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Garden Route National Park: State of Knowledge.

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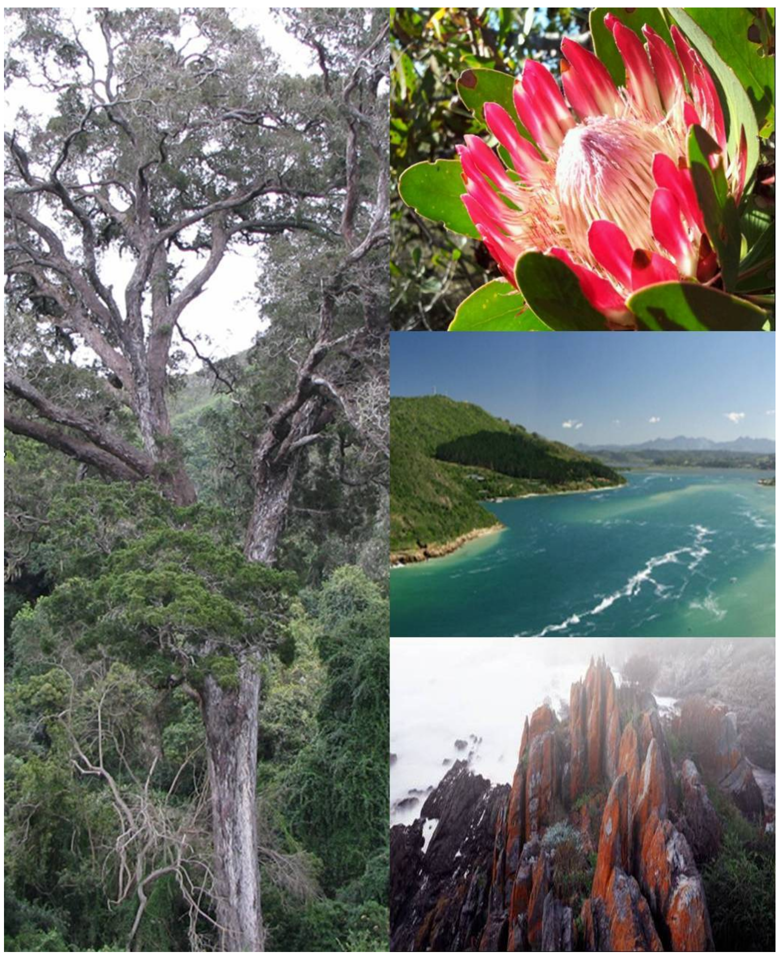
Scientific Services

South African National

Parks

GARDEN ROUTE NATIONAL PARK

State of Knowledge



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1. INTRODUCTION

Scientific Services has compiled State of Knowledge (SOK) reports for the aquatic sections of the Garden Route National Park, namely the Wilderness, Knysna and Tsitsikamma area (Russell *et al*. 2012, Hanekom 2012). The primary objective of these reports was to improve awareness of the information available from various published sources, all of which has relevance to park management, planning and research. It was decided that due to the proclamation of the Garden Route National Park (GRNP) in 2009, which saw the amalgamation of these three sections as well as the Department of Water Affairs and Forestry's indigenous forests, a single SOK should be made available. This document serves to combine the previous reports and add new material relative to newly incorporated areas, thereby forming a consolidated Garden Route report. It must be noted that due to the different administration of the areas, research focus varies across the sections, with greater focus in some areas of the park compared to others.

The SOK report gives a brief introduction to the extensive literature cited and does not purport to be an exhaustive summary of what is available. All information is referenced so that further reading can be undertaken if required. The emphasis of the SOK report on the biophysical and ecological attributes and processes reflects the competencies of authors.

The target audience was initially SANParks staff but it has become apparent that the SOK report has a much wider appeal. It is important that users, especially non-SANParks users, familiarise themselves with the content of the Disclaimer in the SOK report.

2. ACCOUNT OF AREA

2.1 Location

The Garden Route National Park (GRNP), located in the coastal strip between the Outeniqua and Tsitsikamma Mountains and the sea, can be described as a complex of protected areas managed as a single entity by SANParks (*Appendix 12*). The GRNP includes the previously proclaimed Tsitsikamma and Wilderness National Parks, state forests and mountain catchment areas, as well as the Knysna National Lake Area. The latter is managed as a Protected Environment (with promulgated regulations). In this document all the protected areas will be collectively referred to as the Garden Route National Park.

For management purposes the GRNP is divided into three distinct sections:

- The Wilderness section that includes the former Wilderness National Park and former Farleigh Forest Estate, as well as the Outeniqua Mountain Catchments.
- The Knysna section that includes the former Knysna National Lake Area and the former Diepwalle Forest Estate.
- The Tsitsikamma section that includes the former Tsitsikamma National Park and marine protected area, the former Tsitsikamma Forest Estate, as well as the Tsitsikamma Mountain Catchments.

The Wilderness section of the GRNP, located between the towns of George (8 km) and Knysna (25 km), with its unique saline systems, is one of the most integrated urban conservation areas in South Africa. The area incorporates the Touw Estuary, Eilandvlei, Langvlei, Rondevlei, Swartvlei Lake and Swartvlei Estuary, and the marine shoreline from Wilderness (town) to Goukamma Nature Reserve. The national conservation importance of these water bodies has been assessed in several studies, with the Touw systems ranking 9th of South Africa's estuaries in terms of waterbird conservation (Turpie 1995), and the Swartvlei and Touw systems respectively ranking 6th and 24th in terms of overall conservation importance, which includes criteria such as size, diversity of habitat, zonal rarity and biodiversity (Turpie *et al*. 2002). The international conservation importance of the Touw system was highlighted when on 28 June 1991 the majority of the wetland system (Serpentine, Eilandvlei, Langvlei, Rondevlei and interleading channels) was declared a Ramsar site.

The former Wilderness Lake Area (cf. Lake Areas Development Act 39 of 1975) extends seawards (south) from the middle plateau of the Outeniqua Mountains. The section's borders are intertwined with residential estates (Wilderness, Kleinkrans and Sedgefield) and farmlands and the area has seen a significant increase in residential development over the last five years. The George municipality has a completed Integrated Development Plan (IDP) and currently a draft Spatial Development Framework (SDF).

The Farleigh Forest Estate, previously managed by the Department of Water Affairs and Forestry, is part of the Wilderness section, and includes the areas between George and the Knysna River, consisting of the areas known as Groenkop, Bergplaas, Karatara and Goudveld.

The Knysna section includes the former Knysna National Lake Area, adjacent to the town of Knysna, and the former Diepwalle Forest Estate. Knysna is 60 km east of George, 500 km east of Cape Town, and 260 km west of Port Elizabeth. The former Diepwalle Forest Estate lies between the Knysna River and Plettenberg Bay, consisting of Gouna, Ysternek Nature Reserve, Diepwalle, Fisantehoek and Harkerville. The most prominent landscape feature in this section 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).

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.

The Tsitsikamma section of the GRNP straddles the boundary between the Western Cape and Eastern Cape and falls within both the Koukamma Municipality (Cacadu District Municipality area, Eastern Cape Province) and the Bitou Local Municipality (Eden District Municipality, Western Cape Province). It is comprised of the former Tsitsikamma National Park and Tsitsikamma Forest Estate, previously controlled by the Department of Water Affairs and Forestry, now forms the Tsitsikamma section of the GRNP. The centre of this section is approximately 80 km west of Humansdorp and 50 km east of Plettenberg Bay (Chief Director of Surveys and Mapping 1991, Director-General of Surveys 1979). It is situated in a relatively rural area with no highly developed residential areas in close proximity. However, its' scenery and location have attracted developers of golf, sport and residential estates to its borders. It is well known for its Afromontane Forest, hiking- and underwater trails.

The former Tsitsikamma Forest Estate, with its office at the Storms River Village, comprises the areas to the east of Plettenberg Bay, viz. Whiskey Creek Nature Reserve, Bloukrans, Lottering, Storms River, Blueliliesbush, Witelsbos and the Loerie Nature Reserve.

In terms of the marine component, the Tsitsikamma Marine Protected Area (MPA) and the adjacent, marine area off the De Vasselot coast are the only truly marine areas of the GRNP, because the seaward boundary of the Wilderness section extends only to the high water mark and excludes the marine component. The Tsitsikamma Marine Protected Area (MPA) is the oldest marine protected area in Africa (Robinson & De Graaff 1994) conserving seven percent of the rocky shoreline of the Agulhas Biogeographical Region, as well as large populations of recreationally and commercially exploited reef fish (Buxton 1987), which are vulnerable to exploitation (Buxton & Smale 1989; Roberts & Polunin 1991; Halpern 2003). In 2000 the marine section east of the Groot River (west) was proclaimed as the Tsitsikamma Marine Protected Area, a Category 1 (or no-take) MPA (Government Gazette No. 21948, Notice 1429, 29 December 2000, Marine Living Resources Act 1998). At the time of proclamation, the MPA included approximately 61 km of rocky shorelines and 5 km of sandy beaches, extended between 0.5 and 3 nautical miles offshore and had a surface area of some 340 km². The MPA was rezoned in 2016 and reproclaimed as the Tsitsikamma National Park Marine Protected Area under section 22A of the National Environmental Management: Protected Areas Act, 2003 (Act No. 57 of 2003) (Anon, 2016*a*). Regulations were published along with the reproclamation allowing fishing in approximately 20% of the former no-take MPA in three disjoint areas by local communities within a predefined area adjacent to the MPA (Anon 2016*b*). Although the shoreline is primarily rocky, the subtidal area of the park consists chiefly of soft bottom sediments (c. 79%) and dispersed gravel platforms and rocky reefs (c. 21%) (Flemming *et al*. 1986). The MPA protects four percent of rocky shoreline of the Agulhas Biogeographical region (Lombard *et al*. 2005). The adjacent 9 km long De Vasselot section, which was excluded from the MPA, is open to extractive resource use by the public in accordance with the Marine Living Resources Act (1998).

2.2 Proclamation

The Garden Route National Park was proclaimed on 06 March 2009 (Government Notice 248 in Government Gazette No 13981). The Tsitsikamma National Park and Wilderness National Park were included into the GRNP on 11 February 2011 (Government Notice 95 in Government Gazette No 34017). SANParks is responsible for the management of the GRNP, which includes the previously DWAF managed indigenous state forests and mountain catchment areas in the Outeniqua and Tsitsikamma Mountains, as well as the established Wilderness National Park, Tsitsikamma National Park, and the Knysna Protected Area (Knysna National Lake Area).

The proclamations pertaining to the original parks have been listed below.

Wilderness:

The Wilderness National Park was proclaimed in 1983 to protect the unique lakes system (Touw and Swartvlei Systems) of the area, and associated historic and cultural assets and natural landscape features.

(i) 1 April 1983: The Wilderness Lake Area, formally under management of the Lake Areas Development Board was placed under the control of the then named National Parks Board.

(ii) 2 May 1986: The Swartvlei system and surrounding properties proclaimed as a National Lake Area under the management of the then named National Parks Board.

(iii) 6 November 1987: State land within the Wilderness Lake Area proclaimed as the Wilderness National Park.

(iv) 1 April 1991: The Lakes Nature Conservation Station (incorporating Rondevlei and lands between Rondevlei and Swartvlei) formerly under the management of the then named Cape Directorate of Nature and Environmental Conservation placed under the control of the then named National Parks Board.

(v) 17 January 1997: Land in the Duiwe River catchment (72.191ha) under management of the then named Regional Services Council proclaimed as portion of the Wilderness National Park.

(vi) 6 February 2009. Announcement of the proclamation of the Garden Route National Park which incorporates all areas previously proclaimed as Wilderness National Park.

Tsitsikamma:

This reserve has a complex history. In December 1964 the Tsitsikamma Coastal and Forest National Parks were proclaimed. The Forest Park was deproclaimed in 1989, and the name of the Coastal Park was later shortened to Tsitsikamma National Park. Other major changes included the extension of the seaward boundary, the acquisition of the De Vasselot Nature Reserve and the lease of Soetkraal. In the late 1990s this park was some 64 000 ha in extent and included both a terrestrial and a marine component. The size of this conservation area has changed over the years, with the following proclamations:

(i) In 1964 the Coastal and Forest National Parks were proclaimed (Government Gazette No 936; Notice 324, 4 December 1964). The original coastal park stretched some 60 km between Groot River (east) and Groot River (west), and included the areas approximately 0,9 km landward and 0,5 nautical miles (or 0,9 km) seaward of the low water mark (Government Gazette No 4237, Notice 61, 29 March 1974).

(ii) In 1983 the seaward boundary of the park between the Groot (east) and the Bloukrans (23o 39'E) rivers was extended to three nautical miles (or 5,56 km) offshore, while along the rest of the coast (Bloukrans River to Groot River (west)) it remained at 0.5 nautical mile (Government Gazette No 8871, Notice 125, 3 September 1983).

(iii) In 1987 the De Vasselot Nature Reserve (2561 ha) was added to the coastal park (Government Gazette No 11068, Notice No 2814 & 2815, 18 December 1987).

(iv) The small Tsitsikamma Forest National Park was deproclaimed in 1989 (Government Gazette 1989), and the name of the coastal park was shortened to the Tsitsikamma National Park (Government Gazette No 17298, Notice 1077, 28 June 1996).

(v) In October 1991 a 30 year lease was signed with Rand Mines Properties Limited to contractually manage the Soetkraal area in the Tsitsikamma Mountain Range.

(vi) In 1996 the seaward boundary of the De Vasselot section was extended 0,5 nautical miles (0,9 km) offshore (Government Gazette No 17073, Notice 538, 4 April 1996).

(vii) In December 2000 the marine section of the park (excluding the marine area off De Vasselot) became the Tsitsikamma National Park Marine Protected Area (Government Gazette No. 21948, Notice 1429, 29 December 2000, Marine Living Resources Act 1998 (Act No. 18 of 1998)).

(viii) In 1997 Soetkraal was proclaimed a contractual park in terms of the National Parks Act, 1976 (Government Gazette No 17728, Notice 100. 17 January 1997, National Parks Act, 1976 (Act No. 57 of 1976). It status may change in the near future.

(ix) In 1995 Erven 382, 444 and the Remainder of Erf 434, Nature's Valley was proclaimed a contractual section of the park (Government Gazette No 16293, Notice 368, 10 March 1995), followed in 1996 by (Buitenverwachting) Portion 1 of Farm 299 and Portion 3 of the farm Matjies River 295 (Government Gazette No 16927, Notice 30, 19 January 1996),

(x) In March 2009, the Minister of the Department of Environmental Affairs announced the proclamation of the Garden Route National Park, which incorporates the indigenous forest and fynbos areas located to the north of coastal sections of the park and, which were previously administered by the Department of Water Affairs and Forestry.

(xi) In December 2016 the MPA was rezoned and reproclaimed as the Tsitsikamma National Park Marine Protected Area under section 22A of the National Environmental Management: Protected Areas Act, 2003 (Act No. 57 of 2003) (Anon, 2016*a*). Regulations were published along with the reproclamation allowing fishing in approximately 20% of the former no-take MPA in three disjoint areas by local communities within a predefined area adjacent to the MPA (Anon 2016*b*).

Knysna:

The Knysna National Lake Area was proclaimed in 1985 in order to protect the Knysna Estuary. In terms of the National Environmental Management: Protected Areas Act 57 of 2003 this area is now a protected environment and is managed according by SANParks. With respect to the Former State Forests, the former DWAF managed 41 538.6 ha of State Forest land in the southern Cape and Tsitsikamma. This land is scattered on the narrow coastal strip to the south of the Outeniqua and Tsitsikamma Mountain ranges, between George in the west and Kareedouw in the east, with a small area known as Loerie Nature Reserve occurring further east at Longmore Plantation near Hankey. The area was managed from the Area Office in Knysna and is subdivided into three forest estates:

- Farleigh Forest Estate includes the areas between George and the Knysna River, consisting of the areas known as Groenkop, Bergplaas, Karatara and Goudveld. Farleigh now forms part of the Wilderness section of the GRNP (together with the former Wilderness National Park).

- Diepwalle Forest Estate lies between the Knysna River and Plettenberg Bay, consisting of Gouna, Ysternek Nature Reserve, Diepwalle, Fisantehoek and Harkerville (Diepwalle now forms part of the Knysna section of the GRNP (together with the Knysna National Lake Area).

- Tsitsikamma Forest Estate, with its office at the Storms River Village, comprises the areas to the east of Plettenberg Bay, viz. Whiskey Creek Nature Reserve, Bloukrans, Lottering, Storms River, Blueliliesbush, Witelsbos and the Loerie Nature Reserve (Tsitsikamma Forest Estate now forms part of the Tsitsikamma section of the GRNP (together with the former Tsitsikamma National Park).

2.3 Boundaries

Descriptions of the boundaries of the GRNP-WCS (former Wilderness National Park) are given in:

RSA Government Gazette 10211 (2 May 1986)
RSA Government Gazette 11026 (6 November 1987)
RSA Government Gazette 16804 (10 November 1995)
RSA Government Gazette 17727 (17 January 1997)

Descriptions of the boundaries of the former Wilderness Lake Area, which is synonymous with the former Wilderness National Park control area, are given in:

RSA Government Gazette 6162 (22 September 1978)
RSA Government Gazette 7819 (2 October 1981)
RSA Government Gazette 10014 (22 November 1985)

The Wilderness Sections is ± 2 595 ha (25.9 km^2) in extent, and the former Wilderness National Park control area a further 10 000 ha (100 km^2).

The detailed boundaries of the GRNP-KCS (cf. former Knysna National Lake Area) are given in proclamation legislation (see 2.5 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 *Appendix 12*). Total size of the Knysna Section is 15000 ha.

The terrestrial section of the TCNP is long (*c.* 60 km) and narrow (*c.* 0.9 km), stretching from Groot River (east) to Groot River (west). The landward boundaries extend approximately 0.9 km inland of the low water mark, running along the upper slopes of the steep coastal escarpment abutting the shoreline (Statutes of the RSA - National Parks, National Parks Act, No. 57 of 1976). Similarly, the adjoining De Vasselot sector stretches from Groot River (west) to Grootbank, but extends further (3 - 5 km) inland and ‘encircles’ the village of Nature's Valley (RSA. Government Gazette No 1053, 21 June 1974 in Pretorius *et al.* 1980). To the north of De Vasselot, within the Tsitsikamma Mountain Range, Soetkraal extends some 40 km in an east-west direction and consists of eight large farms. These are: Boven Palmiet Rivier (20), Onder Palmiet Rivier (22), Dwars Rivier (23), Slaaps Bosch (15), Langbosch Rivier (16), Keur Rivier (18) both Adjoining Klipheuvel (296), Adjoining Onbedacht (271) (RSA Government Gazette No 17728, Notice 100, 17 January 1997; Chief Director Survey & Mapping 1979a, 1980)

The Tsitsikamma Marine Protected Area (MPA) stretches along the coast of the TCNP, with the seaward boundary extending 3 nautical miles (5,6 km) offshore between the Groot River (east) (24^{o} 12'E) and Bloukrans River (23^{o} 39'E), and previously only 0.5 nautical mile (0,9 km) between the Bloukrans River and Die Punt at Nature’s Valley (23^{o} 35'E)((RSA Government Gazette No. 21948, G.R. 1429, 29 December 2000, Marine Living Resources Act 1998 (Act No. 18 of 1998), which has now also been extended to 3 nautical miles as per the rezoning in 2016 (Anon, 2016a). The entire MPA is a Restricted (or no-take) Zone, but excludes the marine section of the national park that extended 0.5 nautical miles offshore along the De Vasselot coast (RSA Government Gazette No. 17073, G.R. 538, 4 April 1996).

The areas of the various sectors of the Tsitsikamma Section (the ex Tsitsikamma National Park) are as follows:

Sectors	**Hectares (ha)**
TCNP terrestrial	1 960
TCNP marine (Tsitsikamma MPA)	29 464
De Vasselot terrestrial	2 560
De Vasselot marine (adjacent to MPA)	740
Soetkraal terrestrial	24 392
Buitenverwachting	210
Ex Forestry land	120 566

On 22 July 2011 (Government Gazette No 344622) 45 former state forests land parcels (“DWAF properties”) adding up to 120 566 ha was proclaimed as national park. Twentytwo more state forest areas (11 789.6 ha) in respect of which the transfer will be done progressively but immediately following the termination of plantation forestry on these areas, will still be proclaimed in future. The land stretches from Saasveld east of George to East of Storms River village (150 km), often from the crests of the Outeniqua and Tsitsikamma mountains south to

the farming or plantation areas and up to the coast in some areas (Harkerville State Forest). The properties can be seen in President's Minute No.77.

2.4 Controlling authority

- South African National Parks (SANParks) is the controlling agency of the GRNP.

- Soetkraal was leased from Rand Mines Limited (IProp) on a 30 year basis and was managed by SANParks as a contractual (Schedule 5) park. In 2004 the Department of Public Works registered an expropriation notice against IProp for this property, and in December of that year the Minister of Public Works issued and instruction to the Department of Environmental Affairs and Tourism that the Soetkraal properties be purchased from the owners. Currently negotiations are still in process.

- The sand dunes to south and southwest of Nature's Valley village (Erven 382, 444 and a portion of 434) are contractually managed by the Bitou Municipality, Nature's Valley Ratepayer's Association and SANParks according to initially the National Parks Act and since 2003 the National Environment Management: Protected Areas Act (NEMPA).

- Buitenverwachting (just northwest of Grootbank) is contractually managed together with the owners of the property (Buitenverwachting (Pty) Ltd.) on a 30-year contract.

- SANParks management in the Knysna section 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. In terms of the National Environmental Management: Protected Areas Act 57 of 2003 this area is now a protected environment. 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.

2.5 Legislation

The management practices of South African National Parks must comply with several national policies and legislation, as well as international conventions. In this regard, relevant legislation includes:

<u>Water Management</u>

- National Water Act 36 of 1998
- Mountain Catchment Areas Act 63 of 1970
- Water Services Act, 1997
- National Building Regulations and Building Standards Act, 1977
- Conservation of Agricultural Resources Act 43 of 1983
- National Buildings Regulations and Building Standards Act, 1977
- Nature Environmental Conservation Ordinance No 19 of 1974

<u>Waste Management</u>

- Environment Conservation Act, 1989
- National Road Traffic Act, 1996
- Advertising on Roads and Ribbon Development Act, 1940
- The South African National Roads Agency and National Roads Act, 1998
- Occupational Health and Safety Act, 1993
- Hazardous Substances Act, 1973
- Health Act, 1977
- National Building Regulations and Building Standards Act, 1977
- Marine Living Recourses Act, 1998 (Act No. 18 of 1998)

Land and soil
- National Environmental Management Act, 1998
- Environmental Conservation Act 73 of 1989
- Conservation of Agricultural Resources Act, 1983
- Expropriation Act 63 of 1975

Planning of new activities
- Environmental Conservation Act 73 of 1989
- Development Facilitation Act 67 of 1995
- Sea Shore Act 21 of 1935
- Physical Planning Act 125 of 1991

Biodiversity
- Conservation of Agricultural Resources Act, 1983
- National Veld and Forest Fire Act, No. 101 of 1998
- Agricultural Pests Act, 1983
- Animal Health Act, 2002
- Convention on International Trade in Endangered Species of Wild Fauna and Flora
- Animals Protection Act, 1962
- Conservation of Agricultural Resources Act, 1983
- Marine Living Resources Act, No. 18 of 1998
- Sea Birds and Seals Protection Act, 1973 (Act No. 46 of 1973)
- National Environmental Management: Biodiversity Act, No. 10 of 2004
- NEM Integrated Coastal Management Act, No 24 of 2008
- National Environmental Management Act, No. 107 of 1998
- National Forests Act, No. 84 of 1998

Heritage resources
- National Heritage Resources Act 25 of 1999
- National Parks Act, 1976
- World Heritage Convention Act, No. 49 of 1999

Protected Areas
- National Forest Act, 1998
- Environment Conservation Act, No. 73 of 1989
- National Environmental Management: Protected Areas Act 57 of 2003

International Conventions, Treaties and Principles
- Convention on Wetlands of International Importance especially as Waterfowl Habitat, 1971
- 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

3 HISTORY

3.1 Archaeology

Two sites of archaeological interest are located in the Duiwe River catchment in the Wilderness section. The Oakhurst shelter was excavated from 1932 to 1935 by Goodwin (1938a, 1938b, 1938c, 1938d) with additional examination of human remains and artefacts by Drennan (1938a, 1938b) and Schofield (1938). Based on the stratography of the site and material recovered it was concluded that there were three different cultures superimposed on one another, the Smithfield B, Smithfield C and Wilson. A re-examination of the Oakhurst material by Fagan (1960) led him to disagree with earlier conclusions, saying that the assemblage represented a gradually changing culture rather than three different cultures. He tentatively assigned the industry to the late Wilson culture. In a further re-examination of Oakhurst material, Schrire (1962) concluded that earlier conclusions by Goodwin (1938d) had been correct.

The Glentyre shelter is located “one mile” south-west of the Oakhurst site (Fagan 1960) and is only about 100m from the existing shoreline of Eilandvlei. Human remains from five graves and artefacts including stone tools, bone tools, rubbers, grindstones, beads and pottery were excavated from 1938 to 1940. Fagan (1960) concluded that the superficial levels dated at the latest to the end of the eighteenth century A.D., and that the industry represents one of Late Stone Age culture (Late Wilson) and not three different occupations as suggested for Oakhurst.

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 strandlooper burial site close to Knysna where excavations were made for filling material for the railway. Mortelmans (1945) and Davies (1971) have reported Acheulian artefacts from reworked gravels of the Keurbooms Formation east of Knysna.

Deacon (1970) not in reference list excavated two San middens close to the Storms River Mouth. Although the two caves were within two kilometers of each other, significant ($P<0.01$) differences were found in the shell remains of marine invertebrates found in the two caves, suggesting that foraging was very localised. Furthermore, two sinker like objects and skeletal remains of a wide range of fish species suggested that these nomadic people fished with hand-lines.

F.W.FitzSimons, Director of the Port Elizabeth Museum (1906-1936) conducted surveys and excavations in the Tsitsikamma coast area (FitzSimons 1923, 1926; Schauder 1963 not in reference list). Later Turner (1970) searched for these caves and provided descriptions of the locations, caves and deposits, as well as the material stored in the Port Elizabeth Museum. Skead (1972) suggested the likely locality of Whitcher's Cave. Robinson (1977) reviewed some of the archaeological work performed in the Coldstream and "Tsitsikamma" caves and he concluded that the two caves were synonymous.

Soetkraal may also have notable archaeological artifacts, as one of the few rock shelters inspected contained indigenous rock art (Riley 2003).

3.2 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).

3.3 Historical aspects

Prior to the arrival of the first European settlers in the southern Cape, the area was inhabited by Khoikhoi and San, semi-nomadic hunter-gatherers. Their influence on ecological systems was probably slight except perhaps for starting fires to drive out game animals. Artefacts suggest that Strandlopers inhabited the caves along the coast. Much of the recent history is built up around the logging of surrounding forests.

By 1711 the occurrence of large tracts of forest in 'Outeniqualand' had been reported to the Cape administration. Exploitation of the surrounding indigenous forests in the Knysna area started around 1763 (Grindley 1985) and has continued for over 200 years. A woodcutter's post was established near the present-day town of George in 1776, from where timber was transported overland to Cape Town.

Reckless forest destruction was already taking place when the area was visited by Governor Joachim van Plettenberg in 1778. He appointed Johann Meeding as resident at Plettenberg Bay to try and curb the rate of exploitation. Meeding built a timber shed and entered into a contract with the woodcutters to supply timber. No conservation measures were introduced, but there was a semblance of control. Controlling and limiting wood harvesting to a 'sustainable' level in the southern Cape forests was a long and difficult task (Von Breitenbach 1974; Van der Merwe 1998).

The early European explorers and travelers tended to avoid the Tsitsikamma area, because of the deep gorges and dense indigenous forests (De Ronde 1995). It was only from 1780 that timber was exploited between the Salt River and Groot River area. The first shipment of timber left Plettenberg Bay for Cape Town in 1788.

The town of George was founded in 1811. The timber market was boosted and forest destruction continued to accelerate. The forest began to be exploited for the British Royal Navy in 1812 and, in spite of the dangerous passage through The Heads, a port was developed at Knysna for the transportation of timber. The estuary was one of the country's 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. 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. The use of the estuary with its dangerous sea passage as a harbour for tall ships; the short-lived gold rush in 1876; and the lives and exploits of the colourful characters that lived in the area, is described in Tapson (1961) and Metlerkamp (1961). The Knysna harbour was deproclaimed in 1959 (Reddering & Esterhuysen 1984).

There was an increase in the demand for timber for the construction of wagons when the Great Trek commenced in 1836. It was also at this time that the Tsitsikamma forests were opened up for the first time. In 1846 all worked-out forests were closed by the Government, divided up into lots and sold by public auction. The remaining forests were reserved as Crown forests and put under the control of local magistrates who were to issue felling licenses. However, by 1847 forest destruction was so bad that all Crown forests were closed for harvesting. The first Conservator of Forests, L. Haswell, was appointed to protect the reserved forests. The Crown forests re-opened in 1856 because of the timber shortage. A second Conservator, Captain Christopher Harison, was appointed to protect the Tsitsikamma forests. During 1866 the Bloukrans Forest and Witelsbos Forest were opened up for timber exploitation. This was probably the first time Europeans settled permanently on the fringes of the Tsitsikamma district (De Ronde 1995). The "Great Fire" of 1869, which stretched from Humansdorp to Riversdale, caused considerable damage in the region and spurred the Cape government to strengthen control over the forests.

Captain Harison was appointed Conservator over the whole area in 1874, based in Knysna. An attempt was made to stem the tide of destruction, but public pressure and the increased demands for timber due to the discovery of gold at Ruigtevlei in 1876 and later at Millwood, leading to the first gold rush in South Africa, frustrated efforts (Bulpin 1978). The mining was short-lived and had collapsed by 1894. The diamond rush at Kimberley in the 1870's, and the gold rush in the Witwatersrand during the 1880's further hindered these efforts. Professional French forest officer, Count M. de Vasselot de Regné, was appointed as Superintendent of Woods and Forests for the whole Cape Colony in 1880. He introduced the first real efforts towards conservation of the forests. The Forestry Department was developed and professional forestry officers were appointed who played important roles in the development of forest management in the region and rest of the country for decades to follow. The section system for controlling timber harvesting was introduced in 1884.

The Cape Forest Act was passed in 1888, which made demarcated forest inalienable. This gave a greater degree of protection to the forests. The first timber plantations were established near Knysna so as to reduce the timber demand on the indigenous forests. However, even under the section system forest destruction continued because the demand for timber made the woodcutters exceed the recommended volume to be removed. Finally in 1939 the right of the woodcutters to work the forests was annulled, and state owned forests in the region were closed to non-sustainable harvesting (Von Breitenbach 1974).The Department of Forestry closed the forests to all exploitation from 1940 to 1964 except for the cutting of dead and dying trees and the working of windfalls. The focus of the Department shifted to the establishment and management of plantations of exotic timber trees.

An indigenous forest research station was established at Saasveld, near George in 1964, under the leadership of Dr. Friedrich von Breitenbach. A system of multiple-use conservation management was developed and applied that formed the basis for the management system applied today. The selection system for timber yield regulation was introduced, based on basal area. This has subsequently been modified and improved upon. After extensive negotiations between the National Parks Board and the then Secretary of the Department of Forestry and his Minister, the Tsitsikamma Coastaland Forest National Parks were proclaimed in 1964 (Knobel 1989, Robinson 1989) to establish South Africa's first marine protected area and conserve the associated coastal forests of the region.

4 ABIOTIC CHARACTERISTICS

4.1 Climate

The GRNP extends over roughly 150 kilometers east-west and 40 kilometers north-south. This area is large enough to show some variability in climate in both directions. In a north-south direction the altitude varies from 0 m a.s.l. to 1675 m.a.s.l. (Peak Formosa). The Outeniqua and Tsitsikamma mountain ranges influence the climate significantly by acting as a barrier to the inland penetration of the weather system and give rise to orographic precipitation. (Kruger 2004).
In summer South Africa has semi-permanent high-pressure cells (South Atlantic Anticyclone and South Indian Cyclone) in the adjacent oceans. The movement of these cells plays a dominant role in the circulation and climate of South Africa. In winter the high-pressure cells are displaced slightly to the west and north which makes the chances for convection and rain much lower than in summer. The northern movement of the westerly winds causes the cold fronts to reach the subcontinent, which bring the bulk of the rain to the southern parts of South Africa (Kruger 2004).

The climate of the Southern Cape is often referred to as moderate. The weather is mainly shaped by a succession of east moving subtropical low-pressure cyclones interacting with subtropical high-pressure anti-cyclones lying over the oceans (Heydorn and Tinley in Scriba, 1984).

Scriba (1984) describes three distinctive rainfall patterns that affect the GRNP area. The Tsitsikamma area has a higher rainfall in spring, with September and October being the wettest months. The George area shows the months from September to March to have above average rainfall and the late autumn to winter months being relatively dry. Annual rainfall is between 600 and 700 mm (Schafer 1992) with little seasonal variation (Whitfield *et al.* 1983), but slight peaks do occur from January to March, and again from August to November (Robinson & De Graaff 1994, Fijen & Kapp 1995d). Mean rainfall in the upper catchments is 900-1000 mm y^{-1} (Adamson 1975; Fijen & Kapp 1995d), and mean monthly rainfall varies between 11 and 244 mm.

Torrential rains recorded in the Southern Cape region in 2006 where the largest observed annual maximum daily rainfall of 230mm was recorded at George on 1 August 2006 had a return frequency of 1222 years, whereas the second-largest observed annual maximum daily rainfall (132mm in September 1964) has a return period of 23 years (Mélice & Reason 2007). The Knysna area reflects the previous areas with higher than average spring rainfall (September to November), and average figures for December to March and for May. 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). Tyson (in Scriba, 1984) describes rainfall fluctuations in the Southern Cape and Tsitsikamma evident in three, ten and 30 year cycles. Kruger (2007) mentions that nationally variability in annual rainfall is lowest in the coastal belt from the south western Cape to the east Cape. The maximum annual rainfall can be in the order of 150% of the mean and the minimum annual rainfall as low as 60% of the mean.

Temperature in the GRNP is moderate. In the rare event of snow or frost, temperatures can decrease to close to or below freezing. Scriba (1984) reports minimum and maximum temperatures for George as 1.3°C in July and 41.3°C in January. Topography influences temperature over the north south gradient. The effect of altitude on air temperature is a drop of about 0.6°C for each 100 m rise. This can lead to a 10°C difference in temperature over this gradient. As the sea on the southern boundary of the park has a moderating effect on temperature, especially during the day when cool breezes from the sea will cool down the land temperature, this 10°C change may not always be apparent.

In the Wilderness area mean daily minimum and maximum air temperatures are 15-25°C (summer) and 7-19°C (winter). Temperature extremes recorded at Swartvlei (1975 to 1982) are minimum 2°C, and maximum 33°C (Whitfield *et al.* 1983). 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). At Storms River Mouth the mean monthly maximum and minimum air temperatures recorded over a 12 year period (1992 - 2003) ranged from 19.0 - 24,8°C and 9.9°- 17.8°C respectively (Hanekom 2005).

Wind is an important climatic aspect in the Southern Cape. A year round feature of the south coast is the prevailing westerly winds (Stone *et al.* 1998), while onshore easterly winds are prevalent during summer (Schumann *et al*. 1982). Generally the south-western winds are associated with the rain patterns while the south-easterly winds are associated with fair weather. Scriba (1984) describes the winter months as overall windy with northerly (bergwinds), and westerly winds dominating. The desiccating north-western bergwinds are caused by dry subsiding air moving off the interior plateau in response to strong coastward pressure gradients (Bond, 1981). These strong winds drive the fire patterns in the fynbos and thus the distribution of natural vegetation (forest and fynbos) on the landscape. Rain often follows bergwind. Northerly winds are more evident in the Plettenberg Bay region than in Knysna. The summer months are characterized by fairly even westerly winds in the Knysna area and west to west-south-westerly winds are dominating in the Plettenberg Bay area (S.A.W.S.). Mean wind speeds vary little monthly in Knysna and Plettenberg Bay. South-west winds predominate throughout the year (Howard-Williams & Allanson 1978b) in the Wilderness area. Strong winds are uncommon with 97% below 30 km hr^{-1} (Whitfield *et al.* 1983). Solar radiation varies between 2.25 kJ m^{-2} day^{-1} in summer and 0.75 kJ m^{-2} day^{-1} in winter (Howard-Williams & Allanson 1978b).

Daily average sunshine duration is 60% for the Southern Cape and Tsitsikamma area (Kruger 2005) with little variation (60% for 11 months and 70% for July).

4.2 Geology & soils

4.2.1 Geology

No geological surveys have been done specifically for the GRNP. Various authors that are quoted throughout this discussion give broad descriptions of land covered by the park. *Appendix 14* shows a map of the southern Cape geology.

Two authoritive publications that cover geology of the South African geological landscape are Kent (1980) and Johnson *et al.* (2006). These publications give extensive coverage of the South African geological history and stratigraphy and lend understanding to what the geology underlying the GRNP entails. These publications further reference older and historical works on geology that are of lesser importance for the GRNP but add to the total knowledge base.

Rocks of the Cape Supergroup underlie most of the area, while Pre-Cape and Cretaceous rocks and unconsolidated deposits of recent age occupy smaller areas. The Pre-Cape rocks comprise the Maalgaten Granite to the west and east of George (including the Woodville - Beervlei area), separated by a variety of sedimentary and metamorphic rocks of the Kaaimans Formation that include phyllite, quartzite, grit, hornfels and schist (Saasveld and Karatara areas).

A few authors focused their efforts on the greater area, covering the GRNP. Rust (1999) describes the geology of the "south eastern Cape coastal zone". Similarly Toerien (1979) describes the area covered by the 1:250 000 sheet (3322, Oudtshoorn), between 22°- 24°E and 33° – 34.15°S in work for the Council of Geoscience. Mucina and Geldenhuys (2006) offers a very brief description of the area covered by Southern Afrotemperate Forest. This vegetation type is almost completely within the GRNP boundaries. Deacon and Geleijnse (1988) describes how sea level changes influenced the coastal landscape at Klasies River 18km east of the GRNP. Marker & Holmes (2010) describes the geomorphology of the coastal platform of the southern Cape and its importance as sediment sink, particularly with respect of the deposition and accumulation of marine, aeolian and lacustrine sediment. They provide up to date geomorphic context and new evidence supporting the polycyclic nature of the Coastal Platform surface is introduced. Altitude analysis shows bimodality for the Sedgefield–Knysna area and the Knysna–Concordia belts but not unequivocal evidence for bimodality for the Wilderness–Knysna area. Harkerville area is unimidal. Coversands are described by Marker & Holmes (2002, 2005), Holmes *et al*. (2007) and suggest that its origin is a currently inundated offshore source. Carr *et al.* (2010) and Bateman *et al*. (2004) provides insights into the age of the coversands.

The three main geomorphological formations in the Wilderness area are the Outeniqua mountain range, the coastal plateau, and the coastal embayment (Rust 1989). Some of the oldest known geomorphological forms occur in the Outeniqua Mountains, being approximately 120 million years old. River catchments in the Outeniqua Mountains comprise primarily sandstones and quartzites of the Table Mountain Group. Erosion resistant quartzites and sandstones of the Skurweberg (=Kouga) formation predominate with softer shales of the Goudini (=Tchando) Baviaanskloof and Cedarberg formations occurring in inter-mountain valleys. The Goudini formation contains iron and manganese that often weathers brown on the surface (Schafer 1991).

The coastal plateau is an old sea floor dating back to the Tertiary period (Rust 1989), which in places has been deeply incised by rivers (Touw, Duiwe, Hoëkraal, Karatara, Diep etc.). The plateau is underlain by pre-Cape granite, Kaaiman Group metal sediments (phyllites, schists, shales) and Table Mountain sandstones, mantled in places by alluvium and aeolian deposits. Remnant high-level terraces capped by silcrete and fellicrete occur in places (Schafer 1991).

The geological history of the Wilderness Lakes is given by Martin (1956, 1959, 1962) and Hill (1975). The coastal embayment dates predominantly from the Pleistocene period, though the landform is not static with some areas still in the process of formation (Rust 1989). It is comprised predominantly of dune deposits, with Quaternary sands in which dune rock or aeolianite has been formed from the cementing of sandy ridges by calcium carbonate (Martin 1962). Four ages of aeolian depositions can be zoned (Schafer 1991), represented by three dune cordons on land, and one underwater at sea (Rust 1989). Illenberger (1996) describes the "Geomorphological Evolution of the Wilderness Dune Cordons" comprehensively. The local complex sea-level history built dunes over numerous phases, followed by coastal and river erosion altering the cordon morphology. Inland coalesced dune deposits age back to the Middle Pleistocene, about 1 million years ago. The Wilderness lakes formed as a result of the cutting off of the rivers by these dune cordons, thus preventing them from flowing directly into the sea. The lakes and estuaries are thus transient features that through natural erosion and deposition processes are slowly silting up.

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). 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.

Marker (2003) discusses the Knysna basin's geomorphology in detail and offers a comprehensive geological description of the Knysna river catchment. She adds a description of Post Gondwana tectonics and formation of the local Coastal Platform (as does Helgren & Butzer (1977), Marker & Holmes (2010) with upliftment due to the breakup of Gondwana during the Mesozoic era, planation to close to sea level in the mid-Cenozoic African cycle and upliftment of the Coastal Platform to the current approximate 200m, in the early Pliocene. Sea level fluctuations and its effect are also described. Helgren & Butzer (1977) further describes sea level fluctuations, planation and eolianite formation (any rock formed by the lithification of sediment deposited by the wind), in the Knysna and Plettenberg Bay area. Marker & Holmes (2010) touches on tectonic stability and sea-level change. They explain why the bays at Wilderness and Nature's Valley are of a different geological origin than many other zeta (long-spiral or half-moon) bays, or logarithmic-spiral bays, as Rust (1999) calls them. Rust (1999) describes, among others, sandy beaches and its dynamics from a geological point of view. The dune complex south of the estuary (Brenton dune), is a steep (±24°) coastal dune from the Tertiary and Pleistocene period (Reddering & Esterhuisen 1987).

Scriba (1984) describes the geology underlying the forested areas in the GRNP comprehensively. Schafer (1992) also describes geology and soils of 'forest land' in the Southern Cape. His description is comprehensive but does not cover the Tsitsikamma area of the GRNP. A popular work by Norman & Whitfield (2006) describes the geology from Riversdale to Storms River, and from Storms River to Port Elizabeth in laymen's terms that brings understanding to otherwise foreign terminology in the scholarly works.

The quartzitic sandstone of the Goudini (Tchando) and Peninsula Formations of the Table Mountain Group underlie the terrestrial areas of the Tsitsikamma area (Toerien 1976; Chief Director of Surveys and Mapping 1991, Director-General of Surveys 1979). The main formations of De Vasselot are the Gydo Formation (shale and subordinate siltstone) of the Bokkeveld Group, as well as Skurweberg (Kouga) - and Baviaanskloof formations of the Table Mountain Group (Pretorius *et al*. 1980; Director-General of Surveys 1979). The Table Mountain Group also underlie the nearshore regions of the Tsitsikamma MPA, but they give way to a strongly folded Cretaceous Group some 2-3 km offshore (Flemming *et al*. 1986). Soetkraal lies along the backbone of the Cape Fold Mountains. Its geology is part of the Cape Supergroup system, and the formations present are the Goudini, Peninsula and small areas of Skurweberg (quartzitic sandstone, profusely crossbedded) and Cedarberg (shale, arenceaous shale). (Director-General of Surveys 1979). The Soetkraal valleys are lined with a layer of grey clay derived from a shale layer from within the Table Mountain group (Wagener pers. comm. in McIlleron 2003).

4.2.2 Soils / Sediments

Scriba (1984) describes soil for the total area of the GRNP although relatively little is known about the soils of the Southern Cape (Scriba 1984) which Schafer (1992) confirms in stating that pedological investigations have been limited in the Southern Cape. Tyson (1971) in Scriba (1984) states that soils can broadly be classified into three types namely, youthful azonal soils on the steeper Table Mountain Sandstone slopes, brown and grey soils in the foothill zone and, Lateritic Paleaosols mainly on the coastal platform. Heydorn & Tinley (1980) in Scriba (1984) also classify local soils in three groups: as weakly developed shallow soils of arid regions, littoral sands in the Lake's region and lithosols for the mountain and foothill zone. Von Breitenbach (1968) also covers the soils of the Southern Cape and Tsitsikamma and classifies the soils texturally into sand, sandy loam, loam and clay soils. Schafer (1992) describes soils of 'forest land' in the Southern Cape and define it as diverse due to extremes in topography, varying parent materials and a complex history of geomorphological events. His description is comprehensive but does not cover the Tsitsikamma area of the GRNP. He further describes the soils as mostly acid, poor in nutrients and having a low buffering capacity. Geldenhuys (1994a) briefly describes local soils in the GRNP area. *Appendix 15* indicates the soils in the region.

Fey (2010) comprehensively describes soils of South Africa. It is the most up to date publication on soils in South Africa and is an update of Van der Merwe (1941) that also describes soil groups of South Africa. Fey (2010) mentions 73 soil forms in RSA that can be grouped into 14 soil groups. The soils found in the GRNP are described.

Although Phillips (1931) is an old reference it has a detailed and probably the most comprehensive description of soil. He emphasizes that undue emphasis is laid upon the underlying geology when referring to soil as some soils were removed from their origin and deposited elsewhere, but some areas like the plateau do have soil derived from its underlying geology. He discusses chemical characteristics, nutrient values and the effects of high rainfall on leaching of soils. He further describes physical properties of soil, the general physical composition, moisture relations, chemical characters of the soils, available soluble salts and hydrogen ion concentration of soils of the Knysna region.

Rebelo *et al* (2006) describes the major soil types underlying the GRNP's major different fynbos communities as acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (TMG) with plinthic catenas prominent. This is sandstone derived soils. The Cedarberg Formation's shale weathers to clay. The forest soils underlying the GRNP are described by Mucina & Geldenhuys (2006) as varying from shallow Mispah, Glenrosa and Houwhoek forms to sandy humic Fernwood form, derived from TMG sandstone and shale of the Cape Supergroup and partly also from Cape Granite.

Scott (1999) discusses water repellency of soil and in particular with regards to the vegetation cover type and the role of fire in soil water repellency. Some studies were done in indigenous forest, and around Saasveld.

In the Outeniqua Mountains soils are, in general, acidic, leached, low in nutrients, and have a poor buffering capacity. In the upper river catchments soils are derived primarily from sandstones and are typically light textured, acidic, podzolised fine sandy loams. Rocky well-drained soils commonly occur on north-facing slopes, whereas poorly drained or even peaty soils frequently occur on southern aspects. Dark acidic topsoils with high organic matter content frequently occur in wetter areas, particularly at high altitudes. In drier areas topsoils are frequently ash grey in colour and low in nutrients as a consequence of podsolization processes where iron, aluminium and organic matter are stripped from the topsoil and deposited lower down in the profile (Schafer 1991).

Looking at the different sections of the GRNP in more detail, along the coastal plateau in the Wilderness area soils are generally of a duplex nature, with a clay subsoil occurring at between 300 and 500 mm depth, overlain by a thin concretionary gravel horizon. Soils in this region are often poorly drained, acidic and have low biological activity. Topsoil crusting and compaction occurs as a consequence of the fine texturing of the soils (Schafer 1991). Soils under indigenous forests tend to have humic topsoils and are high in organic matter and biological activity (Schafer 1991).

Soils on the coastal embayment are derived primarily from Pleistocene and Recent Coastal Sands rock (Allanson & Whitfield 1983). Soils range from excessively inceptisols on the youngest dunes, to finely textured, poorly drained podzols and duplex soils in older dunes (Schafer 1991). Much of the floodplain of the lake systems are covered with a dark alluvium which is rich in organic matter (Allanson & Whitfield 1983). The high silt and fine clay fraction in the topsoil of older dunes, coupled with underlying impervious clay or rock layers and thin ironpans contribute to restricted drainage (Schafer 1991). Thompson (1983) provides detailed description of soils on the northern slopes of the lakes, and describes the occurrence of relic beach levels.

The development of the barrier dunes in which the lakes are located spanned at least the last two glacial-interglacial cycle (Bateman *et al*. 2004). Aeolianite deposition has occurred at ca 67-80, 88-90, 104-124, 160-189 and >200 ka before the present.

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).

Aeolian sands deposited during the Quaternary cover the coastal plateau between Knysna and Plettenberg Bay (including the Harkerville area). A narrow coastal strip of migrating and vegetation-settled dunes occur on the coastal lowlands.

According to 1:250 000 landtype maps (Institute for Soil, Climate and Water 2004), the Tsitsikamma area has thirteen land types. The dominant ones in the Storms river area (Fa 30) and De Vasselot (Fa 31 & Fa 32) have a large component of lithosols (shallow soils on hard weathering rock), while that (Ib 64) of Soetkraal has a substantial amount of rock and, to a much lesser degree, imperfectly drained soils (Institute for Soil, Climate and Water 2004).

In De Vasselot (and probably in the rest of the Tsitsikamma section) the soils are strongly influenced by the removal of marine clays on the tertiary shoreline. 'Duplex' soils (i.e. sandy surface soils with a sharp transition to underlying clays) are common (Pretorius *et al*. 1980). The underlying clays are often saline, impermeable and seasonally saturated. Seasonally saturated soils (Westleigh, Kroonstad) are dominant on the plateau above the coastal escarpment. They are also associated with dry ground on the rim of the plateau that has underlying clays (Eastcourt, Sterkspruit, and Swartland). Shallow sandy soils overlying rock (Mispah and Glenrosa) are common against the steep coastal slopes of Table Mountain sandstone. Near the coast (especially in the Nature's Valley region) the aeolian influence is visible. Here soils are derived from a mixture of dune sand and clay material from underlying shale (Pretorius *et al*. 1980). Cobble beds are found flanking the major gorges on the plateau (Thwaites 1984).

4.3 *Topography*

The topography of the GRNP is described by many authors. Some of the most comprehensive are Phillips (1931), Scriba (1984), Tyson (1971) and Von Breitenbach (1974).

The main features that characterize the topography of the GRNP is the Outeniqua and Tsitsikamma mountain ranges to the north of the park, the foothills and the coastal plain. Peak Formosa at 1675.2 m is the highest point in the GRNP. On the higher portions the angles of declination are often 70-90 degrees (Phillips 1931).

The southern Cape can be divided into four distinct physiographic regions (Von Breitenbach 1974) which can be explained largely as a result of the highly contorted folding of the Table Mountain Sandstone and the erosion cycle. Scriba (1984) describes the four regions as follows:

- the sandy coastal lowlands, termed "embayments" or "littoral".
- the coastal platform that can be described as the lower and upper plateau. This step occurs at the elevation between 150 – 300 m.
- the foothill zone, a fairly narrow region between the coastal platform and the mountains at an altitude between 350 and 550 m
- the mountains.

Tyson in Scriba (1984) associates the geomorphology with different sea levels over time. The coastal levels seem to have fluctuated from 108 – 240 m above the current position before the Miocene period. This resulted in the coastal platforms. Truswell in Scriba (1984) states that the present coastal littoral zone is associated with the Pleistocene 1.8 million years ago. The receding sea level has resulted in a series of dunes behind which the present Lakes region is situated. Illenberger (1996) describes the formation of the distinctive dunes between Wilderness and Knysna as well as the formation of the lakes during interglacial sea-level high stands.

On the northern boundary of the Wilderness Lakes there are steeply rising hills, representing the remains of old sea cliffs (Allanson & Whitfield 1983). To the south of the lakes are high consolidated old sand dunes. The east-west gradient along the lake chain is very slight (Allanson & Whitfield 1983). Martin (1962) estimates the system was formed in its present shape some 7000 years ago, but with estuarine conditions having existed for only 4000 to 5000 years (Martin 1956). Tyson (1971) includes a description of the lakes as well as the dune cordons.

Long sandy beaches are common between Wilderness and Knysna. A further characterizing feature is the deep ravines cutting through the landscape in a north-south direction (Touw, Homtini, Goukamma, Knysna, Groot, Bloukrans and Storms River). The incisions serve to substantiate the inferred uplift during the Miocene and Pliocene (Partridge and Maud, 1987) in Marker & Holmes (2010).

Marker (2003) reports on the Knysna basin and describes it topographically as three distinct areas. She also describes characteristics of the present landscape. 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.Geldenhuys (1994a) explains how topography influences bergwinds that determine forest localities and thus the landscape.

Except for a small sandy beach at Nature's Valley, a rugged rocky coastline, comprised of ridges and interlying troughs running parallel to the coast, is characteristic from Knysna eastwards. Above the narrow shoreline, the coastal escarpment rises steeply to a height of 150 - 220 m, and then flattens off onto a plateau, which extends approximately 8 km to the base of the Tsitsikamma Mountain Range (Toerien 1976). The erosive powers of the sea, together with changing sea levels, have formed a series of caves on the coastal escarpment, and many of these have been mapped.

The seafloor shelves fairly quickly reaching a depth of approximately 25 m and 80 m at 0.9 km and 5.6 km offshore (Flemming *et al.* 1986). Most (c. 80%) of the seafloor is covered by fine sandy sediments, reaching a local thickness of up to 35 m. (Flemming *et al.* 1986)**.** The subtidal rocky reefs are fragmented and confined mainly to the near- and mid-waters of the western sector of the MPA, and many of these outcrops consist of low platforms mantled in thin gravel sheets (Flemming *et al.* 1986)**.**

Soetkraal extends along the length of the Tsitsikamma Mountain Range, and includes several valleys (*c.* 450 m above sea level) and steep and high mountain slopes (*c.* 1000 - 1675 m ASL). The terrain is rugged and crisscrossed by many streams.

4.4 *Bathymetry*

Flemming *et al*. (1983) described the bathometry of the lakes in the Wilderness area. A bathymetric chart for Swartvlei Lake is given in Birch *et al*. (1978) and CSIR (1978a). A simplified version is given in Whitfield *et al*. (1983) indicating Swartvlei Lake to be in excess of 12m deep. Detailed cross sectional profiles and resultant bathymetric map of Swartvlei Estuary are given in CSIR (1975). Bathymetric charts for the Touw system are given in CSIR (1982). Eilandvlei has a maximum depth of 6.5m, Langvlei 4.0m and Rondevlei 6.0m, while the Touw River Estuary varies between 1 and 3.5m (Hall *et al*. 1987).

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.

In the Tsitsikamma area, the seafloor shelves quickly reaching a depth of approximately 25 m and 80 m at 0.9 km and 5.6 km offshore (Flemming *et al*. 1986)

4.5 *Drainage*

The catchment area of the Touw system in the Wilderness section, comprises three rivers – Touw River (96.2 km^2), Duiwe River (42.1 km^2) and the Langvlei Spruit (8.2 km^2) (Hughes & Filmalter 1993, Fijen & Kapp 1995c). Rivers draining into the Swartvlei System are the Diep River (98.3 km^2), Klein Wolwe River (17.2 km^2), Höekraal River (111.0 km^2), and Karatara River (101.6 km^2) (Whitfield *et al.* 1983, Hughes & Filmalter 1993).

Further east, 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.

The catchments of most rivers flowing through the Tsitsikamma area extended well beyond the boundaries of the former Tsitsikamma National Park into the foothills of the Tsitsikamma Mountains. However, the amalgamation of the DWAF land in the Southern Cape with that of SANParks provides SANParks with greater jurisdiction over the catchment of tributaries of the Elands-, Storms-, Elandsbos-, Bloukrans- and Groot (west) rivers. Soetkraal 'encompasses' the upper catchment of Langbos, Palmiet and Diep rivers (Russell 2002 not in reference list).

4.6 *Hydrology*

Various hydrological studies have been conducted along the Garden Route over the years however a large percentage of the work has been focused in the Wilderness area of the GRNP. The map in *Appendix 16* gives an overview of the catchments in the area.

General descriptions of the hydrology of temporarily open and closed estuary systems are given in Schumann *et al.* (1999) and Perissinotto *et al.* (2010). The Hydrological Research Unit of Rhodes University produced a series of reports with the objective of developing a conceptual model of the rainfall runoff process in the Wilderness catchments. Issues investigated included the general hydrology of the area (Hughes & Görgens 1981; Hughes 1983a), calibration of three monthly input conceptual catchment models and assessment of the feasibility of model parameter transfer (Hughes 1982; Hughes 1983b), and the modelling of isolated flood events and model testing (Hughes 1983c). A summary of this work is provided in Hughes & Görgens (1983). Much of the hydraulic work undertaken within the Wilderness lake systems has been published in the reports CSIR (1975, 1978a, 1978b) and Fijen (1995c) (Swartvlei system), and CSIR (1981, 1982) and Fijen (1995a) (Touw system). In both Swartvlei and Touw system early investigations concentrated on the movement of water between different waterbodies. In the Swartvlei system emphasis was later placed on tidal exchange, whereas in the Touw system the impact of freshwater inflows from the catchment received priority.

Swartvlei system: Freshwater input into the Swartvlei system is given in CSIR (1978a), Whitfield *et al.* (1983) and Fijen (1995c), with the latter also providing data on current and predicted future abstraction by various user sectors. Rivers draining into the Swartvlei System are the Diep River (98.3 km2), Klein Wolwe River (17.2 km2), Höekraal River (111.0 km2), and Karatara River (101.6 km2) (Whitfield *et al*. 1983, Hughes & Filmalter 1993). Total evaporation from the Swartvlei system was estimated by Whitfield *et al.* (1983) as 12.1 x 10^6 m^{-3} (cf. 1127 mm y^{-1}) or approximately 20% of the average total annual freshwater input of 66 x 10^6 m^{-3} (CSIR 1978a) indicating that under natural conditions Swartvlei Lake is unlikely to become hypersaline.

There has been a long standing debate about the impact that the rail-bridge dividing Swartvlei Lake and Swartvlei Estuary has on the movement of water between these two systems. Whitfield *et al.* (1983) indicated that the rail-bridge does interfere with the flow of water, though added that the influence is confined to the immediate vicinity of the bridge as the main restriction to outflow in the system is the narrow estuary mouth. Mathematical modelling of the water flow regime in the Swartvlei system (CSIR 1978a) revealed that the complete removal of the rail-bridge would result in a 40% increase in tidal exchange between the lake and the estuary. This increase in tidal exchange, however, would result in a change in the lake level of only a few millimetres, and would have no discernible effect on the estuary mouth (CSIR 1978a). Later modelling exercises provided revised information on flow rates and volumes (Huizinga 1987), though conclusions regarding the low impact of the rail-bridge remained.

Severe floods in the Swartvlei system are infrequent. However, when river floods coincide with periods when the estuary mouth is closed, or even with very high spring tides when the estuary is open, then flooding of adjacent land can be expected, especially in the Sedgefield Extension 1 area (Howard-Williams & Allanson 1979). It has been recommended that for hydrological, ecological and social reasons Swartvlei Estuary mouth be artificially breached at 2.0 m amsl (CSIR 1978a, Howard-Williams & Allanson 1979, Whitfield *et al.* 1983).

Touw system: Freshwater input into the Touw system are given in Görgens (1979) and Fijen (1995a), with the latter also providing data on current and predicted future abstraction by various user sectors. The catchment area of the Touw system comprises three rivers – Touw River (96.2 km2), Duiwe River (42.1 km2) and the Langvlei Spruit (8.2 km2) (Hughes & Filmalter 1993, Fijen & Kapp 1995).

Flood hydrograph modelling of theoretical flood events emphasised the short residency time of flood waters and hence potential for rapid increases in water level in the lower lakes, particularly the Touw River Estuary (Görgens 1979). Expected water levels (meters amsl) in the Touw Estuary that would result during flood events of different return frequency are 5 yr. = 3.22; 10 yr. = 3.61; 20 yr. = 3.88; 50 yr. = 4.01; 100 yr. = 4.93 (Görgens 1979). CSIR (1981) and CSIR (1982) concluded that maintaining the height of the sand sill at the estuary mouth at between 2.1 m and 2.4 m amsl should prevent flooding of low-lying properties by floods with a return frequency of 1 in 50 years or lower. It was also concluded that although the dredging of the connecting channels would improve the circulation of water throughout the system, it would not significantly reduce the peak water levels.

Boshoff & Palmer (1989) have argued that the constriction at the Serpentine sluice inhibits flow to the upper lakes in times of flooding, whereas Hall (1985b) has suggested that the effect is minimal. The sluice has not been operational since the 1980's.

Knysna system: The Knysna River runs mainly north south and cut deep narrow incisions into the underlying Table Mountain Sandstone. The Knysna River feeds from two catchments, K50a and K50b. The northern part of K50a hosts Oubos River (4.7 km) and two other unnamed rivers. These originate in mountain fynbos largely planted with plantation. The Bobbejaan River (7 km) is the first major west-east tributary inside the park. The Kruis River (18.7 km) enters below the Bobbejaan River and drains mainly from plantation covered vegetation. Many smaller unnamed tributaries join the Knysna River from both east and west, often from forest, but more often from plantation areas. The next major tributaries are the Lawnwood River (6 km) from the west and the Rooiels River (13.9 km) from the east. From the confluence of the Knysna- and Rooiels Rivers, the Knysna River runs between private land on the west and forestry/farmland on the east. The tributaries from the west drains mainly from indigenous forest and to a lesser extent cultivated land.

The Gouna River (21.8 km) is the largest tributary of the Knysna River. The Steenbras River (9.4 km) is the largest tributary of the Gouna River. Both these rivers drain mainly from indigenous forest and to a much lesser extent, fynbos. Tributaries entering the Knysna River below the confluence of the Knysna and the Gouna Rivers drain from indigenous forest and to a lesser extent farmland to the west of the Knysna River, and plantation to the east of the Knysna River. A few rivers join the Knysna River in the Knysna Estuary. These rivers run through populated areas, industrial areas and informal settlements and are often of poor quality.

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).

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). 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 3 km during neap tides and 7.5 km 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.

Tsitsikamma systems: Excluding the Groot River (East), 12 perennial rivers flow southward through the Tsitsikamma area of the GRNP. The largest of these rivers are the Groot River (west), the Bloukrans-Vark, Storms-Witteklip and Elands-Kruis systems, which have calculated catchment areas of 87, 80, 98 and 82 km^2 respectively (Morant and Bickerton 1983; Chief Director of Surveys and Mapping, 1979b, 1980, 1981). The mean annual flow rates recorded at the gauging stations on the Bloukrans and Kruis rivers between 1960 and 1980 are 44 and 66 $m^3 \times 10^6$ respectively (Directorate of Water Affairs *in litt*. 1981), and the values estimated for the entire Bloukrans-Vark and Elands-Kruis systems are 65 and 86 $m^3 \times 10^6$ respectively. The estuarine or mouth sections of these rivers are relatively pristine (Heydorn 1986; Harrison *et al*. 1995, 1996). However, the majority of them (Brak, Helpmekaars, Klip, Witels, Geelhoutbos, Kleinbos, Bruglaagte, Langbos, Sanddrif) are merely narrow inlets that offer very little habitat for fishes or estuarine species. A further seven (e.g. Sout, Bloukrans, Lottering, Elandsbos, Storms, Elands and Groot (East)), are located within deeply incised valleys and provide limited littoral habitat for estuary-associated fishes. It is only the Groot (west) system, which serves some estuarine function for both marine migrant and resident fish species (James & Harrison 2009). The delegation of DWAF managed State Forest land in the southern Cape to SANParks in 2005, allows SANParks greater jurisdiction over the catchment of tributaries of the Elands-, Storms-, Elandsbos-, Bloukrans- and Groot (West) rivers. Soetkraal 'encompasses' the upper catchment of Langbos, Palmiet and Diep rivers (Russell 2002).

4.7 *Oceanography*

This section on oceanography deals largely with the Tsitsikamma area of the GRNP due to the presence of the MPA. The Tsitsikamma MPA is situated near the centre of the Agulhas Bioregion, which extends 1706 km from the Mbashe River to Cape Point (Lombard *et al*. 2005). Nineteen percent (or 327 km) of the bioregion's coastline is fully or partially protected through MPA's or closed areas (Lombard *et al*. 2005) with the Garden Route N.P. contributing four percent (Lombard *et al*. 2005). The Tsitsikamma MPA extends between 0.5 and 3 nautical miles offshore and has a surface area of some 340 km. The subtidal area consists predominantly of soft bottom sediments (c. 79%) and dispersed rocky reefs and platforms (c. 21%) (Flemming *et al*.1986). The continental shelf along this coast extends some 90 km offshore (Tilney *et al*. 1996), deflecting the fast flowing Agulhas Current away from the coast (Shannon 1989). The shelf water is fed by frequent intrusions of warm Agulhas Current water, which in summer lies on top of a sharp thermocline. In winter prevailing westerly winds result in strong mixing of the surface water to depths of 70 to 90 m (Beckley 1983, Swart and Largier 1987). Consequently, the nearshore seawater is characterized by uniform temperatures in winter, while stratification in summer is intensified by intermittent upwelling events (Schumann 1999). The adjacent 9 km long De Vasselot section, which was excluded from the MPA, is open to extractive resource use by the public in accordance with the Marine Living Resources Act (1998).

Mean (1993 - 2003) monthly surface sea temperatures measured at Storms River Mouth area ranged from 15.9^{o}C to 19.4^{o}C (Hanekom 2005 not in reference list), and is substantially affected by cold upwelling events during spring and summer (Hanekom *et al*. 1989). Similar upwelling processes have been recorded on the South- and South-east Coast (Beckley, 1983; 1988; Schumann *et al.* 1982; 1988). Coastal surface sea temperature (SST) has been shown to be a very good indicator of wind-forced coastal upwelling conditions along this coast (Schumann *et al.* 1995; Schumann 1999). In general winds and SST are correlated with the southern oscillation index, such that more easterly winds are experienced at high phases (La Nina) with consequent decreases in coastal SST. The summer wind forcing off the south coast is very different to the situation off the west coast of South Africa, with wind variability occurring on much shorter time scales from 2 to 6 days. This has important consequences for plankton blooms and is a likely reason why production on the south coast is less efficient than off the west coast (Schumann 1999).

The continental shelf deflects the fast flowing Agulhas Current far away from the Tsitsikamma coastline (Shannon 1989) and much of the energy in Agulhas Bank shelf water is in the form of coastal trapped waves, generated by synoptic weather patterns. Atmospheric pressure variations produce current speeds an order of magnitude greater than tidal waves (Tilney *et al*. 1996). The current system in the nearshore zone is complex. Attwood *et al*. (2002) deploying current drogues in the MPA recorded reversal in surface current direction. Roberts and van der Berg (2005), using acoustic equipment, found that the eastward (longshore) flow was dominant in the surface (5m) layer, with an absence of an overall seasonal trend. However, at a depth of 31 m flow patterns varied with seasons. In winter the current direction was similar to that of the surface water, but flowed in the opposite direction during mid summer (December and March). This has implication for the dispersal of fish eggs and larvae in and out of the MPA (Tilney *et al*. 1996; Brouwer *et al*. 2003; Roberts & van der Berg 2005).

The current system in the nearshore zone is complex. Much of the energy in Agulhas Bank shelf water is in the form of coastal trapped waves, generated by synoptic weather patterns. Atmospheric pressure variations produce current speeds an order of magnitude greater than tidal waves (Tilney *et al*. 1996). In winter, atmospheric pressure along the south coast is dictated by the subtropical high pressure belt around 30°south. However, in summer intense warming of the land creates a shallow low pressure system (Van Zyl 2003 in Götz 2005).

Wind and wave conditions are important factors influencing coastal hydrology. Wave measurements recorded by ships less than 250 km seaward of the southern Cape coastline (34° - 35° S, 23° - 25 ° E) showed that the prevailing wave form was from a westerly direction, 1.6 - 3.0 m in height, and having a wave interval of 6 - 8 m / seconds (Swart & Serdyn 1981). A similar wave regime, with slightly smaller wave heights (*c.* 1.0 - 2.0 m), is likely along the exposed of the Tsitsikamma area. In the Wilderness area wave roses given in Whitfield *et al*. (1983) show a predominance of the south-westerly waves, with the greatest median wave height of 2.75m also originating from the south-westerly sector. South-easterly waves predominate in summer and autumn, and south-westerly waves in spring and winter (Whitfield *et al*. 1983).

Wave action on the rocky shores at the mouth of the Knysna 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 x $10^6 m^3$ (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 1981b).

4.8 *Water quality*

The physical and chemical properties of the lake systems in the Wilderness area of the GRNP have been extensively studied (see Liptrot 1978, Liptrot & Allanson 1978; Howard-Williams & Allanson 1978b; Howard-Williams & Allanson 1979; Allanson & Howard-Williams 1984; Whitfield *et al*. 1983; Russell 1999a), with Knysna and Tsitsikamma to a far lesser degree.

Swartvlei and Touw systems

Swartvlei Lake is normally meromictic, as a result of its usual stratification into water layers of different densities, caused by vertical stratification in salt concentration (Robarts & Allanson 1977; Howard-Williams & Allanson 1978b). The bottom layer of high salinity water can be up to 5 m thick (Whitfield *et al*. 1983). Stratification prevents wind from mixing the oxygenated surface water with those below, thus decomposition of organic matter in the bottom sediments rapidly uses up the oxygen and increases the concentration of carbon dioxide (Howard-Williams & Allanson 1979) making the bottom half of Swartvlei Lake a very toxic environment for animal life. When Swartvlei Estuary mouth is closed, wind mixing of the surface waters of the lakes gradually breaks down the salinity layering (Robarts & Allanson 1977; Allanson & Howard-Williams 1984). The longer the mouth remains closed the more likely it is that stratification will break down, with resultant oxygenation of the lower waters of the lake.

No definite pattern of stratification has been recorded in the lakes of the Touw system. The salinity of the lakes increases the further removed from the sea with Eilandvlei averaging between 6 and 10 g kg^{-1}, Langvlei 10 and 13 g kg^{-1}, and Rondevlei between 12 and 16 g kg^{-1} (Whitfield *et al.* 1983; Russell 1999a). An analysis of the salt budget of the Touw system suggests that the Serpentine channel dampens tidal processes to the upper lakes to such an extent that they play only a minor role in the overall budget (Hall 1985b). Furthermore, the narrow channel between Eilandvlei and Langvlei prevents any tidal salt input to the upper lakes (Hall 1985b).

Turbidities recorded in the lakes and estuaries of the Wilderness area are moderate, with the average of all waterbodies being below 10 NTU (Whitfield *et al* 1983; Russell 1999a). Water clarity (indicated by secchi disk depth) is greatest in Swartvlei Lake, with all systems undergoing periodic dramatic reductions in clarity which is generally associated with flood conditions (Whitfield *et al*. 1983; Russell 1999a).

Temperature variations in the lakes and estuaries follow a seasonal pattern, with temperatures generally ranging between 10-14°C in winter and 25-29°C in summer (Whitfield *et al*. 1983; Russell 1996a). Water temperatures as high as 32°C have been recorded in Swartvlei Estuary (Russell 1996a). Whitfield *et al*. (1983) maintain that closure of the Swartvlei Estuary mouth has little effect on water temperature, though during summer when the estuary mouth is open, the waters near the mouth are generally 1°C cooler than further up the estuary.

Horizontal variations in dissolved oxygen in the Swartvlei system depend largely on the distribution of aquatic plants, with higher oxygen values being associated with the presence of aquatic plants (Howard-Williams & Allanson 1979). The closing of the estuary mouth has no effect on the mean dissolved oxygen values in Swartvlei Estuary (Howard-Williams & Allanson 1979).

Deoxygenation has been recorded in localised areas in the Swartvlei Estuary towards the end of the closed phase (Howard-Williams & Allanson 1979). These areas are at the sides of the channel where mats of floating algae start to rot, and in deeper portions of the estuary. The only recorded incidence of low oxygen concentrations resulting in the death of organisms occurred in Rondevlei during March 1993 when the senescence of a dinoflagellate/algal bloom resulted the mean oxygen concentration in Rondevlei declining to below 1 ppm, which resulted in the death of several large Cape stumpnose (*Rhabdosargus holubi*) and white steenbras (*Lithognathus lithognathus*) (Russell 1994). The production of hydrogen sulphide (H_2S) gas by anaerobic decomposition of organic matter and the resultant 'rotten egg' odour has been discussed by Russell (1997).

Knysna System

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).

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*. (2000) provide values for water quality indicators (pH, TSS, chlorophyll-a, ammonium, nitrate+nitrite, soluble reactive phosphate), measured in Knysna Estuary during 1996 and 1997.

Allanson *et al*. (2000) undertook comparisons of secchi disk depth with earlier studies in 1991-1994 (Russell 1996b, 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 1996b, Allanson *et al*. 2000), particularly with regard to overall water transparency, the growth of intertidal sandbanks, and the disruption of nutrient pathways for filter feeders.

Tsitsikamma systems
Harrison *et al*. (1995,), using seven parameters (dissolved oxygen, oxygen absorbed, unionised ammonia, E. coli. nitrate nitrogen, phosphate phosphorous and chlorophyll- *a*) calculated a water quality index rating value (between 0 (poor) - 10 (good)) for the various estuaries along the Cape Province. The index ratings for the estuaries (or river mouths) within the Tsitsikamma area ranged from approximately 5.5 to 9.0, with elevated *E. coli* levels impairing the water quality of several of these estuaries. Additional water quality data exists for the estuarine portion of the Sout / Salt River and Groot River (west) (Morant & Bickerton 1983), as well as the freshwater section of the Salt River (De Moor *et al*. 2004). Water analysis of marine environment appears to be restricted to work by Mitchell-Innes (1988), where once-off, spot seawater samples in the Storms River region were analysed for phosphate, nitrate and silicate.

5. BIOTIC SPECIES AND COMMUNITY DIVERSITY

5.1 Viruses

Viruses are small infectious agents that replicate in cells and can infect all biota; which includes humans, other animals, plants and bacteria and other organisms. No studies pertaining to the GRNP specifically have been done.

Alsopp (2006) studied the occurrence of a mite (Varroa destuctor) that occurs in honeybee colonies throughout South Africa but also in the vicinity of George, Knysna and Plettenberg Bay. Varroa destructor is the vector for viruses that causes potential honeybee colony losses. The Cape honeybee shows tolerance to varroa (Alsopp 2006). Between May 2004 and early 2005, Bovin Tuberculosis was reported in cattle on a farm adjacent to Tsitsikamma area, but there appear to be no incidences for the Tsitsikamma area (Mr A. Riley pers comm. 2004). Rift Valley Fever (various Phlebovirus species (family Bunyaviridae)) was confirmed in 2010 from a dairy farm in Tsitsikamma http://www.wuestenschiff.de/phpbb/viewtopic.php?t=35706&start=30. Mosquitoes (Aedes species) are able to act as vectors.

HIV and tuberculosis are present in the GRNP but no statistics are disclosed (pers com C Wiley, HR GRNP).

5.2 Bacteria

No studies pertaining specifically to the GRNP have been done besides the water quality tests which are conducted at various points across the park. The Department of Health routinely monitors the microbiological water quality (in the form of *Escherichia coli* levels) in Swartvlei during peak holiday seasons, whereas sampling in the Touw system is undertaken on an *ad hoc* basis. These data are generally not published, though some results from the Touw system (1993 and 1994) are given in Fijen (1995b), and from Swartvlei system (1991 to 1994) in Fijen (1995d).

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. The local authorities conduct water quality tests on a regular basis in and around the Knysna estuary.

In May 1991 the tests of hundreds of red-bait pods on the coast became infected and substantial declines in the populations were recorded. Standard characterization techniques, coupled with API tests showed that bacterial isolates from infected specimens belonged exclusively to the genus *Vibrio* (Hanekom *et al*. 1999).

The sewerage from the Storms River Rest-camp and housing area is treated by five biofilters. Water quality tests are conducted at the plant.

5.3 Fungi

An abundance of fungi in a variety of colours, size and form are common in the GRNP. Fungi do not have chlorophyll and are not plants but during one part of the life cycle they exhibit animal-like characteristics, and during another part, they exhibit plant like traits (Schooley 1997). Studies and literature related specifically to the GRNP, however, is relatively limited. Crous *et al*. (2006) states that fungi is poorly collected and studied in South Africa. This was confirmed for the GRNP by Jolanda Roux (2012 pers com).

Doidge (1941a, 1941b, 1942, 1950) Laughton (1937) and Bottomley (1948) published extensively on fungi collected in Southern Africa. Many of these species were recorded from Knysna and Tsitsikamma area. Doidge (1950) was digitised and is searchable (http://www.cbs.knaw.nl/publications/mycoheritage/doidge/index.html). Riana Jacobs (Ph.D), Manager: Mycological Culture Collections, Biosystematics Division: Mycology of ARC-Plant Protection Research Institute collated a list of fungi reported for the GRNP area (Jacobs 2013). It only represents the macro fungi (mushrooms and bracket fungi). Micro fungi will be added in due course. A list of fungi is available in *Appendix 1*.

Crous *et al*. (2006a) consider Gorter (1977, 1979, 1981, 1982), Van der Westhuizen & Eicker (1994), and Eicker & Baxter (1999) to be the most influential publishers on fungi. The information on fungi subsequent to 1999 can be obtained via the Internet-based electronic system of CAB abstracts (CAB) (www.cabi-publishing.org). Plant diseases caused by fungi are searchable at http://nt.ars-grin.gov/fungaldatabases/southafrica/.

Crous *et al*. (2006) considers Ascomycetes, Basidiomycetes, Zygomycota, lichen-forming and lichenicolous fungi and Oomycetes as intensively studied groups in South Africa. The abundance of fungi becomes clear from Crous *et al*. (2006) where it was found in a study aimed at exploring the saprobic (litter) microfungi inhabiting Proteaceae and Restionaceae (both families are substantially represented in the GRNP) that at least three unique species of saprobic microfungi are found for each species of Proteaceae or Restionaceae investigated. The authors further point to various studies that show ratios of plants versus fungi. They estimate a ratio of 1:7 for South Africa. This implies the GRNP should have around 14 000 fungi species on plants alone. Taylor *et al* (2001) discus the diversity of fungi in the Cape Floral Kingdom with reference to the Knysna area.

Phillips (1931) lists parasitic and saprophytic fungi and their hosts, of the Southern Cape and Tsitsikamma. Van der Byl (1925) published a preliminary list of fungi from Knysna and surroundings. Phillips (1923, 1924, 1929) describes the influence of fungus on some Afromontane Forest trees. Kamgan *et al*. (2008) has studied fungal species (in Ceratocystis and Ophiostoma) that include important pathogens, associated with insects that typically infect wounds visited or made by their vectors in the Tsitsikamma forests. Lubbe & Mostert (1991) describes the detrimental influence of Phytophtora cinnamomi on forest species throughout the forested areas of the GRNP. Roux *et al*. (2004) discusses the fungal pathogens found in wounds caused by bark harvesting of several local indigenous tree species that leads to deterioration of wood and often the death of the trees.

Hawley *et al*. (2004) reports on mycorrhizal status of indigenous tree species in a forest biome of the Eastern Cape. The study, although done outside the GRNP, mentions the Southern Cape and Tsitsikamma and mycorrhizal associations with indigenous tree species common the GRNP. A preliminary investigation of in the De Vasselot area recorded approximately 40 species of corticoid fungi, or wood-inhabiting basidiomycetes. Phillips (1931) describes the mycorrhizal caused nodules on Podocarpus species in the GRNP area. Van der Westhuizen & Eicker (1987) discuss the importance of mycorrhiza in plantations for the trees' wellbeing and seedling establishment. Morris (1997) discusses the success of the Acacia Gall Rust Uromycladium tepperianum in the Western Cape. This is a fungal pathogen species which affects both reproductive and vegetative growth of its host plant, Acacia saligna (Labill).

Two research studies are currently underway that will provide further information on fungal pathogens. Jolanda Roux of FABI registered a project "Fungal tree pathogens and their insect associates in the GRNP". Ntombizodwa Ngubeni (SANParks Scientific Services) is currently investigating fungal pathogens for an MSc degree.

5.4 Diatoms

Phytoplankton populations in the Wilderness lake systems are low (Robarts 1973), as confirmed by chlorophyll-a determinations undertaken in Swartvlei Lake in 1976 (Coetzee 1978) and 1977-78 (Howard-Williams & Allanson 1981a). Three major categories of phytoplankton have been recorded in Swartvlei Lake viz. diatoms, flagellates and dinoflagellates (Robarts 1976a) with the diatom *Coscinodiscus lineatus* the most abundant species. Other common diatom species include *Chaetoceras wighamii, Cocconus scutellum, Grammatophora oceanica, Grammatophora sepentia, Navicula pseudony, Raphoneis mirabunda, Raphoneis superba* and *Synedra tabulata* (Robarts 1973). Flagellates and dinoflagellates generally form a relatively minor part of the phytoplankton biota (Robarts 1973), though short-lived blooms do occasionally occur.

Studies on marine phytoplankton are limited. Spot samples taken in 1984 indicated that phytoplankton, which was dominated by diatoms, was sparse in the surface waters, but more abundant within and beneath the thermocline, as well as immediately after upwelling. The most common species included *Hemiaulus sinensis*, *Leptocylindrus danicus*, *Nitzschia delicatissima*, *N. pungens* and *Rhizosolenia delicatulum* (Michell-Innes 1988).

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

5.5 Protozoans

Protozoa is a phylum of single-celled eukaryotes (organisms containing a membrane-bound nucleus and membrane-bound organelles). Protozoa are ubiquitous and of great importance in the economy and nature; examples are the amoeba and the malaria parasite.

Except for Phillips (1931), referring to Fantham & Robertson's (1928) studies on protozoa found in forest soil from Diepwalle, no literature was found dealing with the GRNP or the immediate area. Seydack (1990) had the protozoa in the digestive fluids of the bushpig identified and lists seven species. Van der Hoven & Gilchrist (1991) discuss seven species of holotrich protozoan endocommensals found in the hindgut of bushpig. Bennet *et al*. (2009) discuss the cellulose-digesting protozoa found in the hindgut of the dune mole rat, a mammal species occurring abundantly in the GRNP. Schrenzel (2005) discusses protozoa in the faeces of passerine birds, among those, Southern Cape Sparrows.

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).

Tick fever and red water are common in the Tsitsikamma and Southern Cape. It is caused by Apicomplexa, spore-forming single-celled parasites of animals. Tick-borne diseases of domestic animals caused by apicomplexans include redwater (Babesia bigemina and B. ovis), and biliary fever of dogs (Babesia canis) http://www.biodiversityexplorer.org/eukaryotes/chromalveolata/alveolata/apicomplexa/index.htm, all common illnesses in the park's immediate area. No publications could be found for the above.

The phylogeny and geographic distribution of Ganthiidae, a family of fish parasitic isopods, as well as the feeding ecology of *Gnathia africana* from the Tsitsikamma area have been studied (Coetzee & Smit 2007; Coetzee *et al.* 2007). The family Ganthiidae has more than one hundred species (Coetzee & Smit 2007), while the rate of attachment of *G. africana* to fish is highest around midday and late afternoon, and is higher in intertidal pools than in the infratidal zones (Coetzee *et al.* 2007).

5.6 Algae and related organisms

Algae are a very large and diverse group of simple, usually autotrophic organisms that range from unicellular to multi cellular. The largest are sea kelps. Alga may form a symbiotic relationship with a fungus to form lichen. Lichens are composite organisms consisting of a symbiotic relationship between a fungus (the mycobiont) and a photosynthetic partner (the photobiont or phycobiont), usually either a green alga (commonly Trebouxia) or cyanobacterium. Doidge (1950) published the known lichens of South Africa. No specific information on terrestrial lichen in the GRNP is available

Principal genera of epiphytic algae occurring in the Wilderness lakes system include *Enteromorpha, Lyngbya, Cladophera, Percursaria, Cocconeis, Ectocarpus, Polysiphonia, Chondria* and *Hypnea*) (Howard-Williams 1980; Howard-Williams & Liptrot 1980). Howard-Williams & Allanson (1979) assessed the role of algae in the cycling of nutrients in Swartvlei system, which is briefly discussed under the heading of submerged aquatic plants below.

In the Knysna area, 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).

As far as marine algae are concerned, a comprehensive survey recorded 211 seaweed species in the Tsitsikamma area, consisting of 22 green-, 86 brown and103 red algal species, including two previously undescribed species (Bolton and Stegenga 2002, Stegenga *et al*. in lit. 2002; Stegenga *et al*. 2000: 2001) (*Appendix 2*). The two new species of red algae, namely *Scageliopsis tsitsikammae* nov. spec. and *Hypoglossum imperfectum* nov. spec. were recorded (Stegenga *et al*. 2000; 2001), while molecular evidence suggests that *Asparagopsis armata* is an introduced species (Bolton *et al*. 2011). The intertidal seaweed species composition is similar (ca. 85%) to that of the region between Kei Mouth and Haga Haga in the eastern Cape (Bolton *et al*. 2004). Erect coralline algae of the genera *Arthrocardia* and *Coralina* are dominant in the lower intertidal zone of the sheltered shores (Hanekom 2011).

5.7 Higher plants

5.7.1 Submerged Aquatic

Extensive studies have been undertaken on both submerged aquatic plants and semi-aquatic plants in the Wilderness lakes. Submerged macrophytes are widespread in the Wilderness lake systems and consist predominantly of pure and mixed stands of *Potamogeton pectinatus,* Charophyta and filamentous algae (Howard-Williams & Liptrot 1980, Weisser & Howard-Williams 1982, Whitfield *et al*. 1983) with *Ceratophylum demersum (*hornwort) having become widespread and abundant in several lakes during the 1990's. In the estuaries *Ruppia spirralis* and *Zostera capensis* predominate. The Groot River (West) estuary is the largest and probably the only estuary in the Tsitsikamma region that has notable stands of submerged aquatic plants, with stands of *Ruppia maritima* and *R. spiralis* occurring in the creek west of "The Island" (Morant and Bickerton 1983).

The production of organic matter by submerged aquatic plants was calculated in 1978-1979 as 1.84 x 10^6 kg y^{-1} (dry weight) (74% of total production) in the Swartvlei system (Howard-Williams & Allanson 1979), and 334 100 kg y^{-1} (17% of total production) in the Touw system (Howard-Williams 1980). The bulk of this organic matter is produced in the shallow periphery of the waterbodies, in waters to a depth of three meters.

Both long- and short-term changes occur in the abundance, biomass and distribution of submerged aquatic plants, with substantial declines in the abundance and distribution of species were recorded in most waterbodies between 1973 and 1982 (Davies 1982; Weisser & Howard-Williams 1982; Whitfield 1982; Weisser *et al*. 1992), though in 1991 the standing crop of submerged macrophytes in most waterbodies was found to be similar or greater than those recorded prior to 1973 (Russell 1996a). Only in Rondevlei has the biomass of submerged aquatic plants increased consistently with time (cf. Howard-Williams 1980; Hall 1985a, 1985b; Russell 1996a). Weisser *et al*. (1992) suggest that aquatic vegetation proceeds through cycles, from an aquatic macrophyte dominated system through a phytoplankton dominated system and back to a macrophyte dominated system. Theorised reasons for periodic declines in aquatic plants include fungal diseases (Howard-Williams 1980), changing nutrient status of the waterbody (Hall 1985a, 1985b; Weisser 1979), shading by *Enteromorpha* (Hall 1985a) and dinoflagellate blooms (Coetzee & Palmer 1982), reduced water transparency resulting from the influx of turbid water (Whitfield 1982; Allanson & Howard-Williams 1984), and reduced calcium: magnesium ratios in the water column, as a result of persistent flooding (Allanson & Howard-Williams 1984).

Howard-Williams & Allanson (1979) described how a 10% decline in submerged aquatic plants in Swartvlei Lake would result in a 20% decline in the total food production. The ratio of food production to consumption in Swartvlei Lake is approximately 1:1 (Howard-Williams & Allanson 1979), while in the estuary utilisation of organic material by the biological community is greater than the production rate, a deficit made larger by the export of *Zostera* leaves during the tidal phase (up to 500 kg dry mass per tide). Hence any loss in primary production would result in a corresponding reduction in the number of consumer organisms (see section 2.4.1 Suspensoids).

In the Knysna area, 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).

The Groot River (west) estuary is the largest and probably the only estuary in the Tsitsikamma area that has notable stands of aquatic angiosperms. It has a profuse growth of *Ruppia maritima* and *R. spiralis* in the creek west of “The Island” (Morant and Bickerton 1983). Aquatic angiosperms appear to be virtually absent in the marine sector, sparse in the riverine portions in the Tsitsikamma area and fairly common in rivers of Soetkraal, where they must still be described.

5.7.2 Emergent Aquatic

The occurrence and distribution of emergent aquatic plants in the Wilderness area are given in Jacot-Guillarmod (1979, 1981, 1982), Weisser & Howard-Williams (1982), Whitfield *et al*. (1983) and Russell (2003). The GRNP area contains freshwater wetlands (as typified by the Knysna component of the Cape Lowland Freshwater Wetlands of Mucina and Rutherford (2005).

Phragmites australis has been calculated to produce up to 303 000 kg y^{-1} organic matter (dry weight) (12% of total production) in the Swartvlei system (Howard-Williams & Allanson 1979), and 1.08×10^6 kg y^{-1} (55% of total production) in the Touw system (Howard-Williams 1980). Organic matter production by other semi-aquatic plant species is substantially lower, with *Schoenoplectus scirpoideus* producing 351 600 kg y^{-1} (18.0% of total production), and *Typha capensis* 182 800 kg y^{-1} (9.4% of total production) in the Touw system (Howard-Williams 1980). No estimates of annual biomass by *S. scirpoideus* and *T. capensis* are available for the Swartvlei system.

In the Touw system Howard-Williams (1980) found that *P. australis* and *S. scirpoideus* decreased in abundance and biomass from the Touw River Estuary/Serpentine towards Rondevlei, whereas *T. capensis* increased in abundance and biomass in the same direction. Mapping of the distribution of plants in the 1970s (Weisser & Howard-Williams 1982) and 1990s (Russell 2003) indicated localised increases in *P. australis, T. capensis, Scrub or trees,* and Grass or Fields, and decreases in *Juncus kraussii, Schoenoplectus scirpoideus* and Low scrub or fynbos in the Touw system. Probable causes of change in the distribution of wetland plants include the natural tendency of plants to colonise new areas, as well as anthropogenic manipulation of physical, chemical and biological processes, including the cessation of disturbance by large herbivores, water-level stabilisation, changes in soil salinity and the accumulation of plant litter within wetland areas (Russell 2003).

Techniques for monitoring changes in emergent aquatic plants using aerial photographs are discussed by Weisser & Stadler (1983), with particular attention given to the most desirable scale and timing of photographs.

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 Knysna 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.

In the Groot River (west) estuary, the largest estuary in the Tsitsikamma region, wetland species such as *Mariscus thunbergii*, *J. kraussi* and *P. australis* are found on the western bank, while *Samolus porosus* is abundant on the island and eastern bank (Morant and Bickerton 1983). Based on aquatic and semi-aquatic vegetation, this estuary had an intermediate botanical importance rating compared to 31 other estuaries in the Cape Province, while the Salt River estuary was low (Coetzee *et al*. 1997). Nevertheless a high priority should be given to the rehabilitation of the Groot River estuary (Turpie & Clark 2007).

The freshwater vegetation in the Tsitsikamma area is poorly studied. However, the River Health Programme (2007) rated the riparian vegetation of the lower sections of the Salt River and Groot River as natural (excellent) and good respectively.

5.7.3 Terrestrial vegetation

A broad-scale classification and description of the vegetation of the region are provided by various authors (viz. Acocks 1988, Low & Rebelo 1996, Pierce 2003, Mucina & Rutherford 2006, Mucina *et al* 2014). Nine national vegetation types, covering two biomes (fynbos and forest) as well as azonal coastal vegetation (Mucina *et al* 2014), are represented in the park.

A more detailed vegetation classification for fine-scale biodiversity planning for the Garden Route region was conducted by Vlok *et al*. (2008). They identified more than 30 terrestrial habitat types, representing more than 50 forest and fynbos communities within the boundaries of the Garden Route National Park. Most of the Fynbos biome, and also the fynbos in the park, forms part of the Cape Floristic, Kingdom, the smallest of the six Floral Kingdoms of the world. It is categorized by a high plant species richness and endemicity (Low & Rebelo 1996). The natural forests in the Southern Cape and Tsitsikamma form the biggest forest complex in Southern Africa (Geldenhuys 1991a), of which most occur in the Garden Route National Park.

Approximately 2030 plant species, representing 727 genera and 158 families have been recorded for the park, including a number of Red Data species. A vegetation map for the park (*Appendix 17*), based on the classification by Mucina & Rutherford (2006), and a detailed plant species list, are provided in *Appendix 3*.

5.7.3.1 Fynbos

Together with Southern Afrotemperate Forest, Sandstone Fynbos covers the largest terrestrial area of the park, comprising of a range of Dry, Mesic and Wet Mountain Fynbos types (vide Campbell 1985). It has been classified as South Outeniqua Sandstone Fynbos and Tsitsikamma Sandstone Fynbos on the southern slopes of the Outeniqua and Tsitsikamma Mountains respectively, with smaller areas of North Outeniqua Sandstone Fynbos (Mucina *et al.* 2014). In the mountainous areas of both these types, pockets of Afrotemperate Forest are found in gullies and bergwind shadow areas where they are protected against fynbos fires (Geldenhuys 1991a, 1991b, 1994a). South Outeniqua Sandstone Fynbos consists of a tall, open to medium dense shrub layer with a medium tall shrub understorey, and comprises of mainly proteoid and restioid fynbos and extensive ericaceous fynbos on the upper slopes (Mucina *et al.* 2014). The type is also well represented as fynbos islands in the Afrotemperate forest in the park, originating from the expansion of forest vegetation during, isolating it from the mainland fynbos (vide Bond *et al*. 1988, Midgley & Bond 1990). Floristic communities that form part of South Outeniqua Sandstone Fynbos have been described by inter alia Seydack (1977), Bond (1978, 1981), West (1989) and Vermeulen (1995). The conservation status of the type has been described as “vulnerable” (after the classification by Golding 2002) with large areas already transformed through afforestation and agricultural development (Mucina & Rutherford 2006, Lombard *et al*. 2005). Tsitsikamma Sandstone Fynbos consists of mainly proteoid, restioid and ericoid fynbos with thicket in wetter areas, and is found on gentle to steep southern and northern slopes of the relatively low Tsitsikamma mountain range. Floristic communities associated with the types, have been described by Southwood & De Lange (1984), Anon (1985), Hanekom *et al*. (1989), Pretorius *et al*. (1979). North Outeniqua Sandstone Fynbos is dominated by restioid and proteoid Fynbos, with ericaceous and asteraceous fynbos widespread at higher and lower altitudes respectively. Studies on floristic communities associated with this type, have been conducted by Bond (1981).

Two types of Sand Fynbos as described by Mucina *et al*. (2014) have been recorded for the Park. Knysna Sand Fynbos is generally found on undulating hills and moderately undulating plains, and are described as dense, moderately tall, microphyllous shrubland. It is underlain by deep, acid Tertiary sand, forming regic sands and soils of the Lamotte form. Vegetation units that form part of Knysna Sand Fynbos, have also been described by Anon (2005), who distinguish between Wet and Dry Sand Fynbos. Knysna Sand Fynbos has been rated by Mucina & Rutherford (2006) as “endangered” and very poorly researched. Lombard *et al* (2005) who consider it as almost totally transformed, close to extinction and urgently in need of protection. Southern Cape Dune Fynbos is generally found on stabilised old calcareous or neutral dunes built with deep sand, often with steep slopes, but has a limited distribution in the park. It is dominated by sclerophyllous shrubs with a rich restio understorey (Mucina *et al.* 2014). The type and different floristic communities associated with it, are described in more detail by Van der Merwe (1976) and Anon (2005). Although the conservation status of the type has been describes as “least threatened” it hosts endemic species such as *Erica chloroloma*, *Lampranthus algoensis* and *Pentaschistis barbata* subsp. *orientalis*. *Aspalathus cliffortiifolia* is also associated with the type, but is regarded as possibly extinct. Lombard *et al*. (2005), consider the type as heavily transformed

Shale Fynbos is represented by small patches of Garden Route Shale Fynbos found on the coastal foothills of the Outeniqua and Tsitsikamma Mountains. It consists of dense proteoid and ericaceous fynbos in wetter areas and more graminoid on drier sites (Mucina 2014). Further species associated with Garden Route Shale Fynbos are provided by Anon (2004). It is a poorly studied vegetation type, rated as endangered, and hosts the endemic species *Cyphia georgica*, *Disa newdigateae* and *Gladiolus roseovenosus*.

Fynbos Shale Band Vegetation is represented by Eastern Coastal Shale Band Vegetation. As the name indicates, it occurs on narrow, linear shale bands on clayey soils derived from the Cedarberg Formation. Important taxa include the widespread *Leucadendron eucalyptifolium* and *Protea neriifolia*, as well as *L. salignum* and *Leucospermum cuneiforme*. The type has been classified as “endangered” with the park regarded to make an important future contribution towards its protection (Mucina & Rutherford 2006).

Granite Fynbos is represented by small areas of Garden Route Granite Fynbos in the lowland areas in the western part of the park (Wilderness area). It is dominated by proteoid and graminoid fynbos, on deep, prismacutanic- and pedocutanic-dominated soils, underlain by George Batholith of the Cape Granite suite. Important species include the shrubs *Passerina corymbosa*, *Protea coronata* and *P. lanceolata*, and the graminoids, *Tetraria cuspidata* and *Brachiairia serrata*. Garden Route Granite Fynbos has been classified as “endangered” with large areas already transformed for cultivation (Mucina & Rutherford 2006).

Fragmented lowland fynbos

More than 140 patches of fragmented fynbos, collectively covering ca. 7500 ha, occur within the GRNP (Kraaij & Vermeulen 2010). These fynbos fragments are largely associated with scarp and coastal platform forest, and include (i) degraded forest patches, (ii) fynbos islands which are completely isolated and cut off from mainland fynbos, and (iii) fynbos fragments which are partially isolated from mainland fynbos. Isolation or fragmentation in (ii) and (iii) could either have occurred naturally through expansion of indigenous forest, shaped by fire patterns (Geldenhuys 1994a), or artificially through anthropogenic transformation of the surrounding landscape (Cameron 1980; Bond *et al*. 1988). Artificial fragmentation typically resulted from plantation forestry, agriculture, or the development of infrastructure. The fynbos islands or fragments of natural origin are considered remnants of once much larger fynbos areas which have been completely or partially cut off from the mainland by expanding indigenous forest (Bond *et al*. 1988; Midgley & Bond 1990). These natural fynbos islands or fragments are thus of unique conservation value, both from a biodiversity and ecosystem functioning perspective. The fynbos islands and fragmented patches are also considered to be resource refugia and stepping-stone habitats for avifauna (Sandberg 2013, Sandberg et al. 2016). Floristically they mostly consist of South Outeniqua Sandstone Fynbos and Tsitsikamma Sandstone Fynbos, as well as smaller areas of lowland fynbos, i.e. Knysna Sand Fynbos and Garden Route Shale Fynbos (Rebelo *et al*. 2006).

5.7.3.2 Forest

Mucina and Rutherford (2006) follow the Department of Water Affairs and Forestry (DWAF) national forest type classification system for South African indigenous forests (Von Maltitz *et al*., 2003) and identify two national forest types occurring in the Garden Route, viz. Southern Cape Afrotemperate Forest and Western Cape Milkwood Forest. A more detailed floristic classification of forest vegetation in the Garden Route is provided by Geldenhuys (1993a).

Southern Cape Afrotemperate Forest

The Southern Cape Afrotemperate Forests is the largest forest complex in southern Africa (approximately 60 500ha; Geldenhuys, 1991a). They occur from sea level to altitudes of 1 000 metres or more, but most of the high forest occurs on the coastal plateau and foothills of the mountains. They display great variation in forest structure, species composition and species density due to the variations in topography, soils, microclimate and other factors. The forests occur in three distinct zones with distinct stand structure and species composition (Geldenhuys, 1982a). The mountain forests (mostly wet forests) are typical Afromontane forest. Dry forests or scrub forests occur on the coastal scarp or on the steep slopes of the river valleys (Phillips, 1931). These forests are species-rich and include many species of Indian Ocean Coastal Belt forests (Moll & White, 1978 in Geldenhuys, 1982a). The plateau forests are typically moist and medium-moist forests and include mainly species of Afromontane affinity.

A total of 465 plant species are known to occur in these forests. This is relatively high for the southern latitude of these forests and can be attributed to the range of diverse habitat types and dispersal corridors that linked these forests to the east over a very long period (Geldenhuys, 1992a). There are several species that drop out along different zones from east to west within the southern Cape, and many species have a disjunct distribution within the area (Geldenhuys, 1992b).

Following the pattern of the climatic zones, from the hot and dry zone of the littoral over the temperate zone to the cold and wet zone of the mountain ranges, Von Breitenbach (1968, 1974) described eight climax forest types, which were refinements of earlier classifications by Phillips (1931) and Laughton (1938). Of these seven are significant in the management system. The classification is done according to the combined assessment of moisture regime, ground shrub and tree flora as well as features such as tree form and canopy height. However, sites are ecologically complex and produced by varying combinations of interchangeable factors. Forest types are therefore crude, and of necessity artificial groups of areas which have similar site features. This forest type classification however effectively serves the purpose of providing area-specific information on resource nature and utilisation potential and constraints (e.g. ecological sensitivity) and as such strongly influences management objectives and practices.

Western Cape Milkwood Forest

Western Cape milkwood forest occurs as small patches at altitudes between 20 and 340m along the southern coast between Nature's Valley and the Cape Peninsula (Mucina & Rutherford, 2006; Von Maltitz *et al*., 2003). In the Garden Route, patches occur *inter alia* at Nature's Valley, Keurbooms, Knysna, Goukamma and Groenvlei Forests in the Goukamma Nature Reserve, Sedgefield and Wilderness National Park.

The forests are generally low, species-poor and often dominated by only one or a few canopy tree species with large stems and spreading crowns, usually *Sideroxylon inerme* and *Celtis africana* or *Apodytes dimidiata*. The understorey may be open, but is often a shrub layer with a diverse range of species.

5.7.3.3 Coastal Vegetation

Coastal Vegetation of South Africa vegetation group is represented by Cape Seashore Vegetation along the coastal dunes and cliffs between Wilderness and Sedgefield, covering less than 1% of the park area. Important taxa include succulent shrubs such as *Tetragonia decumbens* and *Scaevola plumieri*, the low shrub *Hebenstretia cordata*, and the herbs *Gazania rigens*, *Senecio elegans*, as well as the herb *Arctotheca populifolia* (Mucina & Rutherford 2006). Cape Seashore Vegetation has been classified as "Least threatened" owing to large areas represented in other coastal National Parks and nature reserves.

5.8 Invertebrates

5.8.1 Aquatic invertebrates

Freshwater aquatic invertebrates

The aquatic invertebrates' fauna of the Southern Cape is unique when compared to the rest of Africa, being adapted to the cool, low nutrients, fast flowing acidic waters typical of this region. The distribution of most of these species and genera is restricted to the southern and south Western Cape and they are considered to be endemic to that region (Barber- James 2000, De Moor 2001, De Moor *et al.* 2004)

Early studies of aquatic invertebrates in southern Cape rivers were undertaken by Harrison & Agnew (1962). Filmalter & O'Keeffe (1997) provide a comprehensive list of invertebrates in rivers flowing into the Wilderness lakes. Biotic index values occasionally exceeded 2 in the Diep River indicating slightly enriched waters. In the Höekraal, Karatara, Duiwe and Touw river biotic index values were always below 2. River Health assessments, including SASS scores for Garden Route rivers are given in Rivers Health Programme (2007). In assessments of the Touw, Höekraal, and Karatara Duiwe and upper Diep rivers ecostatus was either good or natural, whereas in the mid and lower Wolwe and Klein Wolwe ecostatus was fair to poor. The SASS5 river health category in the lower Knysna River was defined as Good (River Health Programme 2007).

Two surveys were undertaken in the Salt River (within & outside the park) in the Tsitsikamma area in 2000, as part of an environmental impact assessment, followed by additional study in 2004 (De Moor *et al.* 2004). The results of the first two surveys showed that in the four orders of insects that were examined in detail (Plecoptera, Ephemeroptera, Trichoptera and Diptera) there were 13 previously undescribed species, as well as three new genera, and some remarkable range extension of certain species. The river also produced the richest known diversity of species in the mayfly family Teloganodidae for Africa (De Moor *et al.* 2004). Water abstraction from the catchment of the Salt River is the most serious threat to the continued existence of these macroinvertebrate communities, and reduced flow volumes can exacerbate or result in a multitude of detrimental impacts (De Moor *et al.* 2004). The River Health Programme (2007), using the South African Scoring System, rated the aquatic invertebrate fauna of the lower reaches of both the Salt - and Groot rivers as natural (excellent), but the upper reaches of the former river showed signs of human-related disturbances.

The Cape endemic hydraenid, *Ochthebius capicola,* which was considered extinct on the Cape Peninsula, has been recently re-discovered at two adjacent locations as well as at a new site in the Tsitsikamma area. This species shows a preference for algae-covered rock surfaces in the hypersaline pools of the supralittoral zone (Turner 2004). Genetic studies indicate that the geographic outlying populations of the isopod *Mesamphisopus abbreviatus* in the streams of Tsitsikamma are probably a phylogenetically distinct taxon of a yet undescribed species (Gouws *et al.* 2005). Perkins (2008) recorded *Mesoceration disjunctum* (a new species) at Nature's

Valley and a new distribution record for *Mesoceration dissonum* at Storms river, while a once off collection recorded at least 10 species of Cape water beetles in the Tsitsikamma area of the park (Bilton 2008).

Estuarine aquatic invertebrates
Studies of the zooplankton of the lakes have been undertaken by Grindley & Wooldridge (1973), Grindley (1981) and Coetzee (1978, 1981a, 1983). Zooplankton communities consist primarily of estuarine species, with 45 forms having been recorded by Grindley & Wooldridge (1973). Coetzee (1981a, 1983) described two zooplankton communities during daytime, namely a mixolimnion community occurring mainly under aerobic conditions, and a monimolimnion community occurring primarily under anaerobic conditions and in the presence of H_2S. This division may be an artefact of sampling technique (Coetzee 1981a).Coetzee (1978 1981a 1983) found that at night there was a general upward migration in the water column of zooplankton and other benthic organisms, whereas Grindley & Wooldridge (1973) observed vertical diel migration only in *Acartia* spp, *Halicyclops* spp. and decapod larvae.

The highest diversity of species in Touw River Estuary has been recorded close to the mouth, with the highest daytime number of individuals in the Touw system recorded from Eilandvlei (14 641 indiv. m^{-3}) and Rondevlei (13 108 indiv. m^{-3}) (Coetzee 1983). The highest mean daytime standing crop has been recorded in Langvlei (17 mg m^{-3}), followed by Rondevlei (15 mg m^{-3}) and Eilandvlei (6 mg m^{-3}) (Coetzee 1983). The lowest daytime planktonic standing crop was recorded over deep areas in Swartvlei Lake, where bottom waters were deoxygenated (Grindley 1981; Grindley & Wooldridge 1973). Zooplankton communities in the Swartvlei system consist primarily of estuarine species, with 45 forms having been recorded by Grindley & Wooldridge (1973).
Benthic invertebrates in the open areas of Swartvlei Lake have been sampled by Boltt (1973) who collected 14 species. Aquatic macroinvertebrate communities in the lake systems consist predominantly of estuarine species. The dominant species include the amphipoda *Corophium triaenonys, Cyathura estuaria, Grandidierella lignorum* and *Melita zeylenica*, isopoda *Exosphaeroma hylecoetes* and *Cyathura estuaria*, tanaid *Aspeudes digitalis*, bivalve *Musculus virgiliae*, polychaete *Ficopomatus enigmatica*, crab *Hymenosoma orbiculare* and prawn *Callichirus kraussi* (formerly *Callianassa kraussi*) (Davies 1981). Most of the zoobenthos occur on submerged aquatic plants (Davies 1981), with the mean biomass on *Potamogeton pectinatus* in the Touw system calculated during 1979 and 1980 to be 77.6 g dry mass m^{-2}, compared to the 12.7 g dry mass m^{-2} recorded in sediments (Davies 1981).

Abundant species of benthic invertebrates in Swartvlei Estuary include *Melita zeylinaca*, *Loripes clauses*, *Natica tecta* and *Palaemon pacificus* in vegetated areas (principally *Zostera capensis*), whereas those of bare sand areas are *Urothoe pulchella*, *Callichirus kraussii*, *Iphinoe truncate* and *Pontogeloides latipes* (Whitfield 1989e). The supratidal invertebrate community is dominated by *Orchestia* spp. which feed on wrack detritus. Diet analysis of intertidal and infratidal zoobenthos in Swartvlei Estuary revealed that most invertebrate species feed predominantly on detritus and associated micro-organisms. Filamentous algae and diatoms dominate the gut content of only three out of 18 macrobenthic species, and living *Zostera* is not an important food item for any invertebrate species (Whitfield 1989e).

Hanekom and Russell (2015) noted that there was a decrease in *Callichirus kraussi* abundance in the Estuary, but attributed this decrease to an increase in the abundance of the eelgrass, *Zostera capensis*. The authors noted that, similar to other systems where both species are present, an increase in abundance of *Zosera capensis* results in a decrease in the abundance of *Callichirus kraussi*.

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).

The benthic macrofauna includes approximately 310 species in the Knysna area (Day 1981a). The ecology of some species, such as the endemic mudsnail *Hydrobia knysnaensis* (cf. Barnes 2004) have been the focus of detailed studies. Barnes (2010a, 2010b, 2013a, 2013b) demonstrated that macrobenthic invertebrate diversity is greater in eelgrass beds than in adjacent non-vegetated sediments.

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 Knysna 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 thought 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). Further work has been done in relation to the spatial variation in the macrobenthic assemblages of intertidal seagrass (Barnes & Ellwood 2012). It was found that the overall faunal abundance declined with distance upstream, with the more saline sites supporting greater diversity comparied to the upstream brackish sites (Barnes & Ellwood 2012). Barnes & Ellwood (2011) also investigated the significance of shore height in intertidal macrobenthic seagrass ecology. They concluded that higher seagrass horizons are not just impoverished versions of lower ones and although macrofaunal assemblage composition is heavily influenced by shoreheight much of the ecological structure of faunal assemblages seems little affected by tidal horizon (Barnes & Ellwood 2011).

The mudprawn *Upogebia africana* is abundant and is the most widely used bait species in the Knysna 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). The 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, Allanson & Msizi 2010, Allanson & Fearon 2012).

Three species of indigenous oyster species occur in the Knysna 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.

The life-history of a non-native amphipod was investigated by Hodgson *et al*. 2014 between 2008 and 2010 to determine the reasons for its relative success in suriving in the Knysna Estaury.

Marine aquatic invertebrates

Some 28% of the approximately 9360 invertebrate species found along the South African coast are endemic to this subregion (Griffiths *et al*. 2010), with species richness tending to increase from west to east (Bustamante and Branch, 1996; Scott *et al*., 2012). In a case of six major marine invertebrate taxa (namely prosobranchs, opistobranchs, polychaetes, amphipods, isopods and ascidians) the largest peaks of range restricted endemic species generally occurred around False Bay, Port Elizabeth, Durban, St Lucia and Maputo Bay (Scott *et al*. 2012). These sites are all situated at or adjacent to recognised biogreographic breaks for invertebrate assemblages (Emanuel *et al*. 1992; Bolton & Anderson 1997), but coincidentally also tend to be areas of enhanced research and shipping activities. The documented numbers for the exposed rocky Tsitsikamma coastline are low (Scott *et al*. 2012).

Tietz and Robinson (1980) described the major marine invertebrates found on the Tsitsikamma coast, and this species list has been supplement by records from other research studies. The structure of intertidal invertebrate communities is determined primarily by wave action (McQuaid & Branch 1984; 1985). Filter feeders dominate the wave exposed shores, while herbivores reach their highest abundance on sheltered shores of the Tsitsikamma coast (Hanekom Unpubl.).

Prior to the invasion of the intertidal rocks of the MPA by the alien Mediterranean mussel *Mytilus galloprovincialis* in 1990s, the indigenous brown mussel *Perna perna* was abundant in the lower balanoid zone of exposed shores, and the mean density of mussels recorded at eight sites along the coastline ranged from 900 - 19 860 individuals per m^2 (Crawford and Bower 1983). Secondary settlement of juvenile *P. perna* occurs in spring through to early winter. Growth is fast, with shell lengths of approximately 35 and 50 mm being attained after one and two years of growth respectively (Crawford and Bower 1983). As the invasive *M. galloprovincialis* is a widespread alien species in South Africa (Robinson *et al*. 2016), it has caused significant ecological impacts along the South African coast (Robinson *et al*. 2005). It was absent from the mid shore at Storms River until 1987. Its mean densities were low (< 15 individuals/0.1 m^2) in the mid 1990s, but thereafter increased steadily, peaking in 2004 before declining in 2005 (Hanekom 2008).

The toothed barnacle *Chthamalus dentatus* experienced a significantly ($p \leq 0.05$), but temporary decline in density and biomass values following the *M. galloprovincialis* invasion in the early 2000s (Hanekom 2008). At sites on the south coast where the two mussel species co-occur, *P. perna* was most abundant on the low-shore (despite being less well adapted to cope with sand stress (Zardi *et al*. 2006b)) and *M. galloprovincialis* on the high-shore, with a mixed zone at the mid-shore level (Bownes & McQuaid 2006). Growth rates of juvenile *M. galloprovincialis* decreased upshore, but *M. galloprovincialis* is able to maintain high densities on the upper shore through persistence of successive settlement of slow growing individuals (Bownes 2005; Bownes & McQuaid 2009). The structure of mussel beds (both *P. perna* and *M. galloprovincialis*) along the South African coast is influenced by both upwelling and region, while mesoscale patterns in the composition and abundance of the associated fauna are driven by the direct influence of biogeography and indirect effects of upwelling transmitted via the structure (the density and size of mussels) of the beds (Cole & McQuaid 2010).

In the nearby Goukamma – Wilderness area mussel recruitment did not correlated with adult density or estimated production across sites, and the mean dispersal scale of mussel larvae from the MPA was estimated at about 4.4 km (Pelc *et al*. 2009). In the south–east Cape the influence of marine reserves on promoting recovery of near-by exploited shores through larval spill-over may be fairly limited (Ludford *et al*. 2012), and mussel recruitment in this area is relatively low (Reaugh-Flower *et al*. 2011).

The distribution, abundance and recruitment of alikreukels *Turbo sarmaticus* at Swartrif (near the Storms River mouth) varied markedly during the 1970s & 1980s, but there was an overall decline in numbers (Yssel 1989). The potential life span of alikreukel was calculated to be greater than 10 years, and the mean production/biomass ratio for the population to be 0.55 (Yssel 1989). Exploitation of alikreukel along the south east coast tends to be localized, with refuge and subtidal populations persisting. However, exploitation of abalone *Haliotis midae* is far more extensive and intense (Proudfoot 2006), and sporadic incidences of abalone poaching occur in De Vasselot section of the park.

In May 1991 and to a much lesser extent in February 2012 tunics of hundreds of red-bait specimens in the Tsitsikamma area became infected with bacteria of the genus *Vibrio*, and large declines in the populations were recorded (Hanekom *et al*. 1999; Hanekom 2013). Following the 1991 mortalities recolonization by red-bait *Pyura stolonifera* into the naturally denuded areas was slow, but, nevertheless, much faster than for experimental cleared plots (Hanekom *et al*. 1999).

A study of the octopus *Octopus vulgaris* along the south-east coast (including the MPA) found females dominant in the intertidal area (sex ratio 2:1), but a 1:1 sex ratio in the subtidal, where individuals were substantially larger. Mature females were only found subtidally, and appeared to breed throughout the year, but primarily in summer. The main prey items in both the intertidal and subtidal areas were crustaceans and teleosts (Oosthuizen & Smale 2003).

The Tsitsikamma MPA is situated within the general spawning area of the commercially exploited chokka squid *Loligo vulgaris* reynaudii and spawning individuals have been recorded (sporadically throughout the year, but mainly in summer) at ten areas within the MPA. Spawning occurred either on sand or low profile rocky reefs at depths of between 22 and 35m (Sauer 1995). Current measurements suggests that squid parallavae from the inshore spawning grounds, between Cape St Francis and Plettenberg Bay, are mainly transported eastward and those larvae spawned inside the MPA are likely to be exported beyond its boundaries (Roberts & van den Berg 2005). Adult individuals tagged in the MPA also tended to dispersed eastward (Sauer *et al*. 2000).

In the MPA the sizes of the limpet *Cymbula oculus* decreased progressively between sheltered, intermediate and exposed sites, but recruitment was greater at exposed sites. Females were consistently larger than males, although less abundant (sex ratio 0.6:1) (Branch & Odendaal 2003).

Important physical parameters structuring intertidal communities on the South African rocky shores are gradients of desiccation that produce a vertical zonation, as well as the differential effects of tidal ranges and wave action, which acts as a structuring force and mediates biological interactions (McQuaid & Branch 1984, 1985; Bustamante *et al*. 1997). In the Cochlear zone and entire intertidal (Cochlear- and Balanoid zones combined) of Tsitsikamma MPA biomass values of filter-feeders were higher at semi-exposed shores, while grazer biomass was greater at sheltered sites, and a negative relationship and a moderate to weak correlation as recorded between filter-feeder biomass and grazer biomass (Hanekom 2011). This negative relationship reflected changes in standing biomass of the two dominant filter-feeders (*O. angulosa* and *P. perna*) against that of the dominant grazers (*Scutellastra cochlear*). On sheltered shores the biomass of trophic groups varied across the intertidal gradient studied, with values of grazers and algae decreasing with increased aerial exposure. Similar, but less substantial variations were recorded at semi-exposed sites (Hanekom 2011). The general species composition of the macrobenthos was comparable with that recorded by Bustamante & Branch (1996) for the Agulhas- and Natal provinces, but the biomass in exposed and semi-exposed intertidal areas was dominated by only two to four species.

A preliminary investigation of subtidal macrobenthic communities along a depth profile in the Tsitsikamma area was done (Hanekom & Coetzee 1990). An ordination analysis separated the sites primarily along a depth gradient, but was also influenced by a second factor (probably reef profile). Three clusters were identified, each characterized by certain dominant phyla or species. The first group occurred on corrugated, low relief reefs, where algae were abundant and solitary ascidians (primarily *Pyura stolonifera*) were absent. The second group occurred on high relief ridges where algae were still present, but *P. stolonifera* were abundant. The third group were deep water (20 - 27m) sites with medium to high relief reefs, where poriferans, hydrozoans and bryozoans were common (Hanekom & Coetzee 1990). Heyns *et al*. 2016 conducted a complimentary study at shallow (11-25m) and deep (45-75m) reefs, which similarly showed that communities differed based on the depth at which they occur. The authors found that high light intensity supported benthic algae at shallow depths but at greater depth where light intensity decreased, algal cover diminished and was eventually absent.Upright growth forms and settled particulate matter were found to be positively related to depth and dominated the deep reef.

In other studies a new genus (Tsitsikamma) and species of latrunculid sponge were described (Kelly and Samaai 2002; Samaai *et al*. 2003; Samaai *et al*. 2009), while chemical composition of several marine ascidians and sponges were determined (Hooper *et al*. 1995; McPhail *et al*. 1998; McPhail *et al*. 2000; Antunes 2004; Davies-Coleman & Beukes 2004).

The genus Tsitsikamma is endemic to South Africa and currently comprises *Tsitsikamma favus*, *T. scurra* and *T. pedunculata*, all of which produce pyrroloiminoquinone secondary metabolites (Walmsley *et al.* 2012). Tsitsikammamine A and B, which are unique to *T. favus*, mediate cytotoxicity through the cleavage of DNA (Antunes *et al*. 2004) The source of the tsitsikammamines is hypothesised to be microbial, as specimens of *T. favus* contain a distinct and conserved microbial population, which is stable over time and is dominated by a unique Betaproteobacterium species (Walmsley *et al* 2012). A species list of marine invertaberates can be found in *Appendix 4*.

5.8.2 *Terrestrial invertebrates*

Although insects are the most diverse group of organisms on earth (Picker *et al*. 2002) and the world's forest habitats house a high diversity of invertebrates (Geertsema 1964; Cameron 1982; Scholtz & Holme 1985; Swain & Prinsloo 1986; Van der Merwe 2002), insect collections in the Garden Route National Park (GRNP), to date, have been uncoordinated and are not representative of the entire GRNP's land cover and habitat types. Existing data consists largely of scattered records and species descriptions for individual taxa.

The information that follows is a short description of the studies and surveys that have been undertaken in the GRNP on terrestrial invertebrates.Crewe (1984) surveyed insects in the Harkerville forest and fynbos areas. These surveys revealed that numerous insects belonging to most of the insect families occur within the forests and the area is described as being particularly rich in cryptic insect fauna. Grindley (1985) collected terrestrial invertebrates in the Knysna area. Insects collected included chironomid midges, dragonflies, mayflies, kelp flies, *staphylinid* and other beetles, house flies and water boatmen.

Breytenbach (1988) investigated ant-plant mutualistic interactions in the Outeniqua Mountains near George and Koen & Breytenbach (1988) researched the species richness of ant fauna in fynbos and forest habitats in the Gouna and Diepwalle areas. No significant difference in ant species richness was found between the two undisturbed habitat types, and the only two species common to both are *Lepisiota capensis* and the Spotted sugar ant *Camponotus maculates*. Ant species richness in the Afromontane forest decreased from the drier to the wetter sites and the degree of *Hakea sericea* infestation in the fynbos negatively affected ant species richness. They also indicated that the aggressive alien Argentine ant *Linepithema humile*, has not invaded natural areas to any great extent. Ant species were also collected on fynbos islands, mainland and forest in the Diepwalle area by Midgley & Bond (1990). The African big-headed ant (*Pheidole megacephala*), found in all three study sites, is indigenous to South Africa but has become an aggressive invader world-wide and exhibits invasive behaviour in parts of its native range. An ant species list is available in *Appendix 5.*

Marais (1991) surveyed and compiled a checklist of the butterflies of the Tsitsikamma National Park, which was supplemented by Butler & Terblanche (1997). In the De Vasselot area of the GRNP, 41 butterfly species/subspecies were recorded. Edge (pers comm.) indicated that the forest butterfly species are well surveyed and that about 13 species of butterfly are listed. Three species (*Charaxes karkloof trimenii*, *Symothoe althemeda* and *Charaxes xiphares*) are endemic to the region. Apart from being endemic, *C. karkloof trimenii* was only discovered within the last decade. Edge also mentioned that the mountain catchment areas are poorly surveyed and that the possibility of discovering new species is good. A rare butterfly species *Chrysoritis cottrelli* has been found at Spitskop, but was last seen in 1975 (Muller 1990). Its larvae live on Bitou *Chrysanthemoides monilifera* their host plant. Since this plant species occurs in the Ysternek Nature Reserve area, it is possible that this small orange butterfly may still be found there (Durrheim 1993). A butterfly species list is available in *Appendix 5*.

The Brenton Blue butterfly *Orachrysops niobe* arguably the best known terrestrial invertebrate found in the Knysna area 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 and 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 characterised by a great diversity of shrubs, herbs and graminoids, with a successional gradient to thicket where Candlewood *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).

Geldenhuys (1993b) found that occasional insect outbreaks occur, especially when there is a drought season following a wet period. A moth survey was conducted in the Diepwalle indigenous forest and fynbos area by Kroon (1998) who identified 232 moth species, 9 butterfly and one beetle species. Minuscule moths of the genus's Epiplema, Heteroplema and Monoplema were also identified. Members of Onycophora, a rare, primitive Arthropod phylum, are relatively abundant in the Harkerville area and were collected by researchers from the United Kingdom (Vermeulen *et al*. 1995). A number of apparently new species of *Drosophilae* were also collected in the Harkerville area (Vermeulen *et al*. 1995).

An invertebrate of significance found in the forest areas is Peripatus. It is an ancient life form that is believed to have survived unaltered for 500 million years and can be considered as living fossils dating back to the Cambrian period (Hey 1973). Its kidney and blood system resembles those of worms and the breathing system those of insects. It is also found in the forests of South America, Australia and Asia, providing support for the theory of continental drift. Peripatus is protected under the Provincial Nature Conservation Ordinance (CEN Integrated Environmental Management Unit 1999; Durrheim 2002). Another discovery supporting the continental drift theory is the close resemblance between the swift moth *Phalaena venus*, endemic to the southern Cape forests and the Australian swifts. This moth occurs in close association with its larval host tree, the Pink blossom tree *Virgilia divaricate*,. Almost every sizeable pink blossom tree is infested by the larvae, which bore into the roots and the base of the trees. Some trees die as a result. However, the moth itself is seriously threatened by the spread of the exotic Argentine ant *L. humile.*

Six mosquito species of the genera *Anopheles, Aedes*, and *Culex* have been collected in the Wilderness area (Russell & Russell 1997). *Culex salisburiensis* has been collected at only two localities, one of which is Wilderness (Russell & Russell 1997). Mosquito specimens were collected in 2016 in various areas of GRNP and identified by Alan Kemp, medical scientist at the National Institute for Communicable Diseases – species list available in *Appendix 5.* Thirty-five plant-parasitic nematode species, including two new species of the subfamily *Criconematinae* have been recorded from the park (Van der Berg 1996), and 17 of these species also occur in Wilderness area (Van der Berg 1993, 1996). The general distribution of populations of *Helicotylenchus brevis* and *H. exallus* were investigated by Marais (1998).

Endangered species that possibly occur in the GRNP include all the *Colophon* (Stag Beetles) species (Picker *et al*. 2002). The genus is highly sought after by collectors and is thus listed as a red data book genus. Protected invertebrate species that possibly occur in the GRNP include *Hadogenes* spp, *Harpactira* spp, *Opithacanthus* spp – all species, *Opistophthalmus* spp – all species, *Pterinochilus* spp – all species and *Manticora* spp – all species (Picker *et al*. 2002). These are indigenous species of high conservation value or national importance that require national protection.

5.9 Fish

5.9.1 Freshwater

Russell (1999b) recorded nine freshwater fish species in the Duiwe and Touw rivers within the Wilderness area (See section 7.2). Three of the species recorded were alien. A further one indigenous species, two translocated species and five estuarine species could potentially occur in these rivers (Russell 1999b). Swartz *et al*. 2007 has shown that Eastern Cape Redfin *Pseudobarbus afer* comprises 4 distinct lineages which correspond with paleoriver systems. Specimens in the Garden Route area (Tsitsikamma, Knysna, Wilderness) form part of the forest lineage which in turn has four minor lineages (Swartz *et al*. 2007). The invasion of the Wilderness lakes by four primarily freshwater fish species is described by Olds *et al*. (2011), with the most recent invasion in being that of common carp *Cyprinus carpio*. Details on the distribution and biological characteristics of the alien Mosquitofish (*Gambusia affinis*) within the Wilderness lakes is provided by Sloterdijk (2011, 2015). Significant spatial and seasonal changes observed in relative abundance of Mosquitofish suggest that seasonal fluctuations (in particular water temperature) and habitat charactiersitics dictate their distribution and relative abundance within the Wilderness Lakes (Sloterkijk 2011, 2015).

Freshwater species recorded in the Knysna River include "*Barbus monodactylus*" (Note: probably *Pseudobarbus afer*) "*Sandelia* spp." (Note: probably *Sandelia 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 Mosquito fish *Gambusia affinis* in intertidal marshes in the upper reaches of the estuary.

The fresh water streams in the Tsitsikamma region are generally impoverished (Smith & Smith 1966). Russell (2002) sampled six river systems in the Tsitsikamma area and recorded four indigenous freshwater species Eastern Cape redfin *Pseudobarbus afer*, the Endangered Slender Redfin *Pseudobarbus tenius*, Cape Kurper *Sandelia capensis* and Longfin eel *Anguilla mossambica*) and one alien Largemouth bass *Micropterus salmoides*. The River Health Programme (2007) rated the fish component of the lower portions of both the Salt - and Groot rivers as natural (excellent).

According to Russell (2011) there are few sites within national parks where freshwater fishes are not under threat due to habitat alteration or loss from changes in aquatic systems. Such sites in the GRNP include the Palmiet River (*P. tenuis* Keurbooms–Bitou lineage) and Groot (West)/Bobbejaan river system (*P. afer* Forest lineage) (Russell 2011).

5.9.2 Estuarine

Accounts of fishes in the Swartvlei system are given by Kok & Whitfield (1986) and Russell (1996), and in the Wilderness system by Hall (1985a, 1985b), Hall *et al*. (1987), Russell (1996), Olds (2012), Olds *et al*. (2011) and Olds *et al.* (2016) which demonstrate that communities are typically dominated by juvenile marine species. Hall (1985a), Russell (1996), Olds (2012) and Olds *et al*. (2016) found that the number of species in the Touw system declines the further removed a waterbody is from the sea. Hall *et al*. (1987) and Olds *et al*. (2016)suggested that several fish species may experience difficulty in negotiating the inter-connecting channels between lakes. Thus the closed phase of the Touw system, when water levels are higher, may be important to fish migration as it would reduce the restrictions on distribution imposed by interconnecting channels

Detailed studies of the age structure, growth and reproductive biology of Cape silverside *Atherina breviceps* and Estuarine round-herring *Gilchristella aestuaria* in Swartvlei Lake have been made by Ratte (1989). It was observed that 0-year-old *A. breviceps* and 2-year-old *G. aestuaria* dominated catches in Swartvlei Lake. Annual production of *A. breviceps* was 10 tons, and *G. aestuaria* was 5 tons. Ages attained were three years for *A. breviceps*, and seven years for *G. aestuaria*. The main spawning period for *A. breviceps* is spring-autumn, whereas *G. aestuaria* has continuous spawning.

Extensive studies have been undertaken of the feeding habits of the dominant fishes in the Wilderness lakes, including the leervis *Lichia amia* (Smale & Kok 1983; Coetzee 1982a; Whitfield 1988a), Knysna halfbeak *Hyporhamphus knysnaensis* (Coetzee 1981b; Whitfield 1988a), sea barbel *Galeichthys feliceps* (Coetzee & Pool 1984), Cape silverside *Atherina breviceps* and estuarine round herring *Gilchristella aestuaria* (Coetzee 1982b; Whitfield 1988a), Cape stumpnose *Rhabdosargus holubi* and Cape moony *Monodactylus falciformis* (Whitfield 1988a), as well as the strepie *Salpa salpa*, blacktail *Diplodus sargus*, southern mullet *Liza richardsonii*, groovy mullet *Liza dumerilii*, flathead mullet *Mugil cephalus*, white steenbras *Lithognathus lithognathus*, Sea catfish *Galeichthys feliceps*, Kob *Argyrosomus sp. (cf. hololepidotus*), super klipfish *Clinus superciliosus*, prison goby *Caffrogobius gilchristi (cf. multifasciatus*), barehead goby *Caffrogobius nudiceps*, Knysna sandgoby *Psammogobius* *knysnaensis* and longsnout pipefish *Syngnathus acus* (Whitfield 1988a). Based on these studies, estuarine fish can be grouped into five feeding categories, namely detrivores (e.g. *L. richardsonii, L. dumerilii, M. cephalus*), herbivores (e.g. *S. salpa*), omnivores (e.g. *R. holubi, D. sargus*), carnivores (e.g. *P. commersonnii, M. falciformis*) and piscivores (e.g. *L. amia, A. hololepidotus*). The detrivores are the dominant fish fauna (Whitfield 1988a). Changes in fish communities as a result of alteration in the food resource was observed in the early 1980s where the senescence of submerged macrophyte beds over a three year period resulted in a 60% decline in primary production, a 74% decline in littoral invertebrate biomass, and 54% decline in the abundance of the fishes *M. falciformis* and *R. holubi* associated with the macrophytes (Whitfield 1984). Furthermore, an increase in epipsammic micro-algae production in the littoral during the macrophyte senescence phase resulted in an increase in the abundance of the family Mugilidae (Whitfield 1986). However, the resilience of estuarine fish communities to major habitat and food resource changes was also demonstrated by all fish species recorded in Swartvlei Lake at the beginning of the macrophyte senescence phase still being present after three years of extensive habitat change (Whitfield 1986).

Whitfield (1993) estimated the biomass of the littoral fish community in Swartvlei Lake during 1980 to be 12.4 g m^{-2} wet weight, with detrivorous species contributing 3.2 g m^{-2} , zoobenthic consumers 2.8 g m^{-2} , piscivorous species 2.3 g m^{-2}, herbivorous/epifaunal consumers 2.7 g m^{-2} and zooplanktivorous consumers 1.4 g m^{-2}. It was concluded that estuarine fish biomasses do not exceed those of productive freshwater or marine environments.

In excess of 200 species of fish have been recorded in the Knysna 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).

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, Dwarf goby *Pandaka silvana*, is endemic to Knysna Estuary (Penrith & Penrith 1972).

Le Quesne (2000) investigated the usage by fish of intertidal marshes dominated by Dune slack rush *Juncus kraussii* in the upper reaches of the Knysna 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.

The Noetzie is a small Intermittently Open Estuary (IOE) and although scientific knowledge on the estuary is still relatively poor its condition is thought to be near natural. A preliminary assessment of the fish community of the Noetzie estuary was undertaken by James & Harrison (2008) with a more in depth survey occurring more recently in 2015 (Smith *et al*. 2015). The results indicate that the estuary is important for both estuarine-resident species (numerically dominant) and serves an important nursery function for estuarine dependent marine species. The species list of fishes utilizing the estuary increased by an additional five species and included the presence of an alien invasive freshwater species, the mosquito fish *Gambusia affinis* (Smith *et al*. 2015).

In the major estuaries / river mouths of the Tsitsikamma area, Harrison *et al.* (1996) recorded only 15 fish species. Three of the species were estuarine-dependent, the others were marine species, having various degrees of dependence upon estuaries during the juvenile phase of their life cycle. Preliminary, marine ichthyoplankton studies by Tilney & Buxton (1994) and Tilney *et al.* (1996) were complemented by more detail work by Wood (1998). He identified 75 taxa of fish larvae, described the early life history stages of 30 of these taxa, and refined the estimates of the extent to which the fish larvae could be dispersed by the nearshore currents. Morant and Bickerton (1983) listed more than 25 taxa of zooplankton recorded from the Groot River (west) estuary.

5.9.3 Marine

The marine area of the park is situated west of a nursery area for the ragged-tooth shark *Carcharias Taurus* that extends from East London and Cape St. Francis (Dicken *et al*. 2006a,b). Burger (1991) and Wood *et al.* (2000) supplemented the species list of Buxton and Smale (1984) for the marine sector, and a total 202 fish species from 84 families have been recorded within the Tsitsikamma area. Of these 15 are Red Data species. The size and species composition of fish differ between shallow (< 10 m) and deep (10 - 30 m) reefs (Buxton and Smale 1984, Heynes 2015, Heynes et al. 2016, Heynes-Veale *et al*. 2016). Food availability is the major determinant of ichthyofaunal distribution along the depth profile, and a single species tends to dominate each depth zone, while diversity, species richness and evenness of the ichthyofauna increase with depth (Burger 1990). Heynes-Veale *et al.* (2016) found that rare species, juveniles and low trophic level species dominated shallow reefs whilst large secually mature and predatory fish were characteristics of deeper reefs. They further determined that habitat type was a good predictor of fish assemblage.

The biology and life history changes of several fish species found in Tsitsikamma have been studied. These include dageraad *Chrysoblephus cristiceps*, roman *Chrysoblephus laticeps* (Buxton, 1987, 1989, 1990, 1992, 1993), red steenbras *Petrus rupestris* (Smale 1988, Smale & Punt 1991), blue hottentot *Pachymetopon aeneum* (Buxton & Clarke 1986), hottentot *Pachymetopon grande* (Buxton & Clarke 1992) musselcracker *Sparodon durbanensis* (Buxton & Clarke 1991), poenskop *Cymatoceps nasutus* (Buxton & Clarke 1989), blacktail *Diplodus sargus capensis*, zebra *D. cervinus hottentotus* (Mann & Buxton 1992, 1998) and carpenter *Argyrozona argyrozona* (Brouwer & Griffiths 2004, 2005a, 2005b; Brouwer *et al.* 2003). Carpenter has two distinct areas of abundance, one on the central and other on the eastern Agulhas Bank (Brouwer & Griffiths 2005b), but both these stocks are heavily overfished (Brouwer & Griffiths 2006).

Most (*c.* 80 %) of the above fish species have potential life spans of greater than 20 years, reaching sexual maturity after three or more years (Table 1). Species such as dageraad, roman, blue hottentot and poenskop are all protogynous hermaphrodites, and undergo sexual reversal. Consequently, in these species all males are derived from functional females and are older than six years (Table 1).

In both a boat-based- and a shore-based- mark and recapture programme approximately 4 000 fish have been tagged. Mark and recapture data suggest the reef fish carpenter, roman, dageraad and juvenile red steenbras, as well as inshore species blacktail, zebra, hottentot (bronze bream) and galjoen *Dichistius capensis* have a high degree of residency in the Tsitsikamma area (Brouwer 2002; Cowley *et al*. 2002; Brouwer *et al*. 2003; Cowley 2000 and corresponded with the results from the Agulhas Bank (Griffiths & Wilke 2002). Telemetry studies at Goukamma MPA indicate that the roman has a very small home range of between approximately 1 000 m² and 3 000 m² (Kerwath *et al*. 2007), and simulation models suggest that for resident species, such as roman, even small MPAs (6 km²) can offer protection (Kerwath *et al.* 2008). The slow growth rate and the stenotopic behaviour makes these species vulnerable to over-exploitation, and the catch rates during these studies are much greater than those recorded for fishers in open fishing areas in the southern Cape (Brouwer 1999; Cowley *et al.* 2002; Cowley 2000; Götz 2005; King 2005; Smith 2005; Pradervand & Hiseman 2006). Roman had a higher density, mean size and age at maturity inside the Goukamma MPA than in adjacent exploited areas (Götz *et al.* 2008). In addition microsatellite markers have been determined for roman from caught in Tsitsikamma MPA (Teske *et al.* 2009), and these will be useful to detect whether populations resident in MPAs along the South African coast are genetically connected, and whether there is spillover of recruits into adjacent exploited areas.

Survey selectivity estimates suggest that there is some longshore movement of inshore hake *Merluccius capensis* as they grow. Young hake (< 3 yrs old) are primarily restricted to the west coast, but a large proportion of the intermediate aged fish appear to move to the south coast (Rademeyer *et al.* 2008a). Some of the older (>6 years old) fish move back to the west coast.

The spawner biomass of this species has dropped to about 30% of the pristine level (Rademeyer *et al.* 2008a), and an Operational Management Procedure for the South African (inshore and offshore) hake resource has been developed (Rademeyer *et al.* 2008b).

On the south-east coast, shallow subtidal bays, associated with rocky shores appear to be important nursery sites for late-stage larvae and early juveniles of blacktail and strepie (Strydom 2008), and estuaries crucial for spotted grunter *Pomadasys commersonnii* and juvenile dusky kob *Argyrosomus japonicus* (Childs *et al.* 2008; Cowley *et al.* 2008). Reduction in freshwater inflow into an estuary may lead to a decline in numbers of these spotted grunter and dusky kob utilizing this habitat (Lamberth *et al.* 2008).

The periodicity of opaque zone formation in the ololiths of three of the above reef species has been validated using oxytetracyline markers (Potts & Cowley 2005), while experiments have shown that the rate of tag loss of D-tags and T-tags is high (Kerwath *et al.* 2006). In water shallower than 20 in Goukamma MPA, the selection of legal-sized roman can be increased by about 23% and immediate capture mortality of undersized fish can be reduced by 50% by using large hooks, sardine as bait and by fishing for less than one-angler-hour per site (Götz *et al.* 2007).

In the offshore area of the Southern Benguela system, fishing and to a greater extent anchovy-sardine interaction with zooplankton and predators appear to be important drivers (Shannon *et al.* 2008). Fishing stress and the collapse of small pelagic stocks may lead to a shift towards a bottom-up trophic control mechanism becoming a dominant driver of this system, increasing the impact of environmental events including climate change (Watermeyer *et al.* 2008). From 1997 – 2005, the core distribution of the pelagic sardine *Sardinops sagax* , an important prey item for four seabirds off South Africa, shifted 400 km to the south and east, which influenced its availability to breeding birds. It became progressively less available to seabirds in the Western Cape Province (Crawford *et al.* 2008a & b).

The potential influences of natural forces (climate change, sea-surface temperature anomalies, natural variability, etc.) on near-shore marine fish communities may be of similar temporal and spatial scale as human impacts. Consequently the Elwandle Node of the South African Environmental Observation Network (SAEON) established a research site in the Tsitsikamma area to establish a reliable measure of natural changes in marine ecosystems of the MPA. SAEONS emphasis within Tsitsikamma has been the long-term monitoring of sub-tidal reef fish fishes utilizing standardized bait angling methods To date this dataset represents the longest and most comprehensive sub-tidal reef fish abundance estimate in Southern Africa. In addition, new technologies such as Baited Remote Underwater Video (BRUV) and Remotely Operated Vehicles (ROV) have been incorporated into experimental design projects to assess their feasibility and improve our ability to monitor and describe natural variability which in turn increases our ability to model and predict changes in future situations (see Bernard and Götz 2012). Recent research and publications coming from this research indicates that stereo BRUV are superior to angling surveys for the monitoring of fish populations and size-structure of temperate reef fishes (Parker 2015; Parker *et al*. 2016a; Parker *et al*. 2016b).

Economic benefits through fish exports in terms of larvae (recruitment) and adults from the MPAs in the Garden Route were estimated to be in the order of R33 million annually (Turpie *et al.* 2006). A fish species list is available in *Appendix 6*.

Table 1. Maximum age, occurrence of sex reversal and age at sexual maturity of females and males.
Key. Source: B87; B89; B3 = Buxton 1987, 1989, 1993
B&C6; B&C9; B&C1; B&C2 = Buxton & Clarke 1986, 1989, 1991; 1992

Br&G4,5 = Brouwer & Griffiths 2004, 2005; F6 = Fennessy (2006); M2 = Mann 1992; S8 = Smale 1988; S&P1 = Smale and Punt 1991;

Species	**Max age**	**Sex rev**	**Maturity female**	**Maturity male**	**Source**
Carpenter (*Argyrozona argyrozona*)	30	-	5	5	Br&G4,5
Roman (*Chrysoblephus laticeps*)	18	+	4	8	B7; B9; B3
Dageraad (*C. cristiceps*)	22	+	3.5	12	B7; B9; B3
Red steenbras (*Petrus rupestris*)	33	-	7	7	S8; S&P1
Blue Hottentot (*Pachymetopon aeneum*)	12	+	4	7	B&C6
Poenskop (*Cymatoceps nastus*)	45	+	6	19	B&C9
Mussel cracker (*Sparodon durbanensis*)	31	-	5	5	B&C1
Hottentot (*Pachymetopon grande*)	40	-	5.5	5.5	B&C2
Zebra (*Diplodus cervinus hottentotus*)	33	-	6	6	M2
Blacktail (*Diplodus sargus capensis*)	21	-	4	4	M2
Yellowbellied rockcod (*Epinephelus marginatus*)	16	+	6	c.12	F6

5.10 Amphibians

The GRNP holds twenty-two species (19.1% of SA and 44% of WCP), 10 genera and six families. Fourteen of the listed species (63.6%) have been formally recorded within the Park's boundaries. The true species total is likely to be higher as the distribution ranges of number of species that could possibly occur within the Park end just short of Knysna. Ecological knowledge of the amphibians of the GRNP is limited, consisting primarily of published (see Whitfield *et al*. 1983) and unpublished (SANParks) records of occurrence of species. The only papers produced on frogs in the GRNP to date were by Carruthers and Robinson (1977) and Branch and Hanekom (1987).

Thirteen frog species have been recorded in the Tsitsikamma area, including the Endangered Knysna leaf-folding frog *Afrixalus knysnae* and a southern Cape endemic, the plain rain frog *Breviceps fuscus* (Minter *et al*. 2004). In 2010 an Eastern leopard toad *Amietophrynus pardalis* was recorded at Ngubu hut (Dr I. Russell in lit. 2010)

The preliminary checklist of Carruthers & Robinson's (1977) was supplemented by that of Branch & Hanekom (1987). 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). A species list is available in *Appendix 7*.

5.11 Reptiles

The GRNP forms the eastern limit of a distinct zoogeographic zone, called the Cape Faunal Centre where the fauna gradually changes to include more Ethiopian elements characteristic of much of Africa. Unfortunately, little is known of the reptiles inhabiting the National Parks of the eastern and southern Cape (Branch, 1981, 1983). Knowledge of the reptiles of the GRNP is therefore limited, consisting primarily of published (Whitfield *et al*. 1983, Jacobsen & Randall 2013) and unpublished (SANParks) records of occurrence of species (*Appendix 8*).

The loggerhead turtle *Coretta coretta*, green turtle *Chelonia mydas* and leatherback turtle *Dermochelys coriacea* are marine animals, with individuals occasionally beaching along the Wilderness coastline. All known beached animals have died shortly after coming ashore, presumably as a result of illness contracted or injuries sustained at sea. It is uncertain whether the leopard tortoise *Geochelone pardalis* occurs naturally or has been artificially introduced into the area.

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). The Garden Route National Park is considered to fall within one of the eight major centres of herpetofauna diversity in southern Africa (Branch, 1998) and forms part of the mountainous region stretching from the Cape in the south northwards to tropical Africa that is considered to function as a corridor along which various faunal taxa can move.

A preliminary checklist was compiled by Branch and Hanekom (1987) for the Tsitsikamma area. A total of 13 snake, 10 lizard and agama, 2 tortoise and 4 turtle species have been recorded in the Tsitsikamma area. The blue spotted girdled lizard *Cordylus coeruleopunctatus* and Knysna dwarf chameleon *Bradypodion damaranum* are endemic to the southern Cape. The four turtle species are Red Data Book species, but they are all vagrants to the southern Cape (Branch and Hanekom 1987; Branch 1988).

5.12 Birds

The lake systems are best known for the diversity and abundance of waterbirds, of which 84 species have been recorded. The GRNP with its combination of forest, fynbos, estuarine and marine habitats, has a diverse avifauna (*Appendix 9*). A total of 262 bird species have been recorded in the former WNP (Randall *et al*. 2007) and 257 in the former TNP (Skead & Liversidge 1957; Crawford 1983; N Hanekom & G McIlleron pers comm). 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.

These comprehensive park accounts, together with avifaunal studies in the former State Forests (e.g. Koen 1988), reveal that about 305 bird species have been recorded in what now comprises the Garden Route NP. Species of special concern include representatives of most of the major habitat types in the GRNP: marine (Cape cormorant *Phalacrocorax capensis,* crowned cormorant *P.coronatus* & African black oystercatcher *Haematopus moquini),* wetlands (African marsh harrier *Circus ranivorus,* African finfoot *Podica senegalensis,* halfcollared kingfisher *Alcedo semitorquata* & African grass-owl *Tyto capensis),* forest (Knysna warbler *Bradypterus sylvaticus,* Knysna woodpecker *Campethera notata* & crowned eagle *Stephanoaetus coronatus)* and general (peregrine falcon *Falco peregrinus*).

The wetlands of the Touw and Swartvlei systems support one of South Africa's most significant waterbird assemblages, which was the prime motivation for the listing of parts of the Touw system as a Ramsar wetland. The importance of the Wilderness lakes, and Langvlei in particular, as a waterbird area, has been stressed by both Underhill *et al*. (1980) and Boshoff & Palmer (1981), with the former authors having recorded 2061 duck of nine species during a survey undertaken in December 1978, and Boshoff & Palmer (1981) having counted as many as 65 species of waterbird at Langvlei, comprising more than 7000 individuals. This abundance of waterbirds, and in particular Anatidae (ducks and geese), represents the largest concentration of species and individuals along the southern and eastern Cape coasts (Underhill *et al*. 1980). Six red-data species have been recorded (Boshoff & Palmer 1991). Of these the Wilderness lakes provides important habitat for the Caspian tern as a roosting and feeding area, and the little bittern is thought to breed in wetland areas surrounding the lakes (Boshoff & Palmer 1991).

Most waterbirds which occur on the lakes and estuaries have been observed to undergo a short-term temporal, usually seasonal, variation in abundance (Boshoff *et al.* 1991a, 1991b, 1991c), with six basic trends having been observed in different species, namely (i) decrease in abundance during the spring and/or summer (breeding) months, (ii) increase in abundance during summer months, (iii) present during summer months, though is either absent or occurs only as vagrants during winter, (iv) bimodal abundance pattern, (v) abundance relatively constant throughout the year, and (vi) nomadic, usually present throughout the year in fluctuating numbers.

Reasons for such changes in abundance of bird species include (i) species migrating elsewhere in South Africa to breed, (ii) temporary influx of individuals on post-nuptial moult migrations (Boshoff *et al*. 1991b) (iii) annual influx of palaearctic migrants, and (iv) non-seasonal movements of nomadic species (Boshoff *et al*. 1991a, 1991b 1991c). Boshoff *et al*. (1991a, 1991b, 1991c) discuss correlations between the abundance of waterbird species and environmental variables, including water-level, water transparency, and the status of the submerged aquatic macrophytes.

Community diversity (Menhinich and Shannon indices), as well as measures of the density of species and biomass per unit surface area of waterbird communities on all waterbodies in the Wilderness area indicate that, between 1980 and 1984, Rondevlei and Langvlei supported the most diverse and abundant communities (Boshoff & Piper 1992). Preliminary results (SANParks unpublished data) however, indicate that current (1991-2003) number, density and biomass of waterbirds in Swartvlei Lake are substantially higher than that recorded by Boshoff & Piper (1992). An ordination study of waterbird abundance data indicated that Rondevlei and Langvlei form a single avifaunal unit (Boshoff & Piper 1993) with the suggestion that they be managed as such. About 110 bird species, over 35% of all species at GRNP, are dependent upon or primarily associated with wetlands.

Boshoff & Palmer (1987) provide information on the abundance, breeding density, breeding activity and diet of the Fish Eagle in the Wilderness Lakes during 1980-1984.

Assessments of submerged macrophyte standing crop undertaken between 1992 and 2005 were used by Russell *et al*. 2009 to investigate relationships between the biomass of macrophytes and those waterfowl which utilize these plants and associated zoobenthos as a food source. Significant positive correlations were demonstrated to exist between duck biomass and macrophyte biomass in Rondevlei and Eilandvlei, and between Red-knobbed Coot biomass and macrophyte biomass in Eilandvlei. Trends of change in the biomass of Red-knobbed Coot and macrophyte biomass appear similar in both Rondevlei and Langvlei though statistically significant correlations could not be demonstrated. It was suggested that management of the lakes should include provisions to maintain or restore water quality which is adequate to sustain submerged macrophytes and the abundant waterfowl that they support.

Monitoring of waterbird abundance’s in the Knysna area 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. 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 Sandpiper *Calidris ferruginea*, with Grey Plover *Pluvialis squatarola*, Greenshank *Tringa nebularia*, Kelp Gull *Larus dominicanus* and Whimbrel *Numenius phaeopus* each making up 6% of the avifauna. During winter Kelp Gull, Cape Cormorant *Phalacrocorax capensis,* Reed Cormorant *Phalacrocorax africanus*, Little Egret *Egretta grazetta* and Sacred Ibis *Threskiornis aethiopicus t*ogether 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).

Detailed studies of birds in the Tsitsikamma section are limited compared to the other two sections of the park. The key findings are follows:

- Vegetation structure and composition variation in the Knysna (dry – moist) Forest complex do not appear to influence the bird and invertebrate communities found within these forests (Koen & Crowe 1987).
- Two nests of crowned eagle *S. coronatus* were recorded in or close to the old park (Boshoff 1988).
- Rock hyrax, blue duiker and bushbuck respectively formed 25, 22 and 18 percent of the prey individuals recorded from six crowned eagle nests in the southern Cape forest biome (Boshoff *et al*. 1994).
- More than 50 pairs of the kelp gull Larus dominicanus, 70 of Cape cormorant *P. capensis*, and 20 of white-breasted cormorant *P. carbo* were recorded nesting in the Tsitsikamma Section in 1980 and 1981 (Crawford 1983). However, this represents a very small (<1%) proportion of the overall breeding populations of these species (Du Toit *et al*. 2003).
- A new breeding locality (four nests) for crowned cormorant *P. coronatus* was noted at the Number 12 Stack (Whittington 2004).

Four nests of the African black oystercatcher *H. moquini* were noted in 1982, and shell remains close to the nests suggested that the shellfish diet of these birds was comprised primarily of limpets (*Scutellastra argenvillei* and *S. cochlear*) and brown mussels (*Perna perna*) (Crawford 1983). Climate change and in a substantial shift in the core distribution of the pelagic sardine *Sardinops sagax* have affected distribution and breeding success of several seabirds off South Africa, in particular the African penguin (*Spheniscus demersus*), Cape gannet (*Morus capensis*) and Cape cormorant (Crawford *et al.* 2008a,b & c; Crawford *et al*. 2016), while large numbers of Cape cormorants died of pneumonia between Tsitsikamma and Sundays River in 1965 (La Cock 1985 in Crawford *et al.* 1992).

5.13 Mammals

Species Richness/Diversity

Various species checklists (Robinson 1976, Pretorius *et al*. 1980, Crawford 1982, Whitfield *et al*. 1983, Hanekom *et al*. 1987) and distributions (Von Breytenbach 1974, Grindley 1985) have been determined for mammals over the years in the GRNP. These findings show that eighty-seven species of mammal comprising fourteen orders and thirty-two families occur within the Park of which eighteen species (21%) are restricted to the marine ecosystem. Sixty-nine species (79%) have been formally recorded. From these species lists, it is calculated that, of the 290 mammal species that occur in South Africa (Lloyd 2007), 30% occur in the GRNP. Only 52% of the species occurring in the Western Cape Province (WCP) occur in the GRNP (*Appendix 10*).

Terrestrial mammal species whose distribution ranges fall short of the GRNP but may occur in the area, include:

- Cape gerbil *Tatera afra*, a western Cape endemic whose distribution range ends at Herold's bay (Skinner & Chimimba 2005).
- Cape Golden Mole *Chrysochloris asiatica* , a western Cape Near Endemic (NE) whose range ends in Swellendam (Friedmann & Daly 2004).
- White-tailed mongoose *Ichneumia albicauda* , who reach their southernmost range in the eastern Cape at about 33°27'S, have been observed in the Wilderness National Park (Russell 1998).
- Serval *Leptailurus serval*, a Near Threatened (NT) (Friedmann & Daly 2004) species that has been reported from the Tsitsikamma State Forest (Stuart 1977, 1985).
- Reddish-grey musk shrew *Crocidura cyanea* , a Data Deficient (DD) (Friedmann & Daly 2004) species that is shown to occur throughout the western and eastern Cape (Skinner & Chimimba 2005)
- Lesueur's wing-gland bat *Cistugo lesueuri* , NT (Friedmann & Daly 2004), may occur in Park (Skinner & Chimimba 2005)
- Water rat *Dasymys incomtus* , NT (Friedmann & Daly 2004), is likely to occur within the Park boundaries.

Locally extinct mammals

Species that probably occurred in the GRNP historically, but now locally extinct include Lion *Panthera leo*, Black rhinoceros *Diceros bicornis* , Hippopotamus *Hippopotamus amphibius*, Buffalo *Syncerus caffer*, Eland *Tuarotragus* oryx, Red hartebeest *Alcelaphus buselaphus* and Cape mountain zebra *Equus zebra zebra* (Lloyd 2002, Skead 2011).

Endemism

Even though the western Cape's forest and fynbos environments do not exhibit high levels of mammalian biodiversity (in contrast with many forest habitats elsewhere in the country) there are a few mammalian species and subspecies that are nearly endemic to the forests (Lloyd, 2002). The blue duiker *Philantomba monticola* and the bushpig *Potamochoerus porcus* are species whose major strongholds are within the forests but both species are also found in adjacent thicket or coastal scrub environments (Lloyd 2002).

Twelve species, three of which are Near-Threatened (Friedmann & Daly 2004), have varying degrees of endemism in the GRNP area (Lloyd 2002). Cape spiny mouse *Acomys subspinosus* and Cape dune molerat *Bathyergus suillus* are endemic to the western Cape and the Cape Floristic Kingdom (Lloyd 2002). Long-tailed forest shrew *Myosorex longicaudatus* , Duthie's golden mole *Chlorotalpa duthieae* , Verreaux's mouse *Myomyscus verreauxi* and Fynbos golden mole *Amblysomus corriae*(are endemic to the Cape Floristic Kingdom and near-endemic to the western Cape (Lloyd 2002). *C. duthieae* is only found along the southern Cape coast from George to Humansdorp (Lloyd 2002). Grysbok *Raphicerus melanotis* is both near-endemic to the Cape Floristic Kingdom and western Cape (Lloyd 2002). Hottentot golden mole *Amblysomus hottentotus* , Cape rock elephant-shrew *Elephantulus edwardii* , Cape mole-rat *Georychus capensis* , Spectacled dormouse *Graphiurus ocularis* Cape horseshoe bat *Rhinolophus capensis* are endemic to South Africa (Lloyd 2002). *M. longicaudatus* is near-threatened (Friedmann & Daly 2004) and largely confined to this ecoregion (Hilton-Taylor 2000).

Conservation Status

According to the IUCN (2001) categories that were used to evaluate the threat status of the South African mammals (Friedmann & Daly 2004), the Park protects populations of twenty-eight red data book species. In the Threatened categories, 7.1% of the Parks mammals are listed as Endangered (EN) and 14% as Vulnerable (VU).

Of the mammal species occurring in the GRNP, 36 % is listed as Near Threatened and 42% as Data Deficient (DD) (Friedmann & Daly, 2004). Therefore, about 34 % of the Parks mammals are, or could soon be, facing a threat to their future survival (Lloyd, 2002). Only 58 (66%) mammals species fall in the Least Concern (LC) category and one species, Lobodon carcinophagus (Crabeater seal), has not yet been properly evaluated. Whippomorpha (9), Chiroptera (6), Eulipotyphla (5) and Carnivora (3) account for the bulk (82%) of the red listed species. Only four orders, Whippomorpha, Carnivora, Rodentia and Ruminantia, are in the Threatened category (Threatened and Vulnerable).

Twenty-five species are CITES listed, of which 19 fall in the Appendix II category. Whippomorpha represents the bulk of the CITES listed species, one of which is Endangered and four Vulnerable (Friedmann & Daly, 2004). Eight Carnivora species are CITES listed, one of which is the Near Threatened (Friedmann & Daly, 2004) Honey badger, is the only species in the Park that is listed under CITES Appendix III. Southern elephant seal *Mirounga leonine* and White-tailed rat *Mystromys albicaudatus*(are endangered (Friedmann & Daly, 2004), the former a CITES listed Appendix IIA species. Bryde's whale *Balaenoptera edeni* , *P. monticola*), Sperm whale *Physeter catodon*) and Humpback dolphin *Sousa chinensis* , are Vulnerable (Friedmann & Daly 2004) and are all CITES listed.

Fynbos golden mole *Amblysomus corriae* , Lesser woolly bat *Kerivoula lanosa* , Humpback whale Megaptera novaeangliae , Honey Badger *Mellivora capensis* , Lesser long-fingered bat *Miniopterus fraterculus* , Schreibers' long-fingered bat *Miniopterus schreibersi* , *M. longicaudatus*, Temminck's hairy bat *Myotis tricolor*), Cape horseshoe bat *Rhinolophus capensis* and Geoffroy's Horseshoe Bat *Rhinolophus clivosus*) are near threatened (NT) (Friedmann & Daly, 2004). *M. novaeangliae* and *M. capensis* are CITES listed. *A. corriae* and *M. longicaudatus* are endemic to both the western Cape Province (WCP) and the Cape Floristic Kingdom (CFK). *R. capensis* is Endemic to South Africa.

Twelve species are Data Deficient (DD), namely Hottentot golden mole *Amblysomus hottentotus* , Greater red musk shrew*Crocidura flavescens*), Woodland thicket rat *Grammomys dolichurus* , Risso's dolphin *Grampus griseus* Blainville's beaked whale *Mesoplodon densirostris* , Hector's beaked whale *Mesoplodon hectori* , Dark-footed forest shrew *Myosorex cafer*), Forest shrew *Myosorex varius* , Killer whale *Orcinus orca* , African striped wease *Poecilogale albinucha* l, Least dwarf shrew *Suncus infinitesimus* and Bottlenose dolphin *Tursiops truncates* (Friedmann & Daly 2004).

Ecological Studies

The population sizes and local conservation status of most of the mammal species are largely unknown. Specialized studies in the GRNP, largely concentrated on the large forest mammals. A greater portion of work has been conducted in the Tsitsikamma section (Robinson (1976), Crawford (1982), Hanekom *et al.* (1987) and Pretorius *et al.* (1980)).

Whitfield *et al*. (1983) listed 29 mammal species in the Wilderness area which occur in areas adjacent to the Swartvlei system. Additional species which are known to occur in the area include the Black rat *Rattus rattus*, which have been recorded in the vicinity of dwellings, as well as the Woodland dormouse *Graphiurus murinus* and Baboon *Papio ursinus* (SANParks unpublished data).

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)). While forty-one terrestrial mammal species have been recorded for the Tsitsikamma area. These included 2 primate-, 10 carnivore-, 4 antelope- and 16 rodent- species. Nineteen mammal species have been recorded in Soetkraal, and six of these species, aardvark, grey rhebuck, klipspringer, feral donkey, scrub hare/ and small-spotted genet/ have not been noted in the coastal section.

Detailed studies of some species have been done.

Blue Duiker *Philantomba monticola*

The Blue duiker reaches its most southerly distribution limit in the Afromontane forests of the southern Cape (Crawford 1984). According to Skinner and Chimimba (2005) blue duikers in the southern coastal forests are unique in that the body is dark blue-grey and the limbs light rusty-brown. Population density estimates of the Vulnerable blue duiker in Tsitsikamma are similar to those determined from four southern Cape forests (Seydack *et al*. 1998) and two Zairean forests, but are at least three times lower than densities recorded by Bowland (1990) in KwaZulu - Natal (Hanekom & Wilson 1991). Predation by leopard *Panthera pardus*, caracal *Caracal caracal* and crowned eagles *Stephanoaetus coronatus* may have a local effect on population densities (Crawford & Robinson 1984; Boshoff *et al.* 1994). Faecal pellet counts done at Diepwalle near Knysna suggested marked changes in the blue duiker populations between 1970 and 1997 (Seydack *et al.* 1998), and large temporal variations may occur in the population densities. Substantial spatiotemporal variation in blue duiker population densities have been recorded in the Garden Route National Park (Seydack *et al*. 1998). Population densities were found to be affected by features of forest structure, moist *versus* dry forest types and geological substrate. Blue duiker populations overall had declined to relatively low levels between 1970 and 1980 in the Knysna forests and after 1992 in the Tsitsikamma forests. Climate change effects were implicated to have caused the blue duiker population declines (Seydack 2000c). Before the decline (in the Knysna forest) relatively high densities were encountered in moister forests, whereas after the decline population persistence was associated with drier forests (Seydack 1984; Seydack *et al*. 1998).

Seydack (1984) conducted a camera trap census for larger mammal species in the Knysna section (Goudveld) and of the 596 photo records, 15 were of blue duiker, with 14 of these in the dry forest. Von Gadow (1978) carried out a pellet count survey in the Knysna section. He found that blue duiker are more numerous in the larger, continuous forests and detected mutual avoidance between blue duiker and bushbuck. In addition, he found that blue duiker avoided artificially slashed onderbos areas and significantly favored forest parts with a well-developed litter layer and higher altitude forests. Crawford (1984) investigated activity, group structure and lambing of blue duiker in the Tsitsikamma area and found that they commonly live in pairs, were active throughout the day and spend about eight hours a day foraging. Hanekom and Wilson (1991) reported that duikers mostly foraged on the ground and often in areas where ground cover was low. Kwar *Canthium obovatum* was the most important species selected by duiker and the fruits of *Dietes iridioides* and *Canthium mundianum* were also utilized (Hanekom & Wilson 1991). Blue duiker may play a role in seed dispersal in forests (Feer 1995).

Bushbuck *Tragelaphus scriptus*
Bushbuck population densities in forest habitat were estimated at 5-7 animals km^{-2} (Odendaal & Bigalke 1979; Seydack 1984; Seydack *et al*. 1998); with pronounced variation over space and time. Higher densities were found in moister forests and those situated on nutrient richer geological substrates; the latter notably favoured by female bushbuck (Seydack *et al*. 1998). In the Knysna forests bushbuck generally occur singly, but home ranges overlap, and breeding is non-seasonal (Odendaal & Bigalke 1979) Odendaal & Bigalke (1979) estimated bushbuck forest home range size in the Knysna section to be 102 hectares at densities of 5 bushbuck/km^2. They found that a negative correlation between the size of bushbuck home ranges and population densities. They also reported that home ranges of adult males overlap considerably, as do the home ranges of males and females. Odendaal & Bigalke (1979) also investigated the social behaviour of bushbuck and sighted single animals 58% of the time, pairs 32% of the time while the remaining sightings were of groups of three or more animals. Single males, single females, and male/female associations accounted for most of their sightings. Odendaal (1983) analysed stomach contents of 25 animals in the Knysna Forest and recorded a list of 47 food plants. Bushbuck were found to feed primarily on browse (about 85 % of their diet; Odendaal 1983).

Bushpig *Potamochoerus larvatus*
Bushpig studies in the Knysna forest addressed a variety of topics: social organization, elements of social behaviour, habitat utilization, temperature regulation and energy metabolism, feeding ecology, growth patterns, energy storage, reproduction, population dynamics and life history tactics (Seydack 1990; Seydack 2013). The average home range size was determined as 7.2 km^2, ranging between 3.8 to 10.1 km^2 and population densities of 0.3 to 0.5 bushpig/km^2 were determined. Bushpig traveled between 0.48 and 5.84 km daily and are preferentially active between 18:00 and 22:00h (Seydack 1990). Bushpig social organization is characterized by the family group, usually consisting of a boar and a sow with one or two generations of offspring, monogamy and territoriality (Seydack 1990). Three or four young were found to be born after a gestation period of approximately four months, between October and January (Seydack 1990), in nests, in hollow trees or crevices in wooded krantzes (Phillips 1926; Seydack 1990). Bushpig reach sexual maturity at 1.3-2.0 years of age (Seydack 1990). Methods of age determination for the bushpig were presented in Seydack (1983). A life history model was developed which linked edaphoclimatic environmental conditions with diet quality, metabolic turnover rate and life history features (Seydack and Bigalke 1992). Following this model it was shown that there were regional differences in relative investments made in reproduction and maintenance in bushpig. Southern Cape populations had relatively low reproductive rates, but levels of energy storage and survival rates were high (Seydack & Bigalke 1992). The reverse applied to eastern Cape populations (Seydack & Bigalke 1992). The diets of the two populations were also shown to differ (Seydack & Bigalke 1992). According to the model the rate of reproductive investment (number of viable young per unit of time) relative to somatic investment (energy storage, survival) is determined by the rate at which production nutrients (NPK) are procurable. For herbivorous animals this depends on the rate at which the nutrients are available to their food plants, which in turn is linked to soil fertility and thus to the geological parent material (Seydack & Bigalke 1992).

Honey Badger *Mellivora capensis*
A camera trap mammal survey undertaken in the forests at Goudveld resulted in altogether 120 photorecords of honey badger over six survey cycles; representing 20% of 596 records of all animal species (Seydack 1984).

The 74 recordings of the first three survey cycles represented a minimum of 12 individuals (Seydack 1984); translating into a crude density estimate of 1.5-2.0 honey badgers/km^2. No ecological studies specifically on honey badger have been undertaken in the GRNP to date.

African clawless otter *Aonyx capensis*

The Tsitsikamma section of the GRNP has been the main focus of studies on the African clawless otter and concentrated mainly on their marine habitat. Arden-Clarke (1983) reported the occurrence of about thirty Cape clawless otters along the Tsitsikamma coastal section. Van der Zee (1979, 1981) reported population densities of 1 otter/km^2 of coastline that appeared higher than that of freshwater populations, as estimated by Butler and du Toit (1994). Arden-Clarke (1983) found that activities peaked from 20h00 to 22h00 and that the overall foraging ranges were between 8.5 and 19.5 km (Arden-Clarke 1983). Taylor (1970) found that their nightly movements may reach 13 km per outing and that males move longer distances than females. Home ranges of males and females overlapped (Van der Zee 1982, Arden-Clarke 1986).

Van der Zee (1979, 1981) analyzed over 1 100 spraints and recorded over 30 species of crabs, fish and octopus. The bulk of their diet consisted of Cape rock crab Plagusia chabrus, Rocksucker fish *Chorisochismus dentex*, brown rock crab *Cyclograpsus punctatus* and octopus *Octopus granulatus*. Small rockfish *Clinus cottoide*s made up a small fraction of the diet. Arden-Clarke (1983). Van Niekerk *et al*. (1998) found that spraints occurred mostly on rocks and boulders and <50 m from freshwater sources. On the social behavior of the African clawless otter, Van der Zee (1982) found that they were mostly solitary and only a few observations involved otters in groups, smaller that 4 individuals. Arden-Clarke (1986) found that, on occasion, groups of males foraged together in a clan-type organization and the mean group size was 1.71. Dens were usually located near abundant food supplies, bushy areas or fresh water (<15 m), and always within 50 m from the shore (Van der Zee 1982, Van Niekerk *et al*. 1998). The distance between den sites averaged 1.0 km (van der Zee 1982). The most important factor threatening Cape clawless otters is an increasing human population and associated habitat changes (Van der Zee 1982, Butler 1994, Rowe-Rowe 1986, 1990, 1995).

Cape grey mongoose *Galerella pulverulenta*
This species is widespread in the forested and fynbos areas (Robinson, 1976; Crawford *et al.* 1983). Crawford *et al.* (1983) did a study in the forested areas of the Tsitsikamma section of the GRNP and reported that the species is common in dry scrub forests, uncommon in dry high forests and possibly absent from moist and wet high forests. They are predominantly solitary but can be found in groups of up to five (Stuart 1981, 1991). Similarly, Crawford *et al*. (1983) found that they were predominantly solitary in the Tsitsikamma National Park, and infrequently present in groups of about three. Crawford *et al*. (1983) reported home ranges of over 75 ha and found that adults tended to be territorial. Activity peaked during early mornings and late afternoons (Crawford *et al*., 1983). Seasonally, activities peaked from late autumn to early spring (Crawford *et al*., 1983). Social interactions and mating seemed to peaked in July and August (Crawford *et al*., 1983).

Small-spotted genet *Genetta genetta*
Seydack (1977) recorded this species as abundant in Goudveld’s fynbos, forest and commercial pine plantation habitats. Seydack (1984) also recorded this species in the Knysna forests during his photographic survey.

African wild cat *Felis silvestris*
Pretorius *et al*. (1980) recorded the presence of this species in the GRNP, but from interviews conducted with local people. No individual African wild cat has ever been recorded officially/photographically. It’s presence and conservation status in the Park therefore still need to be established.

Leopard *Panthera pardus*
The ecology of the southern Cape leopard has not been investigated in detail and their population status in the GRNP remains largely unknown. Six leopard records were obtained during a camera census project in the forests at Goudveld, representing three different individuals, two adults and one sub-adult (Seydack 1984). Hanekom and Wilson (1991) investigated the diet of Tsitsikamma leopards and found remains of birds, blue duiker, rodents, dassie, insects, bushpig, bushbuck, baboon, porcupine and caracal.

Braczkowski *et al*. (2012) investigated the diet of leopards in the southern Cape forests in the Wilderness section of the GRNP. They hypothesized that, although leopard-human conflict has not reached serious levels, increasing urban development in this area may change this in future

(Braczkowski *et al*., 2012). They collected scats in forest, plantation and pasturelands and recorded nine mammalian species' remains in the scats which included small and medium-sized ungulates, which formed the largest proportion of the diet, followed by rodents and birds (Braczkowski *et al*., 2012). At the species level, bushbuck had the highest corrected frequency of occurrence (CFO), followed by vlei rat and blue duiker (Braczkowski *et al*., 2012). Bushbuck, blue duiker and domestic cats were the only species preferred by leopards (Braczkowski *et al*., 2012).

Caracal *Caracal caracal*
Caracal presence has been confirmed in most sections and habitats in the GRNP (Seydack, 1977; Seydack, 1984; Hanekom & Wilson, 1991). Liversidge (1966), Robinson (1976), and Crawford and Robinson (1984) theorized that an increase in caracal numbers caused the decrease in duikers in the area. Hanekom and Wilson (1991) investigated caracal diet by analyzing scat piles and found the remains of birds, insects, dassie, blue duiker, and bushpig.

Fynbos Golden Mole *Amblysomus corriae*
The Fynbos Golden Mole is Near Threatened (Friedmann & Daly, 2004) and Endemic to the Western Cape (www.afrotheria.net). No specific ecological studies have been conducted on this species in the GRNP.

Bats (ORDER: CHIROPTERA, Family: Nycteridae)
A numbers of Egyptian fruit bats *Rousettus aegyptiacus* were recorded in a cave in the Storms River gorge (ca. 3 000 individuals) and Elands River gorge (ca. 300 – 400) (Herzig-Straschel & Robinson, 1978; Swart, 2002- internal). This species feeds on the fruit of plants such as essenhout, saffron, poison bush and mistletoe, and their nocturnal activity is significantly longer in summer than in winter (Herzig- Straschel & Robinson, 1978). Parturition occurs between October and June, with a peak in December (Herzig- Straschel & Robinson, 1978). A number of insectivorous bats are also present and it is likely that at least some of the species are highly dependent upon the forest for roosting and hunting habitat (Herzig- Straschel & Robinson, 1978).
Four species, *Rousettus aegyptiacus, Rhinolophus clivosus* (NT, Friedman & Daly, 2004), *Rhinolophus capensis* and *Miniopterus schreibersii* were recorded in the Farleigh area (Seydack, 1977; Lück, 2000 – internal/thesis).

Shrews (ORDER: EULIPOTYPHLA, Family: Soricidae)
According to distribution lists (Skinner & Chimimba, 2005) there are five shrew species in the GRNP, namely Greater red musk shrew *Crocidura flavescens*, Dark-footed forest shrew *Myosorex cafer*, Long-tailed forest shrew *Myosorex longicaudatus*, Forest shrew *Myosorex varius*, and Least dwarf shrew Suncus infinitesimus . Long-tailed forest shrew *M. longicaudatus* is Near Threatened (Friedmann and Daly, 2004) and near endemic (Lloyd, 2002). The conservation status and ecology of shrews in the Park is unknown. Long-tailed forest shrew *M. longicaudatus* is a recently discovered species and its occurrence was confirmed at five localities in the southern parts of the western Cape (Cameron, 1982; Skinner and Chimimba, 2005), two of the sites including the Lottering and Diepwalle Forests. Specimens from Lottering were found to be more reddish-brown in colour than elsewhere (Dippenaar, 1995).

Rock hyrax *Procavia capensis* (ORDER: HYRACOIDEA, Family: Procaviidae)
This species occupy rocky habitats situated on the open land between the sea and the closed evergreen forest along the coast in the Park (Fairall & Hanekom, 1987). Fairall and Hanekom (1987) monitored this species on a yearly basis in the Storms river rest camp area. The numbers increased steadily in the late 1970s and early 1980s, before stabilizing in the mid 1980s (Fairall & Hanekom, 1987). Rock hyrax contributed to 25 % of the prey remains recorded from six crowned eagle nests in the southern Cape forest biome (Boshoff *et al*., 1994).

Hares (ORDER: LAGOMORPHA)
Cape hare *Lepus capensis* and Scrub hare *Lepus saxatilis* have been recorded at Goudveld and Wilderness.

Elephant-shrews (ORDER: MACROSCELIDAE, Family: Macroscelididae)

According to Skinner and Chimiba (2005), the species Cape rock elephant-shrew *Elephantulus edwardii* and Round-eared elephant-shrew *Macroscelides proboscideus* do occur in the GRNP but no official recording have been made to date.

Primates (ORDER: PRIMATES, Family: Cercopithecidae)
Vervet Monkey *Cercopithecus pygerythrus* and Chacma baboon *Papio ursinus* occur in the Park and are both CITES Appendix II listed.

Elephant *Loxodonta africana* (ORDER: PROBOSCIDEA)
The Knysna elephants and their chances for survival have been a topic of concern and debate for over a century. Based on an estimated 3 000 elephants that may have roamed the Cape Floristic Region in pre-colonial times (Kerley *et al*., 2003), it is assumed that about 1 000 elephants occupied the Outeniqua-Tsitsikamma area (Boshoff *et al*., 2002). Between 1856 and 1886 Knysna experienced a marked influx of people and an increase in development which increased human-elephant conflict, often to the detriment of elephant lives (Roche, 1996). In 1874, the Conservator of the Midlands Conservancy, Harrison, expressed his concern over the lack of protection for the region's elephants (Phillips, 1963), and shortly thereafter did a survey and estimated the elephant population to be between 400 and 500 (Phillips, 1925). By 1900, only 30-50 animals were left (Hall-Martin, 1992).

In the late 1890's, the Knysna community's attitude started changing, positively, towards the Knysna elephants and at the turn of the century, when tourism started to develop in Knysna, elephants started being perceived as an asset (Roche, 1996). Since then, the question of "how many elephants are left in the Knysna forest" has prevailed among conservationists, scientists and the public, along with considerable media attention. Numerous survey attempts followed, with varying results (Phillips, 1925; Domisse, 1951; Woods, 1952; Hey, 1962; Carter, 1970; Botha, 1994), often accompanied by suggestions on how to save the remaining elephants. These suggestions included the construction of a fenced-off elephant reserve (Woods, 1958; Hey, 1962; Carter, 1970) and introduction of new blood (Woods, 1958). In the early 1900's, a popular suggestion was to domesticate the elephants to secure their survival (Phillips, 1925)!

In recent times attempts to determine the elephant population status included a DNA study (Eggert *et al*., 2007) which captured five cows, and official photographic records, sightings and surveys (Herd, 2008), with varying results, ranging from 1 to 5 elephants. None of these latest efforts reported the presence of bulls.

The Knysna elephants' taxonomic status has also been a topic of debate since the early 1900s when Lydekker (1907) classified them as a subspecies named *Elephas africanus toxotis*, based on comparisons of ear-shape between Knysna and Addo specimens. After Lydekker's publication, it was revealed that his museum specimen, labelled as a Knysna elephant, was in fact an Addo specimen (Greig, 1982)!

Since 1887, the general belief, also among some scientists, was that the Knysna elephants are among the biggest elephants in the world (Greig, 1982). This belief is based purely on anecdote and by erroneous and over-inflated measurements by the hunters themselves (Greig, 1982), and passed on via literature (for example see Stokes, 1946 and Burton, 1968). Incidentally, one of these hunters, whose specimen measurements shrunk after later re-measurements, was Major Pretorius, who was granted a license to shoot a Knysna elephant to prove that they were a subspecies and larger than normal (Kinloch, 1968).

More recent studies on the Knysna population's historical range and genetics concluded that they once formed part of a larger, continuous population. According to Fairall (1982), over 300 years ago, the Knysna elephant population formed part of a continuous population that ranged from the Cape Peninsula to Limpopo. Essop *et al*. (1996) genetically analysed the Kruger and Addo elephant populations and by extrapolating the Addo results to the Knysna population, concluded that the Knysna and Kruger elephants are of the same sub-species, *Loxodonta africana*.

The Knysna elephant's genetic uniqueness, or rather lack thereof, has been used by some scientists as a measurement of their conservation value, implying that efforts to preserve this relic population is a "non-issue" (Fairall, 1982) and not justified (Essop *et al*., 1996).

One would assume that the estimated 1000 elephants that historically roamed the Outeniqua-Tsitsikamma area, played an ecological role. Data on the ecological role of elephants and their potential impact on biodiversity in the southern Cape is sparse, however (Ferreira *et al*., 2011). Only a few studies have been conducted on the region's elephant feeding patterns (Von Gadow, 1973; Koen, 1984; Milewski, 2002a, b; Patterson, 2004) and one study looked at local tree seed germination in elephant dung (Koen, 1983). Present-day studies involving the ecological role of the Knysna elephants would pose a considerable challenge, because there are only a few elephants remaining. However, theoretical extrapolations on the elephants' potential ecological roles, could be drawn from previous diet studies (Von Gadow, 1973; Koen, 1984; Milewski, 2002a, b), and currently available spatial and diet data.

Apart from the feeding behavior of the Knysna elephants, other ecological studies involved their distribution patterns and movements (Koen, 1984), their history and behaviors (Phillips, 1925)

An important consideration is that all the scientific studies done on the Knysna elephant population to date, were conducted after the elephants were confined to the forest habitat. It is believed that the historical southern Cape elephant population's range was confined to the forest parts around Knysna as a result of human settlement and agricultural development (Koen *et al*., 1988; Seydack *et al*., 2000). The current elephant forest range has been identified as a marginal habitat, lacking important macro-nutrients, which may be a population-limiting factor (Koen *et al*., 1988; Seydack *et al*., 2000). According to Seydack *et al*. (2000), the lack of grasses with an accompanied low dietary N/C ratios in the Knysna elephant's current diet, may have caused low reproductive rates and ultimately the decline of the population. Koen *et al*. (1988) found that the Knysna elephant diet had a low phosphorous content, compared with that of the Kruger and Addo populations, and pin-pointed this as a population-limiting factor.

The Knysna elephant population may therefore represent a refugee species scenario (Kerley *et al*., 2011). Refugee species are defined as those that can no longer access optimal habitat, but are confined to suboptimal habitats, with consequences of decreased fitness and density, and attendant conservation risks (Kerley *et al*., 2011). According to Kerley *et al*. (2011) the identification of refugee species, characterization of their pre-refugee ecology, and the restoration of such species to optimal habitat, is critical to their successful conservation. For the Knysna population, therefore, it would be important to firstly test the refugee hypothesis, and secondly identify other habitats they frequented historically, but inaccessible to them today. This is currently being addressed through ecological studies conducted by SANParks (Moolman, 2012).

ORDER: RODENTIA

This is the largest order with four families and eighteen species, one of which is endangered namely, White-tailed rat *Mystromys albicaudatus*. As with most of the smaller mammals, conservation status knowledge, ecological studies and surveys on these species in the GRNP are absent.

Grammomys dolichurus (Woodland thicket rat)

This species was recorded in the southern Cape forest by Prof. A.K. Lee (University of Natal: Zoology) (Davis, 1974). According to Davis (1974), this record provided an extension to the known distribution of the species. Small mammal population densities and species diversity in the Goudveld area were found to be low (Seydack, 1977). Koen (1991) investigated the effect of rodent granivory on recruitment of the irregularly fruiting tree, *Podocarpus falcatus,* in the Southern Cape and identified Verreaux's mouse *Myomyscus verreauxi* as the major granivore of this tree. No significant correlations were found between the density of seed on the ground and the number of seeds destroyed (Koen, 1991). Koen (1991) concluded that this species forages randomly and not in a density dependent manner.

Marine mammals

Three species of seal have been recorded along the beaches of the GRNP though none are permanently resident in the area. The majority of beached individuals are juvenile or sub-adult Cape fur seals *Arctocephalus pusillus* , which are typically in an emaciated condition. After have been hunted to local extinction in the late 19th or early 20th Century, Cape fur seals returned to the Robberg Peninsula in the early 1990s and the colony grew to over 3 000 largely non-breeding individuals in 2009 (Huisamen *et al*. 2011). Adult seals travel up to 220 km offshore (Shaughnessy 1985) and individuals from Robberg Peninsula are likely to exploit the resources of the Tsitsikamma MPA. The most important prey species in terms of numerical abundance, frequency of occurrence and mass in the diet of the Robberg seals, were anchovy *Engraulis encrasicolus*, sardine *Sardinops sagax*, horse mackerel *Trachurus capensis*, sand tongue-fish *Cynoglossus capensis* and shallow-water hake *Merluccius capensis* (Huisamen *et al*. 2012). Based on estimates of their consumption of exploited fish species, there appears to be little direct competition between seals and boat- and shore-based linefisheries (Huisamen *et al*. 2012). In 1992 a single adult male Southern elephant seal *Mirounga leonina* hauled out at Gericke's Punt, where over a period of five weeks it underwent its annual moult (Randall 1992).

A wide variety of dolphins and whales have been recorded on the south coast, but many are seasonal visitors (Dr V. Cockcroft pers comm. 2007). The Vulnerable Indian humpback dolphin *Sotalia chinensis* forms small schools (c. 7 individuals), feed on inshore reef fish and invertebrates and remained in the area throughout the year (Saayman *et al*. 1972). Further offshore the Vulnerable Indian Ocean bottlenose dolphin *Tursiops aduncus* swims in intermediate size schools (c. 60 individuals). It is abundant during spring and summer, and appears capable of exploiting both reef and off-shore pelagic food sources, while pelagic dolphins, *Delphinus capensis (delphis)* and *Stenella coeruleoalba*, are found in large schools (>100 individuals) far offshore (Saayman *et al*. 1972). The more common whale species found off the Tsitsikamma – Plettenberg Bay coast are the southern right whale *Eubalaena australis*, Near-threatened humpback whale *Megaptera novaeangliae* and Vulnerable Bryde's whale *Balaeoptera edeni* (Anon. 2003; Dr V. Cockcroft pers comm. 2007). Southern right whales calve in sheltered, sandy bays in late winter early spring (Anon. 2003), but their numbers off the Tsitsikamma coast are low compared to that of the south-western Cape (Best 2000). Humpback whales visits the Tsitsikamma area from June to November during their migration to feeding grounds in the Antarctic, while some of the Bryde's whales are resident off the south coast, but are generally seen 6 – 15 km offshore, and in groups of 5 - 6 (Anon. 2003; Dr V. Cockcroft pers comm. 2007). Sightings of Bryde's whales in the Plettenberg Bay area were highest in summer and autumn, with a peak in April that corresponds to increased feeding activity and above average aggregation sizes (Penry *et al*. 2011). During this period they were often seen feeding in association with the common dolphin Delphinus capensis and Cape gannet (Penry *et al*. 2011). Elwen *et al*. (2011) reviewed of cetacean research in the southern African subregion.

6. PROCESSES

6.1 Freshwater

6.1.1 Flow variability

Russell (1999) indicated that natural flow of the seven rivers in the Wilderness area GRNP are perennial with periodic high rainfall events causing short lived peak flow periods. Natural flow patterns have been altered particularly in the Duiwe River, where zero flow conditions occur periodically (Russell 1999). Changes in flow patterns are ascribed to land use practices with approximately 63% of the Duiwe River catchment given over to agriculture, silviculture and human settlement (Filmater & Agnew 1997, Russell 1999). The large numbers of dams in the Duiwe have contributed to little or no flow during dry season. It is evident that apart from the Duiwe River, a considerable percentage of runoff is available to the natural environment: fynbos, forest, and riparian vegetation (Filmater & Agnew 1997).

6.1.2 Nutrient dynamics

No work specific to the GRNP has been located.

6.1.3 Predation

Predation by alien fish particularly *Micropterus* spp is considered to be serious threat to many indigenous fish species in the park (Russell 1999). The probable negative effect of *Micropterus* spp on indigenous fish in Wilderness rivers and in particular Eastern Cape Redfin *Pseudobarbus afer* and Cape Kurper *S capensis,* is demonstrated by large number of indigenous species being recorded only in sites where M*icropterus* spp are absent (Russell 1999).

The complete lack of freshwater fish in the Salt and Wit river makes the unique macro invertebrates assemblages very susceptible to predation (De Moor, 2001, 2004) it was therefore strongly recommended that measures be taken to eradicate bass and trout form all farm dams in this catchment and that the area be granted special conservation status limiting further development (De Moor, 2001, 2004, 2010)

6.1.4 Human modification

It is evident that the percentage of indigenous vegetation declined with increasing forestry and agricultural activities from 1936 to 1991 (Filmater & Agnew 1997). In order to establish more plantation and agricultural land, fynbos and to a lesser degree indigenous forest have to be cleared. This is especially visible is small catchments of the Klein Wolwe and Duiwe river where the fynbos diminished 62% to 2% and 50% to 1% respectively (Filmater & Agnew 1997) catchments. Smaller land use changes have occurred in the Touw River catchment with approximately 21% of the land area no longer supporting indigenous vegetation due to anthropogenic activities ((Filmater & Agnew 1997, Russell 1999). The Duiwe river is heavily impounded with 26 farm dams recorded in 1991, compared to four in the Touw River catchment (Russell 1999)

Barker (1985) measured TSS concentrations as high as 4 590.0 mg l^{-1} in the Klein Wolwe River during a flood event in June 1984, in the Wilderness area. The consequence of these periodic increased inputs of sediment into the lakes was recorded in Swartvlei Lake in the early 1980s where there was an approximate 60% decline in primary production (Whitfield 1982), largely due to a reduction in the standing crop of submerged macrophytes as a consequence of a reduction in light penetration (Whitfield 1982; Allanson & Howard-Williams 1984). This resulted in a 74% drop in invertebrate biomass (Davies (1982), a 69% decline in littoral fish populations (Whitfield 1983), and a 58% drop in the number of red knobbed coot (G. Palmer cited pers comm. in Whitfield *et al*. 1983).

6.1.7 Alien invasion

In the upper reaches of the catchments invaders such as *Hakea* and *Acacia* have replaced the indigenous vegetation along the riparian strips as well as the ridges (Filmater & Agnew 1997).

Attenuation of floods through further impoundments of the Duiwe River catchment in the Wilderness area could facilitate the survival of bass, in particular smallmouth bass *M. dolomieu,* which favours fluvial conditions, to the detriment of the indigenous species (Russell 1999). The effect of Mosquito fish *G affinis* on indigenous fish species in the Garden Route rivers is unknown but in some countries where the *G afffinis* has been introduced they are thought to be responsible for the local extinction of native fish. It is possible that their presence in rivers of the GRNP is having a detrimental effect on indigenous species. In the survey undertaken by Russell (2002) on freshwater fishes in the Tsitsikamma area only one alien species Largemouth bass *M. salmoides* was found. The other two species which could potentially occur in the Tsitsikamma by virtue of their having previously been collected in the Keurbooms system, are the Brown Trout *Salmo tutte* and rainbow Trout *Oncorhynchus mykiss*. Alien fish species are one of the greatest threats to slender redfin *P tenuis* and other indigenous fishes in the Keurbooms system (Russell 2002). Russell (2002) have also demonstrated that *salmoides* have become established in adjacent streams and a threat is also posed by interest shown by local landowners adjacent to the Tsitsikamma area to continue stocking rivers with *O. mykiss.*

6.2 Estuaries

6.2.1 Sedimentation

The geomorphological development of Swartvlei Lake is discussed by Birch *et al*. (1978), with descriptions of the origin and physico-chemical properties of sediments. It was found that virtually pure quartzose sand comprises the lake margin, whereas highly organic muds cover the floor of the lake. In terms of the origin of Swartvlei, it is though that coarse lag material accumulated on the lake bottom during sea regression (20 000 y BP). Depositional phases appear to be controlled by interglacial and subsequent interstadial sea-level high stands (Bateman et al. 2004). Initially the majority of the sediments entering the lake would have been blown in from the surrounding poorly vegetated dunes, but pelagic sedimentation (organic and terrigenous fines) probably became increasingly important, especially as the dunes stabilised. Most of the aeolian material would be deposited close to the lake edge and outward progression of these sands has resulted in the development of a shallow littoral margin around the shores of Swartvlei.

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.

Marine currents in the region of Swartvlei Estuary mouth in the Wilderness area, and their influence on sediment movement are described in Whitfield *et al*. (1983). Eastward longshore sediment transport is estimated to occur 53% of the time, whereas westward longshore drift occurs 23% of the time. Littoral sand movement tends to close gaps in the shoreline such as an estuary mouth. This happens when the longshore sand drift becomes stronger than the forces that keep the inlet open. The majority of mouth closures in Swartvlei Estuary occur in winter, which coincides with the predominance of south-westerly wave conditions that are responsible for the main longshore sand transport.

The substratum of the Knysna 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 Knysna 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.

Reddering (1994) 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).

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 sandpit 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, sand prawn *Callichirus krausii* was the only prawn able to persist.

6.2.2 *Nutrient dynamics*

Soluble reactive phosphate (SRP) (PO_4-P) concentration in Swartvlei Lake is very low (± 1 *u*g l^{-1}) and is often present in undetectable quantities (Whitfield *et al*. 1983). It is thought that dissolved humic matter from the rivers plays a significant role in binding phosphate, and hence contributing to the nutrient poor status of the waterbody (Howard-Williams 1977). Total dissolved phosphorous (TDP) values range from 10 to 20 *u*g l^{-1}, and total phosphorous (TP) up to 30 *u*g l^{-1} (Whitfield *et al*. 1983). SRP, TDP and TP in the stratified bottom waters of the lake all exceed 100 *u*g l^{-1} (Howard-Williams 1977) but are unavailable for plant growth (Howard-Williams 1977). The oligotrophic status of Swartvlei Lake has a number of biological consequences, which include low phytoplankton primary production (Robarts 1976a), low zooplankton biomass (Coetzee 1981a) and low ichthyoplankton densities (Whitfield 1989b).

TDP concentrations in Swartvlei Estuary remains fairly constant at about 24 *u*g l^{-1} (Whitfield *et al*. 1983), though increases in concentration (up to 260 *u*g l^{-1}) have been recorded in deoxygenated saline areas. The main source of P for the estuary is the sea, and during the tidal phase there being a net import and accumulation of P in the estuary (Liptrot 1978; Whitfield *et al*. 1983). An extensive net outflow of P occurs from Swartvlei Estuary during the strong outflow phases immediately after the estuary mouth is opened. Most of the P leaving the estuary is in particulate form, evidenced by the abundance of estuarine plants which usually litter surrounding beaches shortly after the estuary is opened.

The concentration of N-ions in Swartvlei Estuary are generally low, with concentrations in 1976 being found to range from not detectable to 21 *u*g l^{-1} [NO_2+NO_3]-N (Coetzee 1978). Howard-Williams and Allanson (1979) recorded values for nitrate (NO_3-N) ranging from 3 to 30 *u*g l^{-1}, and Robarts (1973) recorded values for ammonia (NH_4-N) ranging from not detectable to 4 *u*g l^{-1}.

The importance of the sea as a source of P in the Touw River Estuary has been emphasised by Allanson & Whitfield (1983), who, from a study undertaken between January 1979 and June 1981, report an increase in TP from 9 to 17 *u*g l^{-1} following the breaching of the bar. SRP concentrations however remained low, not exceeding 2.2 *u*g l^{-1}. Similar concentration of P-ions have been recorded in Eilandvlei during non-flood condition, whereas in Langvlei and Rondevlei, TP levels as high as 66 and 117 *u*g l^{-1} respectively have been recorded (Allanson & Whitfield 1983). Despite these comparatively high levels of TP, only occasionally have SRP levels up to 20 *u*g l^{-1} been recorded in Langvlei and Rondevlei, which is the point at which, if all other factors are propitious, marked algal growth could occur (Allanson & Whitfield 1983).

NO_3-N concentrations in the Touw River Estuary between 1979 and 1981 were found to vary between 7 and 60 *u*g l^{-1} (Allanson & Whitfield 1983) which is well below that which could be considered to constitute serious organic pollution. Similar low levels of NO_3-N were recorded in the other waterbodies of the Touw system during non-flood periods, with the exception of Langvlei, where values as high as 569 *u*g l^{-1} have been recorded. However, as Allanson & Whitfield (1983) point out, elevated levels of plant nutrients in the Wilderness lakes were found to occur contemporaneously with changes in the use of the floodplain by large numbers of waterbirds.

Nutrient cycling between the water column and the bottom sediments has been extensively studied in the Swartvlei system (see Howard-Williams & Allanson 1979). In Swartvlei Lake production rate by submerged aquatic plants is high (e.g. *P. pectinatus* = 16 g m^{-2} day^{-1}) (Howard-Williams 1978). In this waterbody no evidence of phosphorous limitation was found in *Potamogeton* tissues (Howard-Williams 1977), whereas the large algae, *Chara* and *Cladophera* spp. were found to be nutrient limited. *Potamogeton* does not act as an efficient "nutrient pump" (Howard-Williams & Allanson 1979), thus the release of nutrients from the rooted aquatic plants is through decomposition which takes place rapidly predominantly in spring and early summer (Howard-Williams & Davies 1979). Bacteria as opposed to fungi are primary colonisers on leaves resulting in decomposition (Howard-Williams *et al*. 1978; Robb *et al.* 1979). It is unlikely that P once cycling in the macrophyte community, would become transferred to the circulation in the open lake (Howard-Williams & Allanson 1981b). The rate of uptake of nutrients from the water column by epiphytic algae is approximately ten orders of magnitude greater than that of the *Potamogeton* (Howard-Williams 1977, 1981), thus enrichment of the water with P and N compounds would be expected to result in the growth of epiphytic algae. The sediments of Swartvlei Lake also act as a major sink to plant nutrients, absorbing up to 60 % of all phosphorous inputs into the system (Howard-Williams 1977, 1981). In a recent reworking of Swartvlei aquatic macrophyte data collected in the 1970's a model was developed to simulate the decomposition process, and the P and N content of the remaining biomass (Asaeda *et al*. 2000). Model outputs were comparable with measurements of dry matter and nutrient loss as observed by Howard-Williams & Davies (1979). The model can be used to simulate reductions in nutrients in shallow lakes following the harvesting of *Potamogeton*.

In Swartvlei Estuary the eelgrass *Zostera capensis* acts as a nutrient pump during the day adsorbing nutrients from the sediments and secreting them into the surrounding water (Howard-Williams & Allanson 1979). It is postulated that there are two pathways of the take-up of nutrients, the first being a sediment-water exchange system of plant nutrients, the second being that the large mats of *Enteromorpha* algae take up P during the day faster than the rate at which it is released by the *Zostera*, and then in turn release P compounds during the night. During the tidal phases there is a net import of P into the system, primarily in the form of particulate matter from the sea (Howard-Williams & Allanson 1979). There is no evidence of a long-term accumulation of phosphate in Swartvlei Estuary (Howard-Williams & Allanson 1979) which indicates that accumulated nutrients must be periodically removed. The strong currents which follow the opening of the estuary remove large quantities (1.6 tonnes over 20 tidal cycles / 18% of *Zostera* bed biomass per month) of aquatic plants (primarily *Zostera* and *Enteromorpha*), detritus and sediments (Whitfield 1988b), which constitute a loss of plant nutrients from the system. In this manner a long-term equilibrium is maintained. Weed drift also helps redistribute nutrients within Swartvlei Estuary, with the resulting detritus layer supporting large numbers of detritus feeders such as amphipods and mullet.

In terms of the input of plant nutrients in the Knysna Estuary 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 storm water 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.

6.2.3 Human modification

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 clean-up, description of methods of oil collect and disposal, and methods of handling oiled waterbirds.

Percentage land-use categories in river catchments in the Wilderness area given by Filmalter & O'Keeffe (1997) between 1936 and 1991 indicate a decrease in natural vegetation (fynbos and forest) (-11557ha; 30% decrease) and increases in the area given over to plantations (+6605ha; 88% increase), agriculture (+4598ha; 206% increase) and settlements (+376ha; 484% increase). Changes since 1991 are unknown.

Open estuary mouth conditions for the Touw and Swartvlei systems were, in 1995, 25% and 55% of the time respectively (Fijen & Kapp 1995b). Under virgin flow conditions these were estimated to be at least 40% and 65% of the time respectively. As a result of possible future abstractions (see section 5.4.1) the open mouth conditions of the Touw and Swartvlei systems can reduce further to at most 19% and 51% respectively (Fijen & Kapp 1995b).

Perceived changes in sedimentation patterns and the distribution of emergent aquatic plants in portions of the Swartvlei system as a result of the construction of the railway bridge have been reported by Chunnett (1964, 1972). These have also been discussed by NMERI (1964) who considered perceived sediment deposition in Swartvlei Lake upstream of the rail bridge to be due to incorrect comparison rather than actual deposition. Sedimentation in the region of the two box culverts in interleading channels of the Touw system was considered possible, whereas sedimentation in Touw Estuary was considered unlikely (NMERI 1964).

Howard-Williams *et al.* (1975) investigated effects of the N2 road bridge over Swartvlei Estuary on biophysical processes in the upper estuary, concluding that effects on the ecology of the estuary were negligible. Grazing by horses south of the bridge, however, was considered to have significant effect of wetland plant communities and consequently wetland productivity.

Expressing now outdated viewpoints, NMERI (1963) raised concerns about the presence of aquatic plants (both submerged and emergent) in the Swartvlei and Touw systems considering them to “seriously detract from the amenities and scenic beauty afforded by the lakes”. Eradication was considered by means of applying herbicides.

Environmental modification of the wetland environment has been discussed by Russell (2003) as well as their effect on the distribution and abundance of emergent aquatic plants. Macrophyte growth in the interleading channels in the Touw system is considered to be a major factor inhibiting water flow between lakes (Hall 1985a). Submerged aquatic plants in these interleading channels are periodically cut by SANParks to a depth of approximately 1 m below water level using a mechanical reed cutter.

Howard-Williams (1979) has provided recommendations for the cutting of aquatic plants in Swartvlei system, emphasizing the need for controlling aquatic plants only in areas where there is direct and unavoidable conflict with human use of the waterbody. Privately owned holiday resorts on the western bank of Swartvlei Lake maintain access channels to jetties by cutting submerged aquatic plants, and shoreline vegetation is removed presumably to facilitate access to the water edge (Russell 2003). This level of aquatic plant removal is indicated by Howard-Williams & Allanson (1979) as acceptable. Many owners of residential dwellings adjacent to the lower portions of the Touw Estuary remove shoreline vegetation, including *P. australis* stands, either to improve their view of the waterbody, or to construct jetties, slipways or retaining walls (Russell 2003). Cutting of reeds *Phragmites australis* in late summer as a means of controlling reed encroachment was investigated under three different inundation regimes by Russell & Kraaij (2008) It was demonstrated that cutting alone had minimal long-term effect on above ground biomass, whereas reed growth and survivorship can be strongly suppressed through cutting in late summer in conjunction with inundation with moderately saline waters (5.0-7.5 g kg-1)

Harrison *et al*. (1995a, 1995b) assessed the health of estuaries using three parameters, namely (i) biological health (measured as the occurrence of fishes), (ii) aspects of water quality (secchi disk depth, salinity, turbidity, DO, conductivity, NH_3-N, NO_3-N, PO_4-P, chlorophyll-a, pH, *E. coli*), and (iii) aesthetic state. Estuaries (Touw & Swartvlei respectively) scored (out of 10) 6.6 and 5.8 for biological health, 7.5 and 7.2 for water quality, 7.4 and 7.7 for aesthetic state, and (out of 9) 7.0 and 6.0 for overall estuarine health.

Surveillance of water chemistry in the Touw system during flood periods has demonstrated that the inflowing streams are an important source of both N- and P-ions into the system (Allanson & Whitfield 1983). Elevated concentrations of both NO_3-N and PO_4-P have been recorded in the Touw River Estuary, Eilandvlei and Langvlei during flood periods, whereas the concentration of N- and P-ions in Rondevlei, with no feeder streams, remained relatively unaltered (Allanson & Whitfield 1983).

Investigations of the concentration of chlorinated hydrocarbon, PCB and Dieldrin residues in the body tissues of aquatic birds in the Touw system have yielded conflicting results. In 1983 De Kock & Boshoff (1987) detected low concentrations of t-DDT and PCB in the body tissues of reed cormorant, darter, whitebreasted cormorant, blacknecked grebe, great crested grebe and grass owl. Similarly, a fish eagle egg, collected at Sedgefield during 1985 had a low concentration of t-DDT (0.21 ug g-1 wet weight), and no PCBs or Dieldrin residues (De Kock & Lord 1986). In contrast, in 1984 and 1985 De Kock & Simmons (1988) recorded high levels of Dieldrin (1.89 ug g-1) and t-DDT (6.26 & 5.08 ug g-1) in African marsh harrier eggs from the

Touw system, with low ratios of DDE/t-DDT in several eggs indicating recent inputs of DDT into the environment.

Howard- Williams and Allanson (1979) recorded values for nitrate (NO3-N) ranging from 3 to 30 µg l-1, and Robarts (1973) recorded values for ammonia (NH4-N) ranging from not detectable to 4 µg l-1. High levels of nickel from sediments in Swartvlei Estuary may represent contamination from adjacent residential areas. Watling (1977) also suggests that a significant increase in the concentration of lead (and in several instances the concentration of other trace metals) in the upper portions of cores from the Swartvlei system indicate possible pollution from motor fuels or paint.

The distribution of trace elements (copper, lead, zinc, iron, manganese, cobalt, nickel, chromium, cadmium, mercury, magnesium, aluminium, sodium, calcium, strontium, potassium) in water samples, surface sediments and cores from the Wilderness lakes was investigated by Watling (1977). In this study it was found that the concentration of trace metals in water samples were generally low, with the exception of iron and manganese in Swartvlei Lake.

Surveillance of trace metals (iron, copper, cobalt, nickel, zinc, manganese) in the rivers flowing into the Wilderness system during 1991 and 1992 (SANParks unpublished data) revealed that the concentration of iron in the Duiwe, Wolwe, Hoëkraal and Karatara rivers, and Langvlei Spruit, frequently exceeded the concentration of 1000 *u*g l^{-1} considered by Kempster *et al*. (1980) as the upper limit for the protection of aquatic life. High iron concentrations appear to be a natural phenomenon in these rivers, evidenced by the large quantities of ferric oxide which can be seen to cover the rocks along the river beds (Watling 1977). The concentration of other trace metals was low.

A sediment sample collected adjacent to the yacht club in Eilandvlei during April 1977 (Watling 1977) was found to have levels of manganese above those expected when compared with samples collected in Rondevlei and Langvlei. A core sample taken in this locality also showed an overall elevation in values for copper, lead, zinc, cobalt, nickel, cadmium and chromium, with it being hypothesised that these levels represent some degree of anthropogenic contamination (Watling 1977). Similarly, high levels of nickel from sediments in Swartvlei Estuary may represent contamination from adjacent residential areas. Watling (1977) also suggests that a significant increase in the concentration of lead (and in several instances the concentration of other trace metals) in the upper portions of cores from the Swartvlei system and the Touw River Estuary, Eilandvlei and Langvlei in the Touw system indicate possible pollution from motor fuels or paint.

Robarts (1976, 1979) studied the utilization of dissolved organic compounds in Swartvlei Lake by measuring the uptake of ^{14}C-labelled acetate and glucose. The results indicated that acetate uptake was greatest in the aerobic zone while glucose was predominantly utilised in the anaerobic zone. In August and September 1971 acetate was indicated as being utilised predominantly by flagellates, and in December 1971 by dinoflagellates. In other months bacteria were assumed to be responsible for the uptake of acetate.

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 in the Knysna Estuary 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).

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.

In Knysna, Watling & Watling (1977, 1980, 1982) 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 µg l-1 and 25 µg l-1 respectively set by the South African Marine Quality Guidelines (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 naphthalene was the dominant moiety 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.

Further eastwards along the coast, elevated *E. coli* levels recorded by Harrison *et al*. (1996) suggested faecal pollution contaminates the waters of several rivers and estuaries in Tsitsikamma.

6.2.4 *Biota recruitment*

Patterns of recruitment of juvenile fishes into Swartvlei Estuary have been studied by Kok (1981b) and Whitfield (1989a, 1989d) who found strong summer recruitment for most species, with optimum recruitment periods for most dominant species being from October to February. This is similar to the optimal period of September to March given by Kok *et al*. (1981). An extended spawning period is thought to be an adaptive strategy whereby the period of potential juvenile recruitment is prolonged, in effect creating a buffer against failure of recruitment as a result of adverse marine or estuarine conditions (Whitfield & Kok, 1992).

The importance of the surf zone for estuarine associated fishes has been demonstrated by Whitfield (1989c, 1989d), with larvae and postlarvae of 16 families identified from the surf zone off Swartvlei Estuary. Densities peak during summer and when the estuary mouth is open, with concentrations highest closest to the estuary mouth. Time of day and tidal phase may be important in governing ichthyoplankton abundances in the surf zone (Whitfield 1989c). The effect of prolonged closed phases on the recruitment of fishes in the Wilderness lakes was evaluated by Russell (1996). The importance of also having a closed phase in the Wilderness

Lakes estuaries to provide an ideal nursery habitat, in terms of nutrition for juvenile marine fishes is emphasised by Kok & Whitfield (1986). Whitfield (1992) has demonstrated that recruitment of some juvenile fishes form the surf zone into a closed estuary can occur during high seas when the sand bar at the estuary mouth is overtopped.

6.2.5 Alien invasion

Three species of alien fish (*Micropterus dolomieu*, *Micropterus salmoides*, *Gambusia affinis*) and one translocated species (*Oreochromis mossambicus*) occur in the rivers and lakes of the Wilderness area (Russell 1999b). Alien birds occasionally recorded include domestic ducks and geese (SANParks unpublished data). Alien red seaweed *Asparagopsis taxiformis* has been collected in the Knysna and Tsitsikamma areas in 2008 (Bolton, Andreakis *et al*. 2011). Bolton *et al.* (2011) provide molecular evidence of three independent introductions in South Africa, and discuss potential vectors responsible for transport. The Pacific oyster *Crassostrea gigas* was introduced into the Knysna estuary in 1973 for commercial purposes (Calvo-Ugarteburu 1998). No specific programs are undertaken to control alien and introduced animals.

6.3 Marine

6.3.1 Wave action

The South African coastline is generally exposed to strong wave and it has relative few sheltered bays (Branch & Branch 1981). This influences the intertidal communities, as wave action acts as a structuring force and mediates biological interactions on the rocky shores, and the structure of low-shore communities are determined primarily by differences in wave action (Bustamante *et al*. 1997; Blamey & Branch 2009). Similar patterns of horizontal distribution of community biomass and species richness have been recorded in equivalent rocky shore habitats, regardless of geographical location along the South African coast (Bustamante *et al*. 1997; Blamey & Branch 2009).

Limited wave force measurements have been done in the intertidal of Tsitsikamma. The mean maximum wave force values (c.3000 – 3300 N.m-2) recorded during calm sea conditions in Balanoid zone of semi-exposed shores at Storms River and Beyers se Eiland (Hanekom 2011) were comparable with those (c.3500 N.m-2) noted in mid-tide area at semi-exposed sites at Groenrivier (Bustamante *et al*. 1997) and at exposed mussel beds in the Eastern Cape (3100 - 3900 N.m-2; Lindsay 1998). Climate change is likely to lead to greater wind stress and storm turbulence along the coast (Clark 2006). Increased wave turbulence may dislodge a larger proportion of the intertidal mussels (Zardi *et al*. 2006a) and restrict feeding activities of some limpet species (Branch 1975, 1976; Denny *et al*. 1985). These factors in turn may influence the competitiveness of the various mussel-, barnacle- and limpet species, and possibly lead to a shift in species dominance on the shore.

6.3.2 Upwelling

Inshore coastal upwelling is often driven by south-easterly winds (Branch & Branch 1981) and can have a marked effect on both the nutrients and temperature of surface water, as well as recruitment of intertidal invertebrate larvae to the shore (Bustamante *et al*. 1995; Blamey & Branch 2009; Wieters *et al*. 2009). Upwelling processes have been recorded on the South- and South-East Coast, including the Tsitsikamma MPA (Schumann *et al*. 1982; 1988; Beckley, 1983; 1988; Hanekom *et al*. 1989), and coastal surface sea temperature (SST) has been shown to be very good monitor of wind-forced upwelling conditions along this coast (Schumann *et al*. 1995; Schumann 1999). Winds and SST are correlated with the southern oscillation index. More easterly component winds are experienced at high phases (La Nina) with a consequent decrease in coastal SST. The summer wind forcing situation on the south coast occurs on much shorter time scales (2-6 days) than the west coast, and this probably accounts for the lower production on the south coast (Schumann 1999). Nevertheless, local upwelling can influence the dispersal of larvae of fish, squid and possibly intertidal invertebrates within the Tsitsikamma MPA (Brouwer *et al*. 2003; Roberts 2005; Roberts & van den Berg 2005; Hanekom 2011), and size structure of habitat forming species, such as mussels (Cole and McQuaid 2010) and macroalgae (Mostert 2011). Climate change is expected to increase wind stress along the coast, which is anticipated to lead to a higher intensity of upwelling (Clark 2006).

6.3.3 Currents

The coastline of southern Africa is washed by two major currents, namely the strong, southerly-flowing, warm, Agulhas Current on the east and south-east coast, and the colder, north-flowing Benguela Current on the west coast (Branch & Branch 1981). As a consequence of these two systems, there is a gradient in sea temperature, intertidal primary production and nutrient concentration around southern Africa (Bustamante *et al*. 1995).

The continental shelf deflects the Agulhas Current away from the Tsitsikamma coastline, decreasing its influence on the inshore waters, and in general surface (< 1 m deep) flow is determined largely by prevailing winds (Lutjeharms 1998). Measurements in the MPA indicated a complex current system. Attwood *et al*. (2002) deploying drogues in the MPA recorded reversal in surface current direction. Roberts and van der Berg (2005), using acoustic equipment, found that the eastward (longshore) flow was dominant in the upper subsurface (5 m deep) layer, with an absence of a marked seasonal trend. However, at a depth of 31 m flow patterns varied with seasons. In winter the current direction was similar to that of the upper subsurface (5 m) water, but it flowed in the opposite direction during mid-summer (December and March). The average velocity of the current on the surface was more than double that measured at 35m depth (24 vs 10 cm/s vs), and overall displacement was in an easterly direction (Roberts and van der Berg (2005), which has implication for the transport and possible later development of fish eggs and larvae in the MPA (Brouwer *et al*. 2003; Roberts & van den Berg 2005). Similar nearshore current dynamics have been report for Algoa Bay (Pattrick *et al*. 2013)

6.3.4 Alien invasion

Some 86 marine species are currently confirmed to have been introduced along the coast of South Africa, with an additional 39 species suspected (Picker & Griffiths 2011; Mead *et al*. 2011). Most marine introductions remain restricted to sheltered harbours and estuaries, but there are several that are able to colonise the open wave-swept coast (Picker & Griffiths 2011; Mead *et al*. 2011). Probably the most significant is the Mediterranean mussel (Mytilus galloprovincialis), which is now the most abundant mussel species on the rocky shores along the entire west and south coast of South Africa (Robinson *et al*. 2005). This species has had numerous impacts on the west coast, greatly increasing the intertidal macrobenthic biomass, reducing suitable feeding areas for adult granular limpets, but providing habitat for many small invertebrates and additional food resources for predators such as the African black oystercatcher (Hockey & Van Erkom Schurink 1992).

Since the late 1980s, there has been a substantial increase in the abundance of alien Mediterranean mussels on the coast of the Garden Route, but this has been variable and site specific (Robinson *et al*. 2005). At sites where Mediterranean mussels are plentiful, this species tended to dominate the high shore and indigenous brown mussels the low shore, with a mixed zone at the middle level (Bownes and McQuaid 2006; Hanekom 2008). The influx Mediterranean mussels in the lower- and middle Balanoid zone of the Tsitsikamma MPA has resulted in an increase in the overall mussel density, a reduction in indigenous brown mussels numbers, but no apparent change ($P > 0.05$) to the biomass and diversity of the fauna associated with the mid zone of mussel beds (Hanekom 2008), Changes in upper zone appear to be more substantial (Bownes and McQuaid 2006). Given its wide range, prolific reproductive habits and widely dispersing larvae it is probably impossible to control its spread and abundance on the shore (Picker & Griffiths 2011), and no management action has been taken to limit its spread within the MPA. The overall effect will be that the indigenous brown mussel population will be reduced to narrow band on the low shore, while the density of mussels in the upper zone will increase potentially providing additional food resources for predators.

6.3.5 Human modification

Indiscriminate fishing activities can adversely affect subtidal reef communities through damaging delicate benthos and removing top predators. Recreational shore angling has increased over the past century and by the 1990s total effort was estimated at 3.2 million angler-days per year (Brouwer *et al*. 1997). Combined with commercial fisheries that target many of the same species has led to dramatic declines in the abundance of several sought after angling fish species. Indeed, some fish populations have been reduced to a few percent of their numbers a century ago (Griffiths 2000). Large scale poaching of marine resources in the park could adversely impact on the reef fish communities in the MPA. Daylight, aerial surveys done along the coast in 2009 showed that angler density in the MPA (0.03-0.14 anglers.km-1) were significantly less than in adjacent open access areas (0.07-1.51 anglers.km-1). However, illegal fishing activity often takes place at night and evidence of fishing activities (proxy for fishing effort) showed no significant difference between three identified fishing spots in the MPA compared to a popular site (Salt River) outside the park, suggesting that fishing is prevalent at these spots (Murray *et al*. 2011). Most of the reef fish targeted are vulnerable to over-exploitation, and catch returns cards collected from the Storms River area, which was open to angling prior to 2000, indicated that catches were only slightly higher than those at other exploited sites outside TNP (Hanekom *et al*. 1997). Work in and adjacent to Goukamma MPA has provided evidence of the effect of reef fishing on non-target components of fish and invertebrate community (Götz *et al*. 2009a,b). Target fish species are usually dominant predators and their removal causes a cascade of effects through the food web altering species compositions and possibly causing a flip to alternative, less productive or desirable states.

6.4 Forest

6.4.1 Growth

The warm-temperate mixed evergreen natural forests of the Garden Route occur as patches in a rugged landscape, surrounded by fire-prone fynbos vegetation. The forests occur in many small patches in the rugged mountains, but mainly in a few large but isolated patches on the coastal platform and in river valleys (Geldenhuys 1994a). Human induced disturbances, such as exploitation, clearing, grazing and fire, must have eliminated and fragmented forest to some extent in many areas of the Garden Route since the arrival of the Europeans during the latter half of the eighteenth century (Geldenhuys 1991b). The potential limits of forest distribution in the Garden Route are determined by environmental factors, particularly rainfall, and the only true limit to the potential establishment and growth of forest in the Garden Route is annual rainfall below 500mm. Moisture and nutrient levels do not limit the development of forest at above 500mm annual rainfall (Gush & Dye 2004). Forests occur on almost soil types in the Garden Route. Topography and aspect are important in so far as they control soil moisture and the spread of fires (Van Daalen 1981c).

The actual location pattern of natural forest is determined by the fire pattern, which is a result of the interaction between terrain topography and prevailing winds during dry periods (Geldenhuys 1994, Midgley *et al.* 1997). Fires driven by the hot, dry, north-westerly bergwinds are common during the autumn and winter. The forests on the coastal platform have survived in topographic shadow areas protected from the bergwinds, where fires are less likely to occur at frequent intervals. Mountain forests persist due to the wind flow patterns along the slopes and ridges surrounding the forests. Forests can recover from episodic, extreme bergwind fires, and many forest species are adapted to low-frequency fires. Most of the small mountain forests have probably been destroyed by fire at some time and are regrowth forests. It takes centuries for a forest to recover after a severe fire, to the stage with a tall, dense understorey of *Trichocladus crinitus*, which is associated with the mature forest (Geldenhuys 1991b, 1994a). Fire thus influences species composition and diversity in these forests. Fire adapted species dominate near the forest margin, while more species occur in the core, including fire-sensitive species not found in the forest margin (Watson & Cameron 2001, 2002). The legume pioneer tree keurboom *Virgilia divaricata* frequently dominates on the forest fynbos ecotone where it creates conditions favourable for the expansion of forest species into the fynbos in the absence of fire (Coetsee & Wigley 2013).

The forest canopy is dominated by either the keurboom *Virgilia divaricata* in early regrowth stages (Van Wyk *et al.* 1995), or by red-alder *Cunonia capensis* and black stinkwood *Ocotea bullata* in more advanced development stages (Geldenhuys 2002a). The dominant mountain forest tree species (*O. bullata* and *C. capensis*) have bell shaped diameter distributions, indicating that they experience higher rates of disturbance than the plateau forests and establish once, after a major disturbance, typical of a coarse-grained forest (Geldenhuys 2009). Both species show vigorous vegetative regrowth. *O. bullata* often regenerates through sprouting following a fire, sometimes even if the entire crown dies (Lübbe 1990a). However, the regeneration in these forests is dominated by the shade-tolerant species that dominate the platform forests (Geldenhuys 1994a).

The processes of growth, mortality and recruitment in forests are influenced by disturbances, which can operate on a wide range of temporal and spatial scales. The death of a single canopy tree will have a very local and relatively brief influence on the forest dynamics, whereas the forest may take many decades to recover from large-scale disturbances caused by catastrophic storms or fires (Van Daalen 1991).

Forest grain represents the relative similarity between composition of canopy species in the canopy and regeneration of the same stand (Midgley *et al.* 1990). It indicates if tree species in the current canopy can regenerate under that canopy and associated conditions, or if they need other conditions to regenerate and grow through the seedling to sapling to pole to small tree stages (Geldenhuys 2009). The grain analysis of the Garden Route forests indicates a fine grain for the platform and valley slope forests (Midgley *et al.* 1990), intermediate grain for the foothill, coast scarp and river valley forests, and a coarse grain for the mountain forests. Both the canopy and regeneration of the fine-grain platform forests are dominated by the shade-tolerant canopy tree species real yellowwood *Podocarpus latifolius* and black ironwood *Olea capensis* subsp. *macrocarpa*, which both cannot regrow vegetatively. Their disturbance regime is regular, generally small, natural gaps (Geldenhuys & Maliepaard 1983, Midgley *et al*. 1995). Midgley *et al*. (1990) suggest that most of the canopy tree species occurring in the Garden Route forests appear to be shade tolerant and locally persistent, conferring a fine grain on this forest. Most tree species, including the two dominant species in each of the coastal platform (*P. latifolius* and *O. capensis* subsp. *macrocarpa*) and the coast scarp (whitepear *Apodytes dimi*diata and forest spoonwood *Cassine peragua*) forests, showed the typical inverse J-shaped stem diameter distribution, supporting the notion that shade-tolerant species can regenerate and establish continuously without major disturbances, typical of the fine-grained forest (Geldenhuys 2009, Midgley *et al*. 1990). The intermediate grain of the foothill (occasional spot fires from the catchments), coast scarp (occasional landslides or blow-outs by strong winds) and river valley (occasional flooding and larger component of deciduous species) forests represents an intermediate disturbance regime.

Forest tree stem densities and diameter growth rates have been measured in long-term research and monitoring sites, as described by Laughton (1938), Van Daalen (1991), Seydack *et al*. (2011) and others. Stem numbers (all species) per hectare in the medium-moist and moist forest types over a wide range of forest stands vary between 500 and 800 stems of at least 10 cm diameter at breast height (DBH), and 140 - 200 stems of at least 30 cm DBH. Basal areas over a range of forest stands are generally between 30 and 45 m^2/ha (for trees at least 10 cm DBH). The estimated mean standing volume for stems at least 30 cm DBH is about 150 m^3/ha, of which between 50 and 67% is currently considered utilizable volume (Seydack *et al*. 1995). The mean basal area for all species combined at the Diepwalle Research Area changed from 32.7 m^2/ha in 1972 to 34.1 m^2/ha in 1978 and 35.3 m^2/ha in 1987; thus the rates of basal area increment declined from 0.23 m^2/ha/yr during the period 1972 to 1978, to 0.13 m^2/ha/yr during the period 1978 to 1987. During a period of very heavy experimental thinnings in the area from 1942 to 1954 the net basal area growth rate was 1.63% per annum. It declined to 1.42% between 1954 and 1972, to 0.55% between 1972 and 1978, and to 0.35% between 1978 and 1987. Mortality rates of most species increased, and for some species exceeded their recruitment rates. Mortality of stems with DBH greater than 100mm was less than 1% per year and was poorly correlated with tree diameter (Van Daalen 1991). This seems to indicate that in spite of heavy disturbance, forest recovery was relatively fast with the forest approaching a state of equilibrium within 30 – 35 years after disturbance (Lawes *et al*. 2004). Gross volume growth rate for all species (dbh ≥ 10 cm) in moist and medium-moist forests at the Diepwalle Research Area from 1972 to 1987 was very similar to that for unlogged tropical forests elsewhere in the world, i.e. about 2 m^3/ha/yr (Van Daalen 1991). Standing volume increment for trees with DBH ≥ 30 cm (the size classes usually harvested for timber) is 1.31 m^3/ha/yr, but only about 0.83 m^3/ha/yr is utilizable. Irretrievable mortality is estimated at about 15%; thus the total yield productivity potential is estimated at 0.70 m^3/ha/yr (Seydack & Vermeulen 2004).

Growth rates can differ considerably between trees of the same species, with both crown position and crown form playing an important role for many species, particularly canopy species. Many species can survive shading for considerable periods of time, but growth rates increase following increased exposure to full sunlight. Growth of most subcanopy species is influenced by crown form, but less by crown position (Van Daalen 1993b). Geldenhuys (2004) found that growth rates of *O. bullata* vary depending on tree size and crown position in the stand, with fastest growth occurring when the crown is in the canopy with full overhead light, whereas Van Daalen (1993b) found that a good crown form and enough foliage are more important than the crown position. Mean diameter growth rates for different size classes of the main canopy tree species are provided by Seydack (1995).

Seydack *et al*. (2011) found that stand-level increment of canopy species in the canopy layer (>30cm dbh) was significantly determined by inherent species-specific growth capacities (i.e. species composition of the stand), water availability, forest matrix crowding and age-related deterioration of tree condition (indicated by signs of crown dieback, damage and stem rot). In contrast, stand-level increment of trees of canopy species in the subcanopy layer (10–20cm dbh) was prominently shaped by light availability, as mainly determined by the degree of canopy-level disturbance (as indicated by the mortality rate of trees >30cm dbh), crowding (canopy-level overhead and forest matrix crowding) and proximity to adults of the same species (within 6–8 m). In addition to species-inherent and resource factors, considerable variation in stand-level growth resulted from site–climate interactions. Further complexities of forest growth and implications for timber yield regulation were discussed in Seydack (2012). Forest structure, as described in terms of stem densities and tree size, is largely controlled by resource conditions (moisture and nutrient availabilities) and the degree of resource-level fluctuations, i.e. seasonality (Seydack *et al*. 2012). The moist, less seasonal Tsitsikamma forests have relatively high densities of subcanopy trees and comparatively high stem densities of relatively large-sized trees. The cooler, moist and more seasonal Knysna forests have lower densities of relatively large-sized trees at the canopy level, attributed to the lateral growth mode and extended persistence of the largest trees. The warm, seasonal Outeniqua forests, on relatively nutrient-rich soils towards the western edge of the Garden Route National Park, have high stem densities at the canopy level relative to the subcanopy stratum, attributed to a combination of low subcanopy tree persistence, fast ingrowth of trees into the canopy stratum, and high canopy tree turnover, with trees lost to mortality before they reached large sizes. Seydack *et al*. (2011, 2012) developed a metabolic performance trade-off model that provides a framework for the interpretation of forest structure and its underlying dynamics.

Competition between trees of different species, as well as between trees of the same species, plays a significant role in forest dynamics (Van Daalen 1993a), but these interactions between trees are still poorly understood. Competition between trees, as characterised by crowding and overtopping, produces responses that vary between species and for different size classes. Canopy and sub-canopy species display distinct differences in their reactions (Seifert *et al*. 2014).

More than 200 forest species reach their distribution limits within the southern Cape region, or have disjunct distributions within this area and wider distributions outside. Geldenhuys (1992a) relates this to natural processes of environmental change, particularly climate change and associated changes in sea levels. Geldenhuys (1981) described the occurrence and growth of the rare red stinkwood *Prunus africana*.

Most of the forest tree species in the Garden Route forests flush during the moist and warm spring and early summer, and leaf fall reaches a peak during summer. This allows for the translocation of nutrients from old to new leaves prior to dropping of the old leaves. Flushing also occurs sporadically throughout the year with sufficient rains after dry spells (Kotze & Geldenhuys 1992). Donald & Theron (1983) reported a relatively constant litter fall amongst different forest types of more than 4000 kg/ha/yr, with relatively large variations within forest types. They recorded a peak in June, with smaller peaks in August and November-December. Root and shoot growth of *O. bullata* is most active during the warm summers when there is sufficient moisture, but often not simultaneously (Kotze & Geldenhuys 1992).

6.4.2 Disturbance (human and natural)

The role of gaps in stand dynamics of the southern Cape indigenous forests has been identified as an important research area that requires attention (Ella 2005). The southern Cape indigenous forests are not subject to regular major disturbances (Geldenhuys & Maliepaard 1983). Forests experience perturbations that take place mostly as: 1) single tree wind throws; 2) lightning, destroying woody plants and starting fire 3) minor avalanches on vertical slopes; and 4) sporadic severe weather conditions (Geldenhuys & Maliepaard 1983, Vermeulen 1994, Grau 2002).A number of studies are being conducted in the Garden Route to understand gap dynamics and succession in natural and human-made forest gaps, and in fire disturbed areas. Ella (2005) indicated little difference in the community structure of plant species between gaps of different sizes and origins and as expected from the species-area relationship, large gaps had higher species richness, plant diversity and herbaceous percentage cover than medium and small gaps. Further results are presented by Everard (1994), Euston-Brown *et al.* (1997) and Moolman & Rikhotso 2010. A study by Schmidt & Vlok (2002) was aimed at identifying post-fire indicators of fire intensity at indigenous forest margin and found fire intensity levels to be correlated to *Virgilia divaricata* seedling density, species richness, the width of the *V. divaricata* strip and width of the burnt forest margin. Along the forest boundaries, appropriate pioneer woody plants do not occur in large numbers following a single perturbation such as fire (Van Daalen 1980, 1981). For instance, the tree species *V. oroboides* is said to be a suitable pioneer plant following forest fire perturbations that occur particularly in the humid mountain sites, but it reduces the re-growth of other woody plants (Van Daalen 1980, 1981).

Environmental factors such as rainfall regime, geology and soils determine the potential limits for forest distribution, but berg wind fire patterns determine the actual location pattern of forest (Geldenhuys 1994a). Louw (2007) studied the impact of the 2005 wildfire on the soils of a fynbos-forest ecotone in the Witteklip forest of the Tsitsikamma region and findings indicated that soil erosion levels were minimal, and other soil physical functions were found to be normal.

Intensive harvesting of indigenous forest species has been practiced since 1776 (Von Breitenbach 1968, Von dem Bussche 1975, Van Daalen 1980). From 1985 to 1991 timber yield regulation followed one of two systems: 1) OPH (Optimum Productivity Harvesting); or 2) MRH (Mortality Retrieval harvesting) (Seydack *et al*. 1990). Geldenhuys & Maliepaard (1983) investigated the causes and sizes of canopy gaps in the southern Cape forests and found that most trees die standing, and recommended that the gaps created during logging operations should be minimized so as to simulate the natural disturbance processes. In 1992, a science based Senility Criteria harvesting system (SCH) was introduced (Seydack *et al*. 1995). Midgley *et al*. (1995) reviewed and researched gap dynamics associated with this harvesting system and concluded that harvesting practices applied at the time were unlikely to affect forest composition. The single tree mortality pre-emption yield regulation system (SCH) applied remains in alignment with the natural disturbance regime and succession patterns in gaps in harvested and unharvested areas are similar, suggesting that harvesting has little impact (Midgley *et al*. 1995).

Geldenhuys *et al*. (1988) investigated the effects of Tsitsikamma toll road building in the Plaatbos indigenous forest and found that in relation to the total forest area cleared; short-term mortality in the remaining forest was minimal. Exposure of the new forest edge by clearance had very little detrimental effect on the trees (Geldenhuys *et al*. 1988).

6.4.3 Nutrient dynamics

Southern Cape forests soils are poor in nutrients due to predominately nutrient-poor geological substrate (sandstone) and in association with the high rainfall and leaching (Geldenhuys & Theron 1994). Geldenhuys & Theron (1994) found the annual total leaf fall to be 4 725 kg/ha/y in the moist site, 3164 kg/ha/y in the dry site, and 6002 kg/ha/y under emergent trees, these are low values compared to similar types of forests elsewhere. Van Daalen (1984) sampled the physical and chemical characteristics of soils of the indigenous forest-fynbos interface in the Southern Cape and findings suggested that apart from some higher elemental concentrations in forest than in fynbos A1horizons due to a high carbon content, forest soils are not richer in nutrients than the surrounding fynbos soils. According to the study of Koen & Crowe (1987) historical and biogeography factors, as well as low nutritional values in the soils and vegetation may be the cause of low bird and invertebrate densities and diversity in southern Cape forests. Louw (2007) found that the ash bed effect following a forest fire, results in increased levels of some basic cations, with high levels of phosphorus and soil pH that will generally facilitate nutrient recycling patterns and forest recovery.

6.4.4 *Reproductive biology and dispersal*

Tree regeneration is generally good in the Garden Route forests (Von Maltitz *et al*. 2003). There has been very little research on the reproductive biology of Garden Route forest trees, and very few quantitative data on the germination ecology of southern African forest plants (Midgley *et al*. 1997). Geldenhuys (1993c) found that bisexuality (i.e. male and female parts in the same flower) is most common in all growth forms except woody shrubs. Dioecy (separate male and female plants) and monoecy (separate male and female flowers on the same plant) occur mainly in woody plants.

Pollination systems are largely unknown for most species, although insect pollination probably dominates in woody plants. Small dry seeds are more common than small fleshy fruits, while large fruits for specialized dispersal are rare. The seeds and fruiting bodies of 58% of tree species in the Garden Route forests seem adapted only for local distribution or distribution immediately under the parent tree (Donald & Theron 1983).

Mast fruiting (the irregular production of large numbers of fruit) occurs in several species, such as whitepear *Apodytes dimidiata,* Outeniqua yellowwood *Podocarpus falcatus, black ironwood Olea capensis* subsp*. macrocarpa* and hardpear *Olinia ventosa* (Gush & Dye 2004). A larger more widespread production of seed contributes to a higher germination capacity (Geldenhuys and Von dem Bussche, 1997). Fruiting is not synchronized nor of equal intensity between species and the period between fruiting events for irregular fruiters ranges from two to ten years, which will influence local seedling numbers. Midgley *et al*. (1990) counted up to 1200 seeds per m^2 of *O. capensis* ssp*. macrocarpa* on the forest floor during its mast year. More dense patches of seedlings may only be localized around mature females of dioecious species such as real yellowwood *Podocarpus latifolius, P. falcatus,* black stinkwood *Ocotea bullata* and Cape-beech *Rapanea melanophloeos*. Many shade-tolerant species have short seed dormancy and thus germination begins almost immediately after seed release, as with *P. latifolius* (Lawes *et al*. 2004). Seedlings go on to form a seedling bank and require intervals of exposure to light to eventually gain the canopy.

Many species can coppice in response to fire, and vigorous resprouters can survive total removal of the aboveground parts, such as by felling. This confers a degree of resilience to the impact of these disturbances. Typical resprouters are multi-stemmed, such as white-alder *Platylophus trifoliatus, O. bullata* and *O. ventosa* (Midgley *et al*. 1990). *O. bullata*, with its thicker than average bark, often regenerates through sprouting following a fire, sometimes even if the entire crown dies (Lübbe 1990a), and also coppices vigorously after felling. Browsing of the coppice shoots by bushbuck *Tragelaphus scriptus*, however, impedes the recovery and survival of stumps (Lübbe 1990b). In contrast, reseeders such as the two *Podocarpus* species and *O. capensis* ssp*. macrocarpa* are typically single stemmed and usually die if the aboveground parts are destroyed (Lawes *et al*. 2004). The two podocarps in the Garden Route forests are exceptionally shade tolerant, long-lived and have a large persistent sapling bank, allowing them to survive in these relatively species-rich, angiosperm-dominated forests (Midgley *et al*. 1990).

Kruger & Midgley (2001) found that canopy tree species richness decreased with increasing abundance of resprouting species, and that resprouting species are more common in forests with a lower canopy height. Taller forests are dominated by reseeding species and are more species-rich than shorter forests.

Certain tree species have been referred to as being pioneers, e.g. *R. melanophloeos*, because they are common in artificially disturbed areas. However, the occurrence of regeneration of almost all species in shade of various intensities indicates that there are no true pioneers (Midgley *et al*. 1990). Most of the dominant species are similarly shade tolerant and are capable of regenerating or persisting very close to large stems of their own species, although Lübbe & Geldenhuys (1991) noted the inhibition of regeneration of “own” seedlings under a parent canopy. Midgley *et al*. (1990) estimated that there are 35000 stems/ha with DBH smaller than 10cm and 730 stems/ha with DBH greater than 10cm of canopy and subcanopy tree species. Since only stems > 20cm DBH are in the canopy, a large in situ seedling / sapling bank exists. Most species usually have many individuals of advanced regeneration. By the time a gap occurs, a degree of structure has already been imposed on the advanced regeneration that may occupy the gap. The growth of seedlings is often severely suppressed by herbaceous undergrowth in forest gaps, resulting in increased mortality (Geldenhuys 1975). Midgley *et al*.

(1995) found no large differences among the more common tree species in terms of the size of gaps that they colonized. There were no indications of specific replacement patterns.

In contrast, random replacement appears to be the dominant pattern for the more common species. However, size-class distributions indicate that *O. ventosa* and *P. falcatus* have a life-history strategy significantly different from that of most of the common species (Midgley *et al*. 1990). *O. ventosa* is one of the more infrequent gap fillers and does not usually regenerate from seed under its own canopy. It may require larger gaps or gaps caused by some other event (e.g. fire) to ensure its regeneration (Midgley *et al*. 1995). It flowers and fruits irregularly and a heavily-fruiting tree may bear as many as 70 000 fruits in a season (Phillips 1926a). Most fruits fall to the ground below the parent tree, with 200 – 800 per m^2 on the ground under the tree, but some are dispersed by birds and mammals. Germination occurs from 12 – 18 months and up to 30 – 40 months after the fruits fall, but viability and seedling survival is very low, with very little regeneration found in large parts of the forests.

6.4.5 Alien invasion

Forests are particularly resistant to alien invasion and show remarkable recovery potential following infrequent disturbance (Geldenhuys *et al*. 1986). Baard (2012a) recorded 214 invader plant species for the GRNP, of which 39 are associated with forest. Most of the forest invaders are found in forest gaps (or other disturbed areas) and on forest margins.

The potential impact of invader plants on forest ecosystem functioning relates to forest gap dynamics, forest regeneration and succession following natural or unnatural disturbance, as well fynbos-forest ecotone functioning. Trees with large crowns and prone to windfall, such as Australian Blackwood *Acacia melanoxylon*, could create large forest gaps (Geldenhuys & Maliepaard 1983), and alter gap size distribution and gap dynamics in densely infested forest areas. *Acacia melanoxylon*, together with species such as blackwattel *A. mearnsii*, bramble *Rubus* sp. and bugweed *Solanum mauritianum* invade forest gaps and forest edges to potentially alter regeneration and forest succession following disturbance.Fire is a natural disturbance agent on the forest edge and maintains the fynbos-forest boundary. Invader plants in the ecotone not only alter forest structure and species composition, but the built-up of a heavy fuel load could result in excessive damage during fynbos fires (Watson & Cameron 2001, 2002). In addition, the establishment of exotic plantations adjacent to forest vegetation destroys the ecotone and creates a “hard” edge, which leaves the forest vulnerable to further damage through windfalls and exposure to the elements following clearfelling (Everard 1995). Although no work has been done in this regard in the GRNP, forest invaders, especially legumes, could also potentially alter soil conditions and impact on the regeneration of indigenous species.

Research on forest invaders in the Garden Route and their potential ecological impact, is largely confined to *A. melanoxylon*. This species was actively planted in forest gaps in the Tsitsikamma area of the park from 1968 to 1973 (the so-called Blackwood Group System) to provide a sustainable source of good quality timber with minimum impact on the surrounding forest (Geldenhuys 2002b). Geldenhuys (1986, 1996) report an abundance of recruitment of indigenous tree species beneath the canopies of *A. melanoxylon* stands. As such, the species facilitates succession towards forest and could be used as a nurse stand in forest rehabilitation.

The invasion ecology of the species, population dynamics, growth strategies, regeneration and recruitment success are provided by *inter alia* Phillips (1928), Geldenhuys (1992c) and Seydack (2002). Although blackwood possesses the qualities of an aggressive invader in disturbed forest canopy and floors, forest ecotones and riverine areas (Geldenhuys 2002b), it does not aggressively invade closed, evergreen forests (Geldenhuys 1996; Seydack 2000a). According to Seydack (2002), blackwood does not behave like a typical pioneer and linked blackwood to a group he termed forest matrix invaders, an intermediate between a typical pioneer and shade tolerant specialists. In the forest interior it has a bell-shaped size class distribution (Geldenhuys 1986, 1992d; Seydack 2000a), compared to an inverse J-shape on the forest edge (Seydack 2000a).

Blackwood is a regular and prolific seeder and the seeds have a high germination capacity (Geldenhuys 1986). According to Phillips (1928), the average tree produces 250 000 seeds per annum. Inside the forest, blackwood produces seed from the age of about 13 years and a tree size of ca 10 cm DBH (Geldenhuys 1992c). An annual growth rate of between 0.73 and 1.11 cm has been reported for the species (Seydack 2002).

Mature blackwood trees have large emergent crowns (Geldenhuys 1986, 1996, 2002b; Geldenhuys & Maliepaard 1983) and very shallow root systems, which develop poorly in low light conditions of a closed forest (Milton 1982), and are therefore prone to windfalls (Geldenhuys 1986, 1996, 2002b; Geldenhuys & Maliepaard, 1983). In addition, mature blackwood trees have larger crown volumes than dominant native species such as ironwood *Olea capensis* subsp. *macrocarpa*, which could cause larger gaps and damage more of the surrounding trees than would happen under natural disturbances (Geldenhuys 1986, Geldenhuys & Maliepaard 1983).

The history of *A. melanoxylon* introductions in the Garden Route and its management is provided by Geldenhuys (1992c, 2002b), Stehle (1996) and Vermeulen & Seydack 2000). Blackwood was first introduced to the Garden Route in about 1856 (Phillips 1928) and was planted extensively in the forest from about 1909 until 1930 (Geldenhuys 1996, 2002b). It is now well established in natural forest and surrounding areas (Vermeulen & Seydack 2000). Considering the importance of the species as a timber species, perceptions on the desirability or not of the species in the natural forest alternated since its introduction (Geldenhuys 1992c, Vermeulen & Seydack 2000). The Blackwood management policy has been critically evaluated regularly, and various management proposals with different perspectives formulated (Grewar 1982, Seydack *et al*. 1982, Geldenhuys 1982b, 1992c, 1996; Seydack 2002). The invader qualities of the species as well as its economic value are accommodated with the current blackwood management system (Baard & Vermeulen 2003). Management actions in terms of control and utilization are based on predictions from research data (Geldenhuys 1996, 2002b; Seydack 2000a), that the population in the forest interior would eventually stabilizes at a level of low ecological impact. This is to be assessed during a 10-year monitoring program, after which the blackwood policy/management strategy would be revisited. Preliminary results in this regard, are provided by Moolman (2011).

6.4.6 Climate effects

In a study of tree growth in the Knysna forests it was found that certain trees within the same species had higher diameter growth increments during the 1972-1978 increment period (relatively low mean monthly temperatures) whereas others had increment peaks during 1979-1987, an increment period with relatively high mean monthly temperatures (Seydack 2012).

In another study (Seydack et al. 2011), stand-level tree growth patterns were investigated for the Knysna upper foothill forests (283-503 m a.s.l.; higher rainfall and temperature seasonality) and the Tsitsikamma forests (218-316 m a.s.l.; lower rainfall and temperature seasonality). Growth patterns over two sequential increment periods were analysed: increment period 1 (1985-1995) and increment period 2 (1996-2006: increased Tmax of +0.64 °C). Angiosperm (*Olea capensis ssp. macrocarpa, Pterocelastrus tricuspidatus, Apodytes dimidiata, Curtisia dentata, Psydrax obovata ssp. obovata, Olinia ventosa, Ocotea bullata* and *Platylophus trifoliatus*) and gymnosperm tree species (*Podocarpus falcatus* and *Podocarpus latifolius*) were grouped and analysed separately. Enhanced growth rates of canopy-occupying cohorts (trees > 30 cm diameter) were encountered during the warmer increment period for angiosperm, but not for gymnosperm species. Stand-level growth of subcanopy-level (10-20 cm diameter) angiosperm species was relatively enhanced during the warmer increment period in stands with relatively high light availabilities, whereas that of gymnosperm subcanopy species was relatively depressed during the warmer increment period in stands with relatively low light availabilities. Site-climate interactions in tree growth were revealed (Forests x Site x Climate). Growth enhancements of canopy and subcanopy tree cohorts of angiosperm tree species during the warmer period were more pronounced on dry than moist forest sites in the Knysna forests and more pronounced on moister sites in the Tsitsikamma forests. A plant metabolic performance trade-off model was developed in order to explain differences in forest structure and growth patterns between these forests (Seydack et al. 2011, Seydack et al. 2012

6.5 Fynbos

6.5.1 Fire

Fire is instrumental in maintaining the species- and endemic-rich fynbos shrublands (Van Wilgen *et al.* 1992; Stock & Allsopp 1992; Myers *et al*. 2000) of the Cape Floral Kingdom (CFK) (Kruger & Bigalke 1984). Fire may be considered the most important ecological process and management practice in fynbos ecosystems (recent reviews include Keeley *et al*. 2012 and Kraaij & van Wilgen submitted). Until recently, knowledge of fynbos fire ecology was largely based on the summer-autumn fire regimes of the western, winter-rainfall part of the CFK (Kruger & Bigalke 1984, van Wilgen & Viviers 1985) and the inland, arid mountains (Bond *et al*. 1984, Midgley 1989, Seydack *et al*. 2007). However, the climate in the eastern coastal-CFK, where the GRNP is situated, is milder and rainfall occurs year-round, with presumed effects on fire regimes. A recent research programme improved understanding of fire regimes in eastern coastal fynbos shrublands and provided guidelines for ecologically sound management of fire in the area (Kraaij 2012, Kraaij *et al*. 2013a-d; see 7.4). Earlier (unpublished) accounts of historical fire regimes in the area include those of Le Roux (1969), Marshall (1983), and Brink (1990).

Along the coastal slopes of the eastern Outeniqua- and Tsitsikamma Mountains, plantation protection has historically enjoyed priority over fynbos conservation, influenced by the large extent of plantations in these mountains (Kraaij *et al*. 2011). Fynbos close to plantations has therefore most likely been compromised by short-rotation and low-intensity burning in the past, as well as by invasion by alien trees (Kraaij *et al*. 2011). In terms of area burnt during the period 1900–2010, natural (lightning-ignited) fires dominated the fire regime, particularly in the Tsitsikamma, whereas prescribed burning was relatively unimportant (Kraaij *et al*. 2013a). Typical fire return intervals (FRIs) in the fynbos of the GRNP during the period 1980–2010 were 8–26 years, which are broadly comparable to those in other fynbos protected areas (Seydack *et al*. 2007; van Wilgen *et al*. 2010). FRIs appeared to be shorter in the Tsitsikamma where rainfall and plant growth rates are higher, than in the Outeniqua (Kraaij *et al*. 2013a). Proteaceae juvenile periods (4–9 years) and minimum FRIs to ensure pre-fire maturation and thus successful post-fire recruitment of proteoids in eastern coastal fynbos (Kraaij *et al*. 2013c) were also similar to those from other parts of the CFK (van Wilgen *et al*. 2011). The total area burnt annually in the fynbos of the GRNP has increased significantly since 1980 (Kraaij *et al*. 2013a) and coincided with an increase in weather conditions conducive to fires (Kraaij *et al*. 2013b), suggesting that fire regimes may be responding to climate change. Increases in fire frequency or extent (Forsyth & van Wilgen 2008) and in the severity of fire danger weather conditions (Wilson *et al*. 2010) have similarly been observed elsewhere in the CFK, although evidence is not unequivocal across all meteorological variables affecting fire danger weather (Hoffman *et al*. 2011).

Fire occurrence was more seasonal (concentrated in the summer months) in the Outeniqua than in the Tsitsikamma. An analysis of long-term weather data showed that low or moderate fire danger conditions are the norm year round (Kraaij *et al*. 2013b), and even large fires occurred under these conditions. Fire danger weather peaked in winter (due to low rainfall and the prevalence of bergwinds) (Kraaij *et al*. 2013b), but these conditions were not associated with a winter fire regime (Kraaij *et al*. 2013a). Lightning occurred throughout the landscape at fairly low densities and in all seasons, increasing somewhat during the summer months (Kraaij *et al*. 2013b). Fire season did not have a strong or consistent effect on post-fire recruitment success of serotinous Proteaceae in eastern coastal fynbos (Midgley 1989; Heelemann *et al*. 2008; Kraaij *et al*. 2013c), which is in strong contrast to the responses to fire season of western and inland fynbos where summer-autumn fires result in optimal recruitment (Bond *et al*. 1984, Van Wilgen & Viviers 1985, Midgley 1989). Collectively, findings on the seasonality of actual fires (Kraaij *et al*. 2013a) and the seasonality of fire danger weather, lightning (Kraaij *et al*. 2013b), and post-fire proteoid recruitment (Kraaij *et al*. 2013c) suggest that the fire regime in eastern coastal fynbos is not limited to any particular season.

Fire and fynbos-thicket and fynbos-forest mosaics

Fire is important for the maintenance of dune fynbos-thicket mosaics found along the Cape south- and southeast coasts (Helme 2005). In these dune thicket and dune fynbos mosaics, dune thicket typically occupies fire-protected sites (such as calcrete outcrops or the northern base of dunes) while the more combustible dune fynbos is often associated with fire-prone, usually wetter, locations (Helme 2005). Dune fynbos-thicket is subject, on average, to summer-autumn fires at intervals of 10–20 years, although extremes of 4–40 years are also possible (Pierce & Cowling 1991), with all components of the fire regime showing considerable variation (Cowling 1984). Dune fynbos-thicket needs fire at appropriate intervals (15-25 years according to Wessels & Wolf 2009) as it gets replaced by subtropical thicket in the prolonged absence of fire (Cowling 1984). In dune fynbos-thicket mosaics, most thicket species resprout after fire, while non-sprouting shrubs are mostly dependent on soil-stored seed banks for post-fire regeneration. Germination of six non-sprouting shrubs with small seeds (*Agathosma apiculata, A. stenopetala, Felicia echinata, Metalasia muricata, Muraltia squarrosa, Passerina vulgaris*) in Eastern Cape dune fynbos was not directly cued to fire although removal by fire of the insulating effects of vegetation stimulated germination (Pierce & Cowling 1991). Seed inputs and losses varied widely from year to year, suggesting that fires in different years and seasons would favour recruitment of different proportions of species. Seed bank unreliability in dune fynbos shrubs thus provides a mechanism for the coexistence of trophically equivalent species and over time, contributing to the maintenance of high species richness in these environments (Pierce & Cowling 1991).

Afromontane forest in the CFR typically occurs within a matrix of fire-prone fynbos, and is considered to be fire-free or, at the least, fire-resistant (Geldenhuys 1994a). Afromontane forest within the CFR is most extensive in the eastern coastal zone, occurring largely on the coastal plateau along the foothills of the mountains, and elsewhere in fire refugia such as sheltered ravines, stream banks, scree slopes and bergwind shadows in the mountains (Geldenhuys 1994a). Although fuel loads in mature (12 year old) fynbos (15 tonnes ha^{-1}) may be only half those in adjacent forest (35 tonnes ha-1), the physical and chemical make-up of fuels favours fire in fynbos but not in forest (van Wilgen *et al*. 1990). Under conditions of severe drought, surface fires may occur in forests, where they kill trees by burning their root systems (van Wilgen *et al*. 1990). Hot, dry, katabatic bergwinds furthermore periodically occur in the area and are capable of desiccating most fuels to the extent that they will burn. The distribution of forest patches within the fynbos matrix has accordingly been explained on the basis of fire refugia in relation to topography and bergwind corridors (Geldenhuys 1994a). Forest patches occurring in fire-prone fynbos are characterised by abrupt margins which are maintained by fire (Geldenhuys 1994a). These margins may be scorched by fires and the degree of penetration into the forest will depend on the intensity of the fire in the adjacent vegetation. In the case of small forest patches or narrow riparian forests, the entire patch could be scorched by an intense fire in the adjacent fynbos, even though the patches themselves do not support fires (van Wilgen *et al*. 1990). While frequent fires in adjacent fynbos would prevent the establishment of forest trees along the margin, long fire-free periods would allow forest expansion into fynbos, although larger fuel loads in older fynbos would sustain more intense fires that would potentially be more damaging to the forest margin. Coetsee & Widgley (2013) argues that the forest species, *Virgilia divaricata* may facilitate forest expansion into fynbos by enriching fynbos soils.

6.5.2 Nutrient dynamics

See Cowling (1992) and Allsopp *et al*. (2014) for reviews of nutrient dynamics in fynbos ecosystems. No work has been done on this topic in Garden Route fynbos in particular.

6.5.3 Reproductive biology and dispersal

See Le Maitre & Midgley (1992), Allsopp *et al*. (2014.) and a special issue of the *South African Journal of Botany* (Vol. 75, Issue 4, October 2009) for reviews of fynbos reproductive ecology (including pollination and dispersal). Virtually no work has been done on this topic in Garden Route fynbos in particular apart from Kraaij *et al*.'s (2013c) determination of the juvenile periods of serotinous Proteaceae in relation to estimation of minimum fire return intervals (see 6.5.1). Karlsson & Milberg (2007) studied the germination preferences and seed dormancy patterns of *Papaver aculeatum* collected at Rondevlei in order to assess its invasive potential elsewhere in the word.

6.5.4 Alien invasion

Invasion by alien plants is one of the biggest threats to the conservation of fynbos ecosystems, including those of the GRNP (see 7.5.1; Grindley 1985; Jeffery & Hilton-Taylor 1990; Cowling *et al*. 2009; GRNP management plan 2010, Kraaij *et al*. 2011). General reviews of the topic include Richardson *et al*. (1992), van Wilgen *et al*. (2008), Van Wilgen (2009), and Allsopp *et al*. (in prep.). Alien plants that become invasive in fynbos are of necessity fire-adapted. The most problematic species are trees and shrubs of two types. The first are serotinous pines (*Pinus* species) and hakeas (*Hakea* species) that are spread mainly by mass seed release following fires. The seeds of both *Pinus* and *Hakea* are winged, and can disperse over considerable distances post-fire, assisting their establishment in remote areas, where access for control is difficult.

The second type includes trees and shrubs in the genus Acacia, which produce copious amounts of hard-coated, long-lived, soil-stored seeds. These seeds are stimulated to germinate by fires, resulting in dense impenetrable stands after a few fire cycles. Besides impacts on biodiversity and water resources (van Wilgen *et al*. 2008), invasive alien plants can increase above-ground biomass, thus adding to fuel loads and increasing fire intensity under certain conditions, leading to undesirable impacts such as soil damage, erosion (Scott *et al*. 1998), and increased difficulty of fire control. The large extent and long history of plantation forestry in the Garden Route significantly contributed (and continues to do so) to the severity of the invader plant problem in the area (Cowling *et al*. 2009; Kraaij *et al*. 2011). Studies on alien plant invasion in the Garden Route are summarised here.

Reductions in water runoff due to alien plant invasion vary according to the age and density of infestations, the nature of the vegetation that is replaced, and the position of infestations in the landscape, with the greatest impacts occurring in riparian areas. Preliminary assessments suggested that alien plants use approximately 10% of the mean annual runoff in the primary catchment areas of the southern Cape (Le Maitre *et al*. 2000). In the Keurbooms River catchment, where 54% of the area was invaded by *Pinus* and *Hakea* to some degree in 1999, the reduction in natural river flow attributed to these invasions was estimated at 22% (Le Maitre *et al*. 2002). If the catchment was allowed to be further invaded (up to 77%), the projected reduction in river flow would increase to 96%. Preliminary assessments suggested that the removal of alien plants at Soetkraal produced noticeable improvements in the rivers and their functioning within a few years in the form of restored wetlands and seeps around the river channel (Gelderblom & Rowlinson 1999). Cost-benefit analyses of the Working for Water Programme and pricing of water resources have been done for the Tsitsikamma Mountain Catchment to the east of Soetkraal (Hosking & du Preez 1999, 2002, 2004). Integrated water saving over a 20-year period in the Tsitsikamma catchment was estimated at 1 300 million m3 (Campbell *et al*. 2005).

It was shown along the northern slopes of the Outeniqua Mountains that slashing and burning of *Hakea sericea* can successfully control this alien invasive shrub in fynbos, but due to increased fuel loads and thus fire intensity, undesirable impacts such as soil damage and erosion may occur (Breytenbach 1989). Using historical photography and satellite imagery, Moeller (2010) established that alien invasive tree cover (primarily *Pinus* and *Acacia mearnsii*) more than doubled between 1986 and 2007 in a quaternary catchment (K90B) adjacent to the Witelsbos State Forest and plantations in the Tsitsikamma. Moeller (2010) also studied perceptions of local dairy farmers of the effects that alien trees, compared to indigenous fynbos, have on groundwater levels. Hutchinson (2010) proposed a payment for ecosystem services scheme as a solution to fund the restoration of these invaded catchments and investigated the willingness of dairy farmers to financially support the clearing and restoration of catchment areas for the incentive of increased water supply for farms. Hugo (2011) and Hugo *et al*. (2012) report on the effects of alien plant invasion associated with plantation forestry on plant and dragonfly communities in wetlands of the Tsitsikamma.

6.5.5 Climate change

An analysis of long-term daily weather data at four weather stations (George 1946-64 & 1978-2010, Knysna 1997-2010, Plettenberg Bay 1993-2010, and Port Elizabeth 1939-2010) in the Garden Route showed that weather conditions conducive to fires (expressed as McArthur forest fire danger index, calculated from daily maximum temperature, minimum relative humidity, wind speed at mid-day, and rainfall) increased significantly in the long-term in terms of mean annual values and the number of days with fire danger being moderate or higher (Kraaij *et al*. 2013b). With respect to individual weather parameters, minimum relative humidity decreased significantly at all four stations, while changes in other weather parameters were more variable (Kraaij *et al*. 2013b). Temperature increased significantly at George and Port Elizabeth at rates (0.01-0.02°C year-1) comparable to that measured elsewhere in the CFK (Hoffman *et al*. 2011). Wind speed at mid-day mostly increased contrary to the decrease in wind run reported by Hoffman *et al*. (2011) for 20 weather stations across the CFK.

These authors found consistent increases in temperatures throughout the CFK, but no decline in rainfall, while evaporation and wind run have decreased. The trends predicted by Midgley *et al*. (2003) for the CFK and observed by Kraaij *et al*. (2013b) and Wilson *et al*. (2010) are likely to manifest in increased fire frequencies or severity, although evidence is not unequivocal across all meteorological variables affecting fire danger weather (Hoffman *et al*. 2011). Midgley *et al*. (2003) used bioclimatic modelling to forecast potential climate change impacts on select Proteaceae species in the CFK in order to guide conservation responses.

Apart from changes in long-term averages, climate change is often predicted to manifest as increases in extreme events. The most intense rainfall event in recorded history in the Garden Route (resulting in destructive flooding throughout the region) was that of 1 August 2006, when 230 mm of rain was recorded on a single day in George (Mélice & Reason 2007). The return period of such an extreme event was estimated to be 1 222 years (Mélice & Reason 2007). However, a comparable event occurred the following year with 201 mm of rain recorded in George on 21 November 2007 (South African Weather Service, Unpubl. data).

7. MANAGEMENT PRACTICES

A survey of the management effectiveness of South African National- and Provincial Parks found that the most common and fundamental problem affecting these parks is a lack of management capacity, especially with respect to the inadequacy of: (i) funding, (ii) personnel, and (iii) equipment/infrastructure (Pasquini 2004). There is also a need for increased participation of local communities, NGOs and private stakeholders in reserve management.

7.1 Landuse planning / zonation

The primary objective of a park zoning plan is to establish a coherent spatial framework in and around a park to guide and co-ordinate conservation, tourism and visitor experience initiatives (Management plan 2012). A zoning plan plays an important role in minimizing conflicts between different users of a park by separating potentially conflicting activities whilst ensuring that activities which do not conflict with the park's values and objectives (especially the conservation of the protected area's natural systems and its biodiversity) can continue in appropriate areas. A zoning plan is also a legislated requirement of the Protected Areas Act, which stipulates that the management plan must contain "a zoning of the area indicating what activities may take place in different sections of the area and the conservation objectives of those sections".

The zoning of Garden Route National Park (*Appendix 18*) was based on an analysis and mapping of the sensitivity and value of the park's biophysical, heritage and scenic resources; an assessment of the regional context; and an assessment of the park's current and planned infrastructure and tourist routes/products; all interpreted in the context of park objectives (Management plan 2012).

SANParks has adopted a dual zoning system for its parks. The system comprises:

1. Visitor use zones covering the entire park, and
2. Special management overlays which designate specific areas of a park that require special management interventions.

The zoning for Garden Route National Park is comprehensively set out in the Management Plan (2012) and was underpinned by an analysis and mapping of the sensitivity and value of the biophysical, heritage and scenic resources.

Remote Zone: This is an area retaining an intrinsically wild appearance and character, or capable of being restored to such and which is undeveloped and road less. There are no permanent improvements or any form of human habitation. Remote areas were designated in the mountainous Soetkraal potions of the Tsitsikamma area, as these areas are both logistically difficult for development and sensitive to development pressures (in particular disruption of catchment areas), as well as the coastline east of the Dolphin Trail, which is visually and aesthetically isolated from these transformed landscapes on the plateau above.

Primitive Zone**:** The prime characteristic of the zone is the experience of wilderness qualities with access controlled in terms of numbers, frequency and size of groups. The zone shares the wilderness qualities of the Remote zone, but with limited access roads, hiking trails and the potential for basic small-scale self-catering accommodation facilities such as small bush camps or trail camps. The controlled access Otter and Dolphin trails are in this zone, as well as the controlled, vehicle access routes in the Soetkraal area. Primitive areas were designated to protect the high conservation value and Ramsar listed Rondevlei, Bo-Langvlei and surrounding areas, in the Wilderness area, from tourist and infrastructure impacts. Most forest and fynbos areas identified as environmentally sensitive, that were not included in the Remote zones or subject to existing infrastructure impacts, were include in the Primitive Zone. This included the bulk of the indigenous Harkerville forest as well as forest and fynbos areas north of Knysna.

Quiet Zone**:** This zone is characterized by unaccompanied non-motorized access without specific access control and permits. Tourist infrastructure is limited to trails, viewpoints and hides. Larger numbers of visitors are allowed than in the Primitive zone and contact between visitors is frequent. It is important to note that this zone may have different interpretations in different parks and each park should set the objectives specific to that park. The conservation objective is to maintain the zone in a generally natural state, with the proviso that limited impacts on biodiversity patterns and processes are allowed in order to accommodate park recreational and tourism objectives. Quiet zones were designated to allow visitors access on foot to hiking trails around the higher use Low intensity leisure areas and the major access nodes such as Nature's Valley and Storms River. Sections of beach away from major access points (such as west of Gericke's Point) were also zoned Quiet. River areas limited to non-motorized access such as the Touw River above the railway bridge were zoned as Quiet. In the forest areas previously managed by DWAF, Quiet zones were designated around the access points and development nodes at Goudveld, Gouna, Diepwalle and Harkerville to encourage non-motorised tourist access to these areas. Sensitive estuary areas such as the Salt River and the Groot River were included in this zone to preclude infrastructure development. As far as possible, the sensitive sections of the park which were not included into the Primitive zone were zoned Quiet to protect them from infrastructure development and excessive tourist impacts.

Low Intensity Leisure Zone**::** The underlying characteristic of this zone is motorized self-drive access with basic self-catering facilities. The numbers of visitors are higher than in the Remote and Primitive zones. These camps are without modern facilities such as shops and restaurants. The conservation objective is to mitigate the biodiversity impacts of the relatively high levels of tourism activity and infrastructure that are accommodated within this zone through careful planning and active management, and to ensure that both the negative effects of the activities and infrastructure are restricted to the zone, and that the zone is maintained in a generally natural state that is in keeping with the character of a Protected Area. In lake and estuary areas, Low intensity leisure implies that motorized vessels are generally allowed, but they may be excluded from certain sections either to minimize environmental impacts or to reduce conflict with other recreational water users. Low intensity leisure areas were designated in most of the high use beach areas of the park (except around the Touw River mouth), in the area between the Touw River mouth and the Ebb and Flow Rest camp, Eilandvlei, Swartvlei, Sedgefield Lagoon, and large portions of Knysna Estuary. Park infrastructure at Rondevlei is accommodated within this zone. In lake and estuary areas, In the areas previously managed by DWAF, low intensity leisure areas were designated along the access routes to Diepwalle (including Kom se Pad), the Diepwalle tourism facilities, Gouna, Goudveld and its access, a section of the Harkerville forest near the N2 identified for potential development, the “Big Tree” boardwalk area which allows high numbers of visitors easy access to forested areas, as well as the access routes to Krantzkloof. Most of the Low Intensity Leisure areas represent existing development nodes and access routes to the major forest stations.

High Intensity Leisure Zone**:** The main characteristic is that of a high-density tourist development node with amenities such as shops, restaurants and interpretive centres. This is the zone where more concentrated human activities are allowed and is accessible by motorized transport on high volume transport routes. The conservation objective is to ensure that the high levels of tourism activity and infrastructure that are accommodated within this zone have a minimal effect on the surrounding natural environment. Limited High Intensity Leisure areas were designated in Garden Route National Park. These are the Storms River Mouth Camp (including the staff and administrative areas), Ebb and Flow Camp and the Touw River Mouth.

Overview of the Special Management Overlays of Garden Route National Park

Special management overlays which designate specific areas of the park that require special management interventions were identified. Three overlay types were designated namely Special Conservation Areas, Resource Use Management Areas and Aquatic Access and Activity Control Areas. In the Management Plan (2012) numerous specific areas are currently designated in each of these categories within the park, and others may be designated by park management when required.

Special Conservation Areas – Forest Special Protection: Particular areas of specified forest types were designated for special protection in order to reduce the risk of habitat loss and mitigate any ongoing environmental impacts.

Special Conservation Areas – Wetlands: High conservation value wetlands such as Rondevlei, Bo-Langvlei, Eilandvlei, the Serpentine channel and floodplain, and Swartvlei Estuary below the railway line were identified for special protection in order to reduce any potential habitat loss and minimize tourist and development impacts.

Special Conservation Areas – Catchments: The Palmiet River catchment in the Soetkraal section was designated for special protection to strictly control any development, tourism activity or management activity which may impact on the river (including its catchment and especially the riparian zone) and its biota.

Resource Use Management Areas – Fishing exclusion area: Rondevlei, Bo- Langvlei and the channels between them were designated as fishing exclusion areas to prevent impacts associated with fishing and bait collection.

Resource Use Management Areas – Bait collection exclusion area: The eastern sections of Knysna Estuary were designated as a bait collection exclusion area to prevent impacts associated with bait collection.

Resource Use Management Areas – Marine Restricted: The marine areas of the park except the Groot River estuary, the marine areas west of Nature’s Valley and Nature’s Valley beach were classified as Restricted Marine Protected Areas in accordance with the appropriate legislation (Marine Living Resources Act & National Environmental Management: Protected Areas Act). Effectively this declares the areas a “no-take” zone for any marine living resources.

Resource Use Management Areas – Marine Controlled: The remaining marine areas of the park were identified as Marine Controlled areas. These are currently managed Marine Controlled areas under the PAA legislation, but it is proposed that these areas will also be officially declared Controlled Marine Protected Area within the Marine Living Resources Act. Specified and strictly controlled use of marine living resources is allowed in this zone.

Resource Use Management Areas – Terrestrial: Certain terrestrial areas within the GRNP have been identified for resource use. These areas are mainly located in the Indigenous Forest Areas and Mountain Fynbos areas where historical resource use has taken place. The products identified for resource use include timber; ferns; and certain fynbos species. Additional products are currently being assessed for resource use. These products include species to be harvested for medicinal purposes.

Aquatic Access and Activity Control Areas – Speed controlled areas: Touw River Mouth to Railway Bridge has limits on equipment type and speed (maximum of 5 HP, idle speed only, or electric motor). Lower areas of Swartvlei such as Kingfish Drive Slipway have an idle speed only restriction.

Aquatic Access and Activity Control Areas – Motorised vessel exclusion areas: Canoes are allowed, but motorized boats are prohibited. For example, the Railway Bridge to Waterfall on the Touw River and the mouth region of the Swartvlei Estuary.

Aquatic Access and Activity Control Areas – Jetski exclusion areas: Motorized boats are allowed, but jet-skis are prohibited. This layer is applied on Island Lake.

Aquatic Access and Activity Control Areas – Skiing exclusion areas: Motorized boats are allowed, but skiing is prohibited.

Aquatic Access and Activity Control Areas – Exclusion areas: All vessels are excluded from these areas (including canoes and motorized boats). This layer is applied in Swartvlei, close inshore along the northern and southern banks of the lake.

The management plan expands on the Park Buffer Zone which is the identified area within which activities have an influence on the park. The GRNP has three Buffer Zone categories, namely, Priority Natural Areas, Catchment protection and Viewshed protection. The details and development guidelines are provided in the GRNP Management Plan (2012).

The zoning for Garden Route National Park needs to be seen in the context of the consolidation of this relatively young park. This rapidly changing context will potentially require re-assessment of the current park zoning. The current park use zonation is based on the same biodiversity and landscape analyses undertaken for a Conservation Development Framework (CDF); however certain elements underlying the CDF such as a tourism market analysis are not be fully incorporated into the park use zonation.

7.2 Terrestrial vegetation conservation

7.2.1 Fynbos

Management of fynbos for biodiversity conservation largely centres on the management of fire (see 7.4) and alien invasive plants (see 7.5.1), and in few cases deals with individual plant species of conservation concern (see 7.7.1).

7.2.2 Forest

European settlers began exploiting the Garden Route forests in about 1750, and government attempts to control timber harvesting began during the late 1770s. The history of indigenous forest management in the Garden Route has been documented in some detail by various authors, including Sim (1907), Laughton (1938), Phillips (1963), Von Breitenbach (1968), Brink & Van der Zel (1980), Van der Merwe (1998) and Seydack & Vermeulen (2004). The harvesting of timber by the woodcutters was stopped in the government-managed forests in 1939. The Forestry Department continued with harvesting on a limited scale, but the further development of management systems for the indigenous forests was largely ignored until the 1960s, when a comprehensive indigenous forest management system was developed and implemented (Von Breitenbach 1968). The subsequent development and implementation of management systems were described by Von dem Bussche (1975), Geldenhuys (1982a), Grewar (1983), Van Dijk (1987), Heynes (1995), Seydack & Vermeulen (2004) and others. Today the forests in the Garden Route National Park are managed according to a formal multiple-use system with close monitoring to ensure sustainable use (Seydack 1995; Seydack et al.1995).

The GRNP is divided into three management sections, namely Wilderness, Knysna, and Tsitsikamma, arranged from west to east, which each include different land cover types, such as forests, fynbos, lakes, estuaries and marine areas. Each section includes portions of several forest complexes that are subdivided into smaller management units called blocks, and further subdivided into compartments and sub-compartments for the purposes of description, practical management and data collection. Permanent features such as land cover, forest margins, rivers, roads and slipping paths serve primarily as compartment boundaries. Detailed management maps are available for all areas.

Each compartment or sub-compartment has been allocated to one of five management classes according to the nature of the resource (e.g. vegetation or forest type, location, accessibility, site factors and ecological constraints), and the required or desired long-term management objectives for the particular compartment. The management classes determine which land uses and activities are acceptable and which are prohibited. The management classes are as follows:

- A Timber utilisation (ecologically less sensitive moist and medium moist high forest compartments where timber exploitation is practically feasible (regarding slope and accessibility) and the growing stock potential is favourable for timber utilisation),
- B Protection (mainly compartments of the drier and wetter forest types not suitable for timber utilisation because of their ecological sensitivity and the nature of growing stock),
- C Nature Reserves (representative examples of all the forest types and adjacent fynbos areas have been set aside and are managed as biological reserves),
- D Recreation (compartments of any forest type where high intensity outdoor recreation activities are concentrated) and
- E Research (compartments used specifically for long-term ecological or silvicultural research).

Forest management activities include landscape and ecosystem protection, forest edge management, alien invasive plant control, environmental restoration, fauna management, nature reserve management, forest product utilization, tourism and outdoor recreation, maintenance of infrastructure, and monitoring and research.

Monitoring is an integral part of the management systems applied in the forests. The monitoring programme has been developed over several decades to provide information on natural changes occurring in the ecosystems, the effects of management activities on the ecosystems, and the effectiveness of management activities. Monitoring results are used to change or refine the management systems to ensure that the valuable natural resources are managed sustainably. Most of the projects in the Garden Route were established for long term monitoring, i.e. to gather and provide information for several years, and in many cases, for several decades. This is important because of the slow rates of natural change in the forests, the long periods between management interventions for some activities (e.g. the 10-year felling cycle for timber) and the relatively light impacts of most of the management activities. Some low impact changes may only be detected after several monitoring events, i.e. after several decades. The forest monitoring programme includes the following projects:

- Forest dynamics monitoring is carried out to observe the natural processes occurring in the forest, such as long-term changes in the species composition of the forest, growth rates, regeneration, mortality and condition of the forest. Monitoring sites include the Diepwalle research areas (Van Daalen 1991), the Tsitsikamma strip plots, permanent sample plots (PSPs) in nature reserves and timber utilization areas (Seydack *et al*. 2011, 2012), and a national system of permanent forest plots (Seydack 1991; Vermeulen 2000).
- Forest gap dynamics monitoring investigates the effects of different types of disturbances and canopy gap sizes on the regeneration of forest species. These projects include a gap dynamics research project, the monitoring of the gap caused by the collapse of one of the big trees at Storms River, photo-monitoring of burnt forest areas at Groenkop, Bergplaas and Whiskey Creek and the Koomansbos fire gap (Vermeulen 2000).
- Forest establishment: The Diepwalle arboretum, established in 1926 (Lübbe & Geldenhuys 1991), is still maintained.
- Utilisation of forest products: Long term monitoring of yields, growth rates and regeneration is important to ensure that harvest levels and mixes of products are sustainable. The effects of timber harvesting are monitored in timber utilisation areas by means of permanent sample plots, full count monitoring and post-harvest audits. Various monitoring projects have produced valuable information on long-term changes within the natural fern populations. Other projects evaluate the effects of harvesting tree bark and *Bulbine latifolia*, a medicinal plant.
- Blackwood (*Acacia melanoxylon*) monitoring was established to ensure a conclusive knowledge base for sound decision making on aspects of blackwood control and utilisation.

Fauna monitoring projects include forest antelope population monitoring, rare mammal monitoring, crowned eagle monitoring, elephant monitoring and biomonitoring in rivers.

7.3 Estuarine management

The GRNP Management Plan (2012) contains the implementation plan for estuary management. This plan details the artificial manipulations of the estuary mouths, the cutting of aquatic plants in the Wilderness lake system, sediment removal in the Touw system, wetland rehabilitation, law enforcement, resource use, boat launching and mooring sites, and pollution inputs.

The objectives, purpose and context behind the artificial manipulation of the estuaries is explained in detail (Management Plan 2012). The main objective being to reduce the probability of flood damage to properties built close to the water edge. The history, and current methods used for breaching the Touw River Estuary are given in Fijen (1995a) and for Swartvlei Estuary in Fijen (1995c). The initial recommendations for the management of the Wilderness lakes and their catchments are given in CSIR (1978a), Howard-Williams & Allanson (1979), Jacot-Guillarmod & Allanson (1981), CSIR (1981, 1982), Allanson & Whitfield (1982), Whitfield *et al*. 1983, and Fijen & Kapp (1995b). Management actions include the sandbar skimming, preparation and breaching of the estuaries. Breaching of the Touw Estuary using heavy earth moving equipment is undertaken when water levels in the estuary are between 2.1 and 2.4 m amsl as recommended in CSIR (1981) and CSIR (1982). Swartvlei Estuary is breached using heavy earth moving equipment when water levels in the estuary reach 2.0 m amsl as recommended in CSIR (1978a), and Whitfield *et al*. (1983). Premature breaching is only considered under certain special circumstances (Management Plan 2012).

The cutting of aquatic plants increases connectivity between water bodies in Wilderness lakes system and stimulates disturbance to selected sites, reducing the trend towards single species domination in the system (Management Plan 2012). The removal of sediment from the Touw system also serves to increase connectivity.

Law enforcement pertaining to resource use in the estuarine systems is addressed along with the relevant management actions required. Boat launching and mooring sites, as well as potential pollution inputs are addressed, providing the relevant management actions (Management Plan 2012).

7.4 Fire management

Kraaij *et al*. (2011) outlined the history of fire management within the mountain catchments of the Garden Route, mostly prior to the establishment of the GRNP, while Van der Zel (1980), Seydack *et al*. (1986) and Southwood (1984) covered management policies pertaining to the area during the 1980s. Given the GRNP's location within in a landscape where indigenous forests, fire-prone fynbos shrublands and fire-sensitive plantations of invasive alien trees are interspersed, the park faces considerable challenges related to the management of fire. These include significant pressure from the adjacent plantation industry to reduce wildfire hazard by burning fynbos at short intervals and under cool, safe conditions, and high levels of invasion by alien trees (largely Pinus species originating from plantations) (Kraaij *et al*. 2011). Kraaij *et al*. (2013d) proposed thresholds of potential concern for the management of fire in GRNP fynbos, based on results of a research program that has considered (i) historical fire regimes (Kraaij *et al*. 2013a), (ii) weather and lightning as drivers of fire (Kraaij *et al*. 2013b), and (iii) the vegetation's response to fires at different intervals (Kraaij *et al*. 2013c) and in different seasons (Kraaij 2012). Proteaceae juvenile periods (4–9 years) and post-fire recruitment success (following fires in ≥7 year-old vegetation) suggested that for biodiversity conservation purposes, FRIs should be no less than nine years in moist, productive proteoid fynbos in the Tsitsikamma area of the park, and it is likely to be longer in drier habitat types (Kraaij *et al*. 2013c; cf. Hugo *et al*. 2012). All available evidence (see 6.5.1) suggested that the fire regime in eastern coastal fynbos is not limited to any particular season and therefore management is not constrained by fire season, although the ecological requirements for adequate fire intensity remain (van Wilgen *et al*. 2011). The frequent recurrence of very large fires since the 1990s and the virtual absence of vegetation in older post-fire age classes (as assessed in 2011) in GRNP fynbos were considered to be potential causes for concern in achieving fynbos conservation objectives (Kraaij *et al*. 2013d).

The management of fire in the fragmented lowland fynbos (>140 relatively small, isolated or fragmented patches) of the GRNP is dealt with by Kraaij & Vermeulen (2010). The basic approach entails prescribed burning to be undertaken in artificially (human-induced) fragmented or isolated patches, while only lightning fires are to be allowed in naturally isolated fynbos islands (see 5.7.2). The management of these natural fynbos islands for biodiversity conservation has previously been neglected as they were considered anthropogenic in origin, and some have been converted to pine plantations (Midgley & Bond 1990). Sandberg (2013) and Sandberg *et al.* (2016) indicated the importance of fynbos fragments as resource refugia and stepping-stone habitats for avifauna, and argue that it should be managed for vegetation age, considering both plant and bird requirements. The fire ecology and management requirements of the dune fynbos-thicket mosaic along the coast also differ from that of montane proteoid fynbos. Expert opinion holds that much of the thicket that currently occurs in the lower-lying areas results from human practices (J.H.J. Vlok, pers. comm.). Alien shrubs (*Acacia cyclops* and *A. saligna*) that cover large parts of the coastal dunes (Victor *et al*. 2000) attract frugivorous birds, which disperse seeds of thicket species, thereby propagating thicket vegetation (Cowling & Pierce 1985). Landscape fragmentation, human-induced exclusion of fires, and past eradication of large herbivores further promote succession of fynbos to thicket (Cowling 1984). The dune fynbos cover state which contains several endemics (Cowling 1984) is therefore highly threatened (Pierce 1987, 1990) and prescribed burning is often required (Kraaij & Vermeulen 2010). In contrast, the fynbos on the steep coastal escarpment of the Tsitsikamma area has a large ericoid and sedge component, but very few Proteaceae (Hanekom *et al*. 1989). No prescribed burning is required for this fynbos and natural fires should be allowed to follow their course (J. Midgley pers. comm.; J.H.J. Vlok, pers. comm.).

7.5 Rehabilitation

7.5.1 Invasive alien species

Fynbos

Literature on fynbos rehabilitation (or natural recovery) focuses on that after clearing of invasive alien plant infestations (terrestrial, Holmes *et al*. 1987, 2000; Holmes 1989; 2001; Holmes & Richardson 1999; Holmes & Foden 2001; and riparian, Blanchard & Holmes 2008; Fourie 2008; Reinecke *et al*. 2008; Sieben & Reinecke 2008; Vosse *et al*. 2008), plantations, agricultural transformation (Holmes 2008), or fire (though considered here to be a natural process, rather than rehabilitation in the strict sense). Little research has been done in the Garden Route in particular. Dune fynbos in the Wilderness area of the GRNP has shown remarkable innate recovery potential after having been planted with *Pinus radiata* for approx. 40 years (Kraaij 2005). Flattening and artificial stabilisation (with the alien grass *Ammophila arenaria*) of the coastal foredune at Kleinkrans (Wilderness area of GRNP) for residential development decreased aeolian activity in this dynamic dunefield to a fifteenth of that in an adjacent natural area, while post-disturbance vegetation remained in a pioneer state (Masson 1991). Vlok (1987) described active (assisted) rehabilitation undertaken in mesic proteoid fynbos along roadsides in the Tsitsikamma during the upgrading of the N2, and provide recommendations based on the success of different measures implemented.

Control of invasive alien plants is arguably the biggest management challenge and operational undertaking (in terms of budget expenditure) in the terrestrial environment of the GRNP (Cowling *et al*. 2009; GRNP management plan 2010; Kraaij *et al*. 2011). Control measures, practices and procedures are largely based on studies done elsewhere but which are generally applicable to fynbos environments (see van Wilgen 2009 for a review of the evolution of alien plant management practices in fynbos).

Preliminary assessments suggest that alien plants use approximately 10% of the mean annual runoff in the primary catchment areas of the southern Cape (Le Maitre et al. 2000), and the removal of alien plants at Soetkraal produced noticeable improvements in the rivers and their functioning within a few years in the form of restored wetlands and seeps around the river channel (Gelderblom & Rowlinson 1999). Cost-benefit analyses of the Working for Water

Programme for the Tsitsikamma Mountain Catchment to the east of Soetkraal have been done (Hosking & du Preez 1999; 2002; 2004).

Forest

Most alien invader plants in the forest establish only in disturbed forest margins or large gaps in exploited forest (Geldenhuys *et al.* 1986). The control of invasions (or re-invasions) of alien plants into forests is primarily dependent on the maintenance of a closed forest canopy and a well-developed forest margin (Geldenhuys *et al*. 1986). The eradication of exotic plant invaders and the sustained prevention of re-invasion within or near the forest, however, remain one of the most important conservation management practices (Seydack 2000a, Vermeulen & Seydack 2000; Seydack 2002). Chemical, mechanical and biological control measures could be used with the eradication of invader species, but proper planning is essential to ensure long-term success (see Baard & Vermeulen 2000 for *Acacia melanoxylon* in the GRNP).

Australian Blackwood (*A. melanoxylon*), introduced as a timber species (Geldenhuys 1996), is a well-established in natural forest and surrounding areas in the GRNP (Vermeulen & Seydack 2000). In the GRNP a differential approach was followed with the eradication of the species as invader, depending on the invasive potential of the species in different habitats, also providing for the optimum use of the species as valuable timber tree (Vermeulen & Seydack 2000; Seydack 2002), but this is under revision following long-term monitoring of Blackwood spread (Moolman & Rikhotso 2014). Windfall damage caused by its large crown could be lessened by harvesting Blackwoods when they are smaller and before they become dominant Geldenhuys (1996, 1986). Felled trees result in coppice regrowth, but stump treatment is seldom required because of browsing activities by bushbuck that prevent further coppice development. The seed feeding weevil, *Melanterius acaciae,* was introduced from Australia in the mid-1980s to curb the high seed production of *A. melanoxylon*, thereby potentially reducing the regeneration and rate of spread of the species. The weevil was released in the Garden Route on *A. melanoxylon* in 1987 and is now well established in most forest areas in the region (Vermeulen & Seydack 2000).

Forest vegetation shows remarkably recovery potential following disturbance (Geldenhuys *et al*., 1986). Forest reconstruction could be aimed at the rehabilitation of destroyed forest areas, the reconversion of abandoned plantation areas to consolidate existing forest patches (Von dem Bussche, 1975; Geldenhuys, 1982a) and to consolidate the forest edge into manageable borders e.g. a road or river (Van Daalen, 1988). Von dem Bussche (1975) described three methods of reconstruction on different sites. Along narrow strips of moist and medium-moist forest fringes only regular elimination of alien vegetation is required for sufficient tree regeneration to occur. In wider belts, drier sites and other sites with sparse regeneration, a range of species is planted in scattered mixed groups, followed by intensive tending. In exposed sites, widely spaced blossom tree *Virgilia divaricata* is used as a nurse stand and planted up with other forest species. More detailed guidelines on the establishment of natural forest in the southern Cape (species, species grouping, spacing, etc.) are provided by Van Daalen (1988) and Geldenhuys & Bezuidenhout (2012). Geldenhuys (1994b) discusses the potential and requirements for the establishment of useful indigenous species on the forest edge, which would also support forest expansion and consolidation.

The slow growth of indigenous species established in a monoculture, and regeneration dynamics, is reported on by Lübbe & Geldenhuys (1991). The establishment of pure stands of indigenous species proved to be very expensive (Geldenhuys, 1975, 1982) and the artificial establishment of forest is thus not a common management practice. Stands of light demanding exotic species often serve as nurse stands for the establishment of shade tolerant, indigenous trees species (Van Wyk *et al*. 1995, Geldenhuys & Delvaux 2007). Geldenhuys & Bezuidenhout (2012) advocate the manipulation of such stands by the selective thinning of exotic trees (rather than total clearfelling) to facilitate growth and expansion of indigenous species towards forest establishment, where feasible. Van Wyk *et al*. (1995) report on forest expansion into a Eucalyptus belt on the forest margin at Groenkop Forest in the GRNP, but the regrowth forest was eventually destroyed by an adjacent fynbos fire. Exotic stand manipulated for forest development should thus be outside the natural fire zone where natural forest could be maintained in the landscape (Geldenhuys & Bezuidenhout 2012).

Aquatic

The alien Mediterranean mussel has displaced most of the indigenous brown mussel in the mid- and high-zones of the mussel beds on the Tsitsikamma coast (Hanekom Unpubl. data). After storm-driven dislodgement of mussels at Plettenberg Bay the Mediterranean mussel showed a much faster recolonization rate than the brown mussel (Erlandsson *et al*. 2006), and experiments done elsewhere suggest that selectively harvesting of the Mediterranean mussel causes only a small improvement in the recruitment / recovery of the indigenous mussel populations (Branch and Steffani 2004; Hanekom Unpubl. data). The above together with the prolific reproductive capacity and widely dispersing larvae of the Mediterranean mussel, as well as the ruggedness of the coastline makes it virtually impossible to implement an effective eradication/control programme that would meaningfully enhance the indigenous mussel population (Picker & Griffiths 2011). Nevertheless, because of a difference in spatial distribution on the shore, a small brown mussel population should be able to maintain itself in the lowest section of the mussel beds of the southern Cape (Robinson *et al*. 2005).

7.5.2 Wetlands

According to the Garden Route National Park's management plan (2011), the relevant objectives for wetland rehabilitation include:

- Rehabilitation of estuarine wetland areas with emphasis on the reestablishment of indigenous vegetation in intertidal and supra-tidal areas where changes have resulted from past landuse practices, system manipulation and extralimital invasion.
- To rehabilitate wetland systems in the GRNP
- To control accelerated erosion in the GRNP resulting from human activities

The purpose of wetland rehabilitation programs in the GRNP could include one or more of the following:

- Reinstate natural topography.
- Elimination of alien plants.
- Disposal of dumped material.
- Encourage of re-growth of indigenous vegetation.
- Erosion prevention
- Reinstate natural wetland processes
- Raise awareness of the importance and function of wetlands.

Due to the proximity of wetlands in the Garden Route National Park to towns and their associated infrastructure, wetlands are continuously under threat. The fragile nature and importance of wetlands is often not properly understood and the disturbance and infill thereof was historically not seen as problematic. In a number of cases this sentiment still exists today. It is of crucial importance that wetlands within the Park are not disturbed by, or lost to, any form of unnatural pressures.

It is foreseen that rehabilitation programmes could have positive environmental outcomes in the following instances:

- Re-establishment of indigenous vegetation where disturbance has taken place on estuary margins for e.g. infrastructure and other developments.
- Removal of defunct structures, jetty's, slipways, bridges etc.
- Re-establishment of indigenous vegetation in intertidal and supra-tidal areas where changes have resulted from past land use practices, for example the disused airfield on George Rex Drive on the Knysna estuary.
- Re-establishment of indigenous vegetation in areas where oyster racks have been removed in the Knysna estuary.
- Re-instatement of natural processes in influent rivers in the Knysna system to reduce sedimentation and pollution e.g. proposed Working for Wetland projects in the Bigai and Bongani streams.
- Rehabilitation of estuarine wetland areas with emphasis on the system manipulation and extralimital invasion.

Specific management actions are defined on project initiation and dependent of the availability of resources. Where remedial actions are undertaken by external agencies, SANParks operate in an advisory role during planning and implementation phases.

7.6 Human wildlife conflict management

The Garden Route National Park (GRNP) is predominantly made up of open access areas, which by its very design leads to potential for human-wildlife conflicts (SANParks 2012). The GRNP Management Plan (SANParks 2012) identified monkeys *Chlorocebus pygerythrus*, caracal *C. caracal*, baboons *P. ursinus*, bushpig *Potamochoerus larvatus* and porcupine *Hystrix africaeaustralis* as the animals most frequently involved in human-wildlife conflicts in the area.

Although a human-wildlife conflict management programme has been developed as part of the GRNP Management Plan, with the objective to minimize human-wildlife conflict in and around the GRNP through the development of an appropriate plan (SANParks 2012), very little scientific research has been done on human-wildlife conflict issues in the GRNP. Following is a description of the few studies that did address human-wildlife conflict issues.

Elephants *L. africana* have been affected by human-elephant conflict since an increasing human development in the area (Carter 1971, Roche 1996). Roche gives a historical account of Knysna residents' attitudes towards the elephants during the time spanning 1856 to 1920. Roche (1996) showed, through a comprehensive and systematic assessment of historical data that, although residents' clashes with elephant in the 1800s resulted in resentment and sometimes in elephant death, by the early 1900s attitudes started shifting to a more positive collective attitude towards elephant and consequent efforts to conserve them. Carter (1970) conducted an elephant population survey in 1969 and hypothesized that unless certain areas of the elephant range were fenced, that elephant/human conflict, especially in the Koffiehoek/Harkerville areas will increase with serious consequences to these elephants' survival. He described accounts of where elephant damaged people's property and gardens in the Harkerville area.

Although there is currently no direct human-elephant conflict in the GRNP, elephants do cause damage by removing signage boards, damaging fences, gates, and timber harvesting equipment (data unpublished). The GRNP Elephant Management Plan (Ferreira *et al*. 2011) highlighted the limited information on human-elephant conflict. According to Ferreira *et al*. (2011) it is likely that in neighbouring communities, conflicts could arise as a result of management actions directed at achieving other objectives. If this is so in future, incidences of damage caused by elephants are likely to be associated with spatial use of elephants that in turn are associated with the distribution of critical resources (Ferreira *et al*. 2011). One of the actions in the elephant Management Plan therefore sets out to spatially define potential human-elephant conflict (Ferreira *et al*. 2011).

A study by Braczkowski *et al*. (2012) provided a good example of how human development can alter an animal's feeding behaviour. They investigated the diet of leopards in the southern Cape forests in the Wilderness area of the GRNP and hypothesized that, although leopard-human conflict has not reached serious levels, increasing urban development in this area may change this in future (Braczkowski *et al*. 2012). They collected scats in forest, plantation and pasturelands, analysed these for species' remains and found that domestic cats were one of the three species preferred by leopards (Braczkowski *et al*. 2012).

Baboons and vervet monkeys often frequent rest camps and picnic sites in the park and are primarily attracted by food and refuse bins (SANParks, 2012). On occasions these animals do lose their fear of humans, resulting in "food grabbing" and raiding of chalets and tents (SANParks 2012). Park staff have embarked on a programme to raise awareness levels among park visitors about the problems experienced in these conflict areas with baboons and monkeys, and refuse bins were modified so that they are animal proof (SANParks 2012).

No studies have been done on human-baboon/vervet conflict in the GRNP to date. SANParks (Table Mountain National Park) has developed a baboon management plan with the main objectives setting out to address securing sustainable funding; enabling working partnerships;

implementing an effective monitor programme; ensuring research informs management; communication and education and waste management (SANParks 2009). Although human-baboon conflict in the GRNP has not reached serious levels as in the Cape, TMNPs experiences and baboon management plan could be used for future reference if the problem had to escalate in the GRNP.

7.7 Species of special concern

7.7.1 Threatened biota

7.7.1a Freshwater

Russell (2002) sampled six river systems in the Tsitsikamma area and recorded Eastern Cape Redfin *Pseudobarbus afer* and the Endangered Slender Redfin *Pseudobarbus tenius*. Swartz *et al*. (2007) has shown that *Pseudobarbus afer* comprises 4 distinct lineages which correspond with paleoriver systems. Specimens in the Garden Route area (Tsitsikamma, Knysna, Wilderness) form part of the forest lineage which in turn has four minor lineages.

7.7.1b Estuary

The Knysna seahorse *Hippocampus capensis*, classified as Endangered (Hilton-Taylor 2000), is widespread in Swartvlei and the Knysna estuary though not abundant. In a recent global revision of the seahorses, Lourie *et al*. (2016) maintained the status of *Hippocampus capensis* as a separate species in the *Hippocampus kuda* complex, even though meristic and genetic evidence does not separate it out as a separate species but instead combines it with *Hippocampus kuda*. The distinction between *Hippocampus capensis* and *Hippocampus kuda* was maintained because of the restricted distribution of the former, the worlds most endangered and only fully estuarine species. The three known estuary populations all exibit gentic differences; the Swartvlei population displaying the most distinct characteristics (Toefy 2000, Teske 2003, Teske *et al.* 2003, Mkare *et al*. 2017), although separation of the three populations into disctint management units was not recommended by Mkare *et al*. (2017).

Lockyear *et al.* (2006) estimated the Swartvlei adult population density to be 0.26 individuals m^{-2} (Jan-Feb 2002) and 0.04 individuals m^{-2} (Dec 2002- Jan 2003). Bell *et al.* (2003) estimated the adult population in the Knysna estuary 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 could not 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.

Bell *et al.* (2003) found *H. capensis* most frequently in low density vegetation stands (≤ 20% cover) and grasping *Z. capensis* but otherwise seahorse density could not be demonstrated to correlate with habitat type or depth. Teske *et al*. (2007) found seahorses to be associated with five dominant aquatic plants: *Zostera capensis, Caulerpa filiformis, Codium exticatum, Halophila* *ovalis* and *Ruppia cirrhosa*. Together these comprised 96% of the submerged objects with which seahorses were associated. Although these is some evidence that Knysna seahorses prefer certain plant species over others (Teske *et al*. 2007) they are likely to be encountered anywhere in the estuary where aquatic plants are present. It has thus been recommended that conservation efforts in the Knysna Estuary should concentrate on such vegetate areas.

Claassens (2015, 2016) found that the Thesen Islands marina, an artificial water body in Knysna provided suitable habitat for *Hippocampus capensis*, with significantly higher densities within the reno mattress habitat than adjacent vegetated and unvegetated areas.

Breaching of Swartvlei Estuary has been observed to result in the mortality of Knysna seahorses *Hippocampus capensis* with in 1985 in excess of 100 individuals washed up on the banks of the estuary, presumably killed by low salinity (<15 g kg^{-1}) (A. Whitfield pers comm.) which has been shown to be physiologically stressful for the species (Riley 1986). Most subsequent die-off's have involved less than 100 individuals (SANParks unpublished data) though the largest die-off occurred on the 18 February 1991, with mortality estimated to have exceeded 3000 individuals, resulting from high water temperatures (32°C) which occurred in the shallow marginal areas of the Swartvlei Estuary following an extended period of hot weather (Russell 1994).

7.7.1c Marine

A 3 km stretch of coast west of the Storms River Mouth rest-camp was closed to recreational angling in 2001 and the marine section from Groot River (east) to Groot River (west) was proclaimed as a Marine Protected Area (RSA Government Gazette No. 21948, 29 December 2000, Marine Living Resources Act (Act No. 18 of 1998). The no-take status of the MPA was decided in recognition of the growing evidence that extractive resource use is the biggest threat to the marine environment in the southern Cape (Lombard *et al*. 2004). The stock status of 14 angling fish species, which are recorded in the park, is regarded as collapsed in South Africa and in urgent need of protection (Wood *et al*. 2000; Mann 2000; SAMLMA 2001). As a consequence of this no bait collecting, fishing or spear fishing, except for approved research purposes, is allowed within the MPA. However, along the De Vasselot section of the park, these activities are permitted subject to the regulations of Marine Living Resources Act (1998). SANParks personnel have been appointed as fisheries control officers responsible for the enforcement of the Marine Living Resources Act. They undertake regular patrols to encourage compliance with the legislation in along the MPA and De Vasselot coast, and such activities are detailed in the Security and Safety Program section of the Management Plan. One of the major problems is the sporadic, illegal harvesting of abalone *Haliotis midae*, a CITES (Appendix III) species. Abalone stocks in South Africa are presently facing a severe crisis as a result of large scale poaching and ecological changes in parts of it distributional range (Griffiths *et al.* 2004). Special attention is paid to limiting poaching activities.

Table 2. Species recorded in the park whose stocks are regarded as collapsed.

Species name	Common name
*Chrysoblephus cristiceps**	Dageraaad
*Chrysoblephus gibbiceps**	Red stumpnose
*Chrysoblephus laticeps**	Roman
Chrysoblephus puniceus	Slinger
*Lithognathus lithognathus**	White steenbras
*Petrus rupestris**	Red steenbras
*Polysteganus undulosus**	Seventy-four
*Sparodon durbanensis**	White musselcracker
*Dichistius capensis**	Galjoen
*Epinephilus andersoni**	Catface rockcod
Epinephilus emarginata	Yellowbelly rockcod
Argyrosomus innodorus	Silver kob
Argyrosomus japonicus	Dusky kob
Atractoscion aequidens	Geelbek

Protection of the invertebrate and fish stocks in the reserve will also ensure an adequate supply of food for breeding seabirds. Three Near-threatened seabird species have been recorded breeding in the park, namely Cape cormorant *P. capensis*, African black oystercatcher *H. moquini* and in 2003 crowned cormorant *P. coronatus* (Crawford 1983; Whittington 2004). However, only the Cape cormorant breeds in substantial numbers (> 35 pairs). This species is endemic to southern Africa, and there are approximately 60 breeding colonies, which vary greatly in extent (Cooper *et al*. 1982; Berruti 1989). The Tsitsikamma colony is one of the smallest, but by restricting boating and fishing activity in the MPA the park provides an undisturbed breeding site for these birds

7.7.1d Terrestrial

Flora

Raimondo *et al*. (2009) published the fourth national Red List assessment. Threatened taxa, as a percentage of RSA's threatened flora, occurs most in the Western Cape (71.1%) and second most in the Eastern Cape (10.1%). This has implications for vegetation in the GRNP.

Baard & Kraaij (2012a) list 100 Species of Conservation Concern (SCC) and discusses plant SCC in the GRNP. Threats per taxa are assessed, as well as number of species per growth form and family. Monitoring and managing prescriptions are discussed as well as how the unique shape of the park increases potential threat. SCC that potentially occurs in the GRNP or surrounds were extracted from Raimondo *et al*. (2009) and are listed. A field guide of IUCN Red List Plant Species of the GRNP showing the various species and a concise description of the most important features are available for the GRNP (Baard & Kraaij 2012b).

A number of unique plant populations are found within the boundaries of the park. This includes disjunct populations of the forest species such as Prunus africana and Rothmannia globosa. Geldenhuys (1981) describes population dynamics of Prunus africana (Vulnerable) in the Bloukrans River Gorge. Two recent articles in Veld & Flora discuss recent finds (location, habitat and population dynamics) of Acrolophia lunata (Liltved, 2008) and Gasteria polita (Baard 2012b). G. polita is also discussed in Cactus World (Baard 2012c). A number of wide-spread species reach their most eastern (e.g. Platylophus trifoliatus) and western (e.g. Zanthoxylum davyi) distribution limit in the park (Geldenhuys 1992b).

Fauna

Of faunal Species of Special Concern, most work has been done on Blue duiker *P. monticola* and elephant *L. africana*.

Blue Duiker *P. monticola*

Forty-one terrestrial mammal species have been recorded for the coastal sector of the park. These include the Vulnerable Blue duiker *P.monticola* and six Near-Threatened species, namely the Honey badger *M. capensis*, Fynbos golden mole *A. corriae*, and four bat species. Those Red Data Book species that significantly benefit from the park are the Blue duiker *P. monticola* and the four insectivorous bat species which roost in caves in the park.

The GRNP is situated close to the southern distribution limit of the Blue duiker *P.monticola* (Skinner & Chimimba 2005), which is the most threatened of the terrestrial mammals in the park. Potential dangers to the local populations are dogs and poaching, as well as habitat fragmentation due to human activities on the borders of the park (Friedmann & Daly 2004).

Results from faecal pellet counts done between 1970 and 1997 in the Diepwalle State Forest suggest that the population densities of both Bushbuck *T. scriptus* and blue duiker *P. monticola* may undergo large temporal variations (Seydack *et al*. 1998). The possibility of such variations in antelope abundance, together with new environmental legislation in South Africa, has increased the need for conservation authorities to monitor the densities of important mammals in these forests. Consequently, faecal pellet counts are currently been done approximately every 10 years in eight forest reserves in the park. A failure to record Blue duiker in three or more forest reserve, will the regarded as a threshold of concern.

Management actions that could be undertaken should the threshold of concern be activated include:

- Undertake regular patrols to remove snares and identify sites where dogs are hunting.
- Erect boundary fences in key areas of the park to keep dogs out of the park.
- Remove any stray dogs.
- Attempt to influence development activities on the border of the park to reduce the fragmentation of the forest habitat.

7.7.2 Reintroduction of biota

Bontebok were introduced into the then “Lakes Nature Conservation Station” at Rondevlei (now incorporated into the GRNP) in 1973 (J.H. Glynn, pers comm.). The area is, however, marginal for bontebok, and the herd size rarely exceeded 15 individuals, despite the clearing of vegetated areas in the late 1970s in an attempt to create suitable grassland habitat (Cape Nature unpublished records). All but two of these animals were translocated to the Goukamma Nature Reserve in 1991, with the remaining two dying in the mid-1990s.

Two attempts at introducing antelope to the Tsitsikamma region were carried out. In 1974 four blue duikers from the Queens Park Zoo at East London were translocated to the area, but they all died within a year of their arrival (Crawford & Robinson 1984). Then during 1973/74 seven eland from Coleford, Loteni and Willem Pretorius Nature Reserves were released in the foothills of the Tsitsikamma Mountains, an area controlled by the then Department of Forestry (internal records, NPB). These animals adapted well to the environment, and their numbers increased. Unfortunately the local inhabitants complained that the elands were damaging their gardens and orchards. Consequently, the Department of Forestry was forced to cull these animals (Hanekom & Bower 1996).

SANParks decided to adopt a cautious approach to re-introductions of mammals to Soetkraal, because of the nutrient poor status of the fynbos, the relatively fragile nature of the fynbos plant communities and the lack of boundary fences (National Parks Board, 1993). Initially SANParks will probably concentrate on smaller herbivores, such as grey rhebuck and klipspringer, but re-introductions of mountain zebra, eland and red hartebeest are distinct possibilities once proper evaluations of the habitat have been done (Randall *et al*. 2004).

In 1994 three sub-adult elephant cows from the Kruger National Park were introduced to the Knysna forest (Diepwalle area) in an attempt to sustain the presence of elephants in the forest area (Seydack *et al*. 2000). After release from the boma, one of the cows died. Seydack *et al*. (2000) monitored the remaining two elephants for almost 5 years and found that, although the Knysna elephants ranged in an area that is predominantly Afromontane forest, the introduced elephants progressively selected more open habitat. Upon analysis of nutrient contents in the Knysna and Kruger cows’ dung, Seydack *et al*. (2000) came to a conclusion that the Kruger cows, who roamed outside the forest area, had a more nutritious diet than the Knysna elephants. They hypothesized that the limited nutrients and the low N/C ratios in the Knysna elephant diet may have ultimately lead to their population decline (Seydack *et al*. 2000).

7.8 Social sciences

Interest in social-ecological challenges within SANParks has a long history of deliberation although lacking in practise (see Swemmer *et al.* 2015 on benefit-sharing). Early discussions of incorporating social research within SANParks took place as early as 1990’s covering a wide range of research themes including perceptions of local communities on conservation, visitor’s experience/perceptions to recent themes of exploring the goods and services that protected areas provide. In addition, Cock & Fig (2000) made the assertion that Tsitsikamma and West Coast national parks were some of the first parks to have social ecologists working with neighbouring communities. Only a few parks have community settlements within the borders of the park, thus the work reported on in this section covers communities residing in close proximity with the different sections of the Garden Route National Park (GRNP).

Neighbouring communities and perceptions

Within the Garden route, Odendal & Krige (1988) highlighted the importance of incorporating perceptions of all stakeholders in solving the then ecological challenges and how developments should be visually compatible with scenic beauty of the Wilderness/Knysna lake system. Being a largely open access, the park is faced with a myriad of challenges emanating from a very diverse base of stakeholders with an equally diverse set of needs. This means that challenges may also differ based on the area and thus approach. For instance, fishing is allowed in certain sections of Knysna/Wilderness lake system but not allowed in other closed sections such as Tsitsikamma (until recently - 2016). This lack of access to natural resource in the Tsitsikamma section of the park has been a subject of debate of late, fuelling tensions between management authority and neighbouring communities, although the parity may have been restored as the decision to open sections of the coast for fishing to the neighbouring communities was announced on December 19, 2016 by the minister of Environmental affairs. Faasen & Watts (2007) concluded that the "no-take" policy of the MPA that was introduced in the year 2000 was the main reason for the deteriorating relations between neighbouring communities and park management. Subsequently, Watts and Faasen (2009) also looked at a number of options that the communities deemed viable to repair their relations with the management authority. Following this, Muhl (2016) assessed the effects of the 'no-take' policy on food security and livelihoods in one of the communities (Thornham) surrounding the Tsitsikamma sections of the GRNP. This study concluded that in addition to food security and livelihoods, the 'no-take' policy on fishing in the Tsitsikamma section of the GRNP also took away the cultural and heritage identities of this community.

Stakeholder engagement

Roos (2015) used the concept of collective identities to classify stakeholders in the Wilderness and Swartvlei lake systems. This author then assessed how stakeholder engagement impacts on the use and benefit sharing of ecosystem services provided by the lake systems.

Tourism and marketing

Numerous studies have looked into profiling the types of tourist that frequent the region as well as understanding their contribution to SANParks revenue generation and the broader region. Using insights from different stakeholder groups (business, community and tourists); Saayman *et al*. (2009) also studied the socio-economic impact of the Wilderness national park. This study concluded that the park provided more social benefits to the stakeholders than financial. Furthermore, Mouton (2009) found that residency time played a huge role in influencing perceptions to the benefits communities derived from the park. In contrast, Oberholzer *et al.* (2010) found that the Tsitsikamma section of the Garden Route National Park yielded largely economic benefits for the neighbouring communities, while also using surveys from different stakeholder groups (business, community and tourists). Kruger & Saayman (2010) looked at factors influencing visitor motivations between Kruger and Tsitsikamma National Parks. This study concluded photography was the leading motivation among patrons visiting the Tsitsikamma national park, this owing to the picturesque scenery of the park. Kruger *et al* (2010) looked at pin-pointing the socio-demographic and behavioural variables that influenced spending patterns in the Tsitsikamma National Park. In an attempt to compare between national parks with a conserved marine section, Tiedt (2011) analysed factors influencing travel motivations between the Addo Elephant and Tsitsikamma National Parks. Scholtz *et al* (2015) concluded that SANParks should focus on attracting visitors who would stay longer during off-peak seasons, because such visitors have more time to explore and visit more tourist attraction sites. This study was undertaken in three SANParks coastal parks; Addo Elephant, the Wilderness and Tsitsikamma sections of the GRNP.

Ecosystem services

Conserved spaces provide numerous benefits to society at large. These benefits are not only limited to the maintenance of biodiversity and protection of species. Recently, a lot of focus has been channelled in understanding how maintaining the ecological intactness of these areas provides free benefits to mankind. The concept of ecosystem services focus on these "free nature services" that are in most instances a by-product of conservation action. Ecosystem services are categorised as: i) provisioning (e.g., food and water), ii) regulating (e.g., climate control, flood attenuation, disease control), iii) cultural (spiritual, recreational) and, iv) supporting services (e.g., nutrient cycling). Mander & Van Niekerk (2013) used systems model and participatory expert workshops to assess ecosystem services for Knysna Estuary and Catchment. This study assessed supply of and demand for ecosystem services. Four future scenarios were developed, considering various population growth rates, economic growth, and investment or neglect in natural assets or ecological infrastructure management. It was found that investment in Knysna's natural assets will be critical to augment engineered services to meet future needs. However, for water security services, this will not suffice, and demand management will be necessary. Focusing on the cultural provisioning ecosystem services, Barendse *et al.* (2016) assessed how invasive alien species in the Garden Route National Park affect visitors' visual experiences and how this further influence place attachments. This study found that to date these concepts have received relatively poor research attention in South Africa. Furthermore, perceptions on invasive alien species were largely driven by prior knowledge and exposure thus leading to varied and complex results, despite current understanding of the socio-ecological impacts of invasive alien plants species.

Institutional arrangements

Mc Culloch (2016) explored the routines and processes that determine the absorptive capacity of three public-sector organisations (SANParks, CapeNature, Eden District Municipality) with mandates for environmental management in the Garden Route. Absorptive capacity is described as the ability of an organisation to recognise the value of external information, acquire and assimilate it within the organisation, and transform it with existing knowledge to enable its use. While the concept has been applied widely to the private sector, the public-sector application of this study was novel. Key findings included that absorptive capacity is enhanced by in-house research capabilities as well as through mechanisms for cross-functional functional interfacing (e.g. science-management meetings).

Cultural and heritage management

The GRNP management plan provides a cultural heritage programme which serves to conceptualise, plan, strengthen and oversee the implementation of Cultural Resource Management and Indigenous Knowledge in the park. It aims to acknowledge the area's diverse cultural heritage and commits to ensuring the safeguarding of this heritage.

The SANParks managed areas in the Garden Route incorporate various cultural heritage sites. These range from Khoisan cultural heritage sites such as caves, shell middens and rock art to the more recent historical sites such as the ruins of small fishing settlements, remnants of the past forestry and mining industries, railway lines, shipwrecks and grave sites. The conservation of these sites and their related oral history are part and parcel of the conservation mission of SANParks.

Running concurrently is an ongoing Oral History Collection and Cultural Mapping Project and an Oral History Collection project, both of which are implemented with the purpose of keeping an up to date catalogue of all Cultural Heritage assets (tangible and intangible) associated with the Park. Site management plans are developed for cultural sites and a living heritage survey conducted to ensure appropriate management of and controlled access to sites (Management plan).

The GRNP programme furthermore aims to develop opportunities to interpret and promote Cultural Heritage as part of the experiences offered to park visitors. These projects are implemented in conjunction with local community members, the organisations representing community interests, as well as relevant academic institutions and researchers.

7.9 Sustainable extractive resource use

7.9.1 Terrestrial

Extractive resource use from terrestrial ecosystems is an important component of the management of the GRNP, both historically and to comply with new policy directives to accommodate the need for access to resources, to optimise socio-economic benefits to neighbouring communities, and to generate income for the organisation. The resource use programme makes provision for the harvesting of timber and non-timber forest products, as well the harvesting of fynbos products. The area zoned for extractive resource use includes a diversity of vegetation types to allow for the harvesting of a wide range of species and products.

7.9.1a Timber

Timber has been harvested almost continuously from the Garden Route forests since about 1750, the longest for any South African natural forest. It has been estimated that between 1,5 and 3 million m^3 of timber was removed from these forests between 1776 and 1939, reaching a peak at the beginning of the nineteenth century when 20 000 m³ was removed annually. These forests have thus played an important role in the economic development of the region, providing timber for building construction, furniture, wagons, ship building, poles, railway sleepers, mining timber, etc. Their history reveals a continuous struggle between exploitation and development towards effective forest conservation (Stehle 1993, McCracken 2004, Seydack & Vermeulen 2004). After 1939 the harvesting of timber was restricted to selective removal of occasional dead and dying trees and windfalls in accessible areas.

Controlled harvesting through a sophisticated and conservative single-tree selection system was implemented in about 20 per cent of the forests from 1965, as detailed by Von Breitenbach (1968). A single tree selection system was adopted as this most closely resembles the natural disturbance processes (Geldenhuys 1982a, Geldenhuys & Maliepaard 1983). Harvesting takes place on a 10-year felling cycle, which represents a compromise between the cost-effectiveness of management, which favours long felling cycles, and the prevailing disturbance regime, which favours short felling cycles (Midgley *et al*. 1997). Tree volume tables based on DBH as sole predictor variable of the tree volume, were developed for the main timber species of the Garden Route forests, based on the work by Van Laar & Geldenhuys (1975). The subsequent application, modification and development of the timber yield regulation and harvesting systems were described inter alia by Von dem Bussche (1975), Geldenhuys (1980, 1982a,c), Seydack *et al*. (1982, 1990, 1995) and Seydack (1995).

Today, timber from the indigenous forests is used mainly for the manufacture of high quality furniture and ornaments, in an industry that is important in the local economy. Approximately 9 200 ha of the indigenous forest area is allocated to the timber utilisation management class. Nature conservation remains the primary aim of management in these areas, so a yield regulation system was developed that has minimum ecological impacts, causes minimum deviation from the natural turnover and disturbance mechanisms of the forests and produces an optimal sustainable yield.

Since 1992 timber has been harvested according to the senility criteria harvesting (SCH) yield regulation system which is based on natural mortality patterns (Seydack 1995, 2000b, 2000d Seydack *et al*. 1995, Seydack & Vermeulen 2004). Harvesting is limited to forest types and sites that are the least ecologically sensitive. The system aims to pre-empt, and thus utilise natural mortality, resulting in the harvesting of the most senile trees. Individual trees are selected for harvesting by applying selection criteria that are based on external, visible signs of senility, declining vigour and low future life expectancy. The criteria are described for each of the main canopy species, and are calibrated to the natural senility patterns as determined by long-term research results. Trees falling within the selection criteria are marked for removal by trained markers if they can provide marketable utilisable timber.

The maximum yield level currently achievable according to the SCH yield regulation system is approximately 5 m³/ha every 10 years, or 0.5 m³/ha/yr (Seydack & Vermeulen 2004). All harvestable trees (i.e. meeting selection criteria and with utilizable timber) with dbh ≥ 30 cm of all canopy species would have to be removed to achieve this (8 – 12 trees per ha every 10 years from the same areas). However, due to market demands only real yellowwood *Podocarpus latifolius,* black stinkwood *Ocotea bullata and* hardpear *Olinia ventosa* are currently harvested to full potential. The actual annual yield is about 0.2 m³/ha/yr, which is approximately 40% of total forest productivity.

The alien Australian blackwood *Acacia melanoxylon*, occurs in all the main forests in the Garden Route. It is a valuable timber tree that contributes more than 50% of both timber volume and revenue obtained from the forests. Outside the forest it is a serious invader of open and disturbed sites, but does not aggressively invade closed, evergreen forest (Geldenhuys 1992c, 1996). A medium-term harvest optimisation approach was adopted in about 1999 whereby initial annual harvests of about 1500 m³ were expected to drop to about 500 m³ annually after about 17 years (Vermeulen & Seydack 2000; Seydack 2002).

Specialised harvesting techniques and equipment are used to limit damage to the forest. (Gush & Dye 2004) Reduced-impact logging techniques were introduced into the southern Cape forests in the 1960s and have been applied consistently since the early 1980s, with a continuous development and improvement in techniques and equipment. Measures applied to reduce the impacts of timber harvesting include the following:

- No harvesting is carried out in ecologically sensitive areas.
- Large crowns are removed before trees are felled, a procedure known as topping.
- Logs are slipped out of the forest with horses or winches.
- Large, specially designed machinery is only used on the main slipping paths.
- Slipping of logs is only carried out when the soils are sufficiently dry.
- Branches are packed around the stumps of *Ocotea bullata* to reduce browsing by bushbuck (Lübbe 1990b).

The harvested timber is taken to depots where it is usually sold on public auction, sometimes on tender.

An integral part of the yield regulation system is the monitoring of stand dynamics in both harvested and unharvested forest stands (Seydack 1991, 2000b; Seydack *et al*. 1995). Long term monitoring of yields, growth rates and regeneration is important to ensure that harvest levels and mixes of products are sustainable. The effects of timber harvesting are monitored in timber utilisation areas by means of permanent sample plots, full count monitoring and post-harvest audits (Vermeulen 2000). Tree senility monitoring has been carried out in parts of the Diepwalle research area since 1991 to define yield regulation parameters and harvest tree selection criteria (Seydack *et al*. 1995).

Much potential exists for the harvesting of plant products as by-products from timber harvesting areas. This includes, for example, the harvesting of tree seedlings from forest roads (that would get damaged during harvesting operations) for establishment in indigenous trees nurseries, and the harvesting of timber off-cuts (branch wood and logs of small dimensions are not harvested during normal timber harvesting operations) for carving and turning. In addition, the bark of many timber species is also in demand for medicinal use, e.g. assegai *Curtisia dentata,* Cape-beech *Rapanea melanophloeos* and red candlewood *Pterocelastrus tricuspidatus*.

7.9.1b Non-timber forest products (NTFPs)

The harvesting of NTFPs gained momentum when a new forest policy and legislation that promote access to forest resource and the equitable distribution of benefits from forest areas, was introduced DWAF (2005). Currently the only NTFP harvested on a commercial scale is seven-weeks fern *Rumohra adiantiformis*. Controlled harvesting of rooiwortel *Bulbine latifolia* (for medicinal use) by local Rastafarian community has been put on hold while alternate arrangements are being explored. Illegal bark harvesting for medicinal purposes has been reported in the Southern Cape indigenous forests, especially in Knysna municipal forests adjacent to the informal settlements. Other medicinal plants harvested in a small scale in the park include *Gerbera cordata*.

Seven-weeks fern (*Rumohra adiantiformis*)

The fronds of *R. adiantiformis* have been harvested on an economic scale since 1982 (Geldenhuys & Van der Merwe 1988, Geldenhuys 1994c, Kok 1988, 2004). Geldenhuys & Van der Merwe (1988) & Milton & Moll (1988), Vermeulen (2009), Kok (1998, 2004) & Vermeulen *et al*. (2005) provide history of *R. adiantiformis* harvesting in the southern Cape forests.

Milton (1987a, b, 1991), Geldenhuys & Van der Merwe (1988, 1994c), Milton & Moll (1988), Geldenhuys (1994c) & Vermeulen (2009) conducted studies on the population structure and demography of *R. adiantiformis* to provide a basis for the development (and refinement) of a harvest system for the species. Milton (1987a &b) found that harvesting of fern fronds have an effect on frond production and that natural populations of *R. adiantiformis* appear to be unable to maintain their quality, and suggested nursery production to be a viable alternative for the fern industry. Milton (1991) reported the ferns of the Southern Cape Forests to be relatively unproductive and that fronds are slow to return to normal size after complete or partial defoliation. Geldenhuys & Van der Merwe (1988) studied the population structure and growth of R. adiantiformis in relation to frond harvesting in the Southern Cape forests and provided recommendations for better resource conservation, and guidelines for cultivation of the fern. Geldenhuys & Van der Merwe (1988) stressed the need for continued monitoring. Vermeulen (2009) reviewed *R. adiantiformis* harvesting over a period of two decades and demonstrated that the adaptive management approach was followed effectively in the development and implementation of a harvest system for the species. The study also indicated that the current harvesting prescriptions for *R. adiantiformis* are scientifically sound and provide for sustainable harvesting of the species.

Medicinal plants

An increased demand for *Bulbine latifolia* from a Rastafarian community resulted in illegal and uncontrolled harvesting of the species in the region (Vermeulen 2005). In the spirit of the then PFM (Participatory Forest Management) policy adopted for the management of natural forests in the southern Cape (DWAF undated, 2005a) an interim arrangement was made with the Rastafarian community for limited, controlled access while applied research is conducted to develop harvest prescriptions for its sustainable use (Vermeulen 2005). Baard (2002) identified and mapped populations of *B. latifolia* using GIS techniques, based on known habitat characteristics. The species is confined to the coastal strip of Harkerville state forest and to the upper slopes of river valleys cutting through the coastal plateau (Baard 2002, Geldenhuys 1993a). Vermeulen (2009) studied the phenology of the species and found the plant to flower in winter and spring (June to November). Vermeulen (2009) found the population dynamics of the species to be complex. It has a slow rate of renewal, measured by corm diameter- and length growth.

Lübbe *et al*. (1991) identified the need to develop a strategy and to explore different options for the sustainable harvesting of bark for medicinal use from the southern Cape forests. Vermeulen & Geldenhuys (2004, 2005), Vermeulen (2009),Vermeulen *et al*. (2012) and Ngubeni (2015) report on the response of selected tree species (stinkwood *Ocotea bullata*, red stinkwood *Prunus africana*, assegai *Curtisia dentata*, cape holly *Ilex mitis*, red currant *Searsia chirindensis* and Cape beech *Rapanea melanophloeos*) to bark stripping, provide management options and expands on the potential for medicinal bark harvesting from Southern Cape forests. *Ocotea bullata* and *P africana* showed adequate bark re-growth, while *C. dentata, I.* mitis, *S*. chirindensis and *R*. *melanophloeos* showed poor bark re-growth (Vermeulen 2009, Vermeulen *et al*. 2012). Ngubeni *et al*. (2016) showed different trade-offs between wound closure and compartmentalisation between O*. bullata* and *C. dentata,* with the former faster tree and bark regrowth and containing wood decay much better,

A total of 21 tree species have been identified from which bark is harvested for medicinal use from natural forest in the southern Cape. This is based on observations of bark stripping (Reynell & Durrheim 1989, Geldenhuys & Lübbe 1990, Lübbe *et al*. 1991, Mostert & Lübbe 1991, Ferguson 1995) and resource surveys (Berry 1993a, b).

7.9.2 Aquatic (freshwater and estuarine)

Water abstraction

Water is abstracted from rivers in the catchments for a variety of uses. In the Wilderness area total abstraction in the Touw system in 1995 was estimated to be 7.1 x 10^6 m^3 y^{-1} (29% of average virgin MAR of 24.6 x 10^6 m^3 y^{-1} (Fijen & Kapp 1995b; Fijen 1995a). Estimated abstraction by different users was Forestry 3.7 x 10^6 m^3 y^{-1} (15% MAR), Agriculture 2.9 x 10^6 m^3 y^{-1} (12% MAR) and Domestic 0.5 x 10^6 m^3 y^{-1} (2% MAR). It was predicted in 1995 that future abstraction for Agriculture will increase by 1.6 x 10^6 m^3 y^{-1}, and Domestic by 0.6 x 10^6 m^3 y^{-1} with runoff to the Touw system reduced to 15.3 x 10^6 m^3 y^{-1} (62% MAR) (Fijen & Kapp 1995b; Fijen 1995a).

Total abstraction from the Swartvlei system in 1995 was estimated to be 22.6 x 10^6 m^3 y^{-1} (32% of average virgin MAR of 70.6 x 10^6 m^3 y^{-1} (Fijen & Kapp 1995b; Fijen 1995c). Estimated abstraction by different users was Forestry 18.7 x 10^6 m^3 y^{-1} (27% MAR), Agriculture 3.6 x 10^6 m^3 y^{-1} (5% MAR) and Domestic 0.3 x 10^6 m^3 y^{-1} (<1% MAR). It was predicted in 1995 that future abstraction for Agriculture will increase by 2.8 x 10^6 m^3 y^{-1}, and Domestic by 1.0 x 10^6 m^3 y^{-1} with runoff to the Swartvlei system reduced to 44.2 x 10^6 m^3 y^{-1} (63% MAR) (Fijen & Kapp 1995b; Fijen 1995c).

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

Hanekom and Bower (1996) described the system used to supply freshwater to the rest-camp and housing areas of the Tsitsikamma area. An environmental study by van Tonder and De Villiers (1996) recommended several options for improving the water supply to the Storms River Mouth Rest- camp. These included

(i) pumping from the freshwater portion of the Storms River,
(ii) pumping from the freshwater layer lying above the denser saline water in the marine section of the Storms River, and
(iii) upgrading the sewage works and treating effluent for re-use as irrigation water.

Bait harvesting and fishing

Within the GRNP Extractive resource use in the form of linefishing and associated bait collecting currently occurs within the De Vasselot portion of the Tsitsikamma area, the Harkerville and Sedgefield to Wilderness coastlines, the Knysna estuary, the Swartvlei system (estuary and lake) and within the Touw estuary and Island lake of the Wilderness Lake system (Table 3). The spatial and temporal disitribution of rock and surf anglers between Groot River East (eastern border of Tsitsikamma MPA) and the Kaaimans River Mouth near Wilderness is described by Smith *et al*. (2015). In accordance with the regulations of the Marine Living Resources Act (1998), individuals participating in these activities need to be in possession of the relevant permits and abide by species specific size and harvest (daily bag limits) restrictions.

The Knysna and Swartvlei estuaries are on the urban fringe, easily accessible and hence subjected to heavy fishing pressure by both recreational anglers and unemployed subsistence fishers. Estuaries are ecologically important, because they act as both nursery areas for juveniles and feeding grounds for adults of many fish species, several of which form important components of the recreational and commercial marine linefisheries. Based on rating scores for size, habitat importance, zonal type rarity and biodiversity importance, the Knysna- and Swartvlei estuaries are the 1st and 7th most important estuarine system in South Africa (Turpie & Clark 2007),

Table 3: Sections of the Garden Route National Park open to consumptive resource use in terms of fishing and bait collecting.

Estuary / Coastline	Consumptive Resource Use	Park Restrictions	Permits Required
Touw Estuary	Recreational fishing and bait collecting Subsistence fishing & bait collecting?	Paid Access	Recreational bait and fishing permit (DAFF)
Island Lake	Recreational fishing and bait collecting Subsistence fishing & bait collecting?	Paid Access Vessel permits	Recreational bait and fishing permit (DAFF)
Swartvlei Lake	Recreational fishing Subsistence fishing?	Vessel permits	Recreational bait and fishing permit (DAFF).
Swartvlei Estuary	Recreational fishing and bait collecting Subsistence fishing & bait collecting	Vessel permits	Recreational bait and fishing permit (DAFF). Subsistence exemption permits (DAFF).
Knysna	Recreational fishing and bait collecting Subsistence fishing & bait	Vessel permits	Recreational bait and fishing permit (DAFF). Subsistence exemption

	collecting		permits (DAFF).
Groot Estuary	Recreational fishing and bait collecting Subsistence fishing & bait collecting?	No powerboats	Recreational bait and fishing permit (DAFF)
De Vasselot	Recreational fishing and bait collecting Subsistence fishing & bait collecting		Recreational bait and fishing permit (DAFF). Subsistence exemption permits (DAFF).
Platbank - Kaaimans	Recreational fishing and bait collecting Subsistence fishing & bait collecting Oyster harvesting		Recreational bait and fishing permit (DAFF). Subsistence exemption permits (DAFF).
Harkerville	Recreational fishing and bait collecting Subsistence fishing & bait collecting		Recreational bait and fishing permit (DAFF). Subsistence exemption permits (DAFF).

Participation and Demographics:
The estuarine linefisheries are predominantly recreational with an estimated subsistence sector comprising 10% of all anglers on Swartvlei and 21% on Knysna (SANParks unpublished data). Napier *et al*. (2009) estimated that 30 full-time and 200 part-time subsistence fishers were involved in bait collection, mud crab harvesting and linefishing on the Knysna Estuary. The majority of anglers at both estuaries are male, (SANParks unpublished data) withmost anglers utilizing these estuaries living in the immediate vicinity (52% Swartvlei, 78% Knysna) or within the greater Garden Route. Most visiting anglers live within the Western Cape.

Effort:
Typical of recreational dominated fisheries fishing effort is seasonal with an increase in fishing effort occurring over school holidays with particular emphasis over the December, January and April holiday periods. Effort decreases over the winter months with June, July and August having the lowest effort counts. Estimated annual total fishing effort in terms of angler outings ranges between, 5 764 and 8 904 for Swartvlei and between 20 000 and 25 000 for Knysna (SANParks unpublished data). In both estuaries distinct spatial patterns in fishing effort can be seen with anglers preferring fishing hot spots that can be linked to ease of access. Boat angling is minimal on Swartvlei with only 10% of anglers fishing from a boat whilst Knysna with its larger size and deeper channels has more boating activity with 30% of observed anglers fishing from a boating platform (SANParks unpublished data).

Catch:
During 2009 at Swartvlei although most anglers (45%) indicate that they were not targeting specific species of those species actively targeted, spotted grunter (28%) was the most popular followed by leervis (9%), white steenbras (7%) and cape stumpnose (4%). However, catch rates show that despite being actively targeted only 4% of the time cape stumpnose was the most commonly caught fish making up 43% of all fish caught. White steenbras comprised 30% of all fish caught whilst spotted grunter made up 10% and leervis 4% (SANParks unpublished data).

At Knysna, as with Swartvlei, most anglers (45%) indicated they were not targeting specific species and would be happy catching anything. Of those species actively targeted, spotted grunter (17%) was the most popular followed by white steenbras (10%), cape stumpnose (6%), strepie (5.5%), kob (5%) and leervis (5%). However, analysis of anglers catches shows that despite being actively targeted 17% of the time spotted grunter only made up 4.2% of total catches. Cape stumpnose was the most frequently caught species (44%) followed by strepie (19%) and white steenbras (12%) (SANParks unpublished data).

Bait Collection:
A total of 25 different bait types were used by anglers fishing on Swartvlei with the most common used bait being sandprawn *Callichirus krausii*. Roughly 60% of interviewed anglers used sandprawn having collected on average 31 prawns per trip. Average time taken to collect their bait was 36 minutes. An estimated 202 766 sandprawn were harvested over a year long period (SANParks unpublished data). The quantity of bait removed from the Swartvlei estuary appears to be one-tenth of that removed from Knysna (Turpie & Clark 2007).

Twenty seven different bait types, including artificial lures, were used by anglers fishing on Knysna with 18 of these bait types being collected in the Knysna Estuary. These included mud prawn *Upogebia Africana*, sand prawn *Callianasa krausii*, bloodworm *Arenicola loveni*, mullet Mugilidae spp, cracker shrimp, tape worm, moonshine worm, red bait and polychaete worm. The most frequently collected bait organism was mud prawn(SANParks unpublished data).

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). It is estimated that approximately 1.9 million mud prawns or about 740 kg are removed from six key bait-collecting sites in the Knysna estuary per year (Hodgson *et al*. 2000b). This presents about 8.5% of the prawns at these sites and about 1% of the entire stock. Approximately 85 % of these mudprawns were taken by 'non-leisure' fishers/collectors. Bait collecting in Knysna estuary and Langebaan Lagoon during the early to mid-1990s was not resulting in a noticeable over-exploitation of the standing biomass of prawns (Wynberg & Branch 1991,1994; Cretchley 1997). However, Wynberg and Branch (1994) showed that disturbance associated with bait digging at Langebaan Lagoon causes a decrease in numbers, biomass and species richness and that this component of the benthos more than 18 months to recover.

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).

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).

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). Research undertaken by Smith (2016) highlightes ongoing compliance issues with many recreational and subsistence anglers illegally collecting their bait within this reserve.

7.9.3 Marine

The history of recreational shore angling in the Tsitsikamma area and angling catches made in the then 3 km recreational fishing zone between 1991 and 1995 is described by Hanekom *et al*. (1997). The recorded capture rates were at least 2.5 times lower than that from the De Hoop Nature Reserve and Terrace Bay in the Skeleton Coast National Park. Moreover, the catch was comprised primarily (> 45 %) of small sized species. The recreational fishing area was closed to angling in 2001 and the marine section from Groot River (east) to Groot River (west) was proclaimed as a Marine Protected Area (RSA Government Gazette No. 21948, 29 December 2000, Marine Living Resources Act (Act No. 18 of 1998). Currently no angling or spear fishing, except for approved research purposes, is permitted in the MPA, but is allowed along the De Vasselot portion of coast near Nature's Valley.

Faasen & Watts (2007) found that responses from local communities to the exclusion of fishing within the MPA were defined by their residence status, ethnicity, gender, income, and educational level. There is a general understanding by local communities that the purpose of the MPA is to conserve nature within its boundaries. However, there is a mismatch in the understanding of the term 'conservation' between the local communities and conservation officials of the South African National Parks (SANParks). Local communities consider conservation to include sustainable utilization while conservation officials from the practice pursue absolute protection of the marine fisheries resources. The majority of local communities in Tsitsikamma resent this SANParks 'no-take' policy on fishing. They would like access to the fisheries resources in the Tsitsikamma National Park for both subsistence and recreational purposes (Faasen & Watts 2007). Local communities desire active participation in the management of the park through democratically elected representatives, benefit sharing, creation of more job opportunities by the Park Management, free and increased access to the park, and regular communication with park officials (Watts & Faasen 2009).

Bait collecting was prohibited in the TCNP in 1978 (Hanekom *et al.* 1997), and the ban continues to be enforced in the Tsitsikamma Marine Protected Area (RSA Government Gazette No. 21948, 29 December 2000, Marine Living Resources Act (Act No. 18 of 1998). However, bait harvesting, in accordance to the legislation of the Marine Living Resources Act (Act No. 18 of 1998), is currently permitted in De Vasselot. This section of coastline has a very high line fish habitat rating (Clark & Lombard 2007). King (2205) assessed the Plettenberg bay shore-based fishery including De Vasselot whilst Smith *et al*. (2007) developed fishery indicators for local management initiatives in exploited areas, using Plettenberg Bay as a case study.

SANParks strategy to manage resource use within the open areas is adaptive and ongoing relying on information gathered from monitoring programs aimed at quantifying use, assessing the resource base and relating the two.

Participation and Demographics:
The shore based linefishery within Natures Valley is male dominated with the majority of anglers being recreational. Fifty five percent of interviewed anglers resided within Natures Valley or surrounds whilst 40% were visitors from within South Africa (SANParks unpublished data).

Effort:
Fishing effort is seasonal with increases in fishing effort during the school holidays in December, January and again in April. During 2008 annual effort was estimated at 3 678 angler outings whilst during 2009 this fell to 1 661 angler outings (SANParks unpublished data). The dramatic decrease during the second year can be attributed to roadworks on the passes into and out of Natures Valley along with the introduction of a R35 toll fee for the use of one pass.

Catch:
The majority of anglers target anything (25%) whilst shad is the most commonly targeted species (22%) followed by dusky kob (20%), white musselcracker (9%) and white steenbras

(8%). Sharks and rays were the most commonly caught species comprising 17% of all catch followed by blacktail (16%), strepie (14%) and dusky kob and white steenbras (13% each). During one year's survey total catch was estimated at 6 435 individual fish or 4 tons (SANParks unpublished data)

Extractive over-exploitation of resources has been highlighted as the greatest threat to marine biodiversity (Lombard *et al*. 2005). Conversely the extent and impact of bait harvesting along the South African coast is poorly understood (Griffith & Branch 1997; Mackenzie 2005). A key conservation function of the Tsitsikamma MPA is to provide a safe and pristine refuge for exploited fish and invertebrate species andmanaging the interface between resource use and biodiversity conservation within the marine and estuarine environment whilst taking cognisance of cultural, social and economic incentives of resource users will be a key challenge in ensuring that park objectives are met and resources remain sustainable. SANParks personnel have been appointed as fisheries control officers responsible for the enforcement of the Marine Living Resources Act. They undertake regular patrols to encourage compliance with the legislation in along the MPA and De Vasselot coast, and such activities are detailed in the Security and Safety Program section.

Collaboration also continues around the incorporation of expanded public works programmes (Working for the Coast, WfW and EPWP) into the IDP projects section of the plans.

8. BIBLIOGRAPHY

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Appendices 1 – 18 can be downloaded as independent documents from www.sanparks.org