Mann *et al.* 2002). However, Baird *et al.* (1996) detected no significant differences in monthly catch rates on the Swartkops and Sundays estuaries between 1980 and 1993, and concluded that seasonal migration of fish had minimal impact on catch rates for those systems. Long-time data series on catch rates on the Kowie estuary fishery are required before valid conclusions concerning catch rate on the estuary can be made.

Van der Elst (1989) listed *R. holubi* as a major angling species in South Africa's estuaries. Lamberth and Turpie (2001) estimated annual catch *R. holubi* from South Africa's estuaries to be in the region of 15.89 tons, of which 1.63 tons is from estuaries along the east coast (excluding Transkei and KZN). Although not quantified, Cowley (2000) suggested that exploitation of *R. holubi* in the estuaries between Port Elizabeth and East London is high. The species is absent from the fisheries off the west coast of South Africa, and from some estuaries of KZN (Lamberth and Turpie 2001).

Three possible explanations for the relatively high catch rate of *R. holubi* in the Kowie estuary fishery are: high abundance; high catchability; and high specific targeting, especially in the subsistence sector. The presence of relatively high stock levels of *R. holubi* in the Kowie estuary was implied by high seine-net catches of the species from the estuary (Whitfield *et al.* 1994). This is due to presence of dense beds of *Zostera* in the estuary. On the Great Fish estuary, where *Zostera* is virtually absent, the seine-net catch rate of *R. holubi* was lower (Whitfield *et al.* 1994), and the catch rate in the recreational sector on the estuary was less than  $0.1 \text{ fish.ang.}^{-1}\text{h}^{-1}$  (Pradervand 1998). The fact that most subsistence fishers operate in the lower reaches of the Kowie estuary, which Whitfield *et al.* (1994) showed to contain the highest number of *R. holubi*, probably also improve its catch rate on the estuary. The use of pilchard and chokka squid rather than mud prawn by some recreational anglers could also have contributed to a decline in the catch rate of *R. holubi* in that sector. Another probable explanation for the dominance of *R. holubi* in the catch numbers is increased specific targeting by subsistence linefishers as a result of decreased stock levels of larger species such as the such as *P. commersonnii* and *A. japonicus*.

In spite of contributing over 62% of the catch numbers in this study, *R. holubi* formed only 6.5% of the catch by mass. Pradervand and Baird (2002) reported a much lower estimate (1.5%) for

the species in the recreational catch on the estuary. Recreational anglers most likely released most of *R. holubi* catch due to their small size. Whereas the minimum legal size for *R. holubi* is 200 mm TL, Whitfield *et al.* (1994) reported that almost 90% of the species caught in seine nets on the Kowie estuary were below 150 mm TL. This explains the relatively high number of undersized individuals caught during this study, and underscores the importance of the estuary as a nursery and feeding area for *R. holubi* juveniles. It is probable that along the east coast of South Africa, the Kowie estuary is a major nursery and feeding area for *R. holubi*. Over exploitation of juvenile fish in estuaries poses a threat to coastal fisheries (Cowley 2000). Although for most estuaries in the region there is no historical catch data, such data is available for the Swartkops and Sundays estuaries where Baird *et al.* (1996) reported a drop in the catch rate of *R. holubi* between 1980 and 1992 for both those estuaries.

The importance of *A. japonicus* in estuarine fisheries lies in its contribution to catch biomass rather than catch numbers. The species contributes 48% of the annual fish biomass in Eastern Cape estuaries (Lamberth and Turpie 2001). According to the results of this study, *A. japonicus* dominated the catch biomass on the Kowie estuary (60%). Although Pradervand and Baird (2002) found the species to be dominant by mass in the recreational fishery on the estuary, its contribution was much lower (28.4%). In comparison, the recreational fishery on the Gamtoos and Sundays estuaries, *A. japonicus* was responsible for 82.6% and 69.2% of the catch biomass, respectively (Pradervand and Baird (2002).

Results from this study provide further evidence of the collapse of the stock of *A. japonicus* in South Africa's waters, which is down to 6% of its pristine spawner mass (Lamberth in Mann 2000) The contribution of *A. japonicus* to catch number in the Kowie estuary has decreased to 7% (this study), from 10.1% in 1996/1997 (Pradervand (1998). Although both studies were conducted for only one year, they provide useful data on the trend of the *A. japonicus* fishery on the Kowie estuary. The contribution of *A. japonicus* to the catch numbers in the Kowie estuary fishery is lower than the 10% reported by James *et al.* (2001) for the recreational fishery on the Kosi estuarine system. Among the eight Eastern Cape estuaries studied by (Pradervand (1998), the contribution of *A. japonicus* to recreational catch numbers was highest on the Sundays and Gamtoos estuaries (42.1% and 20.3%, respectively). In the fisheries in Durban Harbour and the

Mgeni estuary, *A. japonicus* was unimportant both in terms of catch biomass and catch number (Pradervand and Baird, in press).

Data on catch rates of *A. japonicus* is available for only a few estuarine fisheries in South Africa (Daniel 1994b; Baird *et al.* 1996; Pradervand 1998; James *et al.* 2001; Mann *et al.* 2002; Pradervand and Baird 2002). In the recreational fishery on the Kowie estuary, Pradervand and Baird (2002) found that *A. japonicus* had a catch rate of 0.02 fish.ang.<sup>-1</sup>h<sup>-1</sup>. This is similar to the estimate obtained during this study (0.03 fish.ang.<sup>-1</sup>h<sup>-1</sup>). Also, it differs little from that reported in the recreational sector on the St Lucia estuary, which decreased from 0.04 fish.ang.<sup>-1</sup>h<sup>-1</sup> in 1986 to 0.03 fish.ang.<sup>-1</sup>h<sup>-1</sup> in 1999 (Mann *et al.* 2002).

This study shows the overall catch rate of *A. japonicus* as third highest on the estuary; hence the rate does not correspond with the species 26<sup>th</sup> position in overall abundance in the seine-net catches on the estuary (Whitfield *et al.* 1994). It is unlikely that “kob runs” have significantly inflated the catch rate since they occur during mid-winter (Pradervand and Baird 2002), a period of relatively low fishing activity on the Kowie estuary. A more likely explanation is that *A. japonicus* are highly targeted by anglers, despite their low abundance. This is suggested by the results of this study, which show that 46% of shore-based recreational anglers specifically targeted *A. japonicus*.

The mean body size of *A. japonicus* caught during this study was 366.6 mm TL, which is not only below the minimum legal size, but is also below the size at which the species reaches sexual maturity (1070 mm TL (Griffiths 1997)). Pradervand (1998) raised concern about the high incidence of juveniles in the recreational catch on the Kowie estuary, although he recorded a higher mean body size for the species (535.5 mm TL). It is apparent that on the Kowie estuary, *A. japonicus* continues to be under severe fishing pressure and that drastic measures are needed to prevent further stock collapse of the species on this estuary. Among the measures recommended by Pradervand and Baird (2002) are raising its minimum legal size to at least 600 mm TL, seasonal banning of fishing in estuaries, banning of certain angling methods, and the introduction of catch-and-release fishing.

*P.commersonnii* is another major angling species in South Africa's estuaries (van der Elst 1989). Lamberth and Turpie (2001) estimated the annual harvest *P.commersonnii* from South Africa's estuaries to be in the region of 416.01 tons, out of which 73.51 tons come from estuaries along the east coast (excluding the former Trankei region and KZN). In the estuaries between Port Elizabeth and East London, the exploitation level of *P.commersonnii* was reported to be high (Cowley 2000).

According to this study, *P. commersonnii* was the second most important species by mass (18.7%), and by number (17.3%). In the recreational catch of a number of Eastern Cape estuaries, for example, the Bushmans, the Great Fish, and the Swartkops, *P. commersonnii* dominated the catch both by number and biomass (Pradervand and Baird 2002). For example, on the Great Fish estuary, 62.8% of the catch by number and 60.5% of the fish biomass were due to *P. commersonnii*. In some estuaries of KZN, the species dominated the recreational catch both in terms of numbers and mass, such as on the St Lucia (Mann *et al.* 2002) and Kosi estuaries (James *et al.* 2001). However, in the shore fishery of the Mgeni estuary, *P. commersonnii* was less dominant: 9.9% by number and 8.4% by mass (Pradervand *et al.*, in press).

Pradervand and Baird (2002) and Pradervand (1998) estimated catch rates of *P.commersonnii* in the recreational sector on a number of estuaries in the Eastern Cape. Their estimate for the Kowie estuary (0.04 fish.ang.<sup>-1</sup>h<sup>-1</sup>) was relatively low compared to that obtained in this study (0.089 fish.ang.<sup>-1</sup>h<sup>-1</sup>). Further studies are needed to ascertain whether there has been a decline in the catch rate of *P.commersonnii* in the Kowie estuary since Pradervand's (1998) study, or whether the differences in the catch rates between the two studies are due to different sampling strategies, natural environmental variation or different levels of fishing efforts.

Since catch rate can be used as an indication of stock level in fisheries (Daniel 1994b), the abundance of *P.commersonnii* on the Kowie estuary as compared to the abundance of *R. holubi* appears very low. This is confirmed by gill net catches on the estuary, in which *P.commersonnii* ranked tenth in abundance (Whitfield *et al.* 1994). On the Great Fish estuary, where the abundance of *P.commersonnii* was recorded as much higher (Whitfield *et al.* 1994), the catch rate estimated by (Pradervand 1998) was also much higher (0.12 fish.ang.<sup>-1</sup>h<sup>-1</sup>).

Despite the low catch rate of *P.commersonnii* in the gill net catches on the Kowie estuary (Whitfield *et al.* 1994), the species had the second highest catch rate by number in this study. This points to specific targeting of the species by anglers, which would explain its comparatively high catch rate in the boat-based recreational sector (0.13 fish.ang.<sup>-1</sup>h<sup>-1</sup>). Specific targeting appeared the main reason for continued dominance of *P.commersonnii* in anglers' catches on the Swartkops and Sundays estuaries, despite a decline in their abundance by 61% and 39%, respectively (Baird *et al.* 1996). The same situation seems to be occurring on the Kowie estuary, as seen from the relatively high proportion of *P.commersonnii* in the catch, despite the species low population level in the estuary. Another factor likely to affect the catch rate of *P.commersonnii* on the Kowie estuary is the occurrence of “grunter runs” into the estuaries along the east coast during November and December (Mann *et al.* 1994). This can explain the increase in catch rate by mass of *P.commersonnii* that occurred in November/December during this study; similarly, Pradervand (1998) reported an increase in Eastern Cape estuaries during November to January.

*L.lithognathus* is listed by van der Elst (1989) as one of the major angling species in South Africa's estuaries. According to van der Elst and Adkin (1991) the *L.lithognathus* fishery in South Africa is sound and not under pressure. However, Bennett (1993a) reported that since the 1970s the catch rate of *L.lithognathus* along the east coast of South Africa has decreased by 90%. Lamberth and Turpie (2001) estimate a total of 65 tons of the species are harvested annually from South Africa's estuaries, of which less than 7% come from estuaries along the east coast (excluding the former Transkei and KZN). Cowley (2000) observed that in the estuaries between Port Elizabeth and East London, the species is highly exploited by subsistence, recreational and illegal commercial fishers, and its stock status ranges from variable to poor.

The low catch rate by number of *L.lithognathus* recorded in this study (0.008 fish.ang.<sup>-1</sup>h<sup>-1</sup>) is explained by the low stock levels of the species in the Kowie estuary. *L.lithognathus* ranked eleventh in abundance out of 19 species taken in the gill net catches on the Kowie estuary (Whitfield *et al.* 1994). The relatively higher catch rate of *L.lithognathus* (0.03 fish.ang.<sup>-1</sup>h<sup>-1</sup>) recorded by Pradervand (1998) in the recreational sector on the Great Fish estuary was due to the higher stocks levels of the species on the estuary. Whitfield *et al.* (1994) found higher densities of *L.lithognathus* in the upper reaches of the Kowie estuary than in the lower reaches. This

probably contributes to the very low catch rate by number of the species among subsistence linefishers ( $0.06 \text{ fish.ang.}^{-1}\text{h}^{-1}$ ), since they operate mostly in the lower reaches of the estuary. The boat-based anglers were able to access the upper reaches of the estuary, resulting in relatively higher catches ( $0.08 \text{ fish.ang.}^{-1}\text{h}^{-1}$ ). On the Swartkops estuary, Daniel (1994b) suggested that a concentration of *L.lithognathus* in the lower reaches of the estuary exposed the species to higher angling pressure.

On the Swartkops estuary, historical records show that whereas *L. lithognathus* was once a dominant species, it is now absent from gill net catches on the estuary (Baird *et al.* 1996). Yet that species formed 2% of the recreational catch by number on the estuary (Pradervand and Baird 2002). Daniel (1994b) identified high targeting of *L. lithognathus* as the reason for its continued presence in line catches on the estuary, despite its absence in gill net catches. *L. lithognathus* was unimportant in the recreational catch on all eight Eastern Cape estuaries investigated by Pradervand (1998), especially on the Sundays and the Kariega. A high degree of estuary dependency, formations of predictable aggregations, and a large size at maturation are other factors that make *L. lithognathus* very vulnerable to over exploitation (Bennett 1993a). Results from this study support Attwood and Bennett (1995) view that a bag limit of five *L. lithognathus* per day per person has failed to protect the species from over exploitation; those authors recommend that the limit be reduced to two per person per day.

Species of Mugilidae were under represented in catches from the Kowie estuary despite their high occurrence in gill net and seine-net catches (Whitfield *et al.* 1994). This is because of the high use of rods and lines in the Kowie linefishery, while mullets, being detritivorous, seldom take bait. The fact that *M. cephalus* is found mostly in the upper reaches of the Kowie estuary (Whitfield *et al.* 1994), where there were fewer subsistence linefishers, also contributed to the very low catch rate of the Mugilidae in the subsistence sector. However, in the shore-based fisheries in the Durban Harbour and Mgeni estuary the Mugilidae were the most important species by mass (Pradervand *et al.*, in press). Sub-tropical species such as *Acanthopagrus berda*, *Clarius gariepinus*, *Caranx* sp. and *Lutjanus* sp. were of little or no importance in the Kowie estuary fishery, although they form a major component of the catch from various estuaries in KZN.

### **3.7.2 The bait fishery**

Much of our knowledge of human utilisation of bait organisms in South Africa has been acquired through supplementary investigations into bait usage by fishers in various fisheries (e.g., Forbes 1998; Pradervand 1998). Little research has concentrated specifically on bait fisheries in South Africa or elsewhere. However, bait fisheries are an important component of estuarine fisheries. Not only do estuarine angling and bait collecting share the same sites, but considerable overlap often exists between the two fisheries in aspects such as fishing period, user groups, and regulation enforcement. Because of this, estuarine bait fisheries should be studied and managed as an integral component of estuarine fisheries; striving for effective management in one fishery while ignoring the other will frustrate progress towards sustainability in estuarine fisheries.

Insufficient published socio-economic data exist on the world's bait fisheries, including that for South Africa. With the exception of the Langebaan lagoon (Wynberg and Branch 1991) and the Knysna estuary (Cretchley 1996) little is known about the people who collect bait from South Africa's estuaries.

According to the results of this study, three user groups participate in the Kowie estuary bait fishery: subsistence bait collectors, subsistence anglers who are also subsistence bait collectors, and recreational bait collectors. Cretchley (1996) reported that the same groups of users operate on the Knysna estuary. For the Langebaan lagoon bait fishery, Wynberg and Branch (1991) used bait collecting seasons to categorise the user groups into: peak holiday, weekend and public holiday, winter weekend, and working-day bait collectors. Being a multi-user rather than a single-user fishery, the Kowie bait fishery is complex to manage. Not only do the different user groups collect bait for different reasons, but also they come from different socio-economic backgrounds, and thus view the bait fishery from different perspectives. A primary challenge facing managers of this fishery is how to formulate a common vision for the Kowie bait fishery from such a diverse user group.

Similar to the situation on the Kowie estuary, subsistence bait collectors formed the majority on the Swartkops estuary (Daniel 1994b), Knysna estuary (Cretchley 1996), and some estuaries in KZN such as Richards Bay and the Kosi and St Lucia systems (Tomalin and Robertson 1997). This differs from the situation on the Langebaan lagoon where 73% of the bait collectors were

recreational (Wynberg and Branch 1991). Close proximity of the Kowie estuary mudflats to the black and coloured townships, lack of alternative job opportunities, the presence of an illegal trade in mud prawns, and the low-level of technology involved in digging up bait are some factors responsible for the relatively high proportion of subsistence bait collectors on the Kowie estuary. Whereas on the Knysna estuary, women formed 75% of the subsistence bait collectors, on the Kowie estuary youths aged below 19 years dominate the fishery (60%).

The estimate of 10-20 bait collectors operating on the Kowie estuary given by Hill (1967) was not based on proper sampling procedures and was probably only a rough guide. The estimate of annual bait collecting outings obtained during this study (2,889) is comparatively lower than what Cretchley (1996) reported for the six popular sites on the Knysna estuary (20,200), and that recorded on the Langebaan lagoon (24,450) by Wynberg and Branch (1991). Not only are the mudflats on the Kowie estuary fewer and smaller than those on the Knysna estuary, but they also contain relatively fewer mud prawns (see below). In addition, the collecting areas around the Kowie estuary are less populated than those around the Knysna estuary, resulting in comparatively less people using the estuary for recreation or for subsistence, thus the demand for bait is less.

The size of the mudflats, abundance of bait, accessibility and probably fear for personal safety seem to be key determinants in the spatial distribution of bait collectors on the Kowie estuary. The mudflats at the Bay of Biscay and Bells Reach are the areas on the Kowie estuary most popularly used for bait collecting, probably due their large area, central position, and relatively high abundance of mud prawns. This pattern is similar to the distribution of bait collectors already described by Forbes (1998). Although the mudflats at the “Wreck” are also easy to access, they seem less popular with bait collectors, probably due to their smaller size, lower number of mud prawn, and heavy trampling. The Bells Reach mudflats are situated further away from the township, hence fewer subsistence bait collectors operate there. On the Langebaan lagoon, a lack of boats excluded some fishers from the centre banks of the lagoon where high numbers of sand prawns are found (Wynberg and Branch 1991). The presence of areas closed to bait collecting will also restrict the distribution of bait collectors on an estuary; on the Kowie estuary bait collecting is not allowed on the Civic Centre lagoon.

This study revealed that organisms collected from the Kowie estuary form the major proportion of bait used by the linefishers on the estuary. A lack of management, ineffective law enforcement, and high demand for bait may result in unsustainable pressure on the bait organisms in the estuary. For example, Daniel (1994a) reported that the illegal sale of bait on the Swartkops estuary was due to the failure of the legal trade to satisfy demand.

Although 10 bait species were collected from the estuary during the survey, the Kowie bait fishery is essentially monospecific since the mud prawn *Upogebia africana* dominates the catch by number. Similar dominance of the bait fishery by mud prawns has been observed on other Eastern Cape estuaries (Daniel 1994a; Forbes 1998; Praverdand 1998), due to the abundance of mud prawns in the permanently open estuaries of the region (Hanekom *et al.* 1988; Forbes 1998). Daniel (1994a) observed that mud prawns occur in the upper 30 cm of the substratum, which makes it easy to dig them out. The geographical distribution of mud prawns is limited by temperature (Hill 1967; de Villiers and Hodgson 1999), and penaeid prawns, such as *Penaeus indicus* and *P. japonicus*, dominate the bait fishery in the sub-tropical estuaries of KZN (Forbes and Benfield 1985).

Sand prawns (*Callinasa kraussi*) were an insignificant catch on the Kowie estuary, unlike in the Langebaan lagoon bait fishery where they are common (Wynberg and Branch 1991). Polychaete worms such as bloodworms (*Arenicola loveni*) and pencil bait (*Solen capensis*) contributed less to total catch by number on the Kowie estuary than what was reported for the Kariega estuary (Forbes 1998). The bait worms *Arenicola marina* and *Nereis virens* are important in the temperate bait fisheries of the northern hemisphere (Blake 1979). It has not been determined whether the low catch of polychaete worms on the Kowie estuary is a result of naturally low population levels, past over exploitation, or habitat degradation on the estuary.

According to Hill (1967), bait collectors on the Kowie estuary could remove up to 48,000 mud prawns every fortnight, which amounts to as many as 1.2 million per annum. Judging from the estimate of 260,648 mud prawn collected during the one-year survey carried out for this study, it seems there has been a dramatic drop in the number of mud prawns collected from the Kowie estuary during the last decades, despite an increase in the number of bait collectors. This conclusion is supported by relatively recent data from Forbes (1998) who reported a decline in

mud prawn density on the Kowie estuary from  $600 \text{ m}^{-2}$  to  $200 \text{ m}^{-2}$ . In comparison, bait collectors annually collect an estimated  $1.858 \times 10^6$  (700 kg dry mass) of mud prawns from the Knysna estuary (Cretchley 1996), and 222,500 individual mud and sand prawns from the Langebaan lagoon (Wynberg and Branch 1991).

The Knysna estuary is the second largest permanently open estuary in South Africa, with extensive mud flats containing an estimated stock of  $2.19 \times 10^8$  mud prawns with a biomass of 82.7 tons (Cretchley 1996). The entire stock of prawns on the Langebaan lagoon has been estimated at over 25 million (Wynberg and Branch 1991). According to Hanekom and Baird. (1992) extensive beds of *Zostera capensis* on the Swartkops estuary contribute to the high population of mud prawns on the estuary. It is likely that the *Zostera* beds on the Kowie estuary play a similar role, and their protection from alternative land use or development should form part of the bait fishery conservation efforts on the estuary.

Catch and effort statistics in the bait fishery show a trend corresponding with the linefishery, with two peaks, one in December and another in April. This may be expected as good summer weather and the Christmas and Easter holiday periods increase linefishing on the estuary, resulting in increased demand for bait. On the Knysna estuary, the three peak bait collecting periods coincided with public holidays rather than school holidays (Cretchley 1996). The lower number of mud prawns collected by subsistence bait collectors in December was probably due to the presence of fewer subsistence bait collectors as they sought alternative income-generating schemes during the peak holiday season. Bad winter weather coinciding with school terms may have accounted for the low number of mud prawn collected during August, since a decline in fishing level will lower the demand for bait. Forbes (1973) suggested that populations of *Callinasa kraussi* in South Africa's estuaries are protected from over exploitation because their main breeding period occurs outside periods of maximum bait collecting effort. Mud prawns on the Kowie estuary could be similarly 'protected' since they breed mostly in September and October (Forbes 1998), also a period of low bait collecting effort on the estuary. Cretchley (1996) showed that recruitment of mud prawn juveniles into the Knysna estuary was four times the exploitation rate on the estuary. High larval recruitment appears responsible for the stable annual harvest of bait organisms from the Kosi system over the last 30 years (Tomalin and Robertson 1997). In view of increasing sedimentation in the lower reaches of the Kowie estuary,

maintenance of a permanent link to the sea could be a crucial factor in the management of the Kowie estuary bait fishery.

Although Hill (1967) studied the reproductive biology of mud prawn on the Kowie estuary, other aspects of its population dynamics in this estuary must be investigated before effective management of the bait fishery can be achieved.

Concern has been raised over the effect of removing large numbers bait organisms from estuaries, especially after the introduction of the bait pump, which improved the efficiency bait collecting (Daniel 1994a). One of the direct impacts of collecting bait is the depletion of their stocks. A decline in mud prawn densities on estuaries could have severe consequences for the rest of the estuarine ecosystem since mud prawns are a source of food to numerous estuary macrofauna, especially birds and fish, and they play a role in the physical and chemical dynamics of estuaries (Wynberg and Branch 1991; Hanekom and Baird 1992; Daniel 1994a). Exploitation has been blamed for the decline in density of mud prawns in the exploited areas of the Langebaan lagoon (Wynberg and Branch 1991) and the Kowie estuary (Hill 1967; Forbes 1998). Although no estimate of population density of mud prawns was conducted during this study, Cretchley (1996) found no significant differences between the numbers of mud prawns in exploited and unexploited areas of the Knysna estuary.

Mud prawn collectors on the Knysna estuary annually remove only 0.85% of the entire stock of the estuary (Cretchley 1996), while on the Langebaan lagoon the figure is less than 0.01% of the entire stock of mud prawn and sand prawn (Wynberg and Branch 1991). Bait collectors along the coast of KZN (excluding the Kosi system) annually remove less than 1% of the available bait biomass (Tomalin and Robertson 1997). Depletion of mud prawn stocks could be more problematic on the Kowie estuary than on other estuaries in South Africa where studies have been conducted, although there are no data to show that this is primarily due to bait collecting. There is a need to study the impact of environmental degradation (especially that of reduced freshwater inflow) on the mud prawn stocks of the Kowie estuary.

Various authors have recommended small-scale commercial exploitation of bait species on South Africa's estuaries as a way of exploiting under-utilised estuarine resources, and likewise

expanding access to estuarine resources among previously disadvantaged population groups. The healthy mud prawn stocks on the Langebaan lagoon (Wynberg and Branch 1991) and the Knysna estuary (Cretchley 1996) make them ideal objects for such ventures. For the Kowie estuary, caution should be exercised since mud prawn abundance seems to be lower than in previous decades. Another direct impact of bait collecting is the change in mean body size of the bait species as bait collectors selectively choose large specimens (Wynberg and Branch 1991). A reduction in mean body size of mud prawns in exploited areas was reported by Hill (1967) in work done on the Kowie estuary, on the Langebaan lagoon by Wynberg and Branch (1991), and on the Knysna estuary by Cretchley (1996). Clearly, there is a need for detailed long-term studies on mud prawn stock levels on the Kowie estuary.

Legal methods of collecting bait in estuaries in South Africa include the use of tins, prawn pumps and prawn pushers; illegal bait collecting methods involve the use of spades or forks, and hands or feet. However, bait collecting with the use of forks and spades has been reported on the Knysna estuary (Cretchley 1996), Swartkops estuary (Daniel 1994a), and Langebaan lagoon (Wynberg and Branch 1994).

Daniel (1994a) reported that use of spades and forks on the Swartkops estuary resulted in areas of troughs and mounds that were slower to be recolonised than areas where other equipment had been used. During this study no mounds and troughs were observed in the popular mud prawn collecting sites on the Kowie estuary, implying that habitat destruction through the use of forks and spades in those areas was not yet a major problem. Cretchley (1996) attributed the low disturbance of sediments on the Knysna estuary to the infrequent use of illegal bait collecting methods and the wide use of tins and prawn pushers instead of prawn pumps. Tins and prawn pushers cause less sediment disturbance because they blow the mud prawns out of their burrows instead of sucking them up together with water and sediment as happens with prawn pumps (Cretchley 1996). On the Langebaan lagoon 97% of the bait collectors used prawn pumps, and 4,840 tons of dry sediments are disturbed every year on the centre banks (Wynberg and Branch 1991). No similar studies have been conducted on the Kowie estuary; however, the majority of bait collectors on the Kowie estuary use tins, and therefore likely cause less sediment disturbance than occurs on the Langebaan lagoon. However, sediment disturbance could increase

significantly if the use of prawn pumps or illegal bait collecting methods on the estuary steadily increase.

Another secondary effect of collecting bait on estuaries is the disturbance caused to other estuarine organisms. Mortality rates may increase due to increased predation, physical damage or suffocation when disturbed sediments collapse (Wynberg and Branch 1991; Cretchley 1996). On the Langebaan lagoon, Wynberg and Branch (1991) estimated that for each bag limit of sand prawns collected, 1,000 to 15,000 items of macrofauna were disturbed. On the Swartkops, there was increased predation of exposed cockles (*Cerastoderma edule*) by opportunistic bird predators (Daniel 1994a), while  $192 \times 10^6$  kJ of exposed mud prawns were eaten by birds and scavenging crabs (Hanekom and Baird 1992). The relatively infrequent use of illegal bait collecting methods on the Knysna estuary and the wide use of tins and prawn pushers limits the damage to other macrofauna on the estuary (Cretchley 1996). During this study no substantial opportunistic predation due to mud prawn collecting was observed on the estuary. Since the mud prawn collectors used the same gear as collectors on the Knysna estuary, it appears the problem of disturbed macrofauna on the Kowie estuary remains less than on the Langebaan lagoon and Swartkops estuary.

## CHAPTER 4

### HOW SUSTAINABLE IS THE KOWIE ESTUARY FISHERY?

#### 4.1 INTRODUCTION

The concept of Maximum Sustainable Yield (MSY) has formed the basis of fisheries management since the middle of the last century. Several authors have challenged this approach to fisheries management in recent years, for example: Botsford *et al.* (1997), Staples (1997) and the FAO (1998). Among the criticisms levelled against the MSY approach to fisheries management (Botsford 1997 *et al.*; FAO 1998) is that:

- It focuses only on the exploited species, while ignoring the rest of the ecosystem.
- It fails to take into account the socio-economic dimensions of the fishery.
- It advocates constant catch despite fluctuations in environmental conditions that affect aquatic productivity.
- An estimation of MSY demands good-quality fishery data.
- MSY must first be exceeded for its estimation, which puts the fishery at risk.

Because of these and other limitations, the commonly perceived goal of fisheries management has shifted away from MSY, or any of its derivatives such as Maximum Economic Yield (MEY) and Optimum Sustainable Yield (OSY), to that of sustainable fisheries (Staples 1997). Since the Earth Summit in 1992, there has been greater impetus to incorporate the concept of sustainable development (SD) into fisheries management. For example, in the USA, fisheries management is now based on the Sustainable Fisheries Act of 1996. In Australia, fisheries are managed on the basis of Ecologically Sustainable Development (ESD). And, South Africa's Marine Living Resources Act 18 of 1998 and the FAO Code of Conduct for Responsible Fisheries are based on sustainability principles.

In addition to striving for maximum yield, a policy of sustainable fisheries takes into account factors such as socio-economics, politics, culture and institutions, which are also integral components of a fishery. The principle of sustainable fisheries also advocates an ecosystem approach to fishery management, as well as a precautionary approach in the face of uncertainty about fish yield and human behaviour (FAO 1998).

However, three major obstacles have hampered the management and monitoring of fisheries for sustainability. Foremost is lack of clarity concerning the meaning of the term sustainable fishery. The concept of sustainability is open to many interpretations, as seen in numerous conflicting definitions and interpretations encountered in the literature. Occasionally this has resulted in poorly defined objectives and strategies in fishery management (Staples 1997). In the initial stages of managing and monitoring South Africa's estuarine fisheries there is a need to clarify what a sustainable fishery means. This chapter puts forward a clearer and more exact explanation of sustainability in small-scale estuarine fisheries within the South African context.

The second obstacle has been the lack of widely accepted sustainability indicators for fisheries. Although Chapter 40 of Agenda 21, the UN blueprint towards sustainability, calls for the identification of indicators of sustainable development by local communities, this is yet to be done for most South African fisheries. Sustainability indicators are needed for: describing the state of a fishery with regard to sustainability objectives, assessing the progress made towards achieving those objectives, and stimulating action towards achieving the objectives (Garcia *et al.* 2000). The large number of possible indicators of sustainability is a potential source of confusion to natural resource managers (Pajak 2000); a major challenge facing researchers in estuarine fisheries everywhere is to identify a limited number of appropriate indicators of sustainability. Here, the task is complicated by a lack of appropriate information on most of South Africa's estuarine fisheries, and by the fact that different estuarine fisheries operate under different socio-economic conditions, and hence possibly require different sets of indicators. In addition, sustainability indicators are needed for all the key components of a fishery system – not only the target species, as has often been the case. This chapter presents a set of simple yet scientifically valid indicators by which a small-scale estuarine fishery with an inadequate database, such as the Kowie estuary fishery, can be assessed for sustainability.

In general, assessing fisheries for sustainability offers a simpler and more robust means to evaluate a fishery than the complex fisheries stock models often applied (Garcia 1997). The process can be carried out with fewer quantitative data, involves multiple dimensions of the fishery, and the results can be easily converted into a form simple enough for the general public to understand. However, the lack of a standardised methodology by which to evaluate sustainability in fisheries is the third obstacle to progress towards sustainability in fisheries. Examples of fisheries that have been assessed for sustainability are still scarce in the published literature. However, some guidelines on how to evaluate fisheries for sustainability have been recently published (e.g., Garcia 1997; IUCN 1998; Garcia *et al.* 2000; Pajak 2000). In this section, these guidelines are used to assess the sustainability of various sectors of the Kowie estuary linefishery and bait fishery. The sectors in the linefishery assessed for sustainability were the shore-based recreational and the subsistence fisheries, and the subsistence sector in the bait fishery.

#### **4.2 METHODOLOGY AND APPROACH**

The process of evaluating sustainability in natural resource use can be condensed into a number of distinct stages (Staples 1997; IUCN 1998; Garcia *et.al* 2000; Chesson and Whitworth 2000):

- Defining the system and goals
- Identifying key issues and objectives
- Choosing indicators and performance criteria
- Collecting data on the selected indicators
- Combining and weighting the indicators (optional)
- Constructing a visual representation of sustainability
- Monitoring and reviewing the indicators.

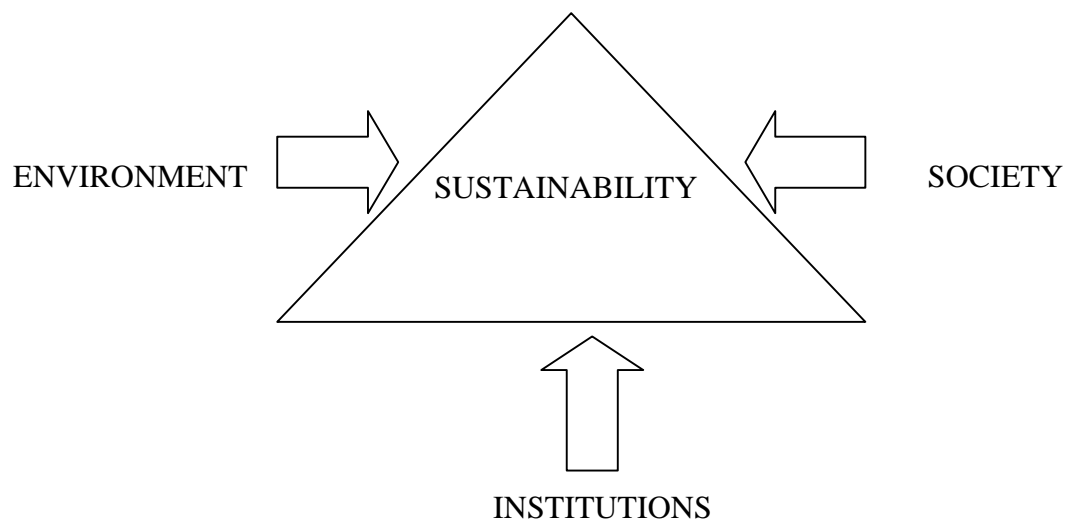
These stages form a Sustainable Development Reference System (Garcia *et al.* 2000), and if their sequence is followed, indicator selection proceeds in an organised and systematic manner. This contributes to the selection of indicators that are not only manageable in number, but are also true representatives of the particular fishery system.

Although the list of stages above suggests a linear process, assessing sustainability in fisheries should in fact be part of a performance evaluation cycle in fishery management (Garcia *et al.*

2000). Rather than being a means to an end, the selected indicators should serve as feedback between trends in the fishery regarding sustainability objectives and management strategies (Garcia *et al.* 2000), thus contributing to adaptive management in the fishery. The stages that make up the assessment process are discussed in detail below.

#### 4.2.1 Defining the system and goals

This involves drawing up a simple model to show the relationship between the local society, the ecosystem and sustainability, as well as defining the broad goals of sustainability. Examples of models depicting sustainability can be found in Charles (1994), IUCN (1998) and Pajak (2000). Those models differ in their terminology and number of constituent components. For example, Garcia *et al.* (2000) recognize four dimensions of sustainability in fisheries: economic, social, ecological and governance. For Pitcher and Preikshot (2001) sustainability in fisheries encompasses five disciplinary areas: ecological, economic, sociological, technological and ethical. The sustainability model proposed by Pajak (2000) was adopted for this study. According to that model, the three domains of sustainability are the environment, society and institutions; and sustainability exists when there is ecosystem, social and procedural integrity (Figure 4.1).

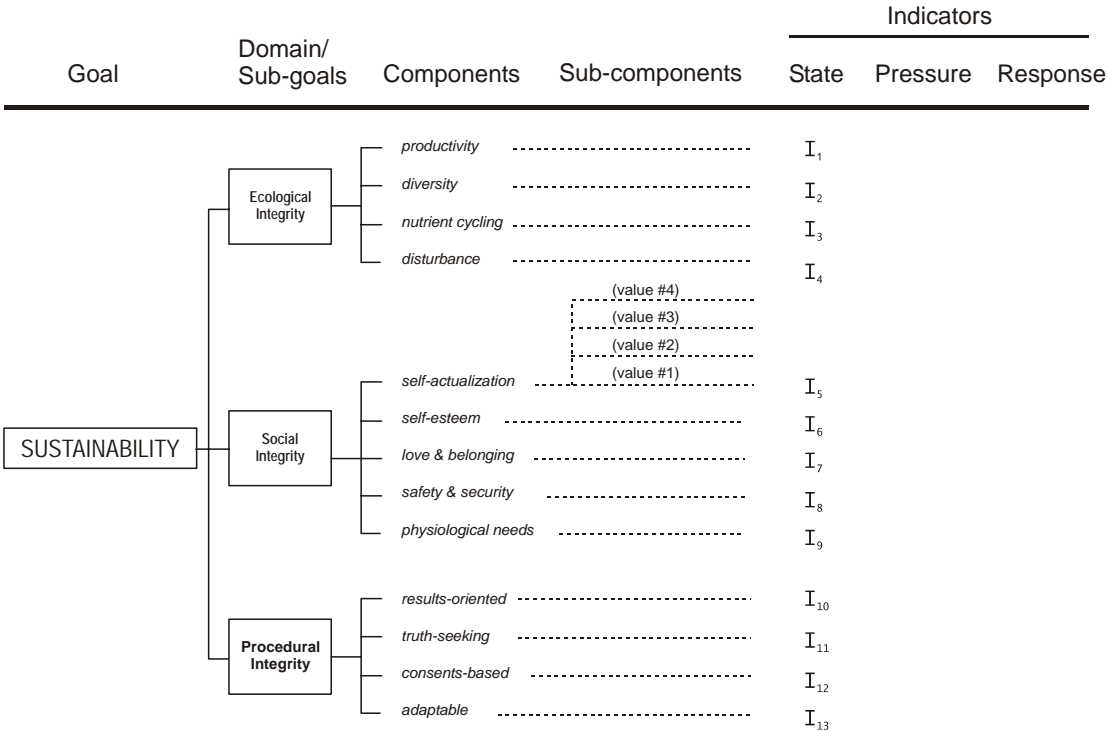


**Figure 4.1:** A model depicting sustainability in fisheries (after Pajak 2000)

#### 4.2.2 Identifying key issues and objectives

The construction (or selection) of a framework of sustainability is a key stage in assessing progress made towards achieving sustainability in fisheries (Garcia and Grainger 1997; Staples 1997; FAO 1998). The framework consists of a number of measurable key issues or components selected from the major dimensions of sustainability. It aids in the evaluation process by breaking up the broad goals of a sustainable fishery into a limited number of widely accepted, explicitly stated key principles that are sufficiently quantifiable to allow performance evaluation (Garcia 1997). The framework also allows the selection of indicators to be conducted in a structured manner (IUCN 1998). According to Pajak (2000) the framework helps to focus selection efforts on the best available indicators from all relevant components of the fishery.

Various organisations and authors have put forward different sustainability frameworks, for example FAO (1995), Garcia (2000), IUCN (2000) and Pajak (2000). The main advantage of Pajak’s (2000) framework is that the key components of sustainability are reduced to a manageable number (i.e., 13). At the same time, these components can be expanded, giving the framework a high degree of flexibility, which allows it to be applied to local or global fisheries (Pajak 2000). Another feature of Pajak’s (2000) framework (Figure 4.2) is that it regards the behaviour of individuals as central to achieving sustainability in natural resource use.



**Figure 4.2:** A sustainability framework proposed by Pajak (2000).

According to Pajak (2000), ecosystem integrity is the degree to which species, habitats and natural processes are intact and functioning in ways that ensure ecological sustainability and long-term adaptation to changing conditions and human uses. Properties seen by Pajak (2000) as contributing to ecosystem integrity, and thus to ecosystem sustainability, are biological productivity, diversity, chemical cycling and natural disturbance regimes.

Pajak (2000) believes that unmet basic human needs contribute to unsustainability. In other words, social sustainability exists where these basic human needs are being met. Basic human needs are arranged in what is known as Maslow's hierarchy (Meyer and Viljoen 1997), starting with physiological needs, followed by the need for safety and security, the need for love and belonging, the need for self-esteem and lastly the need for self-actualisation.

According to Pajak (2000) institutional sustainability exists where there is procedural integrity; characteristics that contribute to procedural integrity are institutions and processes that are results oriented, consent based, truth seeking, and adaptable.

#### **4.2.3 Sustainability objectives for the Kowie estuary fishery**

The sub-goals of sustainability as outlined in Pajak's (2000) framework are too broad to allow for effective assessment and monitoring of progress towards sustainability. They need to be further delineated into distinct sustainability objectives (IUCN 1998). Garcia *et al.* (2000) suggest that input from key stakeholders is crucial. For the purposes of this study, however, input was received during a series of workshops from a limited set of experts in estuarine fisheries, bio-economics and environmental science (see Appendix 3 for a list of participants). Using the Marine Living Resources Act of 1998 (Anon. 1998) and the FAO Code of Conduct for Responsible Fishing (FAO 1995) as guidelines, six sustainability objectives were identified for the Kowie estuary fishery. The objectives are presented below under the three major domains of sustainability according to Pajak (2000).

##### **Ecosystem integrity (ecosystem sustainability)**

*1. To maintain biodiversity on the Kowie estuary.* To prevent depletion of fish stocks and bait organisms, fishing effort on the Kowie estuary should be within the regenerative capacity of the fishery resources. Where it is still possible, degraded areas of the Kowie estuary should be

rehabilitated, and depleted stocks replenished or allowed to recover. Critical habitats on the estuary, such as mudflats, *Zostera* beds and salt marshes, should be protected from degradation or destruction.

### **Social integrity (social sustainability)**

2. *To use the Kowie estuary fishery resources to improve human welfare.* The fishery resources on the Kowie estuary should be used to improve nutrition in the Port Alfred community, and also to provide opportunities for employment, recreation and leisure. As a result, the residents of Port Alfred will have a vested interest in the conservation of the fishery resources.

3. *To increase public participation in the management of the Kowie fishery.* Interested and affected parties should be actively involved in managing the fishery resources on the Kowie estuary. This will enhance transparency, accountability and the use of local knowledge in the management of the resources (FAO 1995; IUCN 2000). Users should share responsibility for attaining the management goals for the fishery. The right of subsistence fishers and other previously disadvantaged user groups to the fishery resources should be recognized.

### **Procedural integrity (institutional sustainability)**

4. *To regulate entry into the Kowie estuary fishery.* Access rights to the fishery resources should be clearly defined and enforceable (FAO 1995; IUCN 2000; Scott 2000). Communities living near the Kowie estuary should enjoy access to its fishery resources and be involved in the granting of access rights. Consequently community members will have a vested interest in the conservation of the fishery resources.

5. *To improve management of the Kowie estuary fishery.* There should be effective legal, financial and administrative structures installed to manage the fishery resources on the Kowie estuary. In order to improve the effectiveness of the management system and increase public participation in fishery management, the institutions should be nested: that is, operate at national, provincial and local level (IUCN 2000). Institutional activities should be coordinated and not conflict with each other. Fishery management protocols should be changed in response to new data. Fishing regulations should be enforceable and adapted to suit local conditions. There

should also be mechanisms for resolving conflicts arising from the use of fishery resources (FAO 1995).

6. *To improve knowledge about the Kowie estuary fishery.* There should be a programme of regular research and monitoring of the fishery (FAO 1998; IUCN 2000). Areas of the fishery that are researched and monitored should include aspects of biology and ecology, as well as socio-economics. Residents of Port Alfred, especially the fishers, should participate in research and monitoring of the Kowie fishery. Research findings should be communicated to interested and affected parties, and should be in a form that is easy to understand. The findings of research and monitoring should form the basis of management decisions in the fishery. There should be public education and training programmes on fishery issues in order to equip the community with knowledge and skills necessary for informed decision making.

#### **4.2.4 Choosing indicators and performance criteria**

Garcia *et al.* (2000) defined sustainability indicators as tools for describing the state of a fishery with regard to sustainability objectives. The indicators selected must be manageable in number, and come from all major sectors of the fishery. Pajak's (2000) framework was chosen as a guide in the identification and selection of suitable indicators of sustainability for the Kowie fishery. As suggested by the IUCN (1998) each indicator has been linked to a specific sustainability objective. Other key factors considered during the selection of the indicators follow the recommendations of Garcia *et al.* (2000):

- Relevance to sustainability
- Relevance to the local fishery
- Availability of necessary data
- Existence of standard and replicable methods and measurements for the indicator
- Ease with which relevant data could be collected
- Simplicity
- Ability to show trends over time.

An effort was made to include a mixture of state, pressure, and response indicators (see Garcia 1997). State indicators describe the existing condition of the fishery, pressure indicators describe the external factors that affect the condition of the fishery, while response indicators describe

action taken to reduce stress in the fishery. In cases where primary data was not available (for example, trends in annual catch) substitute indicators (or proxy indicators) were used.

Once indicators have been selected, the next step is to evaluate their performance in the fishery. According to Garcia (1997), the tools needed to evaluate indicator performance are reference points, performance criteria and performance scales. This approach differs from the procedure given in the IUCN (1998) report, which relies only on performance criteria and scales, and does not involve establishing reference targets for the indicators.

Garcia (1997) defines a reference point or value as a particular state of an indicator corresponding to a situation considered desirable (Target Reference Point) or undesirable and requiring immediate action (Limit Reference Point). Since Pajak (2000) does not provide guidelines on how this can be done, the procedure for reference points in this study follow the guidelines in Garcia (1997) and Garcia *et al.* (2000). Performance criteria are standards of achievement for the indicators (IUCN 1998); they are benchmarks against which the performance of the indicators can be compared, and they form the basis for scaling (or ranking) the performances of the indicators. Indicator scaling refers to assigning a qualitative or quantitative value to the performance of the indicator in the fishery. The process of setting up indicator reference points, and defining and scaling indicator performance involves value judgements and the use of arbitrary scales. Garcia (1997) recommends the involvement of key stakeholders of the fishery in the process, but limits due to time and expense made this impossible for this study. However, input was sought from experts in natural resource management, estuarine fisheries, and bio-economics.

#### **4.2.5 Collecting data on the selected indicators**

Data were collected during the shore-based fishery survey (see Chapter 3). Additional data were obtained from published literature on the Kowie estuary and its fishery.

#### **4.2.6 Visualisation of sustainability**

Examples of visual illustrations that can be used to portray sustainability in fisheries include the sustainability barometer (IUCN 1998), the kite diagram (Garcia *et al.* 2000) and amoeba plots (Pajak 2000). Amoeba is a Dutch acronym for a general method of ecosystem assessment and

description (Lundin 1999). Being a recent concept, amoeba plots illustrating sustainability are still relatively rare in the literature. One example is an amoeba plot used to illustrate the ecological status of the North Sea (Lundin 1999). According to Pajak (2000) the advantages of using amoeba plots to illustrate sustainability are:

- They are simple yet comprehensive
- The factors limiting sustainability are easily identifiable
- The same indicators can also be used for setting goals

In addition, the use of amoeba plots overcomes the problems associated with indicator weighting and aggregation. Because of the above advantages, this study adopted amoeba plots for the illustration of sustainability in the Kowie estuary fishery.

The amoeba plots used here consist of a sphere divided into three equal sections, representing the three major dimensions of sustainability (Figures 4.2 – 4.4). Within each section of the sphere, four or five slices represent four or five indicators. The performance of each indicator was subjectively assessed on a scale that ranged from 1 at the centre of the sphere (indicating minimum probability of sustainability) to a maximum of 4 on the rim of the sphere (indicating maximum probability of sustainability).

The indicators used to assess the sustainability of the Kowie estuary fishery, together with the criteria and scales used to evaluate indicator performance are presented next. The indicators are arranged under the three major domains of sustainability according to Pajak (2000), namely social, ecosystem and institutional (Sections 4.3 – 4.5).

## **4.3 ASSESSMENT OF SOCIAL SUSTAINABILITY**

### **4.3.1 Physiological needs**

Physiological needs are the most basic human needs, for example hunger and thirst (Meyer and Viljoen 1997), as well as the need for recreation. In regard to a fishery such needs concern the nutrition of the fishers, their level of formal employment, trends in income earned from the fishery, and the degree of recreational and subsistence fishing effort.

**Objective:** To enhance formal employment among fishers in the Kowie estuary fishery.

**Indicator:** Proportion of fishers with formal jobs.

**Type of indicator:** State

**Performance criteria:** The proportion of Port Alfred residents with formal jobs is estimated at 34% (Statistics South Africa 1998). The proportion of fishers in the Kowie estuary fishery that have formal jobs should at least match that of the general population of Port Alfred. Therefore, a proportion of 34% of the fishers in formal employment was used as the reference target (Table 4.1).

**Table 4.1:** The criteria and scale used to assess the performance of the indicator ‘proportion of fishers with formal jobs.’

<b>Proportion of fishers with formal jobs</b>	<b>Indicator performance</b>	<b>Score</b>
34% and above	Very good	4
23–33%	Good	3
12–22%	Moderate	2
<12%	Poor	1

**Other indicators for which data are available:**

- Proportion of recreational fishing effort.
- Proportion of fishers who said the fish caught is important in their household diet.

#### **4.3.2 Safety and security needs**

These needs relate to security and stability, and law and order (Meyer and Viljoen 1997). In a fishery, these needs would relate to effectiveness of fishing regulations, especially property rights, regulation enforcement and compliance, and the resolution of fishery-related conflicts.

**Objective:** To provide security of tenure to the fishers.

**Indicator:** The existence of clearly defined and enforced access rights that regulate entry into the Kowie estuary fishery (i.e., type of access rights).

**Type of indicator:** State

**Performance criteria:** Fishing rights provide security of tenure to the fishers, and help to prevent over fishing (France and Exel 1999). To be effective, fishing rights must be clearly defined and was set up as the reference target (Table 4.2).

**Table 4.2:** Criteria and scale used to assess the performance of the indicator ‘type of access rights that exist in the Kowie estuary fishery.’

Type of access rights	Indicator performance	Score
Clearly defined and enforced	Very good	4
Well-defined but not enforced	Good	3
Ill-defined and not enforced	Moderate	2
No access rights; fishery is open access	Poor	1

**Other indicators for which data are available:**

- Proportion of fishers who think current fishing regulations are effective in protecting the Kowie estuary fishery resources.

### 4.3.3 Affiliation needs

Affiliation needs in a fishery relate to a sense of belonging among the fishers, and the formation of groups or societies with similar interests or problems. This would enhance community bonding in the fishery, and facilitate communication and the formulation of a common vision for the fishery.

**Objective:** To increase the proportion of fishers who belong to fishery organisations.

**Indicator:** The proportion of fishers who are formally organised into local clubs or fishery organisations.

**Type of indicator:** State

**Performance criteria:** The reference target was set to where at least 50% of the fishers are members of fishing organisations (Table 4.3).

**Table 4.3:** Criteria and scale used to assess the performance of the indicator ‘proportion of Kowie estuary fishers who are members of local clubs or fishing organisations.’

<b>Proportion of fishers who are members of fishing clubs</b>	<b>Indicator performance</b>	<b>Score</b>
50% and above	Very good	4
31– 49%	Good	3
20–30%	Moderate	2
<20%	Poor	1

#### **4.3.4 Self-esteem needs**

Meyer and Viljoen (1997) define self-esteem as the need to evaluate oneself positively, and is closely linked to personal achievement, capabilities and confidence. Self-esteem among fishers relates to their education levels, fishery management skills and level of knowledge of fishery issues (Table 4.4).

**Objective:** To improve education levels among the fishers.

**Indicator:** Proportion of fishers educated to matric level.

**Type of indicator:** State

**Performance criteria:** A high level of education among fishers improves their degree of literacy; thus they are more likely to read and understand fishery regulations. However, fishery management requires more than literacy. Fishers, as fishery managers, should have negotiation skills and be able to articulate their interests, as well as understand scientific information (Hanna 1995). These skills are likely to be more developed in highly educated fishers than in those with poor or no education. The proportion of fishers educated to matric level should be at least equal to that of Port Alfred residents, which is 6% (Statistics South Africa 1998). This proportion was set up as the reference point to assess the performance of this indicator in the Kowie estuary fishery (Table 4.4).

**Table 4.4:** Criteria and scale used to assess the performance of the indicator ‘proportion of fishers in the Kowie estuary fishery educated to matric level.’

<b>Proportion of fishers educated to matric level</b>	<b>Indicator performance</b>	<b>Score</b>
6% and above	Very good	4
4–5%	Good	3
2–3%	Moderate	2
<2%	Poor	1

#### 4.3.5 Self-actualisation needs

Meyer and Viljoen (1997) define self-actualisation as the process of becoming all that one is capable of becoming, by making full use of one’s abilities, talents or potential. In a fishery, self-actualisation among the fishers relates to equity of entry into the fishery, and the participation of fishers in fishery management.

**Objective:** To increase the participation of local residents in the fishery.

**Indicator:** Proportion of fishers who are residents of Port Alfred.

**Type of indicator:** State

**Performance criteria:** If local residents enjoy access to local fishery resources, they will have a vested interest in their conservation. Hence, fishers who are residents of Port Alfred should form the majority on the Kowie estuary. The proportion 75% and above who are residents of Port Alfred was set up as reference target for this indicator (Table 4.5).

**Table 4.5:** Criteria and scale used to assess the performance of the indicator ‘proportion of fishers who are residents of Port Alfred’.

<b>Proportion of fishers who are residents of Port Alfred.</b>	<b>Indicator performance</b>	<b>Score</b>
75% and above	Very good	4
50–74%	Good	3
25 – 49%	Moderate	2
< 25%	Poor	1

## 4.4 ASSESSMENT OF ECOSYSTEM SUSTAINABILITY

### 4.4.1 Productivity

Productivity relates to the biomass of fish or bait caught from the fishery. In a sustainable fishery the annual catch biomass should not decline over time.

**Objective:** To maintain or enhance annual output of exploited fish or bait from the Kowie estuary.

**Indicator:** Proportion of fishers who said their catch of fish or bait from the estuary was less than in the past.

**Type of indicator:** State

**Performance criteria:** The catch biomass of fish and bait from the estuary should not decrease over time. Since data on past catches from the Kowie estuary is incomplete, the proxy indicator ‘proportion of fishers who said they were catching less fish/bait than in the past’ was used. The reference point set to assess the performance of the indicator was when a proportion of fishers amounting to less than 20% reported a decrease in their catch over time (Table 4.6).

**Table 4.6:** Criteria and scale used to assess the performance of the indicator ‘proportion of fishers who said their catch of fish or bait was less than in the past.’

Proportion of fishers who said they caught less fish/bait than in the past	Indicator performance	Score
<20%	Very good	4
20–39%	Good	3
40–59%	Moderate	2
60% and above	Poor	1

**Other indicators for which data are available:**

- Catch rate of major target species.

### 4.4.2 Diversity

Diversity relates to the number of species caught in the fishery. In a sustainable fishery, the species composition of the fishery does not change over time.

**Indicator:** Proportion of fishers who said they caught fewer species than in the past.

**Type of indicator:** State

**Performance criteria:** A reduction in the number of species caught by fishers over time signals a decline in diversity in the fishery. To assess the performance of the indicator in the Kowie estuary fishery, a proportion of less than 10% of the fishers reporting a decline in the number of species caught was used as the reference point (Table 4.7).

**Table 4.7:** Criteria and scale used to assess the performance of the indicator ‘proportion of Kowie estuary fishers who said they caught fewer species than in the past.’

Proportion of fishers who said they caught fewer species than in the past	Indicator performance	Score
<10%	Very good	4
30–10%	Good	3
50–29%	Moderate	2
>50%	Poor	1

**Other indicators for which data are available:**

- Number of species reported by fishers to be scarcer than in the past.
- Number of species for which fishers manage to reach the daily bag limit.

#### 4.4.3 Disturbance

Human activities such as over fishing, land conversion and river damming threaten estuarine fisheries because they interfere with the ecological processes of the estuary (see Chapter 1). The disturbances to a fishery should be within the regenerative capacity of its ecosystem. In particular, siltation of estuaries smothers benthic flora and fauna, and decreases estuarine habitats (Whitfield 1998). Siltation also interferes with boating activities on an estuary, including boat-based recreational fishing.

**Objective:** To reduce the severity of the siltation problem on the Kowie estuary.

**Indicator:** Since no quantitative data exist regarding the level of siltation in the Kowie estuary, the perception of fishers concerning the severity of a siltation problem in the estuary was used as a proxy indicator. The reference target was set where less than 10% of the fishers regard the siltation problem as a major threat to the fishery (Table 4.8).

**Table 4.8:** Criteria and scale used to evaluate the performance the indicator ‘proportion of fishers who regard siltation as a major threat to the Kowie estuary fishery.’

Proportion of fishers who regard siltation as a major threat to the fishery	Indicator performance	Score
<10%	Very good	4
10–29%	Good	3
30–49%	Moderate	2
50% and above	Poor	1

***Other indicators for which data are available:***

- The proportion of undersized catch in the fishery
- Condition of the estuary
- Species composition of the directed fishing effort

**4.4.4 Chemical cycling**

Certain nutrients, especially phosphorous and nitrogen are essential to the productivity of an estuary (Copeland *et al.* 1983). These nutrients stimulate the growth of phytoplankton, which forms the base of the estuarine food chain. The estuarine water-quality index (EWQI) devised by Harrison *et al.* (2001) is based on six aspects of water quality, including oxygen, nitrate and ortho-phosphate content.

***Objective:*** To maintain or enhance water quality in the Kowie estuary.

***Indicator:*** Estuarine water-quality index (EWQI) score for the Kowie estuary.

***Type of indicator:*** State

***Performance criteria:*** Harrison *et al.* (2001) estimated the average EWQI score for South African estuaries to be 6.2 out of a maximum score of 10. The water quality in the Kowie estuary should at least be equal to the national average. To assess the performance of the indicator in the Kowie estuary fishery, an EWQI score above 6.0 was set as the reference target (Table 4.9).

**Table 4.9:** Criteria and scale used to assess the indicator ‘estuarine water-quality index (EWQI) score for the Kowie estuary.’

<b>EWQI</b>	<b>Indicator performance</b>	<b>Score</b>
>6.0	Very good	4
5.1–6.0	Good	3
4.0–5.0	Moderate	2
<4.0	Poor	1

## 4.5 ASSESSMENT OF INSTITUTIONAL SUSTAINABILITY

### 4.5.1 Results-oriented institutions

Pajak (2000) defined results-oriented institutions as organisations and processes that are outcome based, and that have clearly stated and measurable management objectives that are periodically monitored and evaluated.

*Objective:* To improve the management of the Kowie estuary fishery.

*Indicator:* The existence of an effective management plan for the Kowie estuary fishery.

*Type of indicator:* State

*Performance criteria:* The reference target was the existence of a management plan that incorporates the fishery into coastal development, and is based on sustainability principles (Table 4.10).

**Table 4.10:** Criteria and scale used to assess the performance of the indicator ‘nature of management plan formulated for the Kowie estuary fishery.’

<b>Nature of the management plan for the fishery</b>	<b>Indicator performance</b>	<b>Score</b>
Effective and integrated with measurable sustainability objectives; roles clearly defined	Very good	4
Most sustainability objectives clearly defined and measurable; incorporates coastal development	Good	3
Most management objectives ill defined and not measurable	Moderate	2
Fishery lacks a management plan	Poor	1

#### 4.5.2 Consent-based institutions

Pajak (2000) defined consent-based institutions as organisations and processes that involve input from stakeholders, and also enjoy support from the general public.

**Objective:** To enhance fisher participation in the management of the Kowie estuary fishery.

**Indicator:** Level of fisher participation in the management of the Kowie estuary fishery.

**Type of indicator:** State

**Performance criteria:** The reference target was set at where fishers are responsible for decision making, data collection and regulation enforcement (Table 4.11).

**Table 4.11:** Criteria and scale used to assess the indicator ‘level of fisher participation in the management of the Kowie estuary fishery.’

Level of fisher participation in fishery management	Indicator performance	Score
Fishers responsible for decision making, data collection and enforcement	Very good	4
Fishers consulted during decision making	Good	3
Fishers consulted after decisions are made	Moderate	2
No fisher participation; management is top-down	Poor	1

**Other indicators for which data are available:**

- Number of species under co-management.

#### 4.5.3 Truth-seeking

Pajak (2000) defined truth-seeking institutions as organisations and processes that are proactive, and which involve research and monitoring.

**Objective:** To improve the quality and quantity of data available on the Kowie estuary fishery.

**Indicator:** Existence of a programme in the Kowie estuary fishery to record catch and effort statistics.

**Performance criteria:** The use of access or creel fishery surveys to record catch and effort was set up as the reference target (Table 4.12).

**Table 4.12:** Criteria and scale used to assess performance of the indicator ‘nature of programme used to record catch and effort statistics for the Kowie estuary fishery.’

<b>Nature of programme used to record catch and effort statistics</b>	<b>Indicator performance</b>	<b>Score</b>
Regular access or creel fishery surveys conducted to collect data on catch and effort.	Very good	4
Compulsory filling in of catch cards,	Good	3
Voluntary filling in of catch cards	Moderate	2
No recording of catch or effort statistics	Poor	1

#### 4.5.4 Adaptable institutions

Adaptable institutions are defined by Pajak (2000) as those organisations and processes that accommodate varied contexts and scales, and which adapt management to new information.

**Objective:** To make fishing regulations relevant to local conditions.

**Indicator:** Proportion of Kowie estuary fishing regulations modified to suit local conditions in the fishery.

**Type of indicator:** Response

**Performance criteria:** The reference target set was when the majority of the fishing regulations reflect local conditions in the fishery. (Table 4.13).

**Table 4.13:** Criteria and scale used to assess performance of the indicator ‘proportion of fishing regulations modified to suit local conditions.’

<b>Proportion of fishing regulations modified to suit local conditions.</b>	<b>Indicator performance</b>	<b>Score</b>
Majority	Very good	4
>50%	Good	3
10–49%	Moderate	2
<10%	Poor	1

**Other indicators for which data are available:**

- Trends in cost of fishing licence fees.
- Number of times fishing regulations were reviewed in the last ten years.

## 4.6 RESULTS

In the linefishery, a total of 92 shore-based recreational anglers and 41 subsistence operators were interviewed with the aid of the long questionnaire. In the bait fishery, 73 subsistence bait collectors and 11 recreational bait collectors were interviewed. The performance of the selected indicators in the different fisheries is summarised below. Due to the relatively small number of recreational bait collectors interviewed, however, the sustainability of the recreational bait fishery is not assessed. The performance results of the indicators are again grouped under headings for the three major domains of sustainability as identified by Pajak (2000), namely social, ecosystem and institutional (see Section 4.2.3).

### 4.6.1 Shore-based recreational and subsistence linefishery

#### Social sustainability

*Physiological needs* (see Section 4.3.1): According to the results of the foot patrol, 85% of the shore-based recreational anglers said they had formal jobs; the performance of the indicator ‘proportion of fishers with formal jobs’ was assessed as ‘very good’ and allocated a score of 4. In the subsistence sector, only 17% of the interviewed anglers reported that they had formal jobs; hence, the performance of this indicator in the subsistence linefishery was assessed as ‘moderate’ and given a score of 2 (see Table 4.1).

*Safety and security needs* (see Section 4.3.2): Access rights to the Kowie fishery resources are not clearly defined. Key stakeholders of both the recreational or subsistence fisheries have not been identified. This essentially means that anyone may gain entry to those fisheries. Although a permit is required for fishing on the estuary, the regulation is not strictly enforced. Seventy-four percent of the shore-based recreational linefishers were in possession of a permit, while in the subsistence sector the corresponding figure was only 36%. Thus, in the shore-based recreational sector, the performance of the indicator regarding the nature of access rights was assessed as ‘moderate’ and given a score of 2, while the indicator performance in the subsistence sector was ‘poor’ and scored 1 (see Table 4.2).

*Affiliation needs* (see Section 4.3.3): In the shore-based recreational sector, only 13% of the anglers interviewed were members of fishery organisations, while in the subsistence sector none

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of the linefishers belonged to a fishery organisation. Thus, the performance of the indicator ‘proportion of fishers formally organized into clubs or organisations’ in both fishery sectors was judged ‘poor’ and given a score of 1 (see Table 4.3).

***Self-esteem needs*** (see Section 4.3.4): Among the shore-based recreational anglers, 50% said they had matric qualifications and another 21% reported a tertiary education. The performance of the indicator ‘proportion of fishers with matric education’ was ‘very good’ and given a score of 4. Although most of the subsistence linefishers said they had received some form of primary schooling, only seven of the interviewees said they had matric qualifications. The performance of the indicator in this sector was judged ‘poor’ and given a score of 1 (see Table 4.4).

***Self-actualisation needs*** (see Section 4.4.5): According to results of the foot patrol, the proportion of fishers who said they were residents of Port Alfred were 20% in the shore-based recreational fishery, and 100% in the subsistence linefishery. In the shore-based recreational fishery, the performance of the indicator was judged ‘poor’ and was scored 2. In the subsistence linefishery, the performance of the indicator was judged ‘very good’ and was given a score of 4. (see Table 4.5).

### **Ecosystem sustainability**

***Productivity*** (see Section 4.4.1): The proportion of respondents who said they were catching less fish than in the past was 85% in the shore-based recreational sector and 66% in the subsistence sector. The performance of the indicator in both sectors was ‘poor’ and given a score of 1 (see Table 4.6).

***Diversity*** (see Section 4.4.2): The proportion of linefishers who said they were catching fewer species than in the past was 74% in the recreational sector and 83% in the subsistence sector. The performance of the indicator was ‘poor’ in both sectors and was given a score of 1 (see Table 4.7).

***Disturbance*** (see Section 4.4.3): Shore-based recreational anglers who regarded siltation as a major threat to the Kowie fishery formed 62% of the respondents, while in the subsistence sector they formed 59%. The performance of the indicator was ‘poor’ in both sectors and given a score of 1 (see Table 4.8).

**Chemical cycling** (see Section 4.4.4): Harrison *et al.* (2001) estimated the estuarine water quality index (EWQI) score for the Kowie estuary at 7.5. Based on their work, the performance of the indicator ‘EWQI score for water quality’ was ‘good’ and scored 3 (see Table 4.9).

### **Institutional sustainability**

**Results-oriented institutions** (see Section 4.5.1): There is no management plan for either the recreational or subsistence sectors of the Kowie estuary linefishery. However, there is management plan for the whole estuary (INR 1999). Although some of the goals of that plan relate to fisheries, for example maintenance of water quality and sustainable use of estuarine resources, none refers specifically to the fishery resources. The performance of the indicator ‘nature of management plan formulated for the fishery’ was judged ‘poor’ in both fishery sectors and was scored 1 (see Table 4.10).

**Consent-based institutions** (see Section 4.5.2): Formally, there is no fisher input in the management of the Kowie estuary fishery. None of the shore-based recreational or subsistence fishers interviewed were currently involved in the management of the fishery. The performance of the indicator ‘level of public participation in the management of the Kowie estuary fishery’, in both fishery sectors, was ‘poor’ and scored 1 (see Table 4.11).

**Truth-seeking institutions** (see Section 4.5.3): There is no regular programme for recording catch and effort statistics for either the recreational or subsistence sectors of the linefishery. The performance of the indicator regarding the nature of such a programme in both sectors was judged ‘poor’ and given a score of 1 (see Table 4.12).

**Adaptable institutions** (see Section 4.5.4): None of the fishing regulations used to manage the recreational and the subsistence fisheries was formulated locally, or been adapted to suit local conditions. The performance of the indicator ‘proportion of fishing regulations modified to suit local conditions’ was ‘poor’ in both sectors and was scored 1 (see Table 4.13).

## 4.6.2 The subsistence bait fishery

### Social sustainability

*Physiological needs* (see Section 4.3.1): Results from the foot patrol showed that only 8% of the respondents in the subsistence bait fishery said they had formal jobs. The performance of the indicator was assessed as ‘poor’ and given a score of 1 (see Table 4.1).

*Safety and security needs* (see Section 4.3.2): Access rights to the Kowie estuary bait fishery are neither well defined nor strictly enforced. Key stakeholders in the fishery have not been legally defined. Although a permit is required for collecting bait on the estuary, only 14% of the subsistence bait collectors had a permit. The performance of the indicator regarding nature of access rights was assessed as ‘poor’ and given a score of 1 (see Table 4.2).

*Affiliation needs* (see Section 4.3.3). In the Kowie estuary bait fishery, there is no formal organization to which bait collectors may belong. The performance of the indicator regarding proportion of fishers who are a member of a fishery organisation was judged ‘poor’ and given a score of 1 (see Table 4.3).

*Self-esteem needs* (see Section 4.3.4): Results from the foot patrol showed that the education level among subsistence bait collectors is quite low, as none of the respondents had at least a matric qualification. The performance of the indicator ‘proportion of fishers with matric education’ was judged ‘poor’ and was given a score of 1 (see Table 4.4).

*Self-actualisation* (see Section 4.3.5) Results from the foot patrol showed that all the subsistence bait collectors were Port Alfred residents. The performance of the indicator ‘proportion of fishers who are residents of Port Alfred’ was judged ‘very good’ and was given a score of 4. (see Table 4.5).

### Ecosystem sustainability

*Productivity* (see Section 4.4.1): The proportion of subsistence bait collectors who said they were collecting fewer mud prawns than in the past was 30%. The performance of the indicator ‘proportion of fishers who said they caught less bait from the Kowie estuary than in the past’ was

‘good’ and scored 3 (see Table 4.6).

**Diversity** (see Section 4.4.2): The proportion of subsistence bait collectors who said they caught fewer species of bait in the estuary than in the past was 64%. The performance of this indicator was ‘poor’ and given a score of 1 (see Table 4.7).

**Chemical cycling** (see Section 4.4.4): Harrison *et al.* (2001) estimated the estuarine water-quality index (EWQI) score for the Kowie estuary at 7.5. As for the linefishery, the performance of this indicator for the bait fishery was judged ‘good’ and was given a score of 3 (see Table 4.9).

**Disturbance** (see Section 4.4.3): The proportion of subsistence bait collectors who regarded siltation of the Kowie estuary, as a major threat to the bait fishery was 62%. Thus, the performance of the indicator was judged ‘poor’ and scored 1 (see Table 4.8).

### **Institutional sustainability**

**Results-oriented institutions** (see Section 4.5.1): No management plan has been formulated for the Kowie estuary bait fishery. Thus, the performance of the indicator regarding the existence of a management plan is ‘poor’ and scored 1 (see Table 4.10).

**Consent-based institutions** (see Section 4.5.2): None of the subsistence bait collectors interviewed was involved in the management of the Kowie estuary bait fishery. The performance of the indicator was ‘poor’ and given a score of 1 (see Table 4.11).

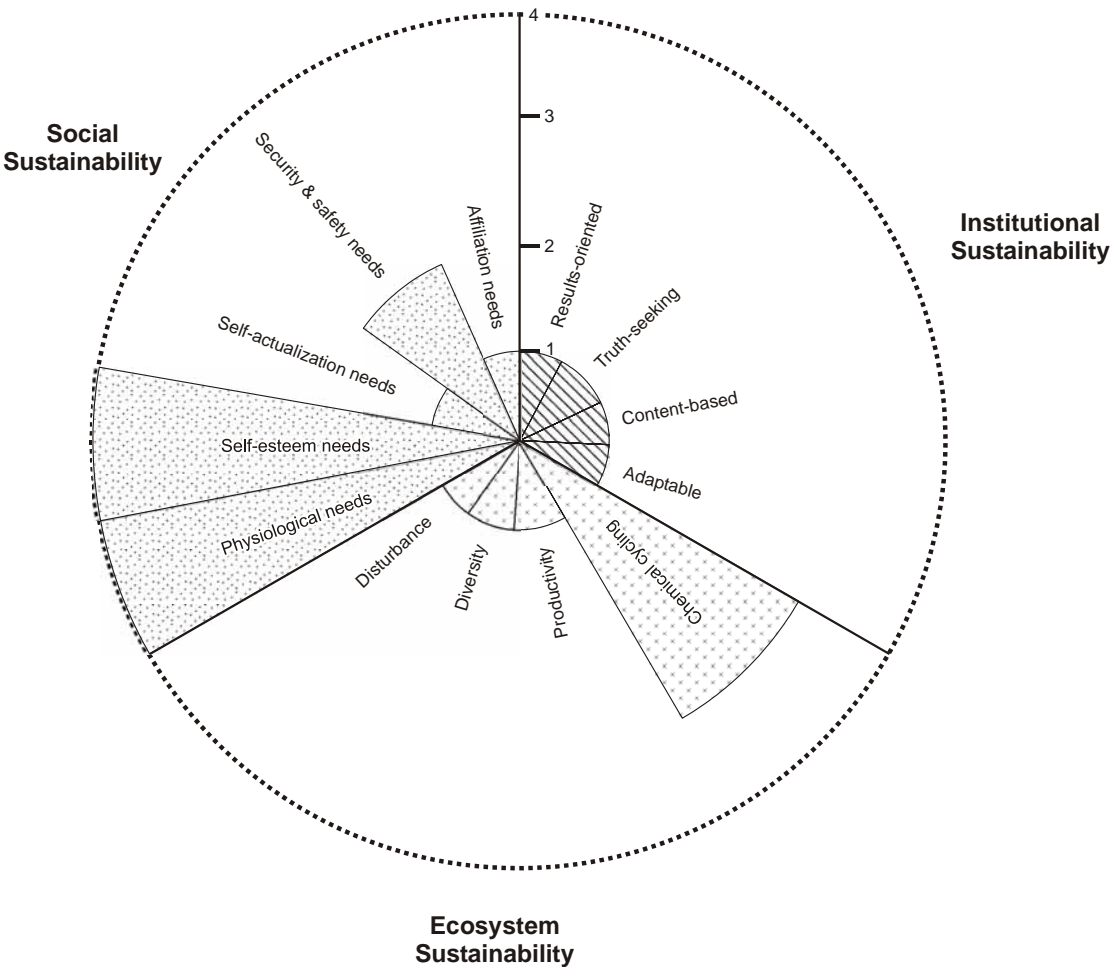
**Truth-seeking institutions** (see Section 4.5.3): No programme exists in the bait fishery to record catch and effort statistics. The performance of the indicator regarding the existence of such a programme was judged ‘poor’ and given a score of 1 (see Table 4.12).

**Adaptable institutions** (see Section 4.5.4): Apart from one by-law that prohibits bait collecting from the Civic Centre lagoon, all the regulations used to control the Kowie bait fishery have been formulated nationally, and none have been reformulated to suit local conditions. The

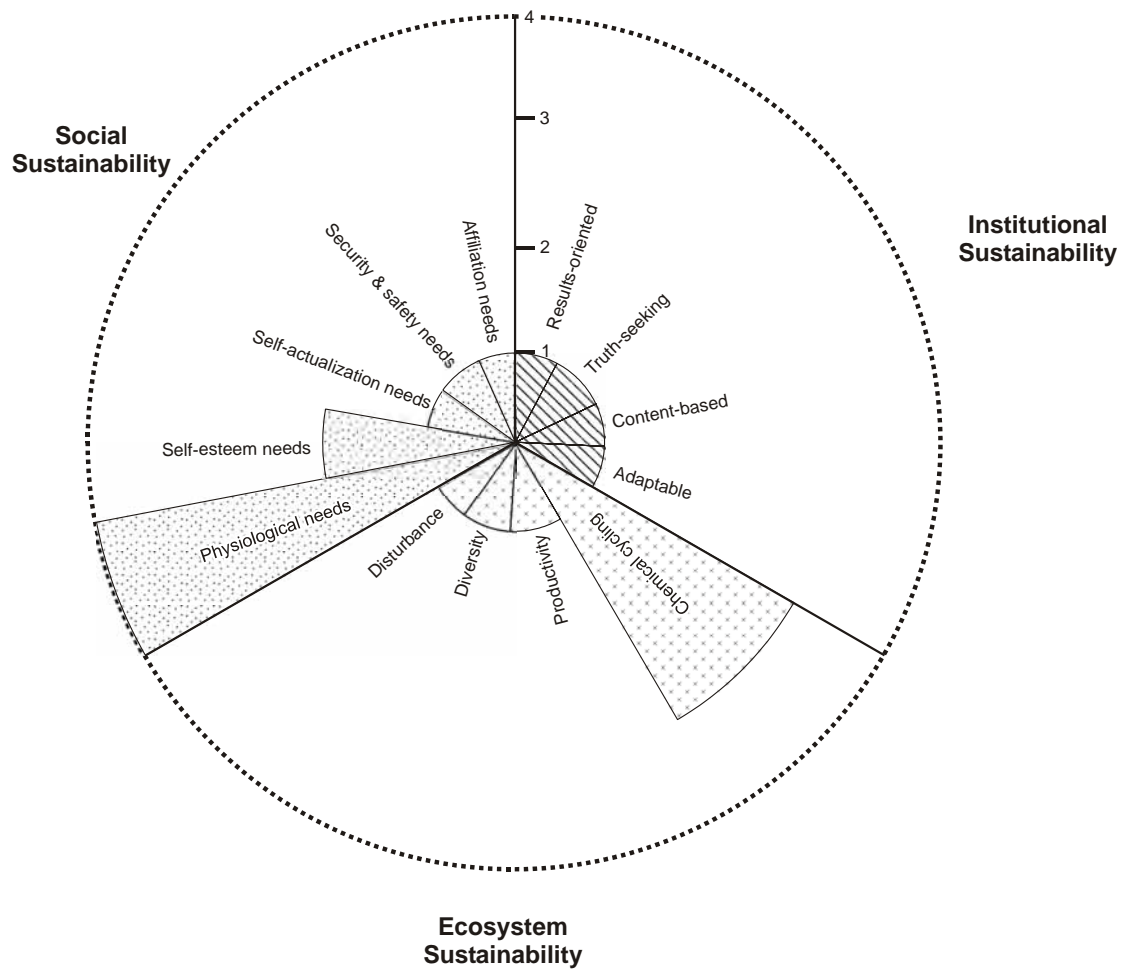
performance of the indicator ‘proportion of fishing regulations adapted to suit local conditions’ was judged ‘poor’ and was scored 1 (see Table 4.13).

**4.7 VISUAL ILLUSTRATION OF SUSTAINABILITY IN THE KOWIE ESTUARY FISHERY**

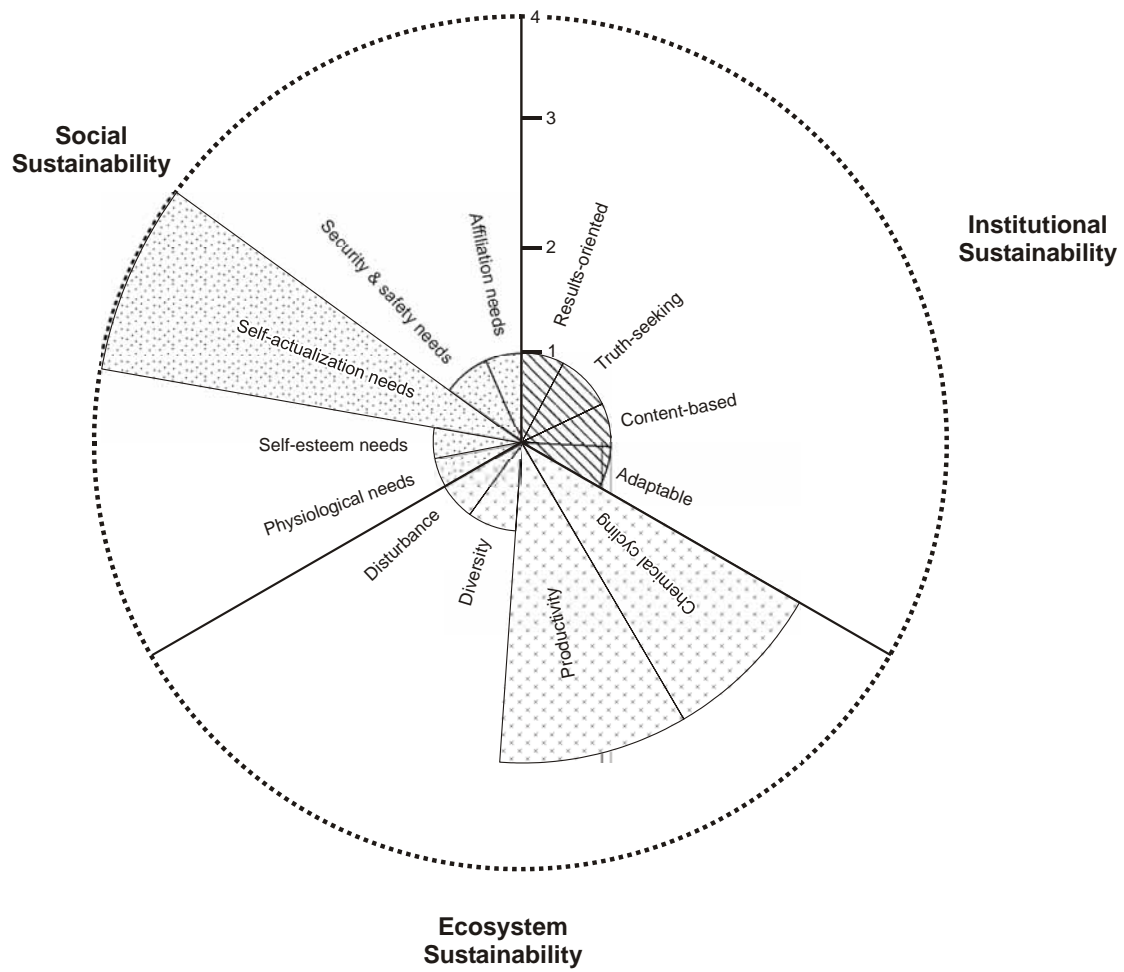
The Amoeba plots in Figures 4.3 – 4.5 illustrate sustainability in the three Kowie estuary fishery sectors investigated.



**Figure 4.3:** Depiction of overall sustainability in the Kowie estuary shore-based recreational line fishery based on data collected during 2000/2001.



**Figure 4.4:** Depiction of overall sustainability in the Kowie estuary subsistence linefishery based on data collected during 2000/2001.



**Figure 4.5:** Depiction of overall sustainability in the Kowie estuary bait fishery based on data collected during 2000/2001.

## 4.8 DISCUSSION

With the adoption of sustainability as the core principle of fishery management (FAO 1995), assessing fisheries for sustainability should become a routine task in fishery management. According to Garcia *et al.* (2000), assessment of sustainability in fisheries serves not only to describe a fishery in terms of sustainability objectives, but also to stimulate action towards those objectives.

Anon. (2002) regards the assessment for sustainability in small-scale fisheries as a better management tool than use of the traditional stock models. Because the assessment process is multidisciplinary it can be carried out with less quantitative data, it is cost effective and it offers fishers an opportunity to be involved in fishery management (Garcia *et al.* 2000).

Despite the above advantages, examples of fisheries that have been assessed for sustainability are still rare in the published literature. Dahl (2000) blames this on the lack of a clear and common methodology for the process, the failure to reach a consensus on the set of indicators that best captures a fishery system, the lack of necessary data, and the complexity of fishery systems. Even so, some progress has been made in developing the necessary methodology, increasing the range of fishery issues that can be assessed, and in the selection of indicators; perhaps the best example to date is the FAO guidelines (Garcia *et al.* 2000). However, much remains to be done, especially in the areas of data collection, indicator weighting and aggregation (Dahl 2000).

The technique adopted to assess sustainability in this study has several advantages over others that have been put forward by various authors. For example, the flexibility of its framework allows it to cover a wide range of fishery issues, unlike the sustainability barometer in Prescott-Allen (1996), for example, which focuses only on human and ecosystem wellbeing. Also, the technique used in this study is simple and easy to understand and follow; by comparison RapFish (Pitcher and Preikshot 2001) requires special statistical skills. This study used reference or target points to grade and score indicator performance, which lends more objectivity and transparency to the process than the technique proposed by the IUCN (1998), where indicator performance is evaluated without the use of these aids. The approach used by Chesson and Whitworth (2000) to evaluate the social sustainability of the south-east trawl fishery in Australia depends on the

availability of historical data on the fishery. The use of fisher views and perceptions during this study overcame the limitation imposed by lack of historical data on the Kowie estuary fishery.

#### **4.9 PRACTICAL CONSTRAINTS AND REALITIES**

This study attempted to evaluate sustainability in three fishery sectors on the Kowie estuary. Alternately, the ecosystem approach to fishery management would advocate the evaluation of the Kowie fishery as one unit. While that approach might be applicable to some fisheries, it is less appropriate for the Kowie estuary fishery due to its multi-user and multi-species nature. For example, the dominance of well-educated recreational fishers on the estuary would result in a rating for 'high self-esteem' if the Kowie fishery was assessed as one unit, and otherwise mask the rating 'low self-esteem' applicable to fishers in the subsistence sector. This implies that the outcome of the evaluation process will likely be affected by the choice of the fishery unit that forms the basis of the evaluation process. Decision makers in the fishery need to agree on the basic unit of assessment before the evaluation process begins.

The sustainability framework adopted to represent the Kowie estuary fishery also affected the evaluation results. One advantage of the framework given by Pajak (2000) is that it reduces the basic components of sustainability to 13, while leaving room for further expansion when necessary. Here, some fishery data (for example, catch structure, habitat quality and water quality) were relatively easy to slot into the framework. However, this was less true for other data (especially in regard to the social domain of the fishery). For example, which fishery data will correspond to self-esteem and self-actualisation needs, and where can basic fishery data such as fisher demographics and regulation knowledge fit in? In the end, the high flexibility of Pajak's (2000) framework increased the level of subjectivity in the assessment process, which may affect the potential for replication. Decision makers evaluating sustainability in fisheries will need to strike a balance between flexibility and objectivity in their choice of a sustainability framework.

Final decisions regarding indicator performance depend on which reference points are used. The biological and ecological reference points offered by Caddy and Mahon (1995) are suitable for well-researched large-scale fisheries. Furthermore, to be acceptable to fishers, reference points need to reflect local societal visions and goals for the fishery. One shortcoming of this study is

that specialists outside the Kowie estuary fishery determined the reference points. And, in the end, the judgements on indicator performance have reflected the vision of myself (the researcher) rather than that of the fishers. In the future, to overcome this shortcoming in the evaluation process, consensus among key stakeholders in the fishery must be reached over the choice of reference points used for an evaluation, as well as for the grading and scoring of indicator performance.

The assessment process was admittedly handicapped by a lack of data on the Kowie estuary fishery, especially data that depict trends. This resulted in the use of indicators that may not necessarily have been the most representative. For example, the indicator for catch trends in the various fisheries was replaced by the proxy indicator concerning fisher perception of changes in catch over time. Fisher perceptions can be misleading, especially where information on fishery issues is inadequate; fisher perceptions over the same issue may differ in the different fishery sectors. The use of high-quality indicators will improve the reliability of any evaluation results. Research and monitoring in the fishery are essential for the successful evaluation of sustainability in fisheries.

# CHAPTER 5

## SUMMARY AND RECOMMENDATIONS

### 5.1 GENERAL DISCUSSION

The Kowie estuary is a major estuary along the Eastern Cape coastline. In a sense the estuary is the lifeblood of Port Alfred, helping to attract thousands of tourists to the town. Among the many activities carried out on the estuary are town development, fishing, bait collecting, boating, water skiing and cattle grazing. The multi-use of the Kowie estuary is a potential source of conflict as different user groups compete for limited estuarine space. There is also concern about exploitation of the estuary's living resources, and the fact that the estuary suffers from sedimentation as a result of agricultural activities in the catchment. An urgent need exists for effective and integrated management of the Kowie estuary to ensure that its supply of goods and services continues into the future.

The Institute of Natural Resources (INR), Pietermaritzburg, under the Eastern Cape Estuaries Programme, has helped to formulate a management plan for the Kowie estuary (Institute of Natural Resources 1999a). However, the success of the management plan depends on availability of key data. Examples of data gaps concerning the Kowie estuary include lack of information on the exploitation of the estuary's living resources and lack of information on the fishers. In view of that, this study has served two important purposes. First, the research has provided data on catch statistics in the Kowie estuary fishery, quantified fishing effort, described fisher demographics and some fisher attitudes and perceptions. Second, the study has assessed the sustainability of three fishery sectors operating on the estuary, and consequently has identified components of the fishery that need urgent management. The overall product is a relatively comprehensive database on the Kowie estuary line and bait fisheries, which should assist decision making both for specific sectors of the fishery and management of the estuary as a whole.

This study showed that the major living resources exploited on the Kowie estuary are fish, mud prawn (*Upogebia africana*) and mud crab (*Scycila serrata*). In total, 26 different species were reported in the catches of linefishers interviewed during the study. Three fish species accounted

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for most of the catch by number: Cape stumpnose (*Rhabdosargus holubi*), spotted grunter (*Pomadasys commersonnii*) and dusky kob (*Argyrosomus japonicus*). Most of the fish species caught were estuarine associated marine species, highlighting the importance of maintaining a permanent link between the Kowie estuary and the sea.

Annual catch on the estuary was estimated at 16,420 fish or (5.99 tons). *Pomadasys commersonnii*, *Rhabdosargus holubi* and *Argyrosomus japonicus* were the most targeted species on the estuary. The dense *Zostera* beds in the estuary support a high stock level of *R. holubi*. Consequently, that species experiences the highest overall catch rate by number on the estuary, and also dominates the catch by number. The relatively high abundance of *R. holubi* in the Kowie estuary pushed the overall linefish catch rate by number to 0.57 fish.ang.h<sup>-1</sup>. In the subsistence sector, where the species was highly targeted, its catch rate by number reached 0.75 fish.ang.h<sup>-1</sup>.

However, *R. holubi* contributes less to catch by mass probably due to the high proportion of undersized individuals. *A. japonicus* and *P. commersonnii* made relatively small contribution to total annual catch by number, but were the two most important species by mass. *A. japonicus* had the highest overall catch rate by mass on the estuary.

High proportions of fish under the minimum legal size typified catches on the estuary. This underscores the importance of the Kowie estuary along the Eastern Cape coast as a nursery and feeding area for the juveniles of popular angling species.

The recreational linefishery was found to be the dominant fishing sector on the estuary, both in terms of fishing effort and in the number of fish caught. Of the annual 30,952 ang.hrs of fishing effort on the estuary, 45% occurred in the boat-based recreational sector and 39% in the shore-based sector. Boat-based recreational fishers caught 38% of the annual catch by number, while 31% of the catch was caught by the shore-based sector. Subsistence fishers were better represented in the bait fishery, where they formed 75% of the bait collectors, and collected 54% of the total number of mud prawns collected from the estuary as estimated annually.

Weather and school holidays appear to be the main factors determining the temporal distribution of fishing effort on the estuary. Fishing competitions and fish runs were less important. Fishing effort increased in summer, and peaked during the December and April holidays for the recreational sector. Subsistence fishing effort peaked in April, but not in December, as subsistence fishers likely switched to bait collecting to satisfy the demand for bait by recreational fishers.

Private ownership of land adjacent to the estuary and steep estuary banks largely restricted the distribution of shore-based anglers to the first eight kilometres of the estuary inland from the sea. Boat-based recreational fishers enjoyed more access to the estuary and were more evenly spread along it.

According to the survey results, five invertebrate species and five fish species were collected from the estuary to be used as bait; the mud prawn (*Upogebia africana*) had the highest frequency of use on the estuary. The annual number of mud prawns collected from the estuary was estimated at 260,648. Four types of bait collectors were identified according to their motivation for collecting bait: subsistence bait collectors who collect bait to sell to recreational linefishers, subsistence linefishers who collect their own bait for fishing; and shore-based and boat-based recreational anglers who also collected bait for their own fishing.

Six major bait-collecting sites on the estuary were identified; the most frequently used sites were the Bay of Biscay, likely due to its area and proximity, and the “Wreck”. The number of bait collectors and the number of mud prawns collected were highest during December and April, when demand due by holidaying recreational anglers increased. An additional 12 bait species were purchased from local outlets; of these, the two most frequently used baits were pilchards (30%) and chokka squid (17%).

Fisher demographics showed the heterogeneous nature of the user groups of the Kowie estuary fishery resources. Different sub-groups are identifiable, for example by race, age, education or fishing gear. However, in terms of motivation the sub-groups are less distinct, due to the large number of fishers who fish for more than one reason. Identification of genuine subsistence fishers on the Kowie estuary should be of key interest to managers of the fishery.

Although historical catch data on the Kowie estuary fishery was scant, the study provided insight into catch trends in the fishery by surveying fishers perceptions of the fishery. The majority of the linefishers believed there has been a decline in the fishery, both in terms of catch by number and species composition.

The results of the study provide data on the attitudes and views of the fishers in regard to the Kowie estuary fishery and its management. Only a small proportion of the estuary's fishers regarded the fishery resources as their own or believed that they should be involved in managing the fishery. Knowledge of fishing regulations among the fishers was generally poor. The majority of survey respondents regarded bag limits as the most effective approach to protecting the fishery resources. Possession of a fishing licence was more frequent in the shore-based recreational sector, and least frequent in the subsistence bait fishery. The majority of the fishers regarded over fishing, siltation, presence of the marina, and boating as the main threats to the Kowie estuary fishery.

The second phase of the study attempted an assessment of sustainability in the Kowie estuary fishery. Assessing fisheries for sustainability should become a routine task in fishery management. According to Garcia *et al.* (2000) sustainability assessment in fisheries serves not only to describe the fishery in terms of sustainability objectives but also to stimulate action towards those objectives.

Garcia *et al.* (2000) regards the assessment for sustainability in small-scale fisheries as a better management tool than the traditional stock models. The process is multidisciplinary, can be carried out with less quantitative data, is cost effective, and offers the fishers an opportunity to be involved in fishery management.

Despite the advantages, examples of fisheries that have been assessed for sustainability are still rare in the published literature. Dahl (2000) blames this on lack of a clear and common methodology for the process, the failure to reach a consensus regarding the set of indicators that best capture a fishery system, the lack of necessary data, and the complexity of fishery systems. However, some progress has been made in developing the necessary methodology, in increasing the range of fishery issues that can be assessed, and in the selection of indicators: one example is

the FAO guidelines (Garcia *et al.* 2000). However, much remains to be done, especially in the areas of data collection, indicator weighting and aggregation (Dahl 2000).

The technique to assess sustainability adopted in this study has several advantages over others put forward by various authors. For example, the flexibility of its framework allows it to cover a wide range of fishery issues, unlike the sustainability barometer of Prescott-Allen (1996), which only focuses on human and ecosystem wellbeing. The technique used in this study is simple enough for fishers and the general public to understand and follow, unlike RapFish (Pitcher and Preikshot 2001), which requires special statistical skills. This study used reference or target points to grade and score indicator performance, resulting in greater objectivity and transparency than the technique proposed by the IUCN (1998) wherein reference or target points are not used. Another advantage of the technique is that it can be implemented even if no historical data on the fishery exists. By comparison, the FAO guidelines (Garcia *et al.* 2000) and those in Chesson and Whitworth (2000) require historical fishery data for sustainability assessment.

The performance of the selected indicators of institutional sustainability was poor in all three fishery sectors investigated. The absence of effective, integrated plans for those fisheries contributes to a lack of ecosystem management, resulting in the current use of species-based regulations. Non-identification of key stakeholders results in open-access fisheries, while the formulation of collective management goals and actions are hindered. The continued exclusion of fishers from decision-making increases non-compliance in the fishery since the fishers do not identify with the decisions made, while the use of local knowledge and skills is not maximised (Hanna 1997). Meanwhile, the absence of regular research and monitoring in the three fishing sectors contributes to rigid regulations and the inability of the present management systems to respond to change in these fisheries (Hanna 1995).

The only indicator of ecological sustainability to perform well in all the three fishery sectors concerned chemical cycling. This is likely due to the estuary's relatively high water quality. The high numbers of mud prawns collected by bait collectors contributed to the good performance of the indicator concerning productivity in the bait fishery. The other indicators performed poorly in all three sectors, reducing the probability of ecological sustainability in the three sectors.

The probability of social sustainability was highest in the shore-based recreational sector, where all the indicators performed well, except the indicator for affiliation needs. The high participation of Port Alfred residents in all three fishery sectors contributed to the good performance of the indicator for self-actualisation in the fisheries. The rest of the indicators performed poorly in the subsistence line fishery and subsistence bait fishery, resulting in low probability for social sustainability in those fisheries.

The methodology for evaluating sustainability in fisheries is still developing. Most work to date has focused on the well-researched large-scale fisheries of the northern hemisphere. Although subject to limitations, this study has served its main aims: to explore the possibility of assessing sustainability in cases where there is insufficient data on a fishery, and to lay the groundwork for similar studies on other small-scale estuarine fisheries in South Africa.

## **5.2 RECOMMENDATIONS TOWARDS ASSESSING SUSTAINABILITY IN ESTUARINE FISHERIES**

Assessing sustainability in estuarine fisheries is a complex process requiring careful planning and implementation. Thus, the potential outcomes should be worth the time and expenses involved. The following assessment strategies are recommended as a practical means to improve the effectiveness of the process as well as increase the ultimate relevance of sustainability assessment to fishery management.

### **1. Formulate appropriate legislation**

South Africa currently has no special legislation that requires evaluation of sustainability in estuarine fisheries. A policy of sustainability evaluation should be initiated at national level, and a well-funded department dealing with the process established. Clearly defined responsibilities should be delegated to provincial and local levels. Guidelines and a specific protocol for assessing estuarine fisheries for sustainability need to be prepared in order to guide local communities managing the process.

### **2. Improve the skills base in the fishery**

Evaluating sustainability in fisheries requires a range of skills. These range from interview techniques, handling scientific equipment, recording and analysing data, and presenting results.

Special training should be offered to estuary managers, fishers and other key stakeholders to improve the skills base in the fishery with regard to sustainability evaluation.

### **3. Increase public participation**

The process of evaluating sustainability involves judgemental decisions, such as during the selection or construction of the sustainability framework, when setting up reference points and evaluating and scaling indicator performance. To increase the likelihood of public support for the process and an acceptance of its findings, the participation of fishers and other key stakeholders must be actively sought.

### **4. Educate the public**

The value of assessing sustainability needs to be communicated to all stakeholders, including the general public, to ensure that an assessment is understood and accepted. This would involve setting up an education programme in the fishery with the main aim of increasing public awareness of sustainability and the evaluation process. Handbooks and pamphlets on the subjects should be readily available in all major languages. The high percentage of student youths participating in the subsistence fisheries on the Kowie estuary will necessitate educational programmes specifically directed at schools.

### **5. Create a fishery database**

The evaluation conducted during this study was particularly limited by a lack of historical and socio-economic data on the fishery. To help create a comprehensive database on the fishery, a programme of research and monitoring should be established. Research carried out by different bodies must be coordinated, and the results centralised for easy access. Fishers should be given the opportunity to conduct some research and monitoring themselves.

### **6. Test the evaluation process**

The evaluation process should not be static, nor should it be a one-off process. New data on the fishery may emerge, which might necessitate the selection of a new set of indicators. A method to test the evaluation process should be devised to assess how well the whole process is being implemented and whether it is meeting its set objectives. In this regard, Garcia (2000) provided a

checklist of desirable characteristics, which includes transparency, inclusivity, and the contribution of the results to decision making in the fishery.

### **5.3 RECOMMENDATIONS TOWARDS EFFECTIVE MANAGEMENT OF THE KOWIE ESTUARY FISHERY**

Currently the poor state of the Kowie estuary fishery reflects a management system that is ill adapted for sustainability. The management system should be transformed to one that can offer long-term protection to the ecological and socio-economic capital of the fishery. The following management strategies were selected by virtue of being not only urgent but also achievable in the short term.

#### **1. Formulate a management plan for the fishery**

A management plan that has sustainability as its core objective should be drawn up for the fishery. To increase the plan's legitimacy, fishers and other key stakeholders should be involved in the formulation of the plan. The plan should be integrated (for example, with town development) so that stakeholders will have influence over outside activities that impact on the fishery. It should also be flexible enough to deal with variability in the fishery system.

#### **2. Identify key stakeholders in the fishery**

The legitimate users of the Kowie fishery resources should be defined and identified in terms of both number and composition. This will help remove "free chancers" from the fishery, while internalising the benefits and costs of conservation. This is especially true for the recreational sector, which is responsible for most of the fishing effort and catch on the estuary. According to Hanna (1997), if resource users are ill defined the benefits of conservation are too diffuse to appeal to individual resource users. The identification of key stakeholders can contribute to the formulation of a common vision for the fishery and help with allocating management responsibilities.

### **3. Improve public awareness of fishery issues**

This study showed that fishers had inadequate knowledge of important fishery issues such as regulation knowledge, and the rights and responsibilities of fishers in fishery management. A public education programme should be established as a means of raising public awareness of the state of the Kowie estuary fishery, and the role the public needs play in the conservation of the estuary's fishery resources.

### **4. Increase the role of fishers in fishery management**

The current “top-down” approach to the management of the fishery excludes key stakeholders from management. Instead, management of the fishery should be vested with a local management committee. This will give the management system more legitimacy and help to improve regulation compliance in the fishery (Jentoft 2000). Local fishery management committees need to be supported by appropriate legislation. Members of the management committees will need specialised training to acquire the skills and knowledge necessary for fishery management.

### **5. Increase research and monitoring in the fishery**

Regular creel or access point fishery surveys should be conducted on the estuary. This will assist in creation of a database on catch and fishing effort in the fishery. Long-term series data are also needed on fish abundance in the estuary; consequently, this necessitates research that monitors the stock levels of at least the major catch species. More socio-economic research related to the fishery is also recommended.

### **6. Protect critical habitats on the estuary**

This study showed that in terms of catch numbers, *R. holubi* is the most important fish species on the estuary. The conservation of *Zostera* beds should be given priority since they are key to maintaining the high stock level of *R. holubi* on the estuary. Serious threats to the *Zostera* beds include siltation of the estuary, loss of habitat to town development, and trampling during bait collecting. The “no-take” zone in the Civic Centre Lagoon is very small and more “no-take” zones should be established on the estuary, especially in the region of the Bay of Biscay, where the *Zostera* beds are most extensive.

## REFERENCES

- AGBAYANI, R.F. and SIAR, S.V. 1993. Problems encountered in the implementation of a community-based fishery resource management project, p. 149-160. In: R.S. Pomeroy (ed), Towards Integrated Community Management and Common-Property Coastal Fisheries in Asia and the Pacific: concepts, methods and experience. Manila, Phillipines.
- AGUERO, N.M. and LOCKWOOD, B.A. 1986. Resource management is people management, p. 345-347. In: J.L. Maclean, L.B. Dizon and L.V. Hosillos (eds), The First Asian Fisheries Forum. 26-31May 1986, Manila, Phillipines.
- ANON. 1998. Marine Living Resources Act (Act No. 18 of 1998). Government Gazette, South Africa 395 (18930).
- ANON. 1999. Management directions for Western Australian's estuarine and marine embayment fisheries: A strategic approach to management. Fisheries Management Paper No. 131. (Available on line: <http://www.gov.au/westfish/comm/broc/mp/mp131>)
- CENTRE FOR MARINE STUDIES. 1999. Assessment of Marine Resources Availability for Subsistence Fisheries along the Coast of South Africa. Unpublished report, University of Cape Town, South Africa.
- ANON. 2000a. Draft Recommendations for Subsistence Fisheries Management in South Africa. Subsistence Fisheries Task Group, Department of Environmental Affairs and Tourism, Pretoria.
- ANON. 2002. Indicators for Sustainable Fisheries. (Available on line: [www.seadec.org/millennium/tech13.doc](http://www.seadec.org/millennium/tech13.doc)) should be removed
- ATTWOOD, C.G. and BENNETT, B.A. 1995. A procedure for setting daily bag limits on the recreational shore-fishery of the south-western Cape, South Africa. South African Journal of Marine Science 15: 241-251.
- ATTWOOD, C.G. and FARQUHAR, M. 1999. Collapse of line fish stocks between Cape Hangklip and Walker Bay, South Africa. South African Journal of Marine Science 21: 415-432.
- BAILEY, K.D. 1987. Methods of Social Research. The Free Press, New York.
- BAIRD, D., MARAIS, J.F.K. and DANIEL, C. 1996. Exploitation and conservation of angling fish in two South African estuaries. Aquatic Conservation: Marine and Freshwater Ecosystems 6: 319-330.
- BARAN, E. 2000. Biodiversity of estuarine fish fauna in West Africa. NAGA, The ICLARM Quaterly 23(4): 4-9.
- BECKLEY, L.E. 1984. The ichthyofaunal assemblage of the Sundays estuary, South Africa, with particular reference to the juvenile marine component. Estuaries 7: 248-250.

- BENNETT, B.A. 1989. A comparison of the fish communities in nearby permanently open, seasonally open and normally closed estuaries in south-western Cape, South Africa. *South African Journal of Marine Science* 8: 43-55.
- BENNETT, B.A. 1991. Conservation in the marine environment: Some problems with the management of shore-angling in the South-Western Cape. *South African Journal of Aquatic Science* 17(1/2): 2-18.
- BENNETT, B.A. 1993a. The fishery of white steenbras *Lithognathus lithognathus* off the Cape coast, South Africa, with some considerations for its management. *South African Journal of Marine Science* 13: 1-14.
- BENNETT, B.A. 1993b. Aspects of the biology and life history of white steenbras *Lithognathus lithognathus* in southern Africa. *South African Journal of Marine Science* 13: 83-96.
- BECKLEY, L.E. 1984. The ichthyofaunal assemblage of the Sundays estuary, South Africa, with particular reference to the juvenile marine component. *Estuaries* 7:248-250.
- BERKES, F. and KISLALIOGLU, M. 1991. Community-based management and sustainable development, p. 567-574. In: J.R. Durand, J. Lemoalle and J. Weber (eds), *Research and Dynamics of Small-scale Fisheries. Artisanal, Symposium Int. ORSTOM-IFFEMER, Montpellier France, 3-7 July 1989, Paris.*
- BLABER, S.J.M. 1997. *Fish and Fisheries of Tropical Estuaries. Fish and Fisheries Series 22, Chapman and Hall, London.*
- BLABER, S.J.M., CYRUS, D.P., ALBARET, J.J., CHONG VING CHING, DAY, J.W., ELLIOT, M., FONSECA, M.S., HOSS, D.E., ORENSAZ, J., POTTER, I.C. and SILVERT, W. 2000. Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems. *Marine Science* 57: 590-602.
- BLAKE, R.W. 1979. Exploitation of a natural population of *Arenicola marina* (L.) from the north-east coast of England. *Journal of Applied Ecology* 16: 663-670.
- BLUMAN, A.G. 1992. *Elementary Statistics: A Step-by-Step Approach. W.M.C. Brown Publishers, Dubuque, Iowa.*
- BOK, A.H. 1983. The demography, breeding biology and management of two mullet species (Pisces: Mugilidae) in the Eastern Cape, South Africa. Ph.D. thesis, Rhodes University, Grahamstown, South Africa.
- BOTSFORD, L.W., CASTELLA, J.C. and PETERSON, C.H. 1997. The management of fisheries and marine ecosystems. *Science* 277: 509-514.
- BRANCH, G.M., HAUCK, M., SIQWANA-NDULO, N. and DYE, A.H. 2002. Defining fishers in the South African context: subsistence, artisanal and small-scale commercial sectors. *South African Journal of Marine Science* 24: 475-487.

- BREEEN, C.M. and MCKENZIE, M. (eds) 2001. *Managing Estuaries in South Africa: An Introduction*. Institute of Natural Resources, Pietermaritzburg, South Africa.
- BROUWER, S.L. 1997. *An assessment of the South African east-coast line fishery from Kei Mouth to Stil Bay*. M.Sc. thesis, Rhodes University, Grahamstown, South Africa.
- BROUWER, S.L., MANN, B.Q., LAMBERTH, S.J., SAUER, W.H.H. and ERASMUS, C. 1997. A survey of the South African shore-angling fishery. *South African Journal of Marine Science* 18: 165-177.
- CADDY, J.F. and MAHON, R. 1995. Reference points for fisheries management. FAO. Fisheries Technical Paper 347, FAO, Rome. 83 pp.
- CAPUTI, N. and LENANTON, R.C.J. 1999. A survey of the recreational usage of coastal fisheries in western Australia. Department of Fisheries and Wildlife Western Australia Report No. 27..
- CHARLES, A.T. 1994. Towards sustainability: the fishery experience. *Ecological Economics* 1: 201-211.
- CHESSON, J. and WHITWORTH, B. 2000. Social indicators of ecologically sustainable development. (Available on line: [www.brs.gov.au/events/country/proceedings.chesson.rtf](http://www.brs.gov.au/events/country/proceedings.chesson.rtf))
- CLARKE, J.R. and BUXTON, C.D. 1989. A survey of the recreational rock-angling fishery at Port Elizabeth, on the south-east coast of South Africa. *South African Journal of Marine Science* 8: 183-194.
- COCHRANE, K.L. and PAYNE, A.I.L. 1998. Purses, people, and power: the role of policy in directing fisheries management as indicated by the debate surrounding a developing fisheries policy for South Africa, p. 73-99. In: T.J. Pitcher, P.J.B. Hart and D. Pauly (eds), *Reinventing Fisheries Management Policy*.
- COETZEE, P.S., BAIRD, D. and TREGONING, C. 1989. Catch statistics and trends in the shore angling fishery of the east coast, South Africa, for the period 1959-1982. *South African Journal of Marine Science* 8: 155-171.
- COETZEE, J.C., ADAMS, J.B. and BATE, G.C. 1997. A botanical importance rating of selected Cape estuaries. *Water SA* 23(1): 81-93.
- COPELAND, B.J., RONALD, G.H. and CANDLE, N. 1983. Fisheries demands on the environment, p. 14-20. In: J.W. Reintjes (ed), *Improving Multiple Use of Coastal and Marine Resources*. American Fisheries Society, Bethesda, Maryland. .
- COWLEY, P.D. 1998. Fish population dynamics in a temporary open/closed South African estuary. Ph.D. thesis, Rhodes University, Grahamstown, South Africa.
- COWLEY, P.D. 2000. Utilisation of living marine resources in the estuaries between Port Elizabeth and East London, Eastern Cape Province. Unpublished report, J.L.B. Smith Institute of Ichthyology, Grahamstown, South Africa.

- COWLEY, P.D., WHITFIELD, A.K. and HECHT, T. 1998. Estuarine mariculture in South Africa: strategic options for development and management. South African Network for Coastal and Oceanic Research Occasional Report No. 4.
- COWLEY, P.D. and DANIEL, C. 2001. Estuaries of the Ndlambe Municipality. Institute of Natural Resources Investigational Report, No. 229. University of Pietermaritzburg, South Africa.
- CRETCHLEY, R. 1996. Exploitation of the bait organism *Upogebia africana* (Crustacea: Amurolo) in the Knysna Estuary. M.Sc. thesis, Rhodes University, Grahamstown, South Africa.
- CYRUS, D.P. 1991. Fish Conservation in South African estuaries: pressures, problems and prospects. South African Journal of Aquatic Sciences 17(1): 19-27.
- DAHL, A.L. 2000. Using indicators to measure sustainability: recent methodological and conceptual developments. Marine and Freshwater Research 51: 427-433.
- DANIEL, C. 1994a. Death by digging: The effect of bait digging on the African mud prawn *Upogebia africana* in the Swartkops estuary. Ichthos 41: 15-16.
- DANIEL, C. 1994b. A comparative assessment of gill net and anglers' catches in the Swartkops and Sundays estuaries, Eastern Cape. M.Sc. thesis, University of Port Elizabeth, South Africa.
- DAY, J.H. 1981a. The nature, origin, and classification of estuaries, p. 1-6. In: J.H. Day (ed), Estuarine Ecology with Particular Reference to Southern Africa. A.A. Balkema, Cape Town.
- Day, J.H. 1981b. Summaries of current knowledge of 43 estuaries in southern Africa, p. 251-329. In: J.H. Day (ed), Estuarine Ecology with Particular Reference to Southern Africa. A.A. Balkema, Cape Town.
- DAY, J.H. and GRINDLEY, J.R. 1981a. The estuarine ecosystem and environmental constraints, p. 345-372. In: J.H. Day (ed), Estuarine Ecology with Particular Reference to Southern Africa. A.A. Balkema, Cape Town.
- DAY, J.H. and GRINDLEY, J.R. 1981b. Management of estuaries, p. 373-396. In: J.H. Day (ed), Estuarine Ecology with Particular Reference to Southern Africa. A.A. Balkema, Cape Town.
- DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM 2000 Key Elements of the White Paper for Sustainable Coastal Development in South Africa. Chief Directorate Marine and Coastal Management, Cape Town.
- DE VILLIERS, C. and HODGSON, A. 1999. Studies on estuarine macroinvertebrates, p. 167-207. In: B.R. Allanson and D. Baird (eds), Estuaries of South Africa. Cambridge University Press.

- DITTON, R. B. (1996) Understanding the diversity among Largemouth Bass anglers. p.135-144. In *Multidimensional Approaches to Reservoir Fisheries Management*. American Fisheries Society Symposium 16.
- DITTON, R.B. and HUNT, K.M. 2001. Combining creel intercept and mail survey methods to understand the human dimensions of local freshwater fisheries. *Fish. Man. Ecol.* 8: 295-301.
- FAO. 1995. *Code of Conduct for Responsible Fisheries*. FAO, Rome.
- FAO. 1997. *FAO Technical Guidelines for Responsible Fishing 6*. FAO, Rome.
- FAO. 1998. *Living marine resources and their sustainable development: Some environmental and institutional perspectives*. FAO Fisheries Technical Paper 353. FAO, Rome.
- FIELDING, P.J., ROBERTSON, W.D., DYE, A.H., TOMALIN, B.J., VAN DER ELST, R.P., BECKLEY, S.A., MANN, B.Q., BIRNIE, S.L. and SCHLEYER, M.H. 1994. *Transkei Coastal Resources*, Special Publication No. 98. Oceanographic Research Institute, Durban.
- FORBES, R. 1973. A study of the burrowing sand prawn *Callinassa kraussi* Stebbing (Crustacea: Thallasinidae). Ph.D. thesis, Rhodes University, Grahamstown, South Africa.
- FORBES, V.R. 1998. *Recreational and resource utilisation in Eastern Cape estuaries and development towards a management strategy*. M.Sc.thesis, University of Port Elizabeth, South Africa.
- FORBES, A.T. and BENFIELD, M.C. 1985. Aspects of the penaeid prawn fisheries in Natal. *South African Journal of Aquatic Science* 81: 430-431.
- FORBES, A.T. and BENFIELD, M.C. 1986. Penaeid prawns in the St Lucia Lake system: post-larval recruitment and the bait fishery. *South African Journal of Zoology* 21(3): 224-228.
- FRANCE, M. and EXEL, M. 1999. No rights, no responsibility, p. 235-240. In: *Use of property rights in fisheries management*. FAO Technical Paper 404/1.
- GARCIA, S.M. 1997. Indicators for sustainable development of fisheries. Paper presented at the 2<sup>nd</sup> World Fisheries Congress Workshop on Fisheries Sustainability Indicators, Brisbane, Australia, August 1996.
- GARCIA, S.M. 2000. The FAO definition of sustainable development and the Code of Conduct for Responsible Fisheries: an analysis of the related principles, criteria and indicators. *Marine and Freshwater Research* 51: 535-541.
- GARCIA, S.M., COCHRANE, K., VAN SANTEN, G. and CHRISTY, F. 1999. Towards sustainable fisheries: a strategy for the FAO and the World Bank. *Ocean and Coastal Management* 42:369-398.
- GARCIA, S.M. and GRAINGER, R. 1997. Fisheries management and sustainability: a new perspective of an old problem? Paper presented at the 2<sup>nd</sup> World Fisheries Congress Workshop on Fisheries Sustainability Indicators, Brisbane, Australia, August 1996.

- GARCIA, S.M., STAPLES, D.J. and CHESSON, J. 2000. The FAO guidelines for the development and use of indicators for sustainable development of marine capture fisheries and an Australian example of their application. *Ocean and Coastal Management*: 43: 537-556.
- GAUSTELLA, L.A.M. 1994. A quantitative assessment of recreational angling in Durban Harbour, South Africa. *South African Journal of Marine Science* 14: 87-203.
- GOODLAND, R. and DALY, H. 1996. Environmental sustainability: universal and non-negotiable. *Ecological Applications* 6(4): 1002-1017.
- GRIFFITHS, M.H. 1997. The life history and stock separation of silver kob *Argyrosomus inodorus* in South African waters. *Fisheries Bulletin* 95: 47-67.
- GRIFFITHS, C.L. and BRANCH, G.M. 1997. The exploitation of coastal invertebrates and seaweeds in South Africa: historical trends, ecological impacts and implications for management. *Transactions of the Royal Society of South Africa* 52(1): 121-148.
- HANEKOM, N., BAIRD, D. and ERASMUS, T. 1988. A quantitative study to assess standing biomasses of macrobenthos in soft substrata of the Swartkops Estuary, South Africa. *South African Journal of Marine Science* 6: 163-174.
- HANEKOM, N. and BAIRD, D. 1992. Growth, production and consumption of the thalassinid mud prawn *Upogebia africana* (Ortmann) in the Swartkops estuary. *South African Journal of Zoology* 27: 130-139.
- HANNA, S.S. 1997. The new frontier of American fisheries governance. *Ecological Economics* 20: 221- 233.
- HARRIS, S.A. and CYRUS, D.P. 1995. Occurrence of fish larvae in the St Lucia Estuary, KwaZulu-Natal, South Africa. *South African Journal of Marine Science* 16:333-350.
- HARRISON, T.D. and WHITFIELD, A.K. 1995. Fish community structure in three temporarily open/closed estuaries on the Natal coast. *Ichthyological Bulletin of the J.L.B. Smith Institute of Ichthyology* 64: 1-80.
- HARRISON, T.D., COOPER, J.A.G. and RAMM, A.E.L. 2001. State of South African estuaries: geomorphology, ichthyofauna, water quality and aesthetics. *State of the Environment Report No. 2*, Department of Environmental Affairs and Tourism, Pretoria.
- HECHT, T. 1990a. Fundamentals of marine linefish research in southern Africa, p. 75-81. In: *Marine Recreational Fishing: research usage, management and research*. South African National Scientific Programme Report No.167.
- HECHT, T. 1990b. The status of the East Cape linefishery, p. 31-37. In: *Marine Recreational Fishing: research usage, management and research*. South African National Scientific Programme Report No. 167.

- HEYDORN, A.E. F. 1989. The conservation status of southern Africa estuaries, p. 290-297. In: B.J. Huntley, (ed), Biotic Diversity in Southern Africa: Concepts and Conservation. Oxford University Press, Cape Town.
- HEYDORN, A.E.F. and GRINDLEY, J.R. 1982. Report No. 10, Kowie (CSE 10), Estuaries of the Cape. Part 2: Synopsis of available information on individual systems. CSIR Research Report 409, South Africa.
- HILL, B.J. 1967. Contributions to the ecology of *Upogebia africana* (Ortmann). Ph.D. thesis, Rhodes University, Grahamstown, South Africa.
- HOUDE, E.D. and RUTHERFORD, E.S. 1993. Recent trends in estuarine fisheries: predictions of fish production and yield. *Estuaries* 16(2): 161-176.
- HVIDING, E. 1991. Traditional institutions and their role in the contemporary coastal resource management in the Pacific Islands. *NAGA, the ICLARM Quarterly*, October. 1991: 3-6.
- HYNE, D.W. 1991. The access-point creel survey: procedures and comparisons with the roving creel survey, p. 123-138. In: D. Guthrie, J.M. Hoenig, M. Holliday, C.M. Jones, M.J. Mills, S.A. Moberly, K.H. Pollock and D.R. Talhelm (eds), *Creel and Angler Surveys in Fisheries Management*. American Fisheries Society, Bethesda, Maryland.
- INSTITUTE OF NATURAL RESOURCES 1999a. The Kowie Estuary Management Plan. Part 1: Vision and Goals. Institute of Natural Resources, University of Natal, Pietermaritzburg, South Africa.
- INSTITUTE OF NATURAL RESOURCES 1999b. Estuary Services Workshop Documentation. Institute of Natural Resources University of Natal, Pietermaritzburg, South Africa.
- IUCN. 1998. Assessing Progress Towards Sustainability: workshop on system assessment methods. (Available on line: [www.iucn.org/themes/eval/documents/pune.pdf](http://www.iucn.org/themes/eval/documents/pune.pdf))
- IUCN. 2000. Sustainable Use within an Ecosystem Approach. Information Paper for the Subsidiary Body for Scientific, Technical and Technological Advice to the Convention on Biological Diversity, 5<sup>th</sup> meeting, 31 February 2000, Montreal.
- IVERSEN, E.S. (ed) 1996. *Living Marine Resources and Management*. Chapman and Hall, New York.
- JAMES, N.C., BECKLEY, L.E., MANN, B.Q. and KYLE, R. 2001. The recreational fishery in the Kosi estuarine system, South Africa. *African Zoology*: 36(2): 217-228.
- JAMIESON, D. 1998. Sustainability and beyond. *Ecological Economics* 24: 183-192.
- JENTOFT, S. 2000. Legitimacy and disappointment in fisheries management. *Marine Policy* 24:141- 148.

- KAPETSKY, J.M. 1981. Some considerations for the management of coastal and estuarine fisheries. FAO Fisheries Technical Paper No. 218. 47
- KIEPIEL, P. and QUINLAN, S. 1997 Micro-tourism and future development of resource utilisation along the Transkei coast, p.107-164. In: P.J. Fielding and W.D. Robertson (eds), Transkei Coastal Fisheries Resources: Phase 2, Resources Utilisation, Development and Tourism. Oceanographic Research Unit Special Publications No. 4. Durban.
- KYLE, R. 1986. Aspects of the ecology and exploitation of the fishes of the Kosi Bay system, KwaZulu-Natal, South Africa. Ph.D. thesis, Rhodes University, Grahamstown, South Africa.
- KYLE, R. 1993. Towards the wise use of the fishes of the Kosi Bay Nature Reserve, p. 107-122. In: L.E. Beckley and R.P. Van der Elst (eds), Fish, Fishers and Fisheries. Special Publication No.2. Oceanographic Research Institute, Durban.
- KYLE, R. 1995. Wise use of wetlands by rural indigenous people, The Kosi Bay Nature Reserve: a case study, p. 273-291. In: G.I. Cowan (ed), Wetlands of South Africa. South Africa Department of Environmental Affairs and Tourism. Pretoria.
- KYLE, R. 1999. Gillnetting in nature reserves: a case study from the Kosi lakes, South Africa. *Biological Conservation* 88: 183-192.
- KYLE, R. and ROBERTSON, W.D. 1997. Preliminary estimates of population size and capture rates of mature *Acanthopagrus berda* in the Kosi lakes system, South Africa, using mark-recapture methods. *South African Journal of Zoology* 32: 124-128.
- KNOX, G.A. (ed) 1986. Estuarine Ecosystems: A Systems Approach. Volume 1. C.R.C. Press, Boca Raton, Florida..
- LAMBERTH, S.J., SAUER, W.H.H., Mann, B.Q., BROUWER, S.L., CLARK, B.M. and Erasmus, C. 1997. The status of the South African beach-seine and gill net fisheries. *South African Journal of Marine Science* 18: 195-202.
- LAMBERTH, S.J. and TURPIE, J. 2001. The role of estuaries in South Africa: economic importance and management implications. Unpublished report submitted to the Institute of Natural Resources, Pietermaritzburg, South Africa.
- LASIAK, T.A. 1983. Aspects of the reproductive biology of the southern mullet, *Liza richardsoni*, from Algoa Bay, South Africa. *South African Journal of Zoology* 18: 25-30.
- LENANTON, C.J. and POTTER, I.C. 1987. Contributions of estuaries to commercial fisheries in temperate western Australia and the concept of estuarine dependence. *Estuaries* 10: 28-35.
- LUNDIN, M. 1999. Environmental sustainability of urban water systems. (Available on line: [http://www.esa.chalmers.se/Publications/PDF files/Lic/Tep-1999.PDF](http://www.esa.chalmers.se/Publications/PDF%20files/Lic/Tep-1999.PDF))
- MALVESTUTO, S.P. 1983. Sampling the recreational fishery, p. 397-419. In: L.A. Nielsen and D.L. Johnson (eds), Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

- MANN, B.Q. 2000. Status Reports for Key Linefish Species. Special Publication No. 7. Oceanographic Research Institute, Durban, South Africa.
- MANN, B.Q., VAN DER ELST, R.P. and TAYLOR, R.H. 1994. Multi-usage of St Lucia's fish resources. Unpublished report to the Southern Nature Foundation, Durban, South Africa.
- MANN, B.Q., BECKLEY, L.E. and VAN DER ELST, R.P. 1997. Evaluation of linefishery participation and management along the KwaZulu-Natal coast. South African Association for Marine Research 134: 1- 17.
- MANN, B.Q., JAMES, N.C. and BECKLEY, L.E. 2002. An assessment of the recreational fishery in the St Lucia estuarine system, KwaZulu-Natal, South Africa. South African Journal of Marine Science 24: 263-279.
- MARAIS, J.F.K. 1984. Feeding ecology of major carnivorous fish from four eastern Cape estuaries. South African Journal of Zoology 19: 210-223.
- MARAIS, J.F.K. 1987. Some factors that influence fish abundance in South African estuaries. South African Journal of Marine Science 6: 67-77.
- MARAIS, J.F.K. and BAIRD, D. 1980a. Seasonal abundance, distribution and catch per unit effort of fishes in the Swartkops estuary. South African Journal of Zoology 15(2): 67-71.
- MARAIS, J.F.K. and BAIRD, D. 1980b. Analysis of anglers' catch data from the Swartkops estuary. South African Journal of Zoology 15: 61-65.
- MATLOCK, G. C. 1991. Overview use of surveys in decision-making. American Fisheries Society Symposium 12: 1-4.
- McGRATH, M.D., HORNER, C.C.M., BROUWER, S.L., LAMBERTH, S.J., MANN, B.Q., SAUER, W.H.H. and ERASMUS, C. 1997. An economic valuation of the South African linefishery. South African Journal of Marine Science 18: 203-211.
- McHUGH, J.L. 1966. Management of estuarine fisheries. American Fisheries Society Special Publication No. 3: 133-154.
- MELVILLE-SMITH, R. and BAIRD, D. 1980. Abundance, distribution and species composition of fish larvae in the Swartkops estuary. South African Journal of Zoology 15(2): 72-78.
- MEYER, W.T. and VILJOEN, H.G. 1997. Personology: From Individual to Ecosystem. Heinemann, Johannesburg.
- MORANT, P. D. and QUINN, N. W 1998. Influence of man and management of South Africa's estuaries, p. 289-320. In: B.R. Allanson and D. Baird (eds), Estuaries of South Africa.
- MORRISETTE, P.M. (ed) 1992. Congress on renewable natural resources: critical issues and concepts for the twenty-first century. Special Report Renewable Resources Journal 3.

- PAJAK, P. 2000. Sustainability, ecosystem management, and indicators: Thinking globally and acting locally in the 21<sup>st</sup> century. *Fisheries* 25(12): 16-28.
- PATERSON, A.W. 1998. Aspects of the ecology associated with salt marshes and adjacent habitats in a temperate South African estuary. Ph.D. thesis, Rhodes University, Grahamstown, South Africa.
- PATERSON, A.W. and WHITFIELD, A.K. 1996. Fish associated with a salt marsh creek in the Kariega estuary, South Africa. *Transactions of the Royal Society of South Africa* 51: 195-218.
- PHILLIPS, B., MORVELL, G., ILETT, A. and Hughes, N. 1997. Managing fisheries sustainably: the Australian solution, p. 752-760. Paper presented at the 2<sup>nd</sup> World Fisheries Congress Workshop on Fisheries Sustainability Indicators, Brisbane, Australia, August 1996.
- PITCHER, T.J. and PREIKSHOT, D. 2001. RapFish: A rapid appraisal technique to evaluate the sustainability of fisheries. *Fisheries Research* 49: 255-270.
- PLUMSTEAD, E.E., PRIMSLOO, J.F. and SCHOONBEE, H.J. 1989. A survey of the fish fauna of Transkei estuaries. Part 2: The Mbashe estuary. *South African Journal of Zoology* 24: 273-281.
- POLLOCK, K.H., JONES, C.M., BROWN, T.L. 1994. Angler Survey Methods and their Applications in Fisheries Management. American Fisheries Society Special Publication No. 25. Bethesda, Maryland.
- POMEROY, R.S. 1995. Community-based and co-management institutions for sustainable coastal fisheries management in South East Asia. *Ocean and Coastal Management* 27: 143-162.
- POTTER, I.C., BECKLEY, L.E., WHITFIELD, A.K. and LENANTON, R.C.J. 1990. Comparisons between the roles played by estuaries in the life cycles of fishes in temperate western Australia. *Environmental Biology of Fish* 28: 143-178.
- PRADERVAND, P. 1998. An assessment of recreational angling in Eastern Cape estuaries. M.Sc. thesis, University of Port Elizabeth, South Africa.
- PRADERVAND, P. and BAIRD, D. 2002. Assessment of the recreational linefishery in selected Eastern Cape estuaries: trends in catches and effort. *South African Journal of Marine Science* 24: 87-101.
- PRADERVAND, P., BECKLEY, L.E., MANN, B.Q. and RADEBE, V. 2002. A survey of the linefishery in two urban estuarine systems in KwaZulu-Natal, South Africa (in press).
- PRESCOTT-ALLEN, 1996. Barometer of Sustainability. What it's for and how to use it. World Conservation Union (IUCN), Gland, Switzerland.
- ROBERTSON, W.D. 1996. Abundance, population structure and size at maturity of *Squilla serrata* (Forsk.) (Decapoda: Portunidae) in Eastern Cape estuaries. *South African Journal of Zoology* 31: 177-186.

- ROBERTSON, W.D. and FIELDING, P.J. 1997. Patterns and economies of resource utilisation and tourism along the Transkei coast, p. 4-105. In: W.D. Robertson and P.J. Fielding (eds), Transkei Coastal Fisheries Resources. Phase 2, Resource Utilisation, Development and Tourism. Oceanographic Research Institute, Special Publication No. 4. Durban, South Africa.
- ROBSON, D.S. 1991. The roving creel survey. American Fisheries Society Symposium 12: 19-24.
- ROSENBERG, A.A., FORGARTY, M.J., SISSEWINE, M.P., BEDDINGTON, J.R. and SHEPHERD, J.G. 1993. Achieving sustainable use of renewable resources. *Science* 262(5): 828-829.
- SAUER, W.H.H., PENNEY, A.J., ERASMUS, C., MANN, B.Q., BROUWER, S.L., LAMBERTH, S.J. and STEWARD, T.J. 1997. An evaluation of attitudes and responses to monitoring and management measures for the South African boat-based linefishery. *South African Journal of Marine Science* 18: 147-163.
- SCHLEYER, M.H. and TOMALIN, B.J. 1994. Biology and exploitation of the burrowing prawn *Callinassa kraussi* in Natal. Oceanographic Research Investigational Report No.100: 17-19.
- SCHNEIDER, C. and MERNA, J.W (2000) Manual of Fisheries Survey Methods. (Available on line: <http://www.dnr.state.mi.us/www/ifr/ifrlibra.htm>>
- SCOTT, A. 2000. Introducing property in fishery management. In: R. Shotton (ed), Use of Property Rights in Fisheries. FAO Technical Paper 404/1: 1-13.
- SKELTON, P.H. 1987. South African Red Data Book – Fishes. South African National Scientific Report No. 137.
- SMALE, M.J. and Kok, H.M. 1983. The occurrence and feeding of *Pomatomus saltatrix* (elf) and *Lichia amia* (leervis) in two Cape south-coast estuaries. *South African Journal of Zoology* 18: 337-342.
- SMALE, M.J. and BUXTON, C.D. 1985. Aspects of the recreational ski-boat fishery off the Eastern Cape, South Africa. *South African Journal of Science* 3: 131-144.
- SMITH, M.M. and HEEMSTRA, P.C. (eds) 1986. Smith's Sea Fishes. Macmillan Publishers, Johannesburg.
- SMITH, N. and CULLINAN, C. 2000. Review of South African environmental laws regulating estuaries. EnAct International 2000, Cape Town.
- STAMATOPOULOS, C. 2001. Sustainable development for fisheries: Sample-based fishery surveys. Fishery Information, Data and Statistics Unit, FAO Rome.
- STAPLES, D. 1997. Indicators of sustainable fisheries development. Paper presented at the 2<sup>nd</sup> World Fisheries Congress Workshop on Fisheries Sustainability Indicators, Brisbane, Australia, August 1996.

- SUAREZ, Y.R., PETRERE, M.J. and CATELA, A.C. 2001. Factors determining the structure of fish communities in Pantanal lagoons (Brazil). *Fisheries Management and Ecology* 8: 173-186.
- STATISTICS SOUTH AFRICA. 1998. Government Printer, Pretoria.
- TOMALIN, B.J., ROBERTSON, W.D. and FIELDING, P.J. 1993. The great bait debate, p.160-164. In: L.E. Beckley and R.P. VAN DER ELST (eds), *Proceedings of the 2<sup>nd</sup> South African Marine Linefish Symposium, Durban, 23-24 October, 1992*. Oceanographic Research Institute No. 2, Durban, South Africa.
- TOMALIN, B.J. and ROBERTSON, W.D. 1997. Estimated landing of coastal invertebrates by recreational collectors in KwaZulu-Natal 1963-1995. Part 1. *Oceanographic Research Unit Special Publication* 96(2): 1-29.
- URBAN DYNAMICS 1995. Port Alfred Structure Plan, Cape Town, South Africa.
- VAN DER ELST, R.P. 1989. Marine recreational angling in South Africa, p.164-176. In: A.I.L. PAYNE and R.J.M. CRAWFORD (eds), *Oceans of Life off Southern Africa*. Vlaeberg, Cape Town.
- VAN DER ELST, R.P. and ADKIN, F. 1991. Marine linefish: priority species and research objectives in southern Africa. *Oceanographic Research Institute Special Publication, South Africa* 1: 1-132.
- WALLACE, J.H., KOK, H.M. and BECKLEY, L.E. 1984. Inshore small-mesh trawling survey of the Cape south coast. Part 2: Occurrence of estuarine-associated fishes. *South African Journal of Zoology* 19: 165-169.
- WALLACE, J.H., KOK, H.M. and BECKLEY, L.E., BENNETT, B., BLABER, S.J.M. and WHITFIELD, A.K. 1984. South African estuaries and their importance to fishes. *South African Journal of Science* 80: 203-207.
- WARD, T.J. 2000. Indicators for assessing the sustainability of Australia's marine ecosystems. *Marine and Freshwater Research* 51: 435-446.
- WARREN, S.J. 1964. Some aspects of the ecology and biology of two estuarine Grapsoid crabs. M.Sc. thesis, Rhodes University, Grahamstown, South Africa.
- WHITE, P.N. and BRUTON, M.N. 1983. Food and feeding mechanisms of *Gilchristella aestuaria* (Pisces: Clupidae). *South African Journal of Zoology* 18: 31-36.
- WHITFIELD, A.K. 1989a. The benthic invertebrate community of a southern African estuary: structure and possible food sources. *Transactions of the Royal Society of South Africa* 47: 159-179.

- WHITFIELD, A.K. 1989b. Estuarine fishes: illustrated by the spotted grunter, p. 73-75. In: R.P. Van der Elst (ed), Marine Recreational Fishing: resource usage, management and research. South African National Scientific Programme Report No.167.
- WHITFIELD, A.K. 1990. Life-history styles of fishes in South African estuaries. *Environmental Biology of Fishes* 28: 295-308.
- WHITFIELD, A.K. 1992. A characterization of southern African estuarine systems. *South African Journal of Aquatic Science* 18(1/2): 89-103.
- WHITFIELD, A.K. 1994. An estuary-associated classification for the fishes of southern Africa. *South African Journal of Science* 90: 411-417.
- WHITFIELD, A.K. 1995. Available scientific information on individual systems. WRC Report No. 577/1/95: 1-204.
- WHITFIELD, A.K. 1997. Fish conservation in South African estuaries. *Aquatic Conservation* 7: 1-11.
- WHITFIELD, A.K. 1998. Biology and ecology of fishes in Southern African estuaries: Ichthyological Monographs of the J.L.B Smith Institute of Ichthyology, No.2, Grahamstown, South Africa.
- WHITFIELD, A.K. 1999. Ichthyofaunal assemblages in estuaries: a South African casestudy. *Reviews in Fish Biology and Fisheries* 9: 151-186.
- WHITFIELD, A.K., PATERSON, A.W., BOK, A.H. and KOK, H.M. 1994. A comparison of the ichthyofaunas in two permanently open eastern Cape estuaries. *South African Journal of Zoology* 29: 175-185.
- WYNBERG, R.P. and BRANCH, G.M. 1991. An assessment of bait collecting for *Callinassa kraussi* Stebbing in Langebaan Lagoon, Western Cape, and of associated avian predation. *South African Journal of Marine Science* 11: 141-152.

### APPENDIX 3

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