GARDEN ROUTE NATIONAL PARK

KNYSNA COASTAL SECTION

State of Knowledge

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1. ACCOUNT OF AREA

The most prominent landscape feature of the Garden Route National Park-Knysna Coastal Section (GRNP-KCS), formerly known as the Knysna National Lake Area, is the Knysna Estuary. The high conservation importance of this estuary has been emphasised in several studies, with it ranking 3rd of South Africa's estuaries in terms of botanical importance (Coetzee *et al.* 1997), 8th in terms of importance for conserving fish (Maree *et al*. 2003), 19th in terms of waterbird conservation, (Turpie 1995) and 1st in terms of overall conservation importance which includes criteria such as size, diversity of habitat, zonal rarity and biodiversity (Turpie *et al*. 2002). This report concentrates predominantly on the state of knowledge pertaining to the Knysna Estuary, with substantially less attention given to surrounding terrestrial and marine areas.

The Knysna Estuary is one of the best researched estuaries in South Africa, being one of only nine of South Africa's 258 estuaries which Whlifield (2000) rates as Excellent (top category) in terms of available information. Since Whitfield's evaluation there has been significant additional output of published scientific information, principally via the Knysna Basin Project (see Allanson 2000b) which has further advanced the scope and quality of available information. Summaries of pertinent literature and research findings are given in this report.

Note: Throughout this report the tidal water body at Knysna is termed the 'Knysna Estuary' or 'estuary'. Many users prefer the term 'Knysna Lagoon' but objection to using the term 'lagoon' lies in its scientific ambiguity.

1.1 Location

The former Knysna National Lake Area (33°57'- 34°04' South; 22°58'- 23°04' East) is located adjacent to the town of Knysna, which is 60 km east of George, 500 km east of Cape Town, and 260 km west of Port Elizabeth.

1.2 Proclamation

Proclamation Date: 13 December 1985.

1.3 Size

Total size of the GRNP-KCS (former Knysna National Lake Area) is 15000 ha.

1.4 Boundaries

The detailed boundaries of the GRNP-KCS (cf. former Knysna National Lake Area) are given in proclamation legislation (see 2.6 Legislation). In general the GRNP-KCS includes the entire Knysna Estuary and all land areas surrounding the estuary, along the coast from Uitzicht in the West to Noetzie in the East, inland up to Portland and including Charlesford, Westford, Eastford, Gouna commonage and the township area of Knysna (see Map 1).

1.5 Controlling authority

SANParks management of the GRNP-KCS has been based on the enactment of control regulations of Article 23 of the Lake Areas Development Act (Act No. 39 of 1975), now repealed. New regulations are being developed under the Protected Areas Act 57 of 2003. Environmental management by SANParks is concentrated primarily on the Knysna Estuary below the high-water mark, with limited management function with respect to water quality, resource utilisation and development in the lower reaches of the catchment area. Environmental conservation above the high-water mark of the estuary is the responsibility of the Western Cape Nature Conservation Board, with Marine and Coastal Management and the Department of Water Affairs and Forestry also actively involved in the conservation of the area. Regional government administrative bodies include the Knysna Municipality, and the Southern Cape Regional Services Council.

1.6 Legislation

The former Knysna National Lake Area (in terms of Article 2 of the Lake Areas Development Act 1975 (Act 39 of 1975), was proclaimed in Government Gazette No. 10036, proclamation number R.224, 1985. In terms of the National Environmental Management: Protected Areas Act 57 of 2003 this area is now a protected environment.

Management by SANParks must comply with national policies and legislation, as well as international conventions that include:

Acts:

- Sea Shore Act 21 of 1935
- Mountain Catchment Areas Act 63 of 1970
- Seabird and Seals Protection Act 46 of 1973
- Lake Areas Development Act 39 of 1975 (repealed)
- Expropriation Act 63 of 1975
- Conservation of Agricultural Resources Act 43 of 1983
- Environmental Conservation Act 73 of 1989
- Physical Planning Act 125 of 1991
- Development Facilitation Act 67 of 1995
- Constitution of the Republic of South Africa Act No 108 of 1996
- Marine Living Resources Act 18 of 1998
- National Water Act 36 of 1998
- National Forest Act 84 of 1998
- Veld and Forest Fire Act 101 of 1998
- National Environmental Management Act 107 of 1998
- National Heritage Resources Act 25 of 1999
- National Environmental Management: Protected Areas Act 57 of 2003

Conventions & Treaties:

- Convention on International Trade in Endangered species of Wild Fauna and Flora 1973
- Convention of Migratory Species of Wild Animals, 1991
- Convention on Biological Diversity 1992

2. ABIOTIC CHARACTERISTICS

2.1 Geology & soils

2.1.1 Geology

The geology of the Knysna area has been documented by Krige (1927), Miller (1975) and Dingle *et al.* (1983), and a comprehensive review given in Grindley (1985). In brief, the catchment area of the Knysna River lies within the Cape Fold Belt with long east-west orientated faults and folds. Most of the catchment lies in quartzites of the Table Mountain Group. Mesozoic rock outcrops that weather into sand and mud occur in low-lying areas north of the estuary. The dune complex south of the estuary (Brenton dune), is a steep (±24°) coastal dune from the Tertiary and Pleistocene period (Reddering & Esterhuisen 1987).

2.1.2 Soils / Sediments

Three categories of soils can be distinguished in the Knysna area including (i) shallow azonal soils with imperfectly developed horizons found on all steep slopes, on recent dunes, and in wetlands, (ii), brown or grey soils forming under present day conditions, most extensive on the forested interfluves, and (iii) palaeosols including laterites and soils with Terra Rossa affinities (Tyson 1971, Butzer & Helgren 1972, Helgren & Butzer 1977).

Along the coastal belt topsoils are fine-medium sand, with A-horizons generally humus rich and of low pH. Deep depositional clays along the coastal platform create strong duplex profiles. The foothill zone exhibits gravels and sands related to ancient alluvial fans and more recent colluviation, with shallow azonal soils occurring on rocky outcrops. The A-horizons under indigenous forest tend to be thick and humus rich. Most soils in the area are found to be nutritionally deficient (Grindley 1985).

The substratum of the estuary consists predominantly of unconsolidated sandy sediments of marine, fluvial and aeolian origin (Reddering & Esterhuisen 1984, 1987). The Knysna estuary is positioned along a rocky portion of the coastline where the longshore sediment transport capacity exceeds supply. Consequently, only small volumes of marine sediments are transported into the estuary (Chunnet 1965, Zwamborn 1980). These are distributed primarily near the mouth of the estuary. Grain size, shape and chemical composition of surface sediments in the middle reaches of the estuary indicate that they consist almost exclusively of aeolian material, which most likely originated from Brenton dune on the southern bank of the estuary (Reddering & Esterhuisen 1987). The angularity and poorly sorted nature of sand grains in the upper reaches of the estuary indicate that these sediments are largely fluvially derived (Reddering & Esterhuisen 1987). Fluvially transported mud also occurs in the area around Thesens Island and Leisure Island where it is mixed with aeolian transported material (Reddering & Esterhuisen 1987).

Sediment loads originating from the catchment are in the order of 100-150 t km^{-2} y^{-1} (Rooseboom 1978). Despite this Chunnet (1965) suggested that over the past 100 years siltation in the estuary from external sources has been virtually absent, with perceived siltation being the internal movement of material. Grindley (1985) suggested that siltation problems generally occur where artificial structures have been erected. For example, CSIR (1989) concluded that there has been an increase in the rate of sedimentation in the Green Hole area as a result of the construction of the Leisure Island causeway and George Rex Drive. The overall low sediment input into the estuary was confirmed by Reddering (1994), who found little evidence of sediment influx in recent years.

Marker (2000) provides accounts of the erosion of estuarine banks on Leisure Isle and in the Belvedere region, as well as sediment movement on the Pansy Bank sandspit in the 1990s, and inflow of sediments, particularly via the Salt River in 1996. It was concluded that storm conditions do not necessarily cause erosion of the beach sand, with erosion being predominantly influenced by wind strength and tide height. The Brenton shore is most affected by strong easterly winds especially when accompanied by rain, since seepage at the base of the clay cliffs causes slumping and sand removal. Another factor controlling erosion is recreational usage of the main channel. Boat wash generates considerable wave action that affects the erodible geology of the incoherent cliffs and the lower beach from mid to high tide (Marker 2000). The effect of land-derived sediments on benthic invertebrates has been addressed by Marker & Maree (2004) who observed that if medium-to-fine deposits did not exceed 0.03m the invertebrate fauna survived and recovered within 2 years, Burial to a depth of 0.20m on a marine bank affected the fauna so that only 42% of the original numbers were present after two years. Where 0.4-0.5 of land sediment accumulated only 6.7% of the pre-flood fauna was evident. In such circumstances *Callianassa kraussii* (sand prawn) was the only prawn able to persist.

2.2 Physiography

2.2.1 Topography

The Knysna estuary is an S-shaped stretch of water, 1633 ha in extent (Duvenhage 1983), with a channel approximately 19 km long and up to 2 km wide. It has a tidal reach of about 17 km (Reddering & Esterhuysen 1984). Hills with steep slopes surround most of the estuary. There are three islands, of which Leisure Island or Steenbok Island (82 ha), and Thesens Island or Paardeneiland (84 ha) have been connected by causeways to the mainland. The third low-lying marshy island, called Rex Island, is situated between the Leisure and Thesens Islands. Dykes have been constructed to prevent flooding of the small airstrip constructed on Rex Island, and its area has been artificially extended by reclamation of the saltmarshes.

2.2.2 Drainage

The Knysna River is approximately 64 km long (Grindley 1985). Some confusion appears to exist regarding the size of the Knysna drainage basin which is given as 400 km^2 (Day *et al*. 1952), 526 km^2 (Noble & Hemens 1978, Day 1981a) and 525 km^2 (Pitman *et al*. 1981), of which the Knysna River basin comprises 426 km^2 (Noble & Hemens 1978), 337 km^2 (Zwamborn 1980) or 315 km^2 (Reddering & Esterhuysen 1984). Presumably the latter two areas exclude the estuary and local drainage (7 streams) which cover approximately 100 km^2 (Noble & Hemens 1978, Day 1981a). Reddering (1994) descries each of 12 sub-catchments draining into the estuary in terms of size, vegetation cover, soils, development and sediment yield.

2.2.3 Bathymetry

Several estimations of the maximum depth of Knysna Estuary have been made. These are 40 feet (cf. 12.2 m) (Krige 1927), 51 feet (cf. 15.5 m) (Day et al. 1952) and 16 m (Day 1981a). More recent determinations of bathymetry include an aerial survey of the estuary in July 1970 which enabled the construction of a contour map, with 0.5 m vertical interval contours, from low water (-0.5 GMSL) to +5.0 GMSL. These data were combined with depth soundings carried out in the estuary in February 1971. Further depth readings were undertaken in The Heads channel on 1

October 1974. According to these studies, portions of the estuary are in excess of 16 meters below MSL.

The channel between the Knysna Heads is 120 m wide and up to 15 m deep (Reddering & Esterhuisen 1987). The bar between The Heads has been chartered as between 4 and 5 meters deep (Day, *et al*. 1952). The main channel follows the broad twists of the estuary, becoming progressively shallower, being approximately 2 m deep at the end of the tidal reach. Wide inter- and subtidal sandbanks line the channel over most of its length.

2.3 Physics

2.3.1 Climate

Mean annual rainfall varies between 700 mm y^{-1} at the coast and 1161 mm y^{-1} in the Outeniqua mountains at Buffelsnek (Station 30/265), with average annual rainfall in the Knysna river catchment estimated as 928 mm y^{-1} (Pitman *et al*. 1981). Rainfall can occur throughout the year, though high rainfall months are usually February, March, May, September, November and December (South African Department of Planning 1970). The average yearly temperature for Knysna is 16.9°C, with the maxima averaging 25.0°C in January, and 18.8°C in July (South African Department of Planning 1970). South-westerly winds predominate most of the year, though warm northerly and north-easterly winds frequently occur in winter.

2.3.2 Hydrology

Flow in the Knysna River is perennial (Reddering & Esterhuysen 1984), with MAR estimated by Noble & Hemens (1978) as 110×10^6 $m^3 y^{-1}$, and by Pitman *et al*. (1981) as 133×10^6 $m^3 y^{-1}$. Haw (1984) however, gives MAR at Charlesford Farm as only 61×10^6 $m^3 y^{-1}$. Day *et al*. (1952) maintain that floods occur, on average, once every 10 to 12 years, at which time the estuary is heavily stained by inflowing sediments. Modelling of flows in Knysna Estuary have been undertaken to assess the effect of flood water on water height (CSIR 1976) and in some cases on proposed developments (CSIR 1974). Run-off frequency curves for catchments K5M01and K5M02 are presented by Hughes & Görgens (1981). The Gouna River (K5M01) generally has lower coefficients of variation that the other as this catchment has lower slopes and less relief than mountain catchments.

The highest flood-level recorded in the estuary between 1965 and 1985 was MSL + 2.0m (Grindley 1985). MSL is given by Grindley as 1.16m, which would equate to a water level in the estuary of +3.16m. Marker (2000) maintains that during a storm event on 16 June 1996 that was accompanied by extreme low pressure at spring tide, water levels at Thesen Jetty reached the highest level on record, 0.20m above maximum spring-tide. Furthermore surges at 15-minute intervals added between 0.10 and 0.05 m to the maximum water level. Although Marker (2000) does not give the actual recorded water height, using values of HAT reported by Grindley (1985) (2.29m), water levels in the estuary would have been between 2.54 and 2.59m amsl.

Haw (1984) assessed the effect of reduced freshwater inflows into Knysna Estuary on salinity, with cessation of flow resulting in salinities up to 36 g kg^{-1} in the upper reaches. Such changes could be expected to have significant effect on biota, with gradual reduction in both primary and secondary productivity (Haw 1984). Modelling of the effects of freshwater flow reductions and flood on salinities was undertaken by Huizinga (1985). Reduced freshwater results in an increase in salinity in the upper reaches of the estuary, with the effects of minor floods (peak 40 $m^3 s^{-1}$) on salinity reduction visible for about 10 days, and the effects of major floods (peak 328 $m^3 s^{-1}$) visible for about 15 days, with at maximum flood the salinity throughout the estuary dropping to almost 0 mg kg^{-1} (Huizinga 1985).

Largier *et al.* (2000) described three hydrographic regimes in the estuary created by the movement of river and ocean waters, and descried the effects of water through-flow, circulation and diffusion on spatial and temporal variability in salinity and water temperature. The bay regime (extending inland from the estuary mouth between 3km during neap tides and 7.5km during spring tides) is well flushed by tidal flows and exhibits salinities and temperatures similar to the ocean. The lagoon regime (extending inland from the upper reaches of the bay regime and seldom beyond White Bridge) is flushed less rapidly, subject only to tidal diffusion effects, and exhibits long residence times. Salinities here are close to ocean salinity, but temperatures may be several degrees warmer. The estuary regime (extending inland from the upper reaches of the lagoon regime) is characterised by the effects of river inflow and stratification, and is fairly well flushed by density-driven estuarine circulation. The lagoon regime expands as the estuary regime shrinks in response to decrease in river flow and as the bay regime shrinks in response to decrease in tidal range (Largier *et al.* 2000). The need for sustained river flow to maintain estuarine conditions in the sector above the White Bridge and to allow some variation in salinity in the lagoon regime has been stressed. If the present retention time of some 20 days in the estuarine regime is increased to greater than 50 days as a result of decreased freshwater inputs, water quality will deteriorate (Largier *et al.* 2000).

Schumann (2000) used temperature variability to demonstrate the hydrodynamics of the estuary, particularly in terms of ocean-estuary exchanges. Ocean temperatures were generally found to be colder than estuary temperatures, with variations in water temperature as a result of tidal fluctuations clearly evident. The influence of cold-water upwelling on estuary temperature was demonstrated in February 1998 where a temperature drop of over 13°C occurred in about 2 hours.

2.3.3 Oceanography

Wave action on the rocky shores at the mouth of the estuary is strong, though seas diminish rapidly as they pass through The Heads, and disappear entirely where the estuary widens upstream of Leisure Island (Grindley 1985). The tidal rise and fall at the mouth at spring-tide is about 1.8 meters (Grindley 1985). High tide at The Heads occurs 37 minutes after high tide in Table Bay. Tidal levels (meters above MSL) for Knysna, obtained from South African Tide Tables (1980) are:

Lowest Astronomical Tide	0.11
Mean Low Water Spring	0.36
Mean Low Water Neaps	0.90
Mean Level	1.16
Mean High Water Neaps	1.43
Mean High Water Spring	1.96
Highest Astronomical Tide	2.29

The delay in the low-tide from the mouth to the Old Drift is approximately two hours at spring-tide, while the delay in high-tide is very much less (Grindley 1985). Thus the ebb is of considerably longer duration than the flood (Day *et al*. 1952). Average tidal flow through The Heads is approximately 1000 $m^3 s^{-1}$, and the maximum tidal flow about 2000 $m^3 s^{-1}$. Mean flow velocities at The Heads are 0.9 $m\ s^{-1}$ (range 0.0 to 1.6 $m\ s^{-1}$). The tidal prism is $19.0 \times 10^6\ m^3$ (CSIR 1974), the largest of any South African estuary. The rocky headlands at the estuary mouth prevent longshore drift of marine sediments, which hence do not enter the estuary (Day 1981).

2.4 Chemistry

2.4.1 Water chemistry

The earliest recorded data about the chemistry of the Knysna Estuary is given in Day *et al*. (1952) who demonstrated that salinity, pH and dissolved oxygen vary along the longitudinal axis of the estuary. Koringa (1956) reported on plant pigment levels and total phosphorous in the water column. Grindley (1976a), Grindley & Eagle (1978) and Grindley & Snow (1983) assessed changes in water quality as a consequence of developments. A summary of these findings are given in Grindley (1985).

Watling & Watling (1977) reported the concentration of metals in water samples and surface sediments for the most part to be low. Some transitional anomalies were reported, most notably being a high mercury levels near The Point. Furthermore, certain of the town drains are responsible for the input of zinc, copper, nickel, cobalt and mercury. The ecological impact of these inputs was considered to be insignificant (Watling & Watling 1977, Grindley 1985). More recently Calvo-Ugarteburu (1998) reported that metal levels in water samples were not detectable and that the concentrations of metals in the surface sediments were similar to those reported by Watling & Watling (1977). Monterio *et al*. (2000) cited in Allanson *et al*. (2000a) however have found that Copper and Zinc in storm-water discharges from the industrial site in Knysna are above the detection limits of 5 $\mu g\ l^{-1}$ and 25 $\mu g\ l^{-1}$ respectively set by the South African Marine Quality Guidelines (DWAF 1995).

Ranges of the water quality parameters water temperature, salinity, dissolved oxygen, pH and secchi disk depth in Knysna Estuary from 1990 to 1994 are given in Russell (1996) and compared with earlier data as given by Day *et al*. (1952), Day (1967, 1981a), Grindley & Eagle (1978) and Haw (1984). It was concluded that no clear long-term changes in recorded water quality parameters were evident.

Allanson *et al*. (2000a) provide values for water quality indicators (pH, TSS, chlorophyll-a, ammonium, nitrate+nitrite, soluble reactive phosphate), measured in Knysna Estuary during 1996 and 1997. In terms of the input of plant nutrients it was concluded that dilution and dispersion by tidal flow is sufficient to prevent overt signs of enrichment either through excessive phytoplankton growth or accumulation of floating macroalgae (Allanson *et al*. 2000a), contrary to the earlier findings of Grindley & Snow (1983). In general the concentration of chlorophyll-a is low, and the water column is oligotrophic. Changes in nutrient levels are closely allied to specific events such as river flooding and sewage treatment plant effluent and/or stormwater inflows from surrounding urban areas. Allanson *et al* (2000a) found there to be a qualitative improvement in chemical water quality when compared to data reported by Grindley & Eagle (1978), thought to be due to an improvement in flow around Thesens Island and an upgrading of the sewage purification works.

Allanson *et al*. (2000a) undertook comparisons of secchi disk depth with earlier studies in 1991-1994 (Russell 1996) and 1947 (Day 1967), and concluded that no significant change had occurred in water clarity. Nevertheless the potential of elevated sediment inflow into the estuary as a result of runoff from quarries and disturbed catchment areas (Reddering 1994) remain an environmental concern (Russell 1996, Allanson *et al*. 2000a), particularly with regard to overall water transparency, the growth of intertidal sandbanks, and the disruption of nutrient pathways for filter feeders.

2.4.2 Pollution

The potential for pollution of the Knysna Estuary is high, with in excess of 111 drainage pipes, drainage ditches and culverts discharging storm-water from residential and industrial areas directly into the estuary. In the Ashmead channel, in the region of the overflow from the Knysna sewage treatment works, elevated nutrient concentrations, increased pH, supersaturation of oxygen, and high Coliform bacilli (1800 $100ml^{-1}$) concentrations have previously been recorded (Grindley & Eagle 1978). It was noted in this study, however, that with the exception of potential pathogenic bacteria, the effects of effluent discharge on water chemistry, substratum, and biota, at the time of sampling, did not appear to be serious (Grindley & Eagle 1978). Later studies indicated elevated nitrogen and phosphorous levels in the region of the sewage works outfall (Grindley & Snow 1983), though due to the short residence time of water in the lower estuary eutrophication is unlikely.

Watling & Watling (1980, 1982) found the concentration of certain metals in sediment and water samples in the estuary to be elevated above true background values as determined for other south-eastern Cape estuaries, though concluded that there was no real indication of metal build up, or of levels which could be considered as a pollution hazard. Calvo-Ugarteburu (1998) measured the levels of metals in the soft tissue of oysters (*Crassostrea gigas*) in 1998 finding that, with the exception of lead and cadmium, levels similar to those found by Watling & Watling (1976). None of these measured levels is above the maximum tolerable standards for heavy metal in the water column in South Africa (DWAF 1995).

Calvo-Ugarteburu (1998) reported DDT and HCB as not being detectable in sediments below oyster culture racks in Knysna Estuary, while Dieldrin and DDO returned levels ranging from 0.01 ng g^{-1} to 7 ng g^{-1} dry mass. Fresh oyster tissue collected at the same time gave traces of DDD (3.5-10.6 ng g^{-1}); DDT 0.08 ng g^{-1} and HCB 0.07-0.60 ng g^{-1}. Dieldrin was not detectable. None of these results is cause for concern at present (Allanson *et al*. 2000a).

The development of the Knysna Quays Marina in 1996 exposed sands contaminated with creosote. Investigating the possible presence of polynuclear aromatic hydrocarbons, Allanson *et al.* (2000a) found that napthalene was the dominant moeity in the creosote-contaminated groundwater seepage (3200 µg l^{-1}) followed by fluorane (74 µg l^{-1}) and phenanthrene (25 µg l^{-1}). The remainder of the array of chemical components commonly found in creosote approached or were below detectable limits (0.1 µg l^{-1}). An initial creosote residue (as phenol) of 350 µg l^{-1} was found to decay to close to 40 µg l^{-1} within 24 days once the seepage was contained.

3. BIOTIC CHARACTERISTICS

3.1 Flora

3.1.1 Phytoplankton / diatoms

Thirty nine phytoplankton species have been identified by Korringa (1956). Phytoplankton biomass has never been investigated, though Day (1981a) maintains that the clarity of the water suggests that it is low. Grindley (1985) lists some of the diatoms recorded in Knysna Estuary, and Grindley (1976a) and Grindley & Eagle (1978) list abundant dinoflagellata.

3.1.2 Algae

The rocky banks at The Heads are colonised by a wide variety of attached algal macrophytes (Day 1981a). Common species within the estuary include *Gelidium pristoides, Ulva lactuca, Enteromorpha* spp. *Chaetomorpha* spp. and *Zonaria tournefortii* (Day *et al*. 1952, Day 1967, Day 1981a, Grindley 1976a, Grindley & Eagle 1978, Grindley & Snow 1983).

3.1.3 Aquatic vegetation

The dominant plant on shelving mudbanks below the mid-tide level is the eel-grass *Zostera capensis* (Grindley 1985). The mean dry biomass of *Z. capensis* is 67.5 g m^{-2} at Ashmead, and 238.4 g m^{-2} north of Leisure Island (Grindley 1976a). In places *Halophila ovalis* grows in association with *Z. capensis*. In the upper reaches of the estuary, from Westford Bridge upstream, *Rupia maritima* becomes common, eventually largely replacing *Z. capensis* at the Old Drift (Grindley 1985).

3.1.4 Semi-aquatic vegetation

The intertidal wetlands of the Knysna Estuary cover an area of 1000 ha (Maree 2000) extending landward of the mid-tide level. Fifty four plants species have been collected in Knysna saltmarshes, of which 27 occur exclusively in this habitat (Maree 2000). *Spartina maritima* is abundant at the mid-tide level, whereas *Sarcocornia, Triglocin, Chenolea, Limonium* and *Plantago* species predominate in the upper levels of the saltmarshes (Grindley 1985). *Juncus kraussii* occurs near the high spring-tide level, and covers extensive areas of mudbanks in the upper reaches of the estuary (Grindley 1976a). Maree (2000) has mapped the distribution of the main types of plant communities as occurring in 1990.

Estimates of biomass production (g m^{-2} dry mass) by saltmarsh plant species in communities on the eastern side of the estuary are given by Grindley (1976a), Grindley & Eagle (1978) and Grindley & Snow (1983). The role of saltmarsh vegetation as a source of detritus has been discussed by Grindley (1976a). Maree (2000) identified several threats to saltmarsh communities, including trampling by people, vehicles and moored boats, bait collecting, constructions, high velocity inflows from drains, and high silt loads.

3.1.5 Terrestrial vegetation

Terrestrial vegetation in the catchment of the Knysna River and surroundings of the Knysna estuary is described by Acocks (1975) as Knysna forest (Veld type 4). Comprehensive descriptions of this forest type are given by Phillips (1931) and von Breitenbach (1974) with approximately 125 tree and woody shrub species recorded in association with a variety of fern, herb, liana and epiphyte species. The distribution of plant communities in the Knysna area has been mapped by Moll & Bossi (1983).

Hughes & Görgens (1981) recorded the land uses in the K5MO2 catchment of the Knysna River (130 km^2 above Gouna) as (i) Indigenous forest 11.4%, (ii) Managed plantation 27.7%, and (iii) Natural vegetation (including pastures) 58.9%.

The invasion of alien plant species has become a problem throughout the Knysna area. *Acacia* species are common with *A. saligna, A. cyclops, A. longifola* and *A. melanoxylon* having invaded large areas (Grindley 1985). Vegetation on the western Knysna Head consists mainly of alien species (Jeffery & Hilton-Taylor 1990). The eastern side of the heads has also been extensively invaded by alien vegetation, though some patches of semi-succulent thicket community that once dominated the area do still remain (Jeffery & Hilton-Taylor 1990). Coastal vegetation in the area around Noetzie is in a relatively unspoiled condition, despite a few small areas of pine plantation (Jeffery & Hilton-Taylor 1990). In the Outeniqua Mountains the indigenous flora is now seriously threatened by *Pinus pinaster* and *Hakea sericea* (Grindley 1985).

3.2 Fauna

3.2.1. Zooplankton

A comprehensive description of zooplankton communities in the Knysna estuary is given by Grindley (1985). The low abundance of planktivores suggests that plankton is not a major source of food in the Knysna estuary (Day 1967). The penetration of sea water into the estuary on each high-tide is thought to limit the survival of true estuarine species to areas where the residence time of water is sufficiently long to enable them to complete their life cycles (Grindley 1985). During cold upwelling events various deep ocean species which do not usually form part of the estuarine or neritic marine plankton community may enter the estuary.

Few freshwater species enter the estuary, as the plankton of the Knysna River was described as very low (Le Roi Le Riche & Hey 1947). Plankton in the channel north of Thesens Island is dominated by true estuarine species. Composition of the zooplankton community is related to tidal exchange (Grindley 1985).

3.2.2. Aquatic invertebrates

The benthic macrofauna includes approximately 310 species (Day 1981a). The ecology of some species, such as the endemic mudsnail *Hydrobia knysnaensis* (cf. Barnes 2004) have been the focus of detailed studies. Day *et al*. (1952) demonstrated that the diversity of aquatic invertebrates progressively declines upstream of The Heads. Furthermore the percentage of typical seashore species decreases progressively up the estuary, with none occurring at Charlesford Rapids (Day *et al*. 1952). Estuarine species are widespread in the estuary, whereas “brack-water species” favour oligohaline conditions at Charlesford Rapids (Day *et al.* 1952). Studies similar to those reported by Day *et al* (1952) were also undertaken in 1997 (Allanson *et al* 2000b). Comparisons of data from different surveys showed that there was no difference between species richness of transects reported in 1952 and 1997. A significant increases was however recorded in species diversity (Shannon-Weiner Index) in quantitatively sampled sediments in the *Zostera* zone which was though to be due to intermittent increases in fluvial derived suspensoids in the water column (Allanson *et al.* 2000b). It has been suggested that an increase in silts and clays (<60 µm) after settling has altered the quality of intertidal sediments, making them more suitable for increases in both the number of individuals of resident taxa as well as new taxa (Allanson *et al*. 2000b).

The mudprawn *Upogebia africana* is abundant and is the most widely used bait species in the estuary (Patterson 1986). *Upogebia africana* occupy 62% of the available intertidal zone, with density (74-76 m^{-2}) and biomass (26-27 g m^{-2} dry weight) usually greatest in the *Spartina* and lower *Zostera* zones (Hodgson *et al.* 2000a). In 1995 the Invertebrate Reserve was found to have a low density and biomass of *U. africana*, (11.7 m^{-2}; 3.9 g m^{-2}) whereas a relatively inaccessible mudbank (Oyster Bank) in the middle reaches of the estuary had a much larger population (176 m^{-2}; 6.5 g m^{-2}) (Hodgson *et al*. 2000a). This difference could be a result of more favourable habitat at the Oyster Bank (e.g. less variable temperature and salinity) and/or the inaccessibility of the site to bait collectors (Hodgson *et al*. 2000a).

The critically endangered false limpet *Siphonaria compressa*, originally described by Allanson in 1958 from the Langebaan Lagoon, has been found living in intertidal eelgrass meadows at Bollard Bay, Leisure Isle (Allanson & Herbert 2005). This represents only the second known site of occurrence of the species. In Langebaan lagoon it is confined to the lower edge of the eelgrass beds (Angel *et al.* 2006). Rarity of *S. compressa* and its endangered status seem dictated by its extremely narrow and temporally changeable habitat range (Angel *et al.* 2006). The Knysna population is considered to be viable (Allanson & Herbert 2005).

Three species of indigenous oyster species occur in the estuary, namely South African Oyster (*Crassostrea margaritacea*), 'weed-oyster' (*Ostrea algoensis*) and Red Oyster (*Ostrea atherstonei*) (Grindley 1985). The Pacific Oyster (*Crassostrea gigas*) was introduced in 1973 and today forms the basis of a flourishing local industry.

The SASS5 river health category in the lower Knysna River was defined as Good (River Health Programme 2007).

3.2.3 Terrestrial invertebrates

Terrestrial invertebrates of the area have to date not been studied in detail, but insects collected included chironomid midges, dragonflies, mayflies, kelp flies, staphylinid and other beetles, house flies and water boatmen (Grindley 1985).

Arguably the best known terrestrial invertebrate in the area is the Brenton Blue butterfly (*Orachrysops niobe*) which became the focus of conservation efforts following the threatened destruction of the habitat of the last known population at Brenton-on-Sea by a housing development (Steenkamp & Steyn 1999). Assessments were undertaken of the life-history, ecology of this species, as described by Edge & Pringle (1996) and Williams (1996) to enable effective conservation of remaining populations. The asteraceous fynbos where *O. niobe* occurs is charcterised by a great diversity of shrubs, herbs and graminoids, with a successional gradient to thicket where *Pterocelastrus tricuspidatus* is dominant (Lubke *et al.* 2003). The eggs of the butterfly are laid on the lower side of the leaves of *Indigofera erecta.* The butterfly appears to require a very specific stage in the coastal fynbos vegetation for breeding sites, and fire probably maintains this mosaic of vegetation types. The vegetation should best be maintained with fire, burning at intervals of more than 10 years (Lubke *et al.* 2003).

3.2.4 Fishes

In excess of 200 species of fish have been recorded in the estuary (Bulpin 1978). A complete species list is given in Grindley (1976a), with the more common species listed in Grindley (1985). Harrison *et al* (1995) recorded 33 fish species of which seven were estuarine dependants, seventeen were inshore marine species whose juveniles utilise estuaries, and seven were marine species which are not dependant on estuaries. The permanently open estuary enables free access to typical marine species, with the result that there are many records of species which do not normally occur in estuaries (Grindley 1985).

The Knysna seahorse (*Hippocampus capensis*), classified as Endangered (Hilton-Taylor 2000), is widespread in the estuary though not abundant. Bell *et al.* (2003) found *H. capensis* most frequently in low density vegetation stands (≤ 20% cover) and grasping *Z. capensis*. Seahorse density is not otherwise correlated with habitat type or depth. Bell *et al.* (2003) estimated the adult population to be 89 000 individuals (range 30 000 to 148 000: 95% confidence interval), and Lockyear *et al.* (2006) estimated the adult population to be 62 000 individuals in the subtidal areas which were estimated to be 5.4 $x10^6m^2$ or 33% of the surface area of the estuary.

Some preliminary studies of the Knysna seahorse included assessments of suitability of environmental conditions for captive breeding (Lockyear 1998, Lockyear *et al*. 1997a, Lockyear *et al*. 1997b), and a description of mating behaviour (Grange & Cretchley 1995). Toeffie (2000) using conventional meristics, morphometric work and limited sequencing of the mitochondrial cytochrome b gene of *H. capensis*, found that a certain amount of variation existed between the Knysna and Swartvlei populations, and recommended that mixing of the two populations should be avoided. An alternative management proposal was forwarded by Teske *et al*. (2003) who investigated the evolutionary history of *H. capensis* using 138 mitocondrial DNA control region sequences. Based on haplotype frequency distribution it was concluded that the three known assemblages (Knysna, Swartvlei, Keurbooms) constitute distinct management units, though it couldn’t be concluded that they are evolving relatively independently under different stochastic processes. The absence of distinctive monophyletic clades of haplotypes unique to individual populations suggested that at this stage there is little reason to discourage the translocation of seahorses amongst the different estuaries. The age of the Knysna population has been estimated to between 46 000 and 486 000 years (late Pleistocene) (Teske *et al*. 2003), which suggests that apart from being geographically isolated from its sister species and living in a habitat that is likely to be inhospitable to other seahorses because of unstable physical and chemical conditions, *H. capensis* may also be phylogenetically distinct (Teske *et al*. 2003). Consequently, the high conservation status of this species seems justified.

What is thought to be a new species of goby from the Knysna river *Gobius maxillaris* sp. n. was described by Davies (1948). No specimens of this species have been recorded in the Knysna estuary, or any other estuary, since this time. A rare estuarine goby, *Pandaka silvana*, is endemic to Knysna Estuary (Penrith & Penrith 1972).

Le Quesne (2000) investigated the usage by fish of intertidal marshes dominated by *Juncus kraussii* in the upper reaches of the estuary. Twenty five, predominantly euryhaline marine species were recorded, which were dominated numerically by juvenile (<30mm) Mugilidae, *Atherina breviceps* and *Liza richardsonii*, and in terms of biomass by *L. richardsonii*, *Lithognathus lithognathus*, *Pomadasys commersonnii* and *Rhabdosargus holubi*. Intertidal marshes are argued to provide areas of refuge from predators and feeding opportunities, with the nine most dominant taxa actively feeding in marsh areas. As such transient marsh nekton may be an important conduit for marsh production into the estuarine and coastal ecosystem.

Freshwater species recorded in the Knysna River include "*Barbus monodactylus*" (Note: probably *Pseudobarbus afer*) "*Sandelia* spp." (Note: probably *S. capensis*) and "springer" (Note: probably *Myxus capensis*) (Le Roi Le Riche & Hey 1947). Both black bass and trout species have been introduced in the past though appear not to have become established (Le Roi Le Riche & Hey 1947). Le Quesne (2000) reported collecting the alien *Gambusia affinis* in intertidal marshes in the upper reaches of the estuary.

3.2.5 Amphibians

Lists of amphibian species potentially occurring in and around the Knysna Estuary, obtained from Poynton (1964) and Passmore & Curruthers (1979) are given in Grindley (1985).

3.2.6 Reptiles

Twenty-four reptile species have been recorded in the Knysna area (Von Breitenbach 1974), which along with unpublished records of Cape Nature Conservation, are given in Grindley (1985).

3.2.7 Birds

Boshoff (1991) lists a total of 208 species recorded in the Knysna area, of which 79 species are commonly found in indigenous forests in the region (Von Breitenbach 1974). Grindley (1985) and Martin *et al*. (2000) together list 74 species that occur predominantly in wetland areas.

The density of waterbirds on the Knysna Estuary is low (Underhill *et al*. 1980, Martin *et al*. 2000). Counts undertaken between 1993 and 1998 indicated a median of 5343 waterbirds present during summer, 76% of them Palaearctic migrants, dropping to a median of 2336 waterbirds in winter (Martin *et al*. 2000). During the summer, 52% of the birds were Curlew Sandpipers, with Grey Plovers, Greenshanks, Kelp Gulls and Whimbrels each making up 6% of the avifauna. During winter Kelp Gulls, Cape and Reed Cormorants, Little Egrets and Sacred Ibises together comprised 62% of the avifauna (Martin *et al*. 2000). Most invertebrate feeding birds are found on the intertidal mudbanks around the Ashmead channel and on the Brenton side of the estuary below the rail bridge, whereas the shallow water areas between the rail and N2 bridges are important for pisciverous birds (Martin *et al*. 2000).

Despite low waterbird densities, Knysna estuary was rated by Underhill *et al*. (1980) as the second most important wetland of importance as habitats for waders in the southern and eastern Cape, and supports the largest numbers of birds of any estuarine system between Cape Agulhas and Durban Bay (Martin *et al*. 2000). It is hypothesised that low waterbird densities may be due to recreational disturbance (Underhill *et al*. 1980, Martin *et al*. (2000) and to the relatively low density and availability of macrobenthic invertebrates (Martin *et al*. 2000).

3.2.8 Mammals

Descriptions of the habits and distribution of 46 mammals recorded in the Knysna area is given by Von Breitenbach (1974) and Grindley (1985). Of the mammals, the rapidly diminishing elephant population has been the best documented (see Phillips (1925), Wildlife Society (1970), Carter (1971), Thesen (1981), Oliver (1982) and MacKay (1983)).

4. HISTORY

4.1 Archaeology

The only archaeological site at Knysna is the cave at the Western Head, which included midden deposits (Grindley 1985). FitzSimons (1928) provided an account of a stradlooper burial site close to Knysna where excavations were made for filling material for the railway. Acheulian artefacts have been reported by Mortelmans (1945) and Davies (1971) from reworked gravels of the Keurbooms Formation east of Knysna.

4.2 Palaeontology

Marker & Miller (1993, 1995) describe the occurrence of shell beds excavated 2.4 to 2.8 m amsl in what is now the town of Knysna, which date (radiocarbon) to 5910 ± 30 BP. These shell beds are evidence of a Holocene high sea-level, with the Knysna Estuary considerably enlarged.

A sequence of estuarine deposits occur in the Knysna Formation north of the town and contain lignites up to 1.5m thick (Thiergart *et al*. 1963). Plant fossils include *Podocarpus* and *Widdringtonia* and pollens which indicate Knysna forest tree species, but work by Thiergart *et al*. (1963) on Early Tertiary pollens reveals that the flora differed from that of the modern forest and included a palm. Microfossils from the Brenton area are described by McLachlan *et al.* (1976) and Dingle *et al*. (1983).

4.3 Historical aspects

Before about 1760 the only human inhabitants of the Knysna areas were the Khoikhoi and San people. Their influence on ecological systems was probably slight except perhaps for starting fires to drive out game animals. Much of the recent history is built up around the logging of surrounding forests; the use of the estuary with its dangerous sea passage as a harbour for tall ships; a short-lived gold rush in 1876; and the lives and exploits of the colourful characters that lived in the area, as described in Tapson (1961) and Metlerkamp (1961). Exploitation of the surrounding indigenous forests started around 1763 (Grindley 1985) and has continued for over 200 years. The estuary was one of the countries oldest commercial harbours, with the first loading wharf being constructed by the Dutch East India Company in 1776 (Reddering & Esterhuysen 1984). In 1820 the Admiralty established a naval dockyard, which was later transferred to Colonial Government in 1862. In its heyday the port would receive up to 80 sailing ships and steamers in a year. Knysna harbour was deproclaimed in 1959 (Reddering & Esterhuysen 1984). In 1876 gold was discovered at Ruigtevlei and later at Millwood, leading to the first gold rush in South Africa (Bulpin 1978). The mining was short-lived and had collapsed by 1894. The best known historical figures were George Rex (a self-proclaimed illegitimate son of King George III) who founded the town of Knysna and who at the time of his death in 1839 owned all of the land surrounding the estuary (Metlerkamp 1961); and John Benn who for many years acted as the harbour pilot by assisting ships in their passage through the heads. Several sites and structures in and around Knysna have been declared national monuments.

5. MANAGEMENT

5.1 Management of vegetation

5.1.1 Burning

Reddering (1994) argues for the prevention of veld fires along hill slopes to the south of the estuary to prevent denudation of vegetation and hence locally accelerated erosion.

5.1.2 Stocking rates

Not applicable

5.1.3 Alien plant control

The invasion of indigenous plant communities by exotic plant species is a long standing problem in the area (Grindley 1985). The problem is now acute on dunes to the west of the estuary and in the Featherbed Nature Reserve (Grindley 1985, Jeffery & Hilton-Taylor 1990). No comprehensive control program has to date been undertaken to address this problem except in areas under the control of the DWAF. Biological control of the *Acacia longifolia* has been attempted. (C.F. Erasmus 1991 in Smit, *in litt*).

Reddering (1994) has argued against the wholesale removal of alien trees (principally black wattle and blackwood) along river courses on the grounds that they assist in the trapping of sediments, and thus reduce sediment influx into the estuary.

5.2 Management of animals

5.2.1 Animal introductions

The Pacific oyster (*Crassostrea gigas*) was introduced into the estuary in 1973 for commercial purposes (Calvo-Ugarteburu 1998). Black bass and trout species have, in the past, been introduced into tributaries of the Knysna river, though appear to have not become established (Le Roi Le Riche & Hey 1947).

5.2.2 Culling

Nil

5.2.3 Alien animal control

Nil

5.2.4 Monitoring

Monitoring of waterbird abundance's is undertaken by local birding enthusiasts, with comprehensive counts undertaken in Summer (January) and Winter (July). Results of past monitoring are discussed in Martin *et al.* 2000.

5.3 Systems management

Procedures for the prevention and combating of oil pollution are given by Retief *et al*. (1979) and Department of Transport (1983), and include prioritisation of areas for cleanup, description of methods of oil collect and disposal, and methods of handling oiled waterbirds.

Reddering (1994) has proposed a number of management actions that could be undertaken in the Knysna catchment to reduce sediment input into the estuary. These include maintenance of ground cover; restoration of old quarries; construction of sediment traps (e.g. Salt and Ouplaas rivers); and engineering works the effect bank stabilisation (Belvedere and Featherbed shorelines).

5.4 Resource utilisation

5.4.1 Water abstraction

Water is abstracted from the Knysna River for domestic supply to Knysna, though no published records exist on the amount abstracted.

5.4.2 Plant harvesting

Nil

5.4.3 Invertebrate collecting

The desire to limit perceived disturbance from bait collecting activities for the conservation of benthic invertebrates was highlighted by Grindley (1985), and led to the proclamation of the salt marshes between Thesens Island and Leisure Island as a marine (bait) reserve (Government Gazette No. 12667 of 27 July 1990).

Harvesting of *U. africana* in Knysna Estuary is undertaken by both leisure and subsistence fishers. Average harvest per bait collecting trip by leisure anglers is 59 prawns, whereas non-leisure fishers took 101 animals, twice the legal limit (Hodgson *et al*. 2000b). Of the mud prawns taken non-leisure fishers used 86%, while recreational anglers use the remaining 14% (Hodgson *et al*. 2000b). The number of bait collectors present per mud bank is highest on public holidays and during summer holidays (Hodgson *et al*. 2000b). Approximately 8.5% of the *U. africana* stocks studied by Hodgson *et al*. (2000b) were harvested annually. Cretchley (1997) estimated that the level of recruitment was more than adequate to replace animals removed.

Upogebia africana are collected predominantly by using a tin can (local bait collectors vs. tourists = 91.3% and 20.0% respectively), pusher (6.6 % and 56.7%) and pumps (2.1% and 23.3%) (Hodgson *et al*. 2000b). However, it was also noted by Hodgson *et al*. (2000b) that illegal collection of bait organisms by digging with a garden fork or spade continues to occur. Digging activities mostly take place at night. Collectors dig trenches 8-20cm deep and about 2-3m long x 1m wide. Trenches more than twice this size (7x2m) have also been recorded. Uprooting of *Spartina maritima* is another illegal method of obtaining bait. Areas disturbed by such activity are still apparent one year later (Hodgson *et al*. 2000b).

5.4.4 *Fishing*

Fishing for fin fish is permitted within the Knysna Estuary, with applied fishing seasons and catch quotas as given in the Marine Living Resources Act 18 of 1998.

5.4.5 *Vertebrate harvesting*

Nil

5.5 Pathogens and diseases

5.5.1 *Virology*

Nil

5.5.2 *Bacteriology*

Grindley & Eagle (1978) give *Escherichia coli* and total coliform counts for water samples collected in the vicinity of a sewage outfall near Thesens Island in January 1978. Counts ranged from 9 to >1800 (*E. coli*) and 70 to >1800 (total coliforms) indicating periodic contamination of the estuary with sewage.

5.5.3 *Parasitology*

Calvo-Ugarteburu (1998) investigated the influence of the protozoan parasite *Perkinsus marinus* on the biology and productivity of the Pacific Oyster *Crassostrea gigas*. It was concluded that *P. marinus* is temperature dependant, causing high oyster mortalities at temperatures over 20°C and becoming inactive at lower temperatures. A triggering mechanism such as an increase in turbidity or decrease in food is required for the onset of *Perkinsus* epizootics, which was recorded in at least 25% of oyster tissues examined. It is suggested that the cause of high mortalities suffered by cultivated oysters in Knysna in 1997 was likely a combination of parasite activities and environmental factors (Calvo-Ugarteburu 1998).

5.6 Environmental modifications

The shoreline and intertidal habitat of Knysna Estuary has been substantially modified by developments. Particularly prevalent are retaining walls with landfills, which skirt much of the northern and eastern shorelines of the estuary as well as the inhabited islands. Two bridges and three causeways have been constructed across various portions of the estuary. Several of these structures alter natural water flow and sediment movement patterns (Day 1981a, Chunnett 1965). Intertidal areas have, in the past, been reclaimed for the development of amongst others a harbour wall, roads, residential areas, factories, a runway, refuse dumping site and a golf course. The scale and pace of development appears to have increased during the 1990s and beyond, despite SANParks involvement. Substantial developments which have occurred since 1990 include the construction of (i) a small-boat harbour, waterfront and two extensive housing developments on the north-eastern shoreline, (ii) a small-boat harbour on Leisure Island, (iii) conversion of the entire Thesens Island into a marina and housing estate, (iv) development of golfing estates of which one was a spectacular failure resulting in environmental damage to the estuary, and (v) infilling of a substantial portion of the northern shoreline with the broadening of the N2 motorway. Some of these developments are discussed in Allanson (1991) and CSIR (1995).

5.7 Zonation

Recommendations for landuse in the Knysna area were made in South African Department of Planning (1970). Constrains and guidelines for future land use were later presented in Department of Constitutional Development and Planning (1983), which although under review is apparently still applicable.

Salt marshes between Thesens Island and Leisure Island have been proclaimed as a marine (bait) reserve (Government Gazette No. 12667 of 27 July 1990). The collection of all invertebrate organisms within this area is prohibited.

5.8 Park expansion

The proclamation of the Garden Route National Park includes the transfer of several portions of state lands along the Garden Route formerly managed by the Department of Water Affairs and Forestry to SANParks. Management transfers could include lands adjacent to the GRNP-KCS, notably the Sinclair Nature Reserve, Kruisfontein State Forest, Krasfontein State Forest, Concordia Sate Forest, Gouna State Forest, and Gounaveld State Forest.

5.9 Social ecology

5.9.1 Opinion surveys

Studies on bait harvesting and utilisation reported by Hodgson *et al.* (2000b) included an opinion survey of both local and tourist bait collectors. Nearly all collectors were aware of the bait restrictions. 87% of recreational anglers believed that the allowed number of 50 prawns per person per day was enough or too many and that it was reasonable to have bait restrictions. 42% of the leisure group released unused bait. By contrast, 71% of the supplementary and subsistence anglers believed that the bait limit was too little, although there was no consensus as to what the limit should be. 64% of this group did not have any bait remaining after fishing or what remained was given to another fisher. The non-leisure group also had divided opinions as to whether it was reasonable to have bait restrictions. Both groups of bait collectors did not think that their collecting activities had any effect on the mud banks. Littering (by tourists) and digging (by locals) were perceived to cause the greatest environmental damage. Most bait collectors do see a need for the presence of a regulatory organisation in the estuary, as 83% of non-leisure fishers and 97% of leisure anglers interviewed saw the need of South African National Parks (Hodgson *et al.* 2000b).

5.10 Research and monitoring

Allanson (2000b) provides a comprehensive bibliography of scientific and environmental literature (published and unpublished) relating to past research in the Knysna River catchment area. Summaries of findings of research and monitoring actions in the Knysna Estuary are given by Grindley (1985) and Allanson (2000a).

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Note: This is a list of references pertaining to the Knysna Estuary in GRNP-KCS, and not all references herein are cited in the text. This bibliography does not include all references relevant to terrestrial ecosystems and associated biota that occur in GRNP-KCS. Notably absent are many references pertaining to Knysna elephants (see J. Koen and others), and most works of some authors on forest ecology such as C. Geldenhuys, J. Phillips and A. Seydack.
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7. APPENDICES

7.1 Species list: Phytoplankton

Diatoms

Achnanthes longipes
Actinocyclus ehrenbergi
Actinoptychus undulatus
Amphora ovalis
Bacillaria paradoxa
Bacteriastrum sp.
Biddulphia pulchella
Biddulphia regia
Chaetoceros sp.
Climacosphemia moniligera
Cocconeis scuttellum
Cocconeis sp.
Coscinodiscus excentricus
Coscinodiscus marginatus
Coscinodiscus nitidus
Coscinodiscus nodulifer
Coscinodiscus radiatus
Coscinodiscus stellaris
Grammatophora angulosa
Grammatophora marina
Isthmia enervis
Licmophora
Licmophora
Mastogloia bonatata
Melosira sulcata
Melosira sp.
Navicula sp.
Nitzschia sigma
Planktoniella sol
Pleurosigma
Rhizosolenia alata
Rhoicosphenia curvata
Skeletonema costatum
Stephanopyxis turris
Striatella unipunctata
Synedra sp.
Thalassiothrix longissima
Thalassionema sp.
Triceratium favus

Insertae sedis

Spermagtogonia antiqua

Silicoflagellata

Dictyocha fibula
Distephanus speculum

Dinoflagellata

Ceratium sp.
Noctiluca miliaris
Peridinium sp.

(Source: Grindley & Eagle 1978; Grindley 1985)

7.2 Species list: Plants

Saltmarsh plant species:

Chenolea diffusa
Halophila ovalis
Limonium scabrum
Plantago carnosa
Sarcocornia decumbens
Sarcocornia perenne
Spartina maritima
Triglochin bulbosa/ striata
Zostera capensis

Marginal vegetation of Knysna Estuary:

Carpobrotus edulis
Chenolea diffusa
Chenopodium album
Cotula coronopifolia
Dimorphotheca pluvialis
Disphyma crassifolium
Eragrostis spp
Falkia repens
Felecia ficoidea
Ficinia lateralis
Gazania rigens
Juncus kraussii
Limonium scabrum
Phragmites australis
Pycreus polystrachyus
Sarcocornia pillansii
Senecio burchellii
Samolus porosus
Sporobolus pungens
Sporobolus virginicus
Stenotaphrum secundatum
Typha capensis

Common species of trees in the Knysna forest:

Cyathea capensis	Tree fern
Podocarpus falcatus	Outenique yellowwood
Podocarpus latifolius	Upright yellowwood
Widdringtonia nodiflora	Mountain cyperess
Strelitzia alba	Wild banana
Celtis africana	White stinkwood
Ficus capensis	Wild fig
Ocotea bullata	Stinkwood
Cunonia capensis	Rooiels
Platylophus trifoliatus	Witels
Trichocladus crinitus	Onderbos
Virgilia oroboides	Keurboom
Fagara davyi	Knobwood
Vepris undulata	White ironwood
Ekebergia capensis	Essenhout
Ilex mitis	Without
Maytenus ocuminata	Sybas
Pterocelastrus tricuspidatus	Kershout
Cassine papillosa	Saffron
Apodytes dimidata	White pear

Scutia myrtina	Katdoring
Kiggelaria africana	Wild peach
Scolopia mundii	Red pear
Olinia cymosa	Hard pear
Cussonia thyrsiflora	Cabbage tree
Curtisia dentata	*Assegai wood*
Rapanea melanophloeos	Boekenhout
Sideroxylon inerme	Milkwood
Diospyror whyteana	Swartbas
Linociera foveolata	Fynblaarysterhout
Olea capensis macrocarpa	Ironwood
Nuxia floribunda	Vlier
Acokanthera oppositifolia	Gifboom
Gonioma kamassi	Kamassie
Haleria lucida	Notsung
Burchellia bubalina	Wild pomegranate
Tarconanthus camphoratus	Camphor bush
Chrysanthemoides monilifera	Bietou

(Source: Grindley 1985; Van Breitenbach 1974)

7.3 Species list: Zooplankton

Protozoa
- *Foraminifera*
- *Noctiluca milliaris*

Cnidaria
- Hydroid medusae
- *Rhizostoma sp.*

Annelida
- Polychaete larvae

Chaetognatha
- *Sagitta* sp.

Cladocera
- *Penilia avirostris*

Ostracoda
- *Perissocytherida sp.*
- *Paracypris sp.*
- *Cyclocypris pusilla*
- *Physcocypria capensis*
- *Cypridopsis assimilis*
- *Cypridopsis viduella*
- *Cypridopsis gregaria*
- *Cypricercus suneatus*
- *Eucypris corpulenta*
- *Eucypris trigona*
- *Heterocypris aurea*
- *Heterocypris incongruens*
- *Hemicypris sp.*
- *Mesocypris terrestris*
- *Potamocypris sp.*

Copepoda
- *Acartia (Paracartia) africana*
- *Acartia (Paracartia) longipatella*
- *Acartia (Acartiella) natalensis*
- *Amphiascus sp.*
- *Calanoides carinatus*
- *Cyclops sp.*
- *Clausidium sp.*
- *Clausocalanus furcatus*
- *Clausocalanus loticeps*
- *Corycaeus africana*
- *Corycaeus sp.*
- *Corycaeus tenuis*
- *Euterpina acutifrons*
- *Halicyclops sp.*
- *Harpacticus gracilis*
- *Harpacticus sp.*
- *Microsetella rosea*
- *Oithona brevicornis*
- *Oithona nana*
- *Oithona oculata*
- *Oithona similis*
- *Oncaea subtilis*
- *Oncaea mediterranea*
- *Paracalanus aculeatus*
- *Paracalanus crassirostris*
- *Paracalanuus parvus*
- *Pseudodiaptomus hessei*
- *Pseudodiaptomus nudus*
- *Saphirella* stages

Mysidacea

Gastrosaccus brevifissura
Leptomysis tattersalli
Mesopodopsis africana
Rhopalopthalamus terranatalis

Cirripedia

Cyperis larvae
Naupliuys larvae

Cumacea

Iphinoe trncata

Isopoda

Parasitic isopod
Paridotea ungulata

Amphipoda

Austrochiltonia subtenuis
Grandidierella bonnieroides
Melita zeylanica
Paramoera capensis

Decapoda

Zoea and Mysis larvae
Palaemon pacificus

Mollusca

Gastropod and *Lamellibranch larvae*

Osteichthyes

Fish eggs and larvae

(Source: Korringa 1956, Day et al. 1952; Grindley & Eagle 1978, Benson & Maddocks 1961, Grindley 1985)

7.4 Species list: Invertebrates

Common burrowing invertebrates:

Assiminia ovata
Sesarma catenata
Ceratonereis erythraeensis
Glycera convoluta
Upogebia africana
Diogenes brevirostris
Natica genuana
Solen capensis
Nassa kraussiana
Alphaeus crassimanus
Macoma littoralis
Dosinia hepatica
Marphysa sanguinea
Loripes clausus
Haminea alfredensis
Tellina trilatera
Cleistostoma spp
Cyclograpsus punctatus
Hymenosoma orbiculare
Talorchestia ancheidos
Lysianassa ceratina
Paridotea ungulata
Lamya capensis
Thaumastoplax spiralis
Cyathura estuaria
Exosphaeroma hylecoetes
Cirriformia tentaculata
Betaeus jucundus

(Source: Grindley & Eagle 1978, Grindley & Snow 1983, Day et al., 1952, Grindley 1985)

7.5 Species list: Fishes

Common fishes in Knysna Estuary:

SCYLIORHINIDAE		
11.13	*Poroderma africanum*	Striped catshark
SPHYRNIDAE		
13.2	*Sphyrna zygaena*	Smooth hammerhead shark
ODONTASPIDIDAE		
19.1	*Odontaspis taurus*	Spotted ragged tooth shark
TORPEDINIDAE		
23.1	*Torpedo fuscomaculata*	Black spotted electric ray
RHINOBATIDAE		
27.2	*Rhinobatos annulatus*	Lesser guitarfish
MYLIOBATIDAE		
28.2	*Myliobatis aquila*	Eagle ray
DASYATIDAE		
30.2	*Dasyatis pastinacus*	Blue stingray
30.7	*Gymnura natalensis*	Backwater butterfly ray
ELOPIDAE		
36.2	*Elops machnata*	Ten pounder
ANGUILLIDAE		
39.4	*Anguilla mossambica*	Longfin eel
CONGRIDAE		
40.8	*Conger wilsoni*	Cape conger
OPHICHTHIDAE		
42.23	*Ophisurus serpens*	Sand snake-eel
CLUPEIDAE		
54.3	*Gilchristella aestuarius*	Estuarine round- herring
54.12	*Sardinops ocellata*	South African pilchard
ENGRAULIDAE		
55.1	*Engraulis capensis*	Cape anchovy
ARIIDAE		
59.3	*Galeichthys feliceps*	Sea barbel
SYNODONTIDAE		
79.10	*Trachinocephalus myops*	Painted lizard fish
GOBIESOCIDAE		
110.1	*Apletodon pellegrini*	Chubby clingish
ATHERINIDAE		
111.1	*Atherina breviceps*	Cape silverside
HEMIRAMPHIDAE		
115.2	*Hemiramphus far*	Spotted halfbeak
115.4	*Hyporhamphus capensis*	Cape halfbeak
SYNGNATHIDAE		
145.15	*Hippichthys spicifer*	Bellybarred pipefish
145.17	*Hippocampus capensis*	Knysna seahorse
145.29	*Syngnathus acus*	Longnose pipefish
PLATYCEPHALIDAE		
155.6	*Platycephalus indicus*	Bartail flathead
TRIGLIDAE		
157.2	*Chelidonichthys kumu*	Bluefin gurnard
SERRANIDAE		
166.76	*Serranus cabrilla*	Comber
TEAPONIDAE		
173.2	*Terapon jarbua*	Thornfish
POMATOMIDAE		
178.1	*Pomatomus saltatrix*	Elf
HAEMULIDAE		
179.10	*Pomadasys commersonnii*	Spotted grunter
179.17	*Pomadasys olivaceum*	Piggy
SPARIDAE		
183.16	*Diplodus cervinus*	Zebra

183.17	*Diplodus sargus*	Blacktail
183.20	*Lithognathus lithognathus*	White steenbras
183.21	*Lithognathus mormyrus*	Sand steenbras
183.35	*Rhabdosargus globiceps*	White stumpnose
183.36	*Rhabdosargus holubi*	Cape stumpnose
183.37	*Rhabdosargus sarba*	Natal stumpnose
183.39	*Sarpa salpa*	Strepie
183.41	*Spondyliosoma emarginatum*	Steentjie
CORACINIDAE		
187.1	*Coracinus capensis*	Galjoen
MONODACTYLIDAE		
193.2	*Monodactylus falciformis*	Cape moony
SCIAENIDAE		
199.1	*Argyrosomus hololepidotus*	Kob
199.8	*Umbrina canariensis*	Baardman
CHAETODONIDAE		
205.11	*Chaetodon marleyi*	Butterfly fish
CARANGIDAE		
210.33	*Lichia amia*	Leervis
MUGILIDAE		
222.7	*Liza richardsonii*	Southern mullet
222.8	*Liza tricuspidens*	Striped mullet
222.10	*Mugil cephalus*	Flathead mullet
222.11	*Myxus capensis*	Freshwater mullet
BLENNIIDAE		
235.30	*Omobranchus woodii*	Kappie blenny
CLINIDAE		
237.22	*Clinus superciliosus*	Super klipfish
GOBIIDAE		
240.23	*Caffrogobius nudiceps*	Barehead goby
240.87	*Psammogobius knysnaensis*	Knysna sand goby
240.93	*Redigobius dewaali*	Checked goby
SOLEIDAE		
262.5	*Heteromycteris capensis*	Cape sole
262.12	*Solea bleekeri*	Blackhand sole
262.15	*Synaptura kleini*	Lace sole
TETRADONTIDAE		
268.1	*Amblyrhynchotes honckenii*	Evileyed blaasop
DIODONTIDAE		
269.6	*Diodon hystrix*	Porcupine fish

(Source: Grindley 1985. Numbers for Marine/Estuarine and diadromous fishes after Smith & Heemstra 1986)

7.6 Species list: Amphibians

BUFONIDAE	
Bufo angusticeps	Cape Sand toad
Bufo rangeri	Raucous toad
HELEOPHRYNIDAE	
Heleophryne regis	Southern ghost frog
HYPEROLIIDAE	
Afrixalus knysnae	Knysna leaf-folding frog
Hyperolius horstocki	Arum lily frog
Semnodactylus wealii	Rattling frog
MICROHYLIDAE	
Breviceps fuscus	Plain rain frog
PETROPEDETIDAE	
Cacostermyn boettgeri	Common caco
Cacosternum nanum	Bronze caco
PIPIDAE	
Xenopus laevis	Common platanna
RANIDAE	
Afrana angolensis	Common river frog
Afrana fuscigula	Cape river frog
Strongylopus grayii	Clicking stream frog
Strongylopus fasciatus	Striped stream frog

(Source: Grindley 1985)

7.7 Species list: Reptiles

TESTUDINES (TORTOISES / TERRAPINS / TURTLES)

TESTUDINIDAE	
Chersine angulata	Anguluate tortoise
Homopus areolatus	Padlopertjie
CHELONIIDAE	
Caretta caretta	Loggerhead turtle
PELOMEDUSIDAE	
Pelomedusa subrufa	Cape terrapin

SQUAMATA - SERPENTES (SNAKES)

TYPHLOPIDAE	
Rhinotyphlops lalandei	Delalande's beaked blind snake
COLUBRIDAE	
Crotaphopeltis hotamboeia	Herald snake
Dasypeltis scabra	Common eggeater
Dispholidus typus	Boomslang
Duberria lutrix	Russett garden snake
Lamprophis aurora	Aurora house snake
Lamprophis fuliginosus	Brown house snake
Lamprophis inornatus	Olive house snake
Lycodonomorphys rufulus	Brown water snake
Philothamnus hoplogaster	Green water snake
Psammophis crucifer	Cross-marked grass snake
Psammophylax rhombeatus	Rhombic skaapsteker
Pseudaspsis cana	Mole snake
ELAPIDAE	
Bitis arietans	Puff adder
Bitis atropos	Cape mountain adder
Causus rhombeatus	Common night adder
Naja nivea	Cape cobra

SQUAMATA - SAURIA (LIZARDS)

SCINCIDAE	
Acontias meleagris	Amber acontias
Mabuya capensis	Striped skink
Pedioplanis lineocellata	Spotted sand lizard
GERRHOSAURIDAE	
Cordylus cordylus	Black zonure
GEKKONIDAE	
Pachydactylus geitjie	Gecko

(Source: Grindley 1985)

7.8 Species list: Waterbirds

PODICIPEDIDAE

6	*Podiceps cristatus*	Great crested grebe
8	*Tachybaptus ruficollis*	Dabchick

PHALACROCORACIDAE

55	*Phalacrocorax carbo*	Whitebreasted cormorant
56	*Phalacrocorax capensis*	Cape cormorant
58	*Phalacrocorax africanus*	Reed cormorant

ANHINGIDAE

60	*Anhinga melanogaster*	Darter

ARDEIDAE

62	*Ardea cinerea*	Grey heron
64	*Ardea goliath*	Goliath heron
65	*Ardea purpurea*	Purple heron
67	*Egretta garzetta*	Little egret
68	*Egretta intermedia*	Yellowbilled egret
71	*Bubulcus ibis*	Cattle egret
76	*Nycticorax nycticorax*	Blackcrowned night heron

SCOPIDAE

81	*Scopus umbretta*	Hamerkop

PLATALEIDAE

91	*Threskiornis aethiopicus*	Sacred ibis
93	*Plegadis falcinellus*	Glossy ibis
94	*Hagedashia hagedash*	Hadeda
95	*Platalea alba*	African spoonbill
102	*Alopochen aegyptiacus*	Egyptian goose
104	*Anas undulata*	Yellowbilled duck
106	*Anas capensis*	Cape teal
108	*Anas erythrorhyncha*	Redbilled teal
112	*Anas smithii*	Cape shoveller
113	*Netta erythrophthalma*	Southern pochard
116	*Plectropterus gambensis*	Spurwinged goose

ACCIPITRIDAE

148	*Haliaeetus vocifer*	Fish eagle
165	*Circus ranivorus*	African marsh harrier

PANDIONIDAE

170	*Pandion haliaetus*	Osprey

RALLIDAE

223	*Porphyrio porphyrio*	Purple gallinule
226	*Gallinula chloropus*	Moorhen
228	*Fulica cristata*	Redknobbed coot

HAEMATOPODIDAE

244	*Haematopus moquini*	African black oystercatcher

CHARADRIIDAE

245	*Charadrius hiaticula*	Ringed plover
246	*Charadrius marginatus*	Whitefronted plover
248	*Charadrius pecuarius*	Kittlitz’s plover
249	*Charadrius tricollaris*	Threebanded plover
254	*Pluvialis squatarola*	Grey plover
258	*Hoplopterus armatus*	Blacksmith plover

SCOLOPACIDAE

262	*Arenaria interpres*	Turnstone
264	*Tringa hypoleucos*	Common sandpiper
266	*Tringa glareola*	Wood sandpiper
269	*Tringa stagnatilis*	Marsh sandpiper
270	*Tringa nebularia*	Greenshank
272	*Calidris ferruginea*	Curlew sandpiper
274	*Calidris minuta*	Little stint
281	*Calidris alba*	Sanderling
284	*Philomachus pugnax*	Ruff

286	*Gallinago nigripennis*	Ethiopian snipe
289	*Numenius arquata*	Curlew
290	*Numenius phaeopus*	Whimbrel
RECURVIROSTRIDAE		
294	*Recurvirostra avosetta*	Avocet
295	*Himantopus himantopus*	Blackwinged stilt
BURHINIDAE		
297	*Burhinus capensis*	Spotted dikkop
298	*Burhinus vermiculatus*	Water dikkop
LARIDAE		
312	*Larus dominicanus*	Kelp gull
322	*Hydroprogne caspia*	Caspian tern
324	*Sterna bergii*	Swift tern
326	*Sterna sandvicensis*	Sandwich tern
327	*Sterna hirundo*	Common tern
339	*Chlidonias leucoptera*	Whitewinged tern
STRIGFORMES		
395	*Asia capensis*	Marsh owl
ALCEDINIDAE		
428	*Ceryle rudis*	Pied kingfisher
429	*Megaceryle maxima*	Giant kingfisher
430	*Alcedo semitorquata*	Halfcollared kingfisher
431	*Corythornis cristata*	Malachite kingfisher
MOTACILLIDAE		
713	*Motacilla capensis*	Cape wagtail

(Source: Martin *et al*. 2000. Species numbers and common names after Maclean 1985).

7.9 Species list: Mammals

SORICIDAE			
3	*Myosorex varius*	-	Forest shrew
12	*Crocidura flavescens*	-	Greater musk shrew
CHRYSOCHLORIDAE			
25	*Chlorotalpa duthieae*	-	Duthie's golden mole
29	*Amblysomus iris*	-	Zulu golden mole
30	*Amblysomus hottentotus i*	-	Hottentot golden mole
PTEROPODIDAE			
46	*Rousettus aegyptiacusi*	-	Egyptian fruit bat
VESPERTILIONINAE			
66	*Miniopterus fraterculus*	-	Lesser long-fingered bat
71	*Myotis tricolor*	-	Temminck's hairy bat
73	*Pipistrellus kuhlii*	-	Kuhl's bat
82	*Eptesicus hottentotus*	-	Long-tailed serotine bat
93	*Kerivoula lanosa*	-	Lesser woolly bat
RHINOLOPHIDAE			
102	*Rhinolophus clivosus*	-	Geoffroy's horseshoe bat
106	*Rhinolophus capensis*	-	Cape horseshoe bat
NYCTERIDAE			
98	*Nycteris thebaica*	-	Common slit-faced bat
CERCOPITHECIDAE			
117	*Papio ursinus*	-	Baboon
119	*Cercopithecus pygerythrus*	-	Vervet monkey
LEPORIDAE			
123	*Lepus saxatilis*	-	Scrub hare
BATHYERGIDAE			
129	*Bathyergus suillus*	-	Cape dune molerat
132	*Cryptomys hottentotus*	-	Common molerat
133	*Georychus capensis*	-	Cape molerat
HYSTRICIDAE			
134	*Hystrix africaeaustralis*	-	Cape porcupine
GLIRIDAE			
136	*Graphiurus ocularis*	-	Spectacled dormouse
138	*Graphiurus murinus*	-	Woodland dormouse
MURIDAE			
156	*Otomys irroratus*	-	Vlei rat
167	*Grammomys dolichurus*	-	Woodland mouse
176	*Myomyscus verreauxii*	-	Verreaux's mouse
201	*Dendromus mesomelas*	-	Chestnut climbing mouse
FELIDAE			
248	*Panthera pardus*	-	Leopard
250	*Felis caracal*	-	Caracal
251	*Felis lybica*	-	African wild cat
253	*Felis serval*	-	Serval
MUSTELIDAE			
262	*Mellivora capensis*	-	Honey badger
264	*Inctonyx striatus*	-	Striped polecat
260	*Aonyx capensis*	-	Cape clawless otter
VIVERRIDAE			
268	*Genetta tigrina*	-	Large-spotted genet
273	*Herpestes ichneumon*	-	Large grey mongoose
275	*Herpestes pulverulentus*	-	Small grey mongoose
278	*Atilax paludinosus*	-	Water mongoose
ELEPHANTIDAE			
289	*Loxodonta africana*	-	African elephant
PROCARVIIDAE			
290	*Procarvia capensis*	-	Rock dassie
SUIDAE			
299	*Potamochoerus porcus*	-	Bushpig

BOVIDAE

311	*Philantomba monticola*	-	Blue duiker
315	*Oreotragus oreotragus*	-	Klipspringer
319	*Raphicerus melanotis*	-	Grysbok
324	*Pelea capreolus*	-	Grey rhebuck
332	*Tragelaphus scriptus*	-	Bushbuck

(Source: Von Breitenbach 1974;, Grindley 1985. Species numbers after Skinner & Smithers 1990).

8. SUMMARY OF AVAILABLE INFORMATION

The summary of available information can be downloaded as an independent document from www.sanparks.org.

9. MAPS

The following maps can be downloaded as independent documents from www.sanparks.org.

9.1 Map: Area

9.2 Map: Geology

9.3 Map: Hydrology

9.4 Map: Soils and landtypes

9.5 Map: Vegetation