A Catchment Based Approach to the Conservation of Rivers and Management of the Niassa Reserve

Prepared for

Sociedade para a Gestão e Desenvolvimento
da Reserva do Niassa
Moçambique

By

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DRAFT

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Executive Summary

The rivers and wetlands of the Niassa Reserve have been identified as a key landscape feature in the Niassa Reserve with significance influence and importance for biodiversity. The diversity of aquatic habitats and associated riparian vegetation support a diverse array of species. Given this importance the objective of this report is to integrate existing information and provide an overview of the rivers within the reserve. This information is used to identify the conservation value of individual catchment units.

The aim is to provide a management tool to guide the process of prioritisation for conservation areas and the designation of human resource utilization and development areas. Through review of the biophysical characteristics of the rivers of the Niassa Reserve, a proposed framework for a decision-support system to aid in the delivery of landscape level strategies and conservation objectives at the catchment scale is outlined.

The report is presented in three sections.

1. The first of these sections provides a contextual review of catchments as tools for protected areas management.

2. The second section examines the individual catchments, summarising existing ecological information and providing an overview of the physical characteristics.

3. The third section provides an outline of the proposed management framework for the Niassa Reserve.

The Niassa Reserve is bounded by two main rivers, the Rovuma River along the northern border with Tanzania and the Lugenda River, along the southern and eastern boundaries. Twenty-five secondary rivers internal to the reserve boundaries were identified. Catchment areas for these rivers were determined and range from 460 to 3 350 km^2. The majority of these are completely contained within the Niassa Reserve with rivers ranging in length from 40 to 140 km.

Both the Rovuma and Lugenda rivers are large, braided, sand-bed rivers with perennial flows. Tributaries within the reserve are seasonal or ephemeral; experiencing cessation of flow during the dry season when water either retreats to isolated pools or disappears altogether. These flow characteristics combined with the braided channel and sand-bed rivers create a diverse array of lotic, semi-lotic and lentic habitats supporting a diversity of species. In certain instances geological transitions result in spectacular features such as the Mapanda Falls. These features provide an important diversity of more stable, permanent habitats and important refuge for certain aquatic species.

Rivers within the reserve face a number of threats, primarily as a result of human disturbance. Unsustainable fishing pressures and techniques, chemical contamination from washing and mining activity accentuate the effects of seasonal flow and the impacts associated with widespread deforestation and agriculture. Given the limited resources, management of the reserve's rivers requires a spatial framework within which priorities can be identified, landscape level processes can be protected and resources prioritised according to need and availability.

With this in mind individual catchments were described according to available bio-physical information. Due limited time and resources, this was based largely on wildlife distribution and density data from aerial surveys as a surrogate for conservation importance. From the synthesis of this information a preliminary classification framework is proposed. This is based on the delineation of individual catchment units and a determination of their conservation importance. Subsequent to this determination catchments are assigned to specific management classes. These require further elucidation through a proper consultative process but preliminarily definitions include;

1. Core Conservation Areas,
2. Tourism Conservation Areas,
3. Co-management Conservation Areas, and
4. Special Conservation Areas.

These are differentiated by the activities that can take place, ranging from integrated high density human settlement and utilisation to more pristine wilderness environments. Such a framework can be interpreted within the current zoning proposals.

Based on interpretation of information from the aerial surveys, those catchments with highest recorded densities and greatest distribution of wildlife include; the Lucheringo River catchment in the north-west of the reserve; a core area in the centre of the reserve including the Ludimule, Chiuwexi, Metapiri and Incalaue catchments; the Misangese catchment in the north-east and tributaries to the Lugenda River in the south, the Lumbuisse and Luambezi catchments.

These Core Conservation Areas were examined to see if they were representative of the different types of ecosystems in the reserve. Based on this an additional two catchments, the Irangwe and Miuro, were included to ensure representation of the deciduous dry miombo savanna woodland vegetation type in the reserve. To this network of Core Conservation Areas were added additional Special Conservation Areas including unique features within the reserve, such as the Mecula Mountain. This is to ensure that unique features that may encompass more than a single are include in the Core Conservation Area and afforded appropriate levels of protection.

In order to identify potential conflicts with the management objectives of these Core Conservation Areas, the distribution of human settlements and infrastructure was subsequently overlayed on this spatial network of catchments. This highlights those priority areas for intervention. From our analysis the village of Matondavela, situated within the central Core Conservation Area, is a priority for management intervention measures. Roads leading to and from this village traverse the centre of this Core Conservation Area, undermining the integrity of the area and limiting the conservation and development potential.

Based on this approach, interventions focussed on minimising the impact of Matondavela should be implemented immediately. Such interventions could include establishing a greater presence in the area, through development of tourism infrastructure or research facilities. However, this should be determined by defined management objectives. According to the Core Conservation criteria used herein the management objective should be to develop incentive programmes for the relocation of this community. Similarly, achieving the management objectives would require re-alignment of the roads into and out of Matondovela.

Ideally, all roads should be aligned along the watersheds. The watershed represents the highest point between two catchments and as such road development would have minimal impact on the ecological integrity of individual catchment units and improve year round access due to lower probabilities of flooding and erosion. Similarly, the road across the Misangese catchment requires more detailed investigation. Adopting the same principles this road should be re-aligned along the watershed to avoid crossing the catchment.

Catchments provide a logical landscape level approach to ensuring the protection of ecological processes, and in so doing biodiversity. The spatial arrangement of catchments across the landscape provides an easily identifiable unit within which to structure and prioritise management interventions. By ensuring appropriate consultation and consensus with communities in the reserve on regulations and designation of management areas, conservation initiatives can be successfully juxtaposed against development initiatives.

Acknowledgements

This project could not have been possible without the assistance and input of the following individuals and organisations;

Anabela Rodrigues, Michelle Souto and staff of the SGRDN for guidance, commitment and continued support.

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All those who have dedicated time and energy to collecting data.

This report is dedicated to the memory of Dr Steven Telford.

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1 Introduction

Traditional protected areas management has focussed on delineation of exclusion zones within which measures are focussed to ensure protection of wildlife and natural resources. This approach has been bought in to question over the past decade or more, with an increasing shift toward the development of community based co-management conservation strategies (Borrini-Feyerabend and Buchan 1997; Borrini-Feyerabend et al. 2000; Roe et al 2000). However, there is a need to develop appropriate frameworks to structure integration of co-management approaches in order to ensure their success while continuing to meet and maintain core conservation objectives.

The approach described herein attempts to do just that. It provides an adaptive framework that allows the management structure to shift in response to predefined objectives and in response to new challenges as they arise. The focus of this framework is based around catchment units. These provide the logical landscape units for the spatial arrangement of management interventions.

Catchment units represent the drainage area of an individual river. As such a catchment can vary in size, depending on the river being used to define it. A river, like the Zambezi, has a huge catchment area, but can be readily sub-divided into smaller catchments according to tributaries. Confined within individual catchment units, rivers provide a mid-point within the terrestrial landscape. They form arterial links that cut across landscapes, integrating different ecosystems, and reflect the characteristics of the catchments they drain.

While rivers themselves provide important habitat for a diversity of insects and fish, as well as nutrients and food for both terrestrial and aquatic vegetation and animals, they also play an important role in shaping the landscape and have considerable aesthetic value. Hydrological processes have myriad influences, with erosion carving out geological features, the resulting run-off carrying sediments that contribute to the formation of soils, while the valleys carved out by streams over thousands of years influence local climatic patterns and the distribution of vegetation. Thus the nature of the catchment and drainage of the rivers within are central to the structure and function of many terrestrial ecosystems.

The definition of catchment units also has a more functional role to play in the development of the Niassa Reserve (RdN). Catchments provide a logical framework for the delineation of conservation and management units. Identification and definition of the conservation value of individual catchments, when over-laid with the level of human resource utilisation and bio-physical characteristics, combine to provide an invaluable management tool to guide the process of prioritisation for conservation areas and the designation of human resource utilisation and development areas.

Riverine habitats have been repeatedly identified by specialist surveys as important areas for biodiversity. Their protection is central to maintaining and meeting the core conservation objectives of the RdN. In addition, the short-term objectives of the RdN within the next 5 years have been stated as establishment of infrastructure, tourism, anti-poaching and training. The preparation of an ecologically based spatial framework within which to develop and implement these activities will ensure that development and implementation is sustainable and environmentally integrated.

The objectives of this study are to integrate existing information and provide an overview of the rivers within the reserve with a view to:

1. Identifying and defining the conservation value of individual catchments units in the Niassa Reserve.

2. Providing a management tool to guide the process of prioritisation for conservation areas and the designation of human resource utilization and development areas.

The report is structure around three sections.

4. The first of these sections provides a contextual review of catchments as tools for protected areas management.
5. The second section examines the individual catchments in detail, summarising existing ecological information and providing an overview of the physical characteristics.
6. The third section provides an outline of the proposed management framework for the Niassa Reserve.

2 River Conservation as a Tool for Reserve Management

The conservation of national parks and reserves has traditionally focussed on the delineation and zonation according to terrestrial attributes. Rivers have typically been used to define the boundaries of such reserves. In long established national parks this is emerging as one of the major constraints. For example, the Kruger National Park runs north-south while the rivers traversing it flow from headwaters outside the Johannesburg area in the west, eastward into Moçambique through some of the South Africa's most productive agricultural areas. As a result, over-abstraction and modification of the natural flow regime upstream of the KNP is undermining long-term conservation initiatives.

Increasing recognition of importance of rivers in structuring and driving landscape processes has led to re-examination of these philosophies. This shift toward landscape conservation reflects the change from individual species protection to a more holistic and integrated approach toward ecosystem management. Ecosystem management is necessary to maintain or restore biodiversity at a landscape scale. In a shift of paradigm, the argument presented herein is to designate reserve boundaries and management zones according to catchment areas and focus the development of the reserve around the rivers within it. Catchments provide a logical landscape unit, encompassing the full range of habitats to ensure protection of ecological processes. The catchment units themselves are defined according to the watershed, or drainage line, which represents the highest point along a ridge between two rivers from which water drains. As such, they encompass different geological profiles, changes in altitude, and with these different climatic conditions and ultimately different ecosystems. Water falling below the watershed drains the land surface into a river, evaporates or infiltrates into the soil profile. While the catchment mosaic covers the landscape the rivers that drain them form arterial links that cut across landscapes.

Rivers, dambos and other aquatic habitats also provide a number of important landscape functions. These include, among others, flood control, nutrient, sediment and contamination retention, food web support, erosion controls and stabilisation of local climatic conditions, in particular rainfall and temperature. These ecosystem functions represent the integration of numerous biological, chemical and physical components and support a number of services, including wildlife and agricultural resources, fisheries and water supply. In addition, wetlands continue to possess important cultural and biological attributes and value. The livelihoods of local communities in rural areas are often heavily dependent and intertwined with wetland habitats.

Given the human dependency upon these systems, aquatic environments also represent some of the world's most imperilled ecosystems. More than 50% of wetland ecosystems have been lost during the 20th Century as a result of numerous threats. These include agricultural development, alterations to the hydrological regime and pollution, among others. This has resulted in the fauna of freshwater environments exhibiting some of the highest levels of extinction and endangerment. It has been estimated that 20% of freshwater species have become, or are in danger of becoming, extinct, with levels far greater than observed in any other system. For example, the rates of imperilment within major aquatic taxa such as fish, crayfish, and mussels are in the order of three to eight times those recorded for birds and mammals in North America (Masters, 1990; in Angermeier, 1995). Of the freshwater fish species for which data exists, 34 have become extinct since late in the 19th century, six of these are known to have become extinct since

1970. Further to this, 24% of mammals and 12% of birds associated with wetland habitats are classified as threatened.

River ecosystems and the associated wetland habitats are vulnerable to changes within the catchment. Successful protection and management therefore requires maintenance of these sources of water and innovative, integrated approaches that differ from the traditional approach to conservation. The idea of fenced exclusionary areas, ensuring that people are kept out and animals are protected within does not ensure protection of wetland systems. The inter-connectedness of the hydrological cycle means that changes away from the river or wetland can have significant impacts. A key requirement for wetland conservation and wise use therefore is to ensure that adequate water of the right quality at the right time is maintained and that ecosystems processes are maintained. Achieving this requires a more holistic approach that ensures integration of activities across the catchment landscape and that actively engages communities.

Translating these characteristics into a tool for conservation planning, catchment units can be considered appropriate because they;

- represent discrete functional landscape units, encompassing major driving ecological and evolutionary processes that create and maintain biodiversity;
- lend themselves to development of spatial networks that can address the maintenance of populations of species that need large areas, that cannot be accommodated at the site scale;
- encompass a logical set of biogeographically related communities for representation analyses; and
- enable determination of the best places to invest conservation efforts and to better understand the role that specific projects can and should play in the conservation of biodiversity over the long term.

Finally, the catchment can be scaled up in accordance with the stream or river of focus. As such small discrete units can be used to make up a larger mosaic. The individual units in this mosaic can be allocated individual objectives and managed appropriately within a structure framework toward a common goal. As such, catchment scale planning and management allows analyses and planning at these scales that provide the best basis for establishing conservation priorities.

3 Background to the Niassa Reserve

3.1 Location

With a total of 42 000 km^2 the Niassa Reserve is the largest protected area in Moçambique. This area includes a 22 924 km^2 core area of the reserve and a buffer zone that contributes another 19 240 km^2.The reserve boundaries today reflect those of the original hunting reserve proclaimed in the 1930's. These boundaries were defined in the north by the Rovuma River, which forms the border with Tanzania, in the west by the Lussanhando River and along the southern and eastern boundaries by the Lugenda River.

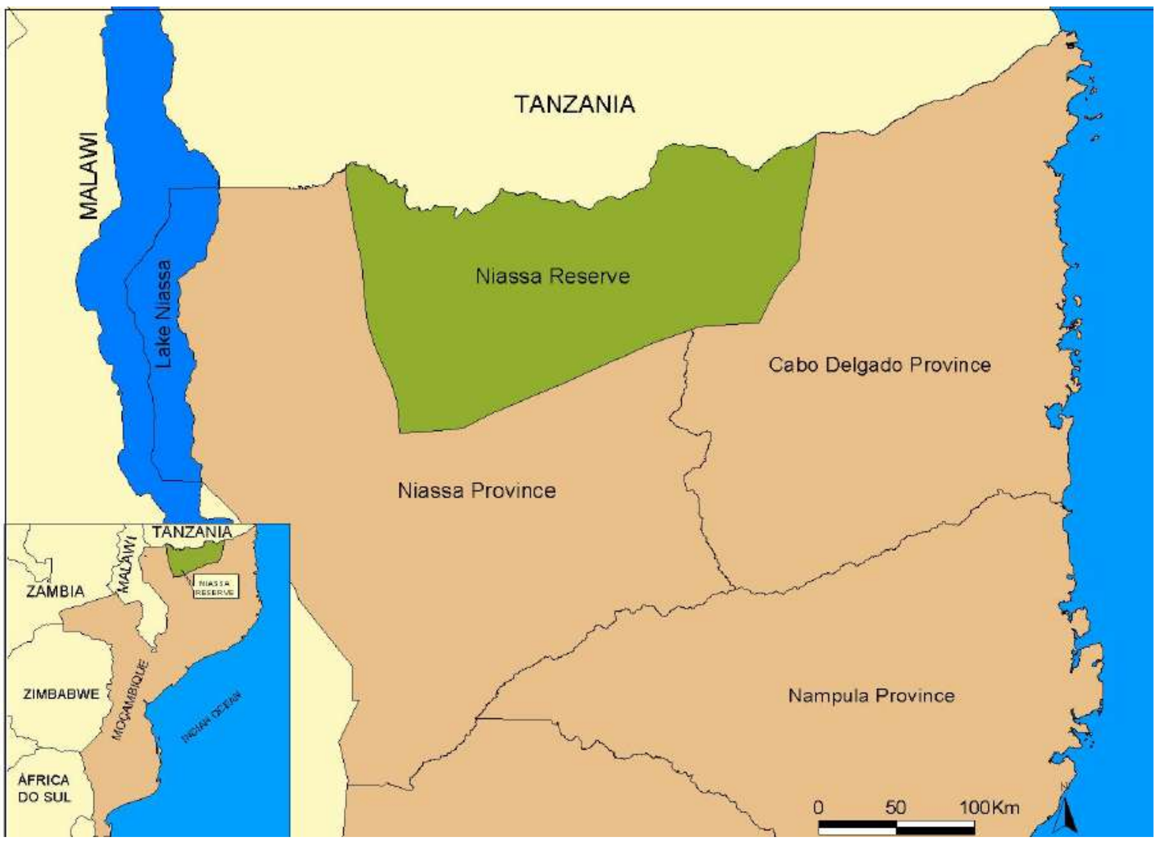


Figure 3.1 Location of the Niassa Reserve

The 1940s saw a reduction in the size of the reserve with the production of cash crops, such cotton, sisal and hemp, impinging along the eastern and western boundaries. As a result the size of the reserve was reduced in 1969 to 12 380 km^2, excluding most of the Mecula district. Numerous discussions during the 1970s and 80s focussed on extending the boundaries to their original position. Subsequent to these discussions DNFFB entered into contract with a private company, Grupo Madal. In 1999 a law decree was gazetted formalising the extension of the reserves boundaries to their existing location along the Rovuma and Lugenda rivers. This agreement also established a joint venture between the state and private sector, granting a 10 year lease to SGDRN with exclusive rights for the promotion, economic development and management of the area.

3.2 Bio-Physical Characteristics

The following brief description of the bio-physical description of the reserve is intended to provide the necessary background to inform the process of delineation and characterisation of the rivers and catchments in the RdN. The RdN is situated in one of the world's largest protected Miombo forest woodland ecosystems. According to the WWF (2001) the Miombo Ecoregion is shaped by six key biophysical determinants or driving forces;

- Long geological stability;
- Long dry season climate (> 5 months);
- Flat topography, interrupted by large monolithic and granite inselbergs;
- Sluggish drainage on plateaux;
- Old nutrient-poor soils;
- Low levels of large mammal herbivore with episodic high level of insect and small mammal herbivory;
- Frequent fires.

3.2.1 Topography

The reserve is characterised by a topographic transition with decreasing gradient from west to east (Figure 3.2). Altitude ranges from above 1400m in the western escarpment to less than 200mASL at the confluence of the Rovuma and Lugenda rivers on the eastern boundary. This topography is interspersed with large granite inselbergs emerging from the landscape.

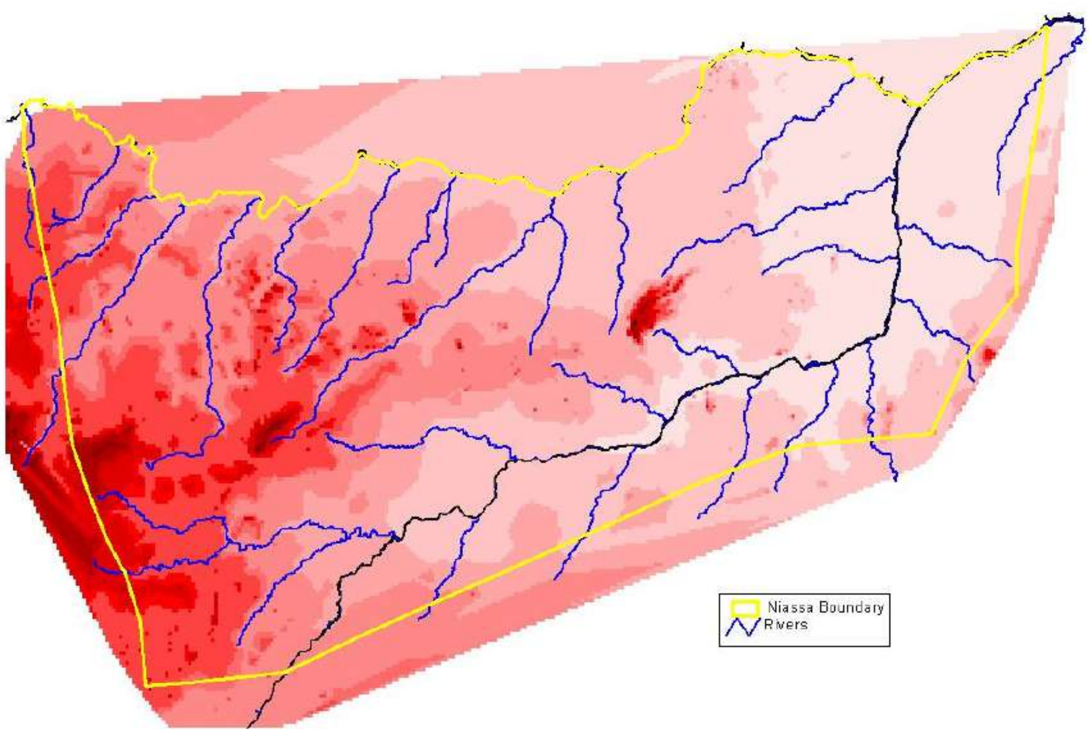


Figure 3.2 Topographic features of the Niassa Reserve.

3.2.2 Climate

The regional climatic characteristics are dominated by three main features. These include the wet southeast trade winds off the Indian Ocean, the southwest monsoon system from the Congo basin, and the northeast trade winds from Ethiopia and Somalia (Hughes and Hughes 1992).

Climatic characteristics are typical of tropical climate with hot wet summer months and dry cooler winter months. Temperatures increase from the cooler climate in the west along the shores of Lake Niassa, where temperatures average around 18ºC toward the eastern seaboard where temperatures average around 25ºC. Monthly temperature data from ten stations in northern Moçambique reveals a monthly average of around 22.5ºC. This typically ranges between 15ºC and 28ºC (Figure 3.3) with highest temperatures recorded in the wet summer months from November through to February.

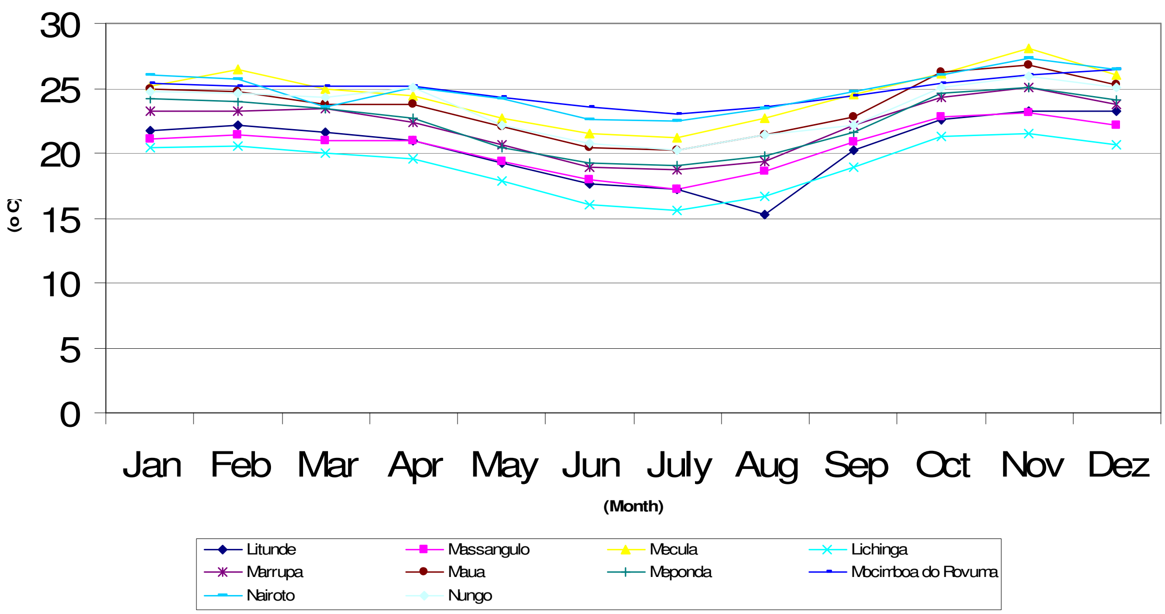


Figure 3.3 Seasonal variations in temperature at stations across northern Moçambique.

Precipitation is influenced by altitude and distance from the coast with the area of the reserve experiencing high rainfall as a result of its altitude and the influence of the global subtropical equatorial anticyclonic zone. The topographic effects of Inselbergs in the northern part of Moçambique stimulate orographic moisture to rise and form clouds that generate rainfall in their surroundings. Further to the east higher rainfall is caused by on-shore winds carrying moist air, producing convectional thunderstorms and rainfall. Given these characteristics, rainfall in the Niassa Reserve ranges from an average of 1418.4 mm per year on Mt Mecula and in the higher altitude western parts of the reserve to less than 1000 mm per year along the Lugenda and Rovuma river valleys in the east at the Nairoto and Mocimboa do Rovuma weather stations (Figure 3.4 and 3.5).

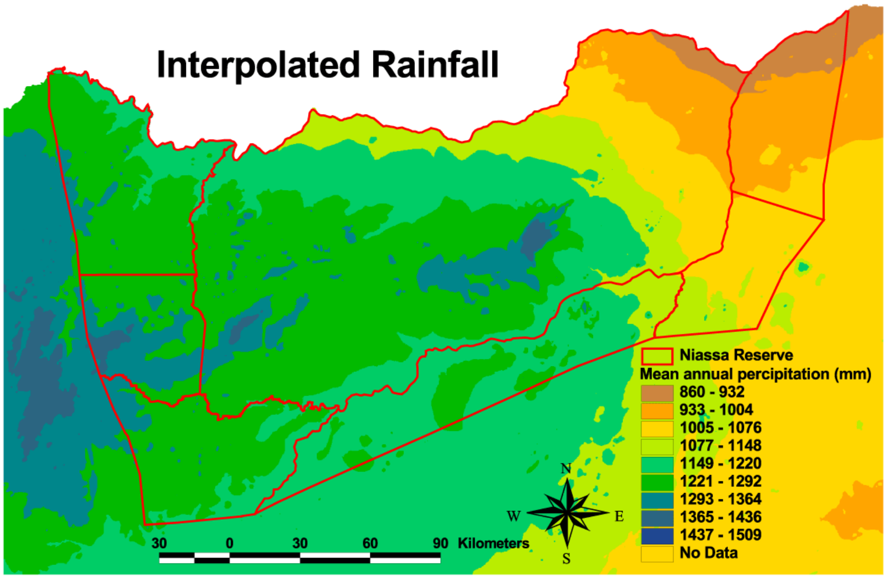


Figure 3.4 Mean Annual Precipitation in the Niassa Reserve (from Desmet, 2004)

Seasonal patterns of precipitation range from the wet summer months beginning in late October through to late April early May where precipitation can averages between 250 and 350 mm per month. During the dry winter months of May through to September there is little if any precipitation.

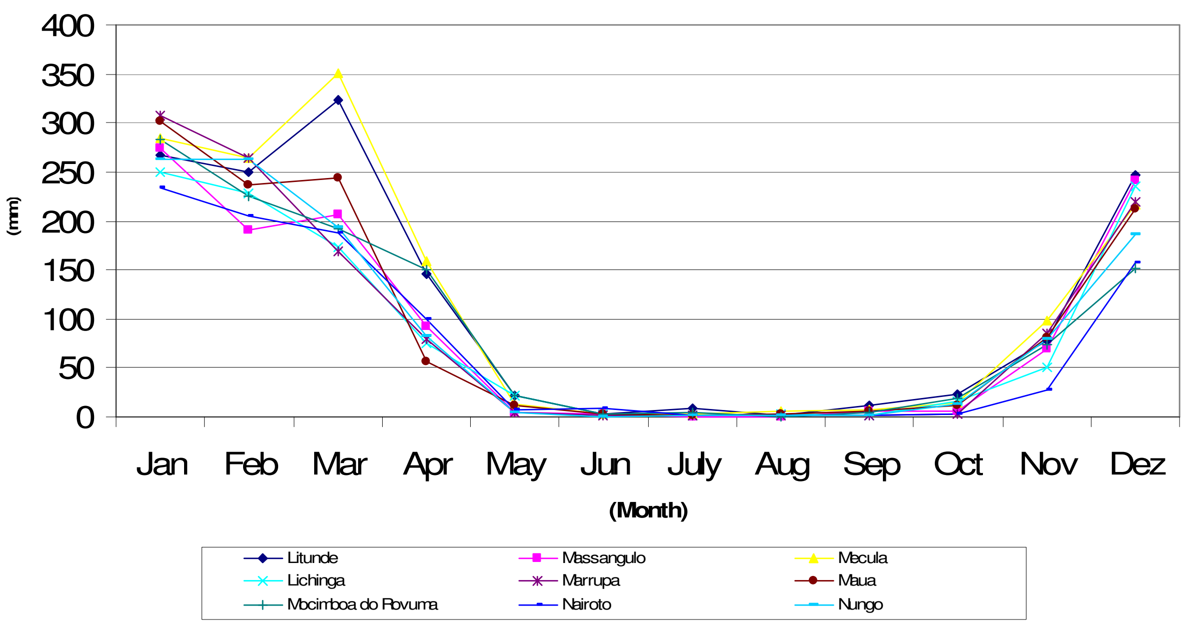


Figure 3.5 Seasonal variations in precipitation at stations across northern Moçambique.

Total annual evaporation is relatively high, averaging around 1800 mm/year. Similarly, the temperature potential evapotranspiration reflects annual patterns in temperature, with evaporative processes directly linked to energy availability. As such, the coolest months of the year, April to September, show lower potential evapotranspiration values.

The values presented in the figure below were calculated using the Thornthwaite method and compared to those derived from the Blaney Criddle methodology, and are based on climatological information obtained for weather stations across northern part of Moçambique.

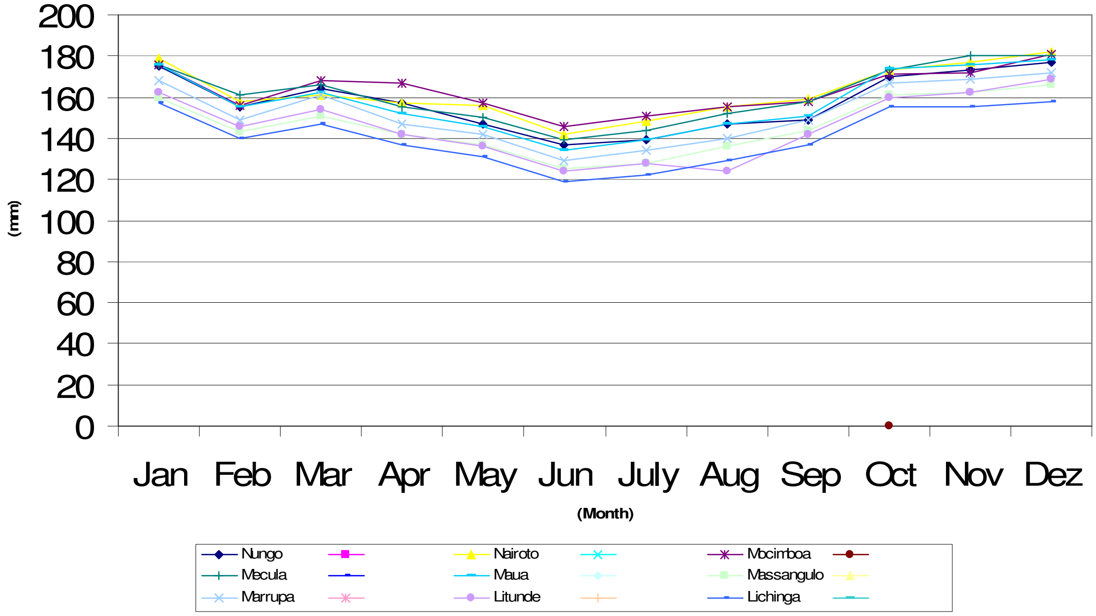


Figure 3.6 Seasonal variations in potential evapotranspiration at stations across northern Moçambique.

3.2.3 Geology

There are no detailed geological maps for the northern part of Moçambique, including the Niassa Reserve. A current project for the National Directorate of Geology should alleviate this situation in the near future making available detailed geological information. However, the only available information available at the time of writing is from the 1:1 000 000 geological maps for Moçambique. Given the scale this is not considered to be of appropriate value for the purpose of this exercise.

The area in question presents a relatively uniform geology predominantly situated within the Migmatitic Gneiss complex and Granite. The most common rock types include gneisses, migmatites and amphibolites; Charnoquitic series, Nephelinic and biotite gneiss. The rock itself is generally prone to erosion but occasional small pockets with highly resistant rock protrude to form inselbergs. These are primarily weathered granite extrusions probably arisen out of etch-plantation with surrounding areas incised by broad shallow river valleys formed by extensive drainage systems. At the head of these drainage systems are typically grassed dambos. These features combine to give the characteristic flat to undulating topography with interspersed by spectacular inselbergs.

3.2.4 Hydrogeology

The entire Niassa Reserve falls within the hydrogeological region known as the Basement Complex in Mozambique. This is characterised by predominantly crystalline and metamorphic rocks. Sands deposits, derived from the weathering of hard rock and sediments, have accumulated in valleys that are today dominated primarily by ferric like soils. This basement complex has very limited groundwater potential. Available groundwater resources are found in fractured and weathered portions of the rock, however these typically have low productivity, are discontinuous and of limited extent. The high run-off potential and the considerably well developed drainage pattern is a good indication of limited groundwater storage and poor soil infiltration capacity. As a result most of the available rainfall is converted into surface runoff.

In general the weathered zone has an average depth of around 25 meters, occasionally reaching as much as 40 meters. The top10 meters are the most weathered and have higher storage potential. A few eluvial pockets, with high groundwater storage potential, occur in the area but these are very limited in extent. These pockets may constitute the main potential sources of groundwater in the area of the reserve and are located to the north, closer to the Rovuma River. Typically boreholes drilled in this region will not deliver more than $3m^3/h$ for an average drawdown of 10 meters.

Water derived from groundwater sources is likely to possess high iron and manganese content, related to the mineralogical composition of parent rock, but should be of good quality for potable supplies.

3.2.5 Vegetation

The Niassa Reserve represents one of the world's largest protected areas of Miombo woodland, with roughly 50% of the reserve dominated by Brachystegia (miombo) woodland. This is characteristically low productivity woodland, occurring on poor soils, where 95% of the biomass is found in herbaceous vegetation. Despite this dominance it has been estimated that there are a total of 21 different vegetation types within the reserve and more than 191 species of tress and shrubs. A more recent study by Desmet (2004) identified 15 broad vegetation communities are defined for the reserve ranging from evergreen forest through different Miombo woodland types to lowland thicket. Wetland areas are estimated to account for 5% of the total area with the remaining 40% dominated by savanna. The savanna is interspersed with the miombo while wetlands are typically grassy sedge covered areas in low lying depressions where water collects. The inselbergs of the reserve include small remnant patches of isolated forest communities, while the main perennial rivers have limited riparian forests accounting for an estimated 2% of the total reserve vegetation.

Desmet (2004) reconciled the vegetation units against the Flora Zambesiaca vegetation categories of which six are predicted to occur in the reserve. These include montane evergreen forest and grassland; three types of Miombo woodland; and one lowland thicket type (Figure 3.7).

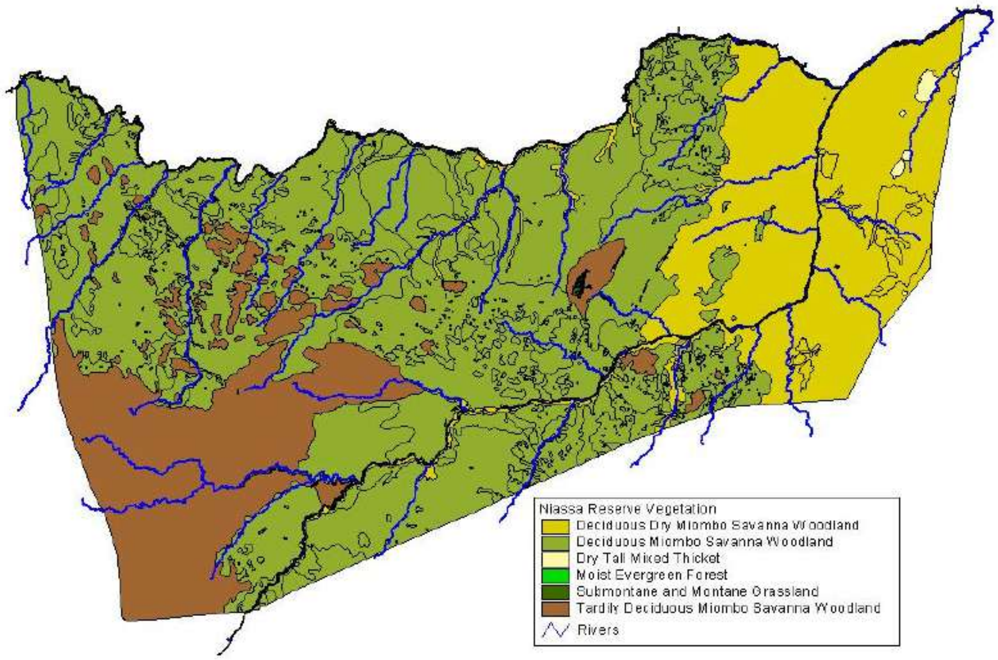


Figure 3.7 Vegetation of the Niassa Reserve (after Desmet, 2004)

3.2.6 Faunal Characteristics

The SGDRN has commissioned regular aerial surveys of wildlife in the RdN. These are typically carried out in October, toward the end of the dry season. According to the results of the aerial census the elephant population is estimated at 12 000 individuals. Results from surveys over the past three years suggest an increase in this population (Gibson, 2002). The Reserve also has over 9000 sable antelope and several thousands each of Cape buffalo, Lichtensteins hartebeest, eland, and zebra. Smaller populations of kudu, bushbuck, impala, wildebeest, waterbuck, reedbuck, and hippo also occur in the reserve, while duiker and warthogs are abundant. Predators such as lion and leopard along with spotted hyena are common and the reserve has an estimated population of 200 African wild dog. The reserve is also home to three endemic subspecies, which exist in Niassa but are rare elsewhere, namely: Niassa wildebeest (Connochaetes taurinus johnstoni), Boehms zebra (Equus burchelli boehmi), and Johnstons impala (Aepyceros melampus johnstoni).

More recently (2004) a series of detailed specialist biological surveys have been undertaken. These examined the presence and distribution of bird, fish and reptile species. One of the common conclusions from these surveys was the importance of the rivers of the RdN as one of the key landscape features.

The following series of maps attempts to summarise the distribution of wildlife as observed during the 2000 aerial survey (Gibson, 2000). This is presented herein to examine distribution patterns in relation to the secondary catchment defined in the following section. It needs to be acknowledged that this information has been derived from data collected during several surveys, although all of which have been conducted in October / November. While most species exhibit specific habitat requirements, all of those presented in the following maps are highly mobile species. The distribution of these species is considered in relation to the framework and used to provide an appropriate example. The information obviously needs to be verified and carried further.

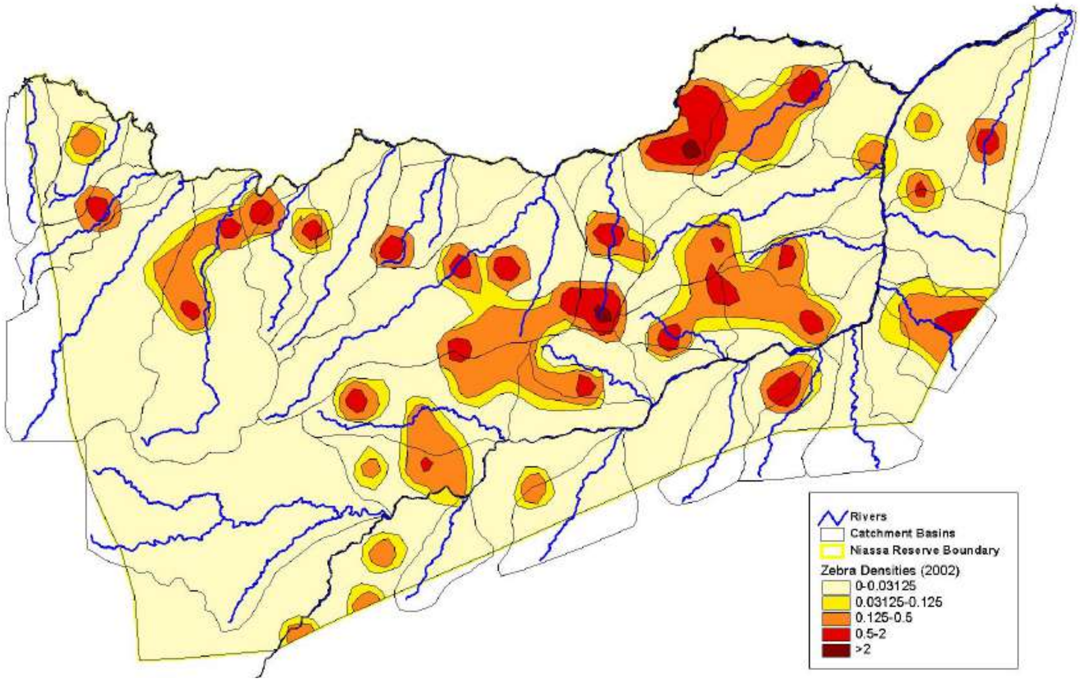


Figure 3.8 Density of Zebra within the Niassa Reserve (2002).

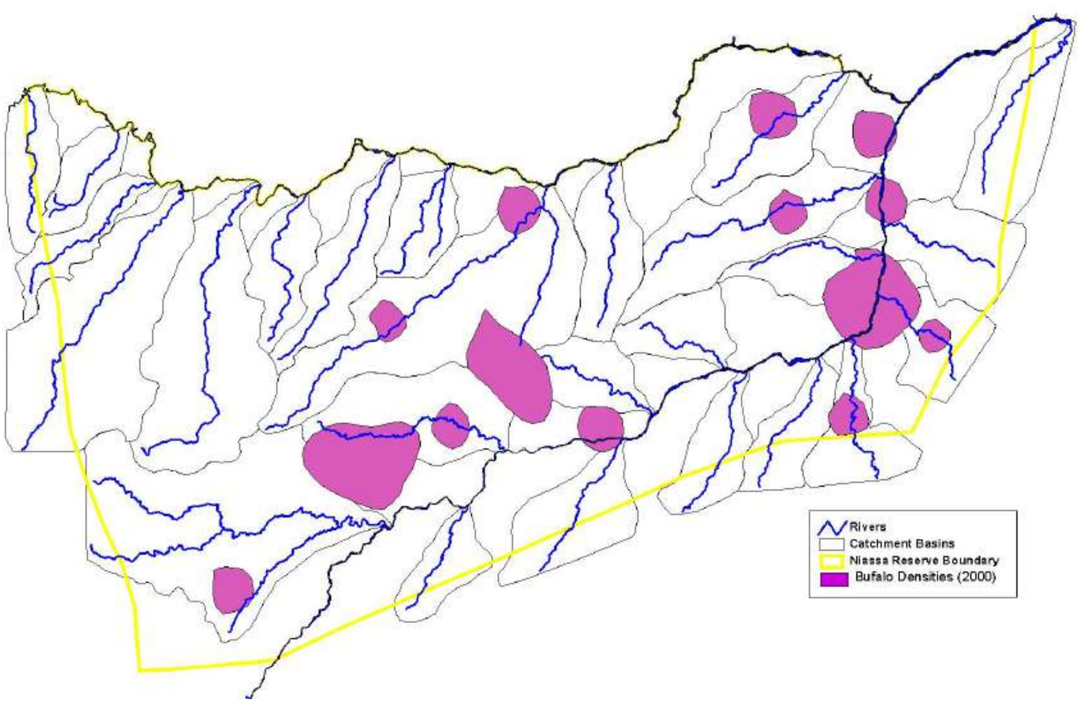


Figure 3.9 Distribution of Buffalo within the Niassa Reserve (2000).

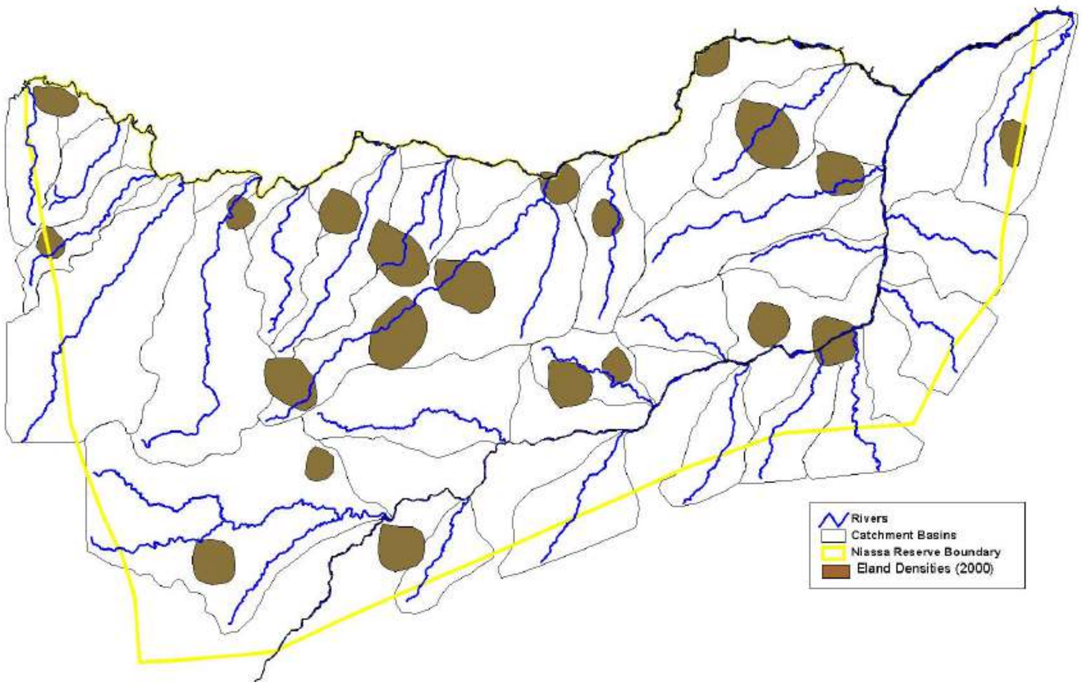


Figure 3.10 Distribution of Eland within the Niassa Reserve (2000).

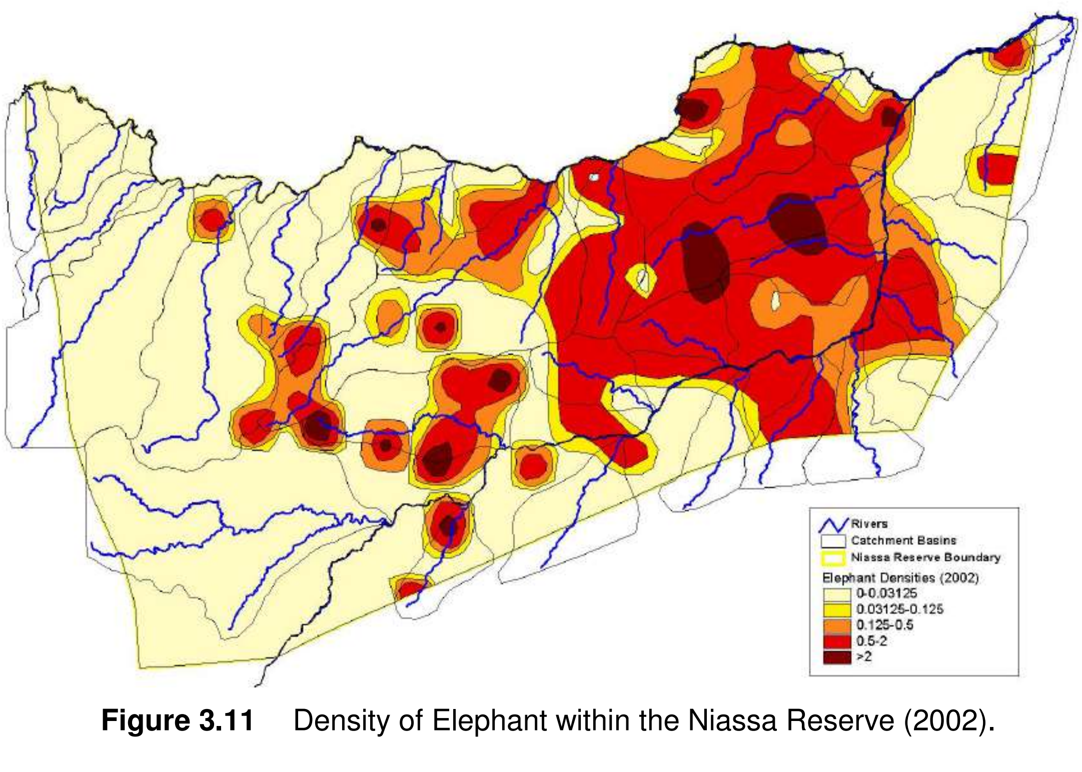


Figure 3.11 Density of Elephant within the Niassa Reserve (2002).

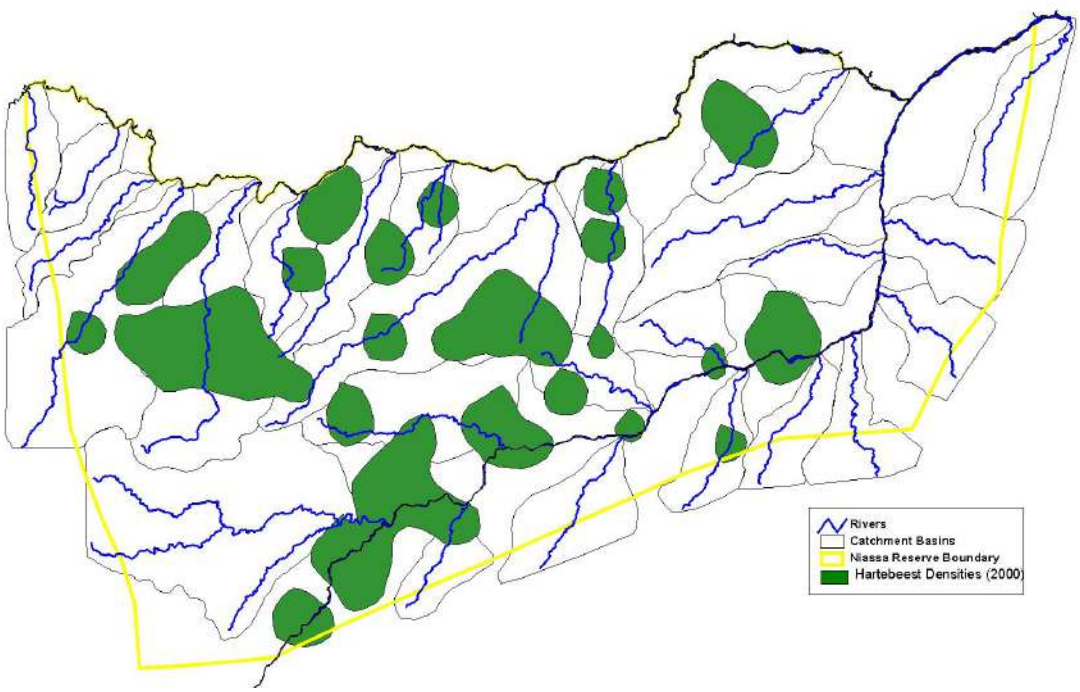


Figure 3.12 Distribution of Hartebeest within the Niassa Reserve (2000).

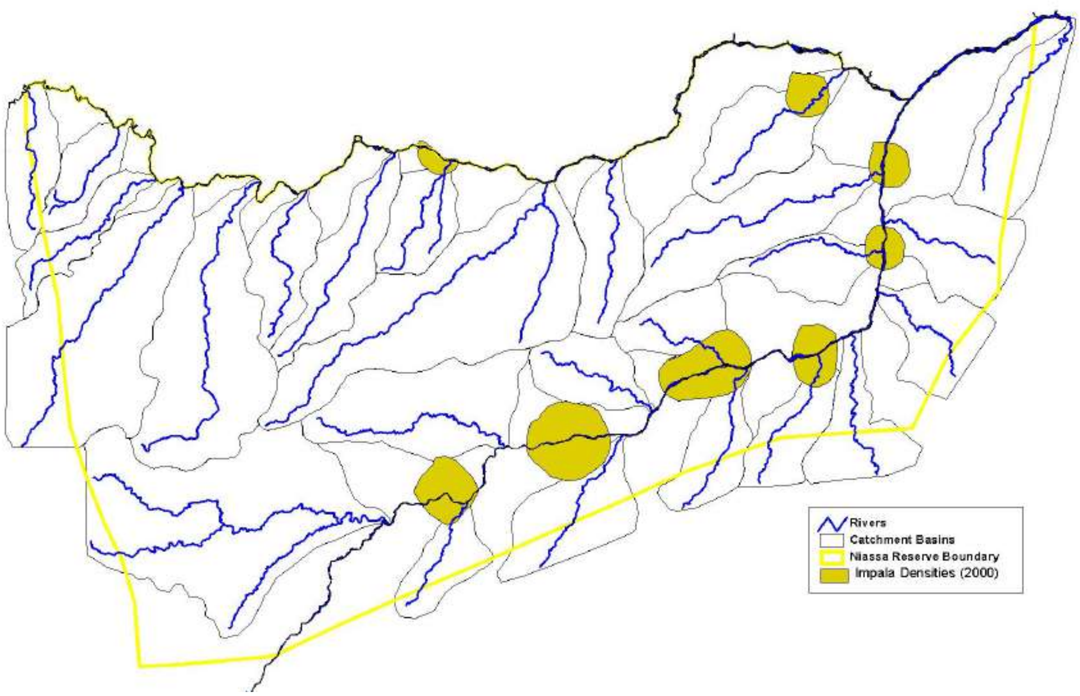


Figure 3.13 Distribution of Impala within the Niassa Reserve (2000).

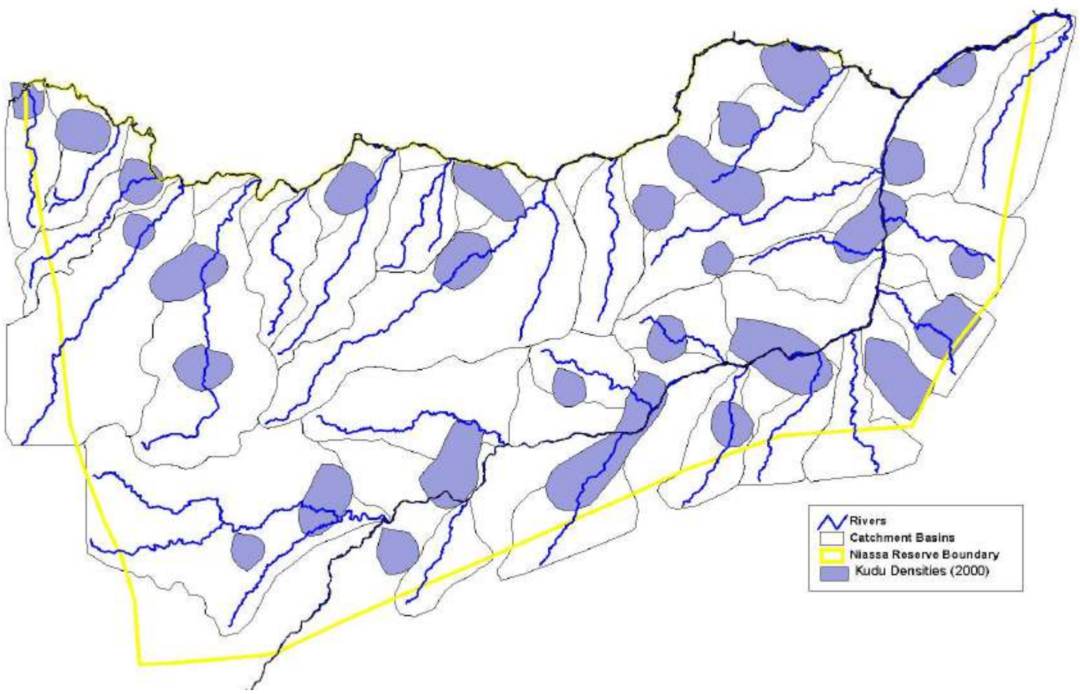


Figure 3.14 Distribution of Kudu within the Niassa Reserve (2000).

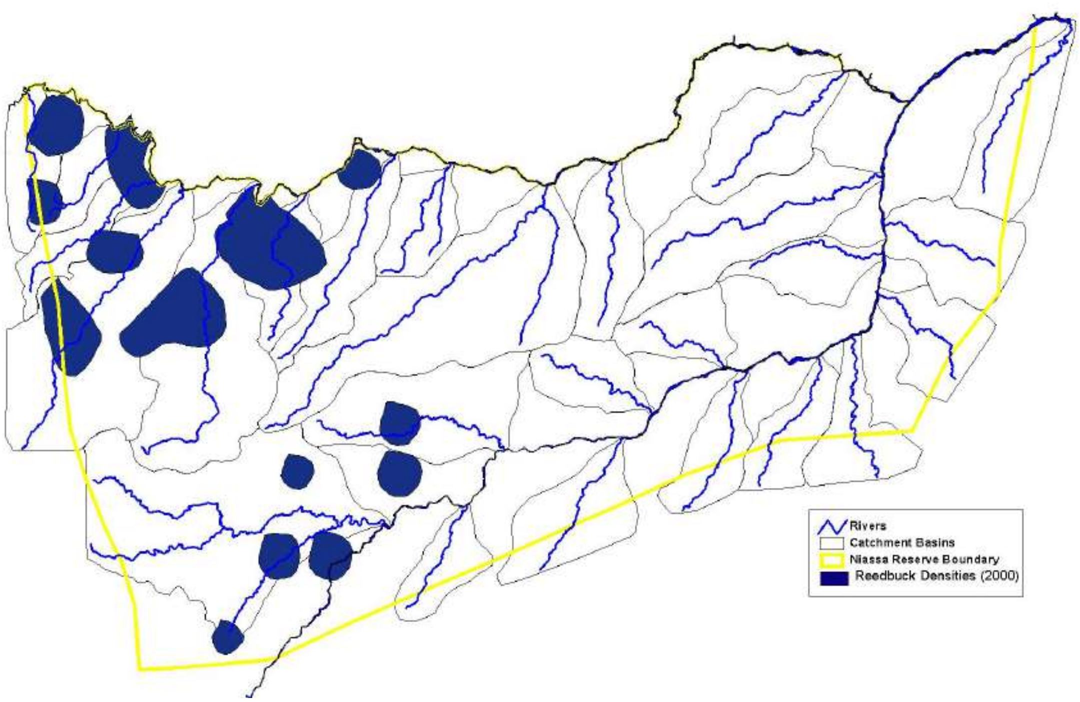


Figure 3.15 Distribution of Reedbuck within the Niassa Reserve (2000).

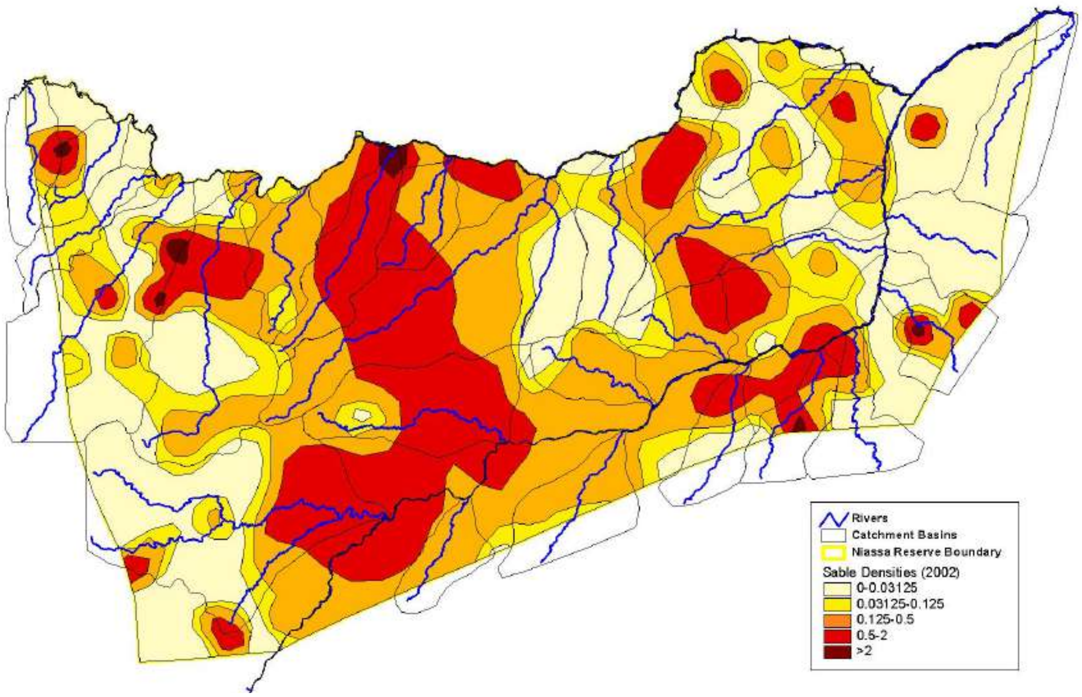


Figure 3.16 Density of Sable within the Niassa Reserve (2002).

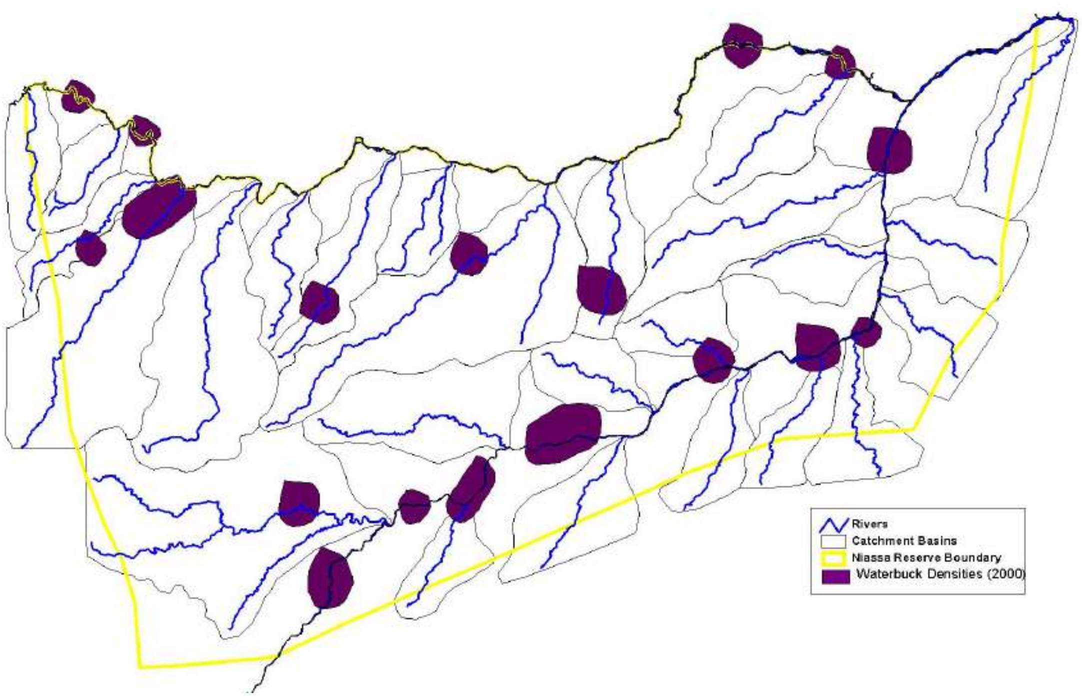


Figure 3.17 Distribution of Waterbuck within the Niassa Reserve (2000).

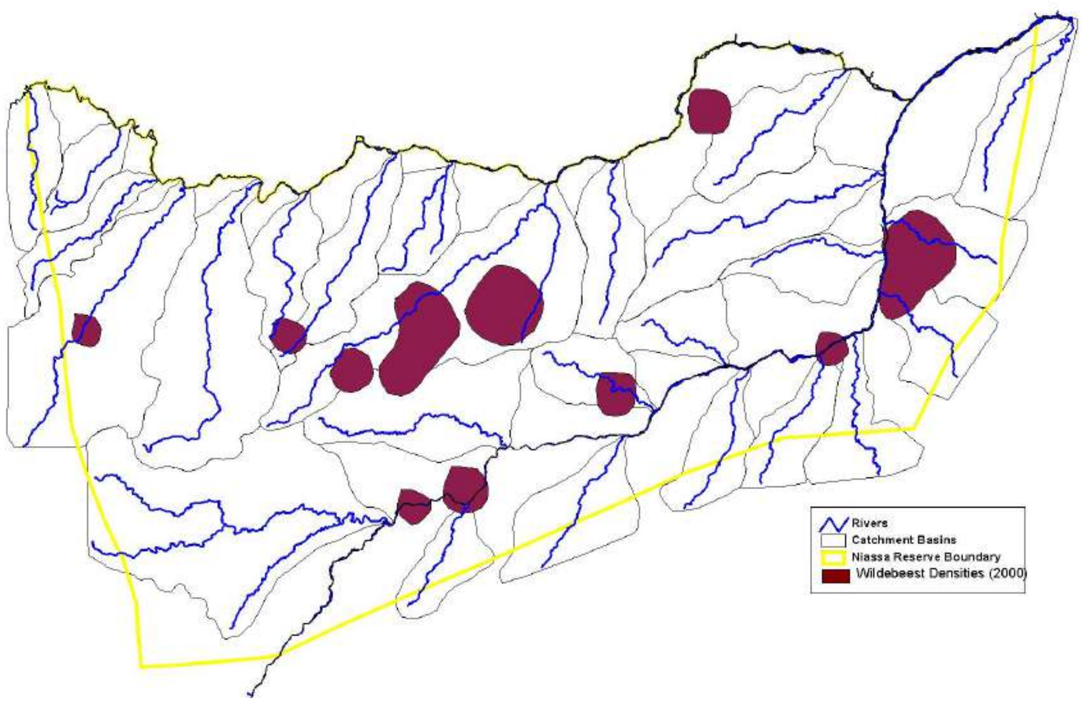


Figure 3.18 Distribution of Wildebeest within the Niassa Reserve (2000).

3.2.7 Human Settlement

Changes in the boundaries of the reserve has meant that nearly 20,000km^2 of former community land has now been placed under the control of the reserve. Although the area has a long history of human settlement and migration, the expansion of the reserve incorporated numerous populations within the official limits. As a result there is a conflict between the need for community development in one of Moçambique's poorest regions and the conservation objectives of the RdN. It is beyond the scope of this report to address the social issues associated with these settlements. It is important to acknowledge their presence, size and distribution. There are essentially three major centres of human settlement in the reserve. These are Mavago, Msawize and the Marrupa-Gomba road (Mecula Corridor). Between the period 1993 and 2001 Desmet (2004) determined a 33% expansion in both Mavago and the Mecula Corridor and a 75% contraction at Msawize. The distribution and approximated size of human settlements is indicated in Figure 3.19. It should be acknowledged that there are numerous other smaller settlements not reflected or recorded

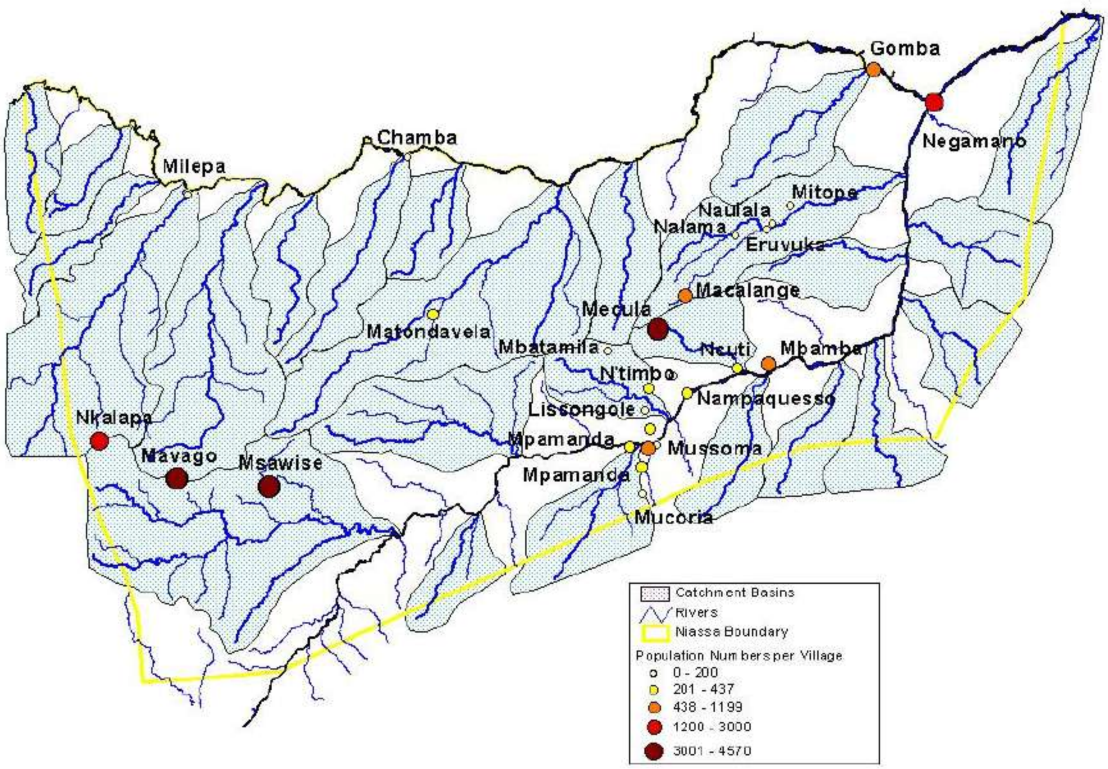


Figure 3.19 Distribution and approximate size of human settlements within the Niassa Reserve.

In acknowledging the shift toward co-management approaches to conservation, the SGDRN has adopted a strategy of community engagement through community based natural resource management (CBNRM) initiatives. In this spirit SGDRN entered into a CBNRM project with the WWF in 2000. This initiative is aimed at involving communities in the natural resource management of the RdN.

Communities engage in numerous activities within the reserve. Slash and burn agriculture is responsible for clearing large areas of the RdN. Such practices, along with fires started while travelling, have resulted in as much as 80% of the reserves total area being burnt annually. The alluvial soils along the river margins provide some of the most fertile and better watered agricultural areas in the reserve. As such they are used extensively for the cultivation of tobacco, maize and other staple foods. The extent of agriculture, as determined by Desmet (2004) from landsat images, has decreased between 1993 and 2001 (42107 ha to 39807 ha: Figure 3.20). However the area impacted by agriculture is estimated to have increased (42107 ha to 60370 ha), representing a 43% increase in the amount of transformed land between 1993 and 2001.

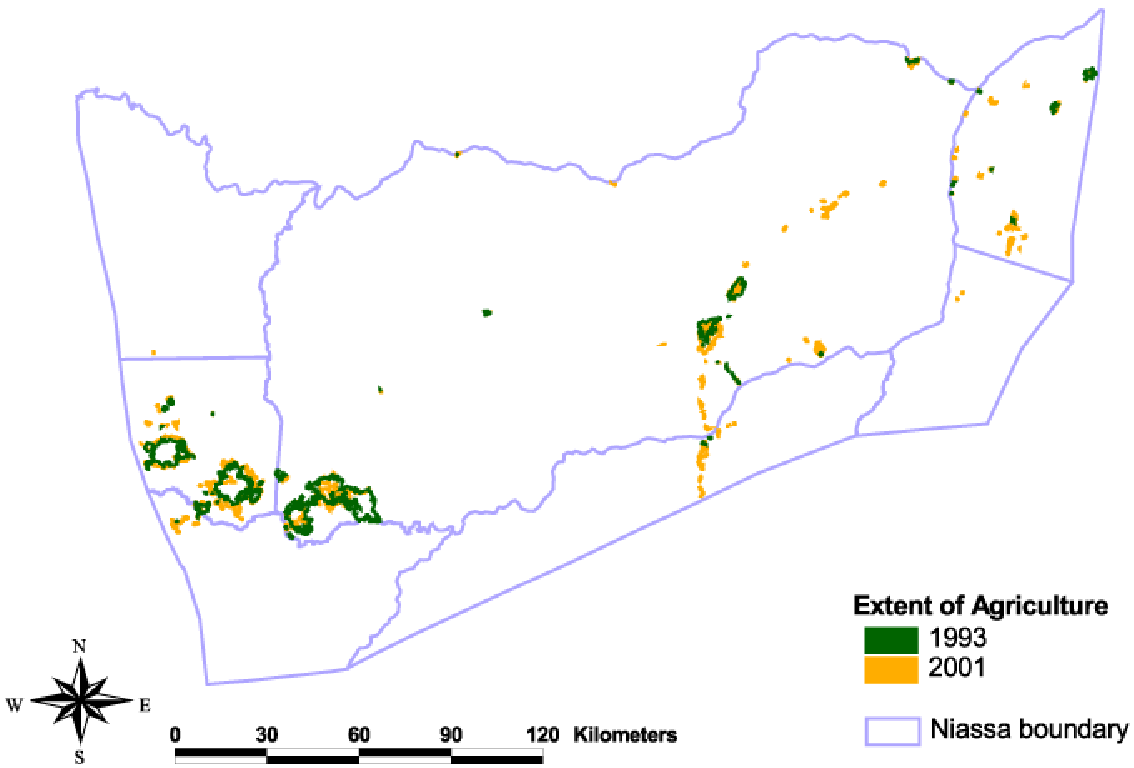


Figure 3.20 Extent of agriculture within the Niassa Reserve as defined by Desmet (2004).

4 Rivers of the Niassa Reserve

The Niassa Reserve is bordered by the Rovuma and Lugenda rivers. Internally the reserve encompasses numerous other smaller streams and rivers. The report differentiates between these. The Rovuma and Lugenda rivers are both large, sand bed rivers with permanent flow all year round. They constitute the northern, southern and eastern boundaries of the reserve. As such they are influence by activities outside of the reserve, be they upstream activities, those in Tanzania or further to the south of the Lugenda River. These two rivers are examined from a broad regional perspective. Characteristics of the river are described and the simulated run-off provides an estimate of the annual volume of water and the seasonal distribution of runoff. Different consideration is afforded to the rivers internal to the reserve (Figure 4.1). These smaller rivers drain catchments completely contained within the reserve. They are typically ephemeral, either drying completely during the dry winter months or experiencing the cessation of flow resulting in the formation of isolated pools. The characteristics of the flow in these rivers are central to determining the ecological and functional characteristics. These smaller internal rives will be considered further in the formulation of the catchment based management framework for the Niassa Reserve.

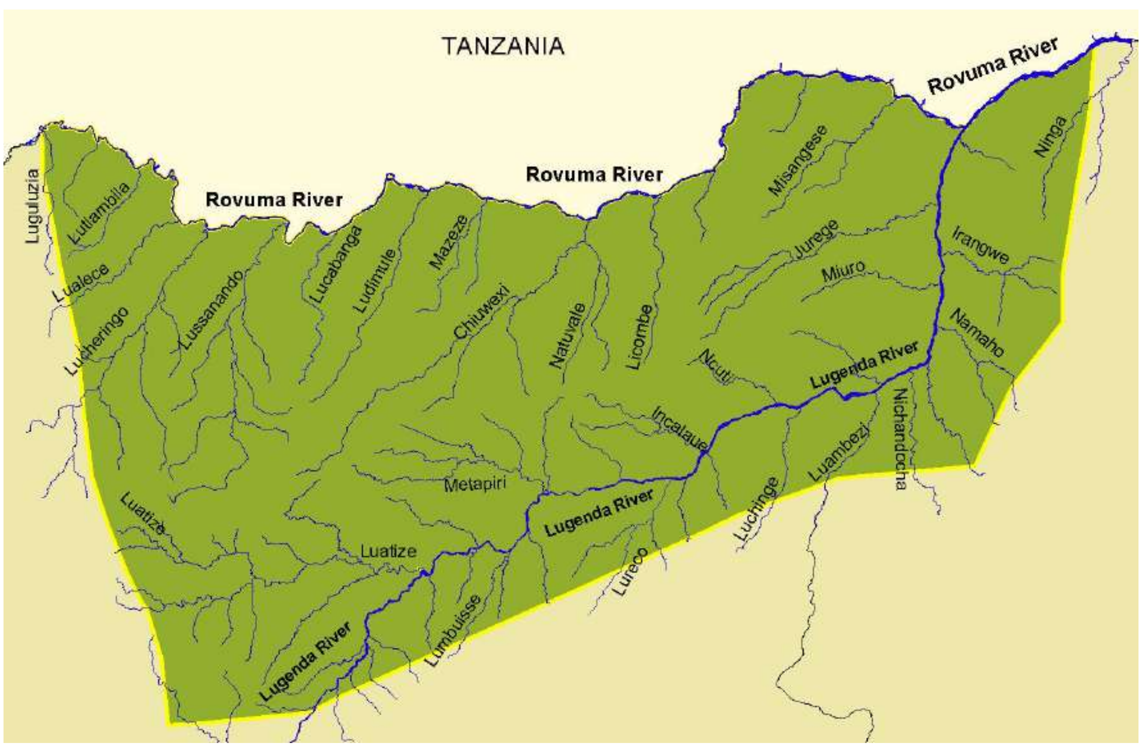


Figure 4.1 The main rivers of the Niassa Reserve.

4.1 Hydrological Modelling

Hydrological data is not available for any of the rivers within the Niassa Reserve. Some preliminary information has been determined for the Lugenda River (REF). This information provides the foundation for the following estimates which have been derived using the Thornthwaite-Mather approach. This is a relatively simplistic method based on the water balance of the top soil.

Calculations are based on meteorological data and soil parameters, such as yield capacity, which are carried out in a sequence of months. At each monthly interval an evaluation is made of the soil moisture balance in order to determine excess rainfall. Based on the sequence of saturation and deficit in soil moisture, estimates of recharge and runoff are calculated within the catchment. Parameters available for the Lugenda River catchment were used to derive estimates of total annual run-off for secondary rivers within the reserve and more detailed consideration, including inter- and intra-annual variations, of the Rovuma and Lugenda rivers.

The objective of the modeling is to;

(i) make a preliminary assessment of the hydrological regime of the rivers in the Niassa Reserve, and
(ii) determine the degree of seasonality associated with the hydrology of the system.

The mathematic formulation used in the Thornthwaite-Mather method is as follows:

$$P - ET_e - Q - R = \Delta S_s + \Delta S_{So}$$

Whenever P is greater than or equal to potential evapotranspiration, that period is considered to have had a hydrological surplus (SH), whereas the contrary situation is considered to have a hydrological deficit (DH).

Where $\Delta S_s >= 0$,

$$SH = P - (ET_p + \Delta S_s),$$

Where $\Delta S_s < 0$,

$$DH = ET_p - ET_e = ET_p - (P - \Delta S_s)$$

$$\Delta S_s = S_s(i) - S_S(i-1)$$

$$S_s(i) = N_u * e^{(L(i)/Nu)}$$

Where L(i) < 0,

$$L(i) = \sum \left[P(j) - ET_p(j)\right],$$

Where:

P is precipitation in the catchment;
ET_e is actual evapotranspiration ΔS
Q is surface runoff;
R is recharge;

N_u is field capacity; and
ΔS is storage at the end of the period above surface and subsurface respectively.

The central tenet of this method is that any precipitation will first be lost through evapotranspiration or used in replenishment of soil moisture until field capacity is reached before any recharge or surface runoff will take place.

Although the method was initially developed and is known to perform well for small catchments, it has been shown that the model can prove useful in deriving runoff estimates in the absence of available hydrological data even for larger catchments. Given the paucity of available data for much of Moçambique this method has been used extensively in the design of hydraulic infrastructures.

Climatic data was obtained for ten stations across northern Moçambique. These included the following:

1. Litunde
2. Massangulo
3. Mecula
4. Lichinga
5. Marrupa
6. Maua
7. Meponda
8. Mocimboa do Rovuma
9. Nairoto
10. Nungo

Total surplus water was calculated for each month using the Thornthwaite-Mather approach. The results for each of the stations are presented in Annex 2.

Given proximity to the Niassa Reserve data from the Mecula climatic station was used to derive an index for calculating total annual run-off in the rivers of the reserve. As mentioned previously poor soil infiltration capacity results in a high run-off potential with most of the available rainfall converted into surface runoff. It needs to be noted that the rainfall at Mecula is likely to be above the average for the Niassa reserve, particularly those areas to the north-east. The Thornthwaite-Mather method is not sensitive enough to allow determination of low flows. These low flows are likely to be important in supporting the aquatic biodiversity and determining the viability of certain populations during the dry season in particular.

4.2 Biogeographic Affiliations

The rivers of northern Moçambique fall within the east coast ichthyofaunal biogeographic province of Skeleton (1994). This biogeographic region stretches from the Tana River in Kenya all the way south to the Lower Zambezi and includes lakes Rukwa and Victoria.

More recently the WWF has developed a continental ecoregion classification for freshwater ecosystems in Africa which defines the rivers of the Niassa Reserve as being part of the Eastern Coastal Basin freshwater ecoregion (Figure 4.2: Oyugi et al., 2004).

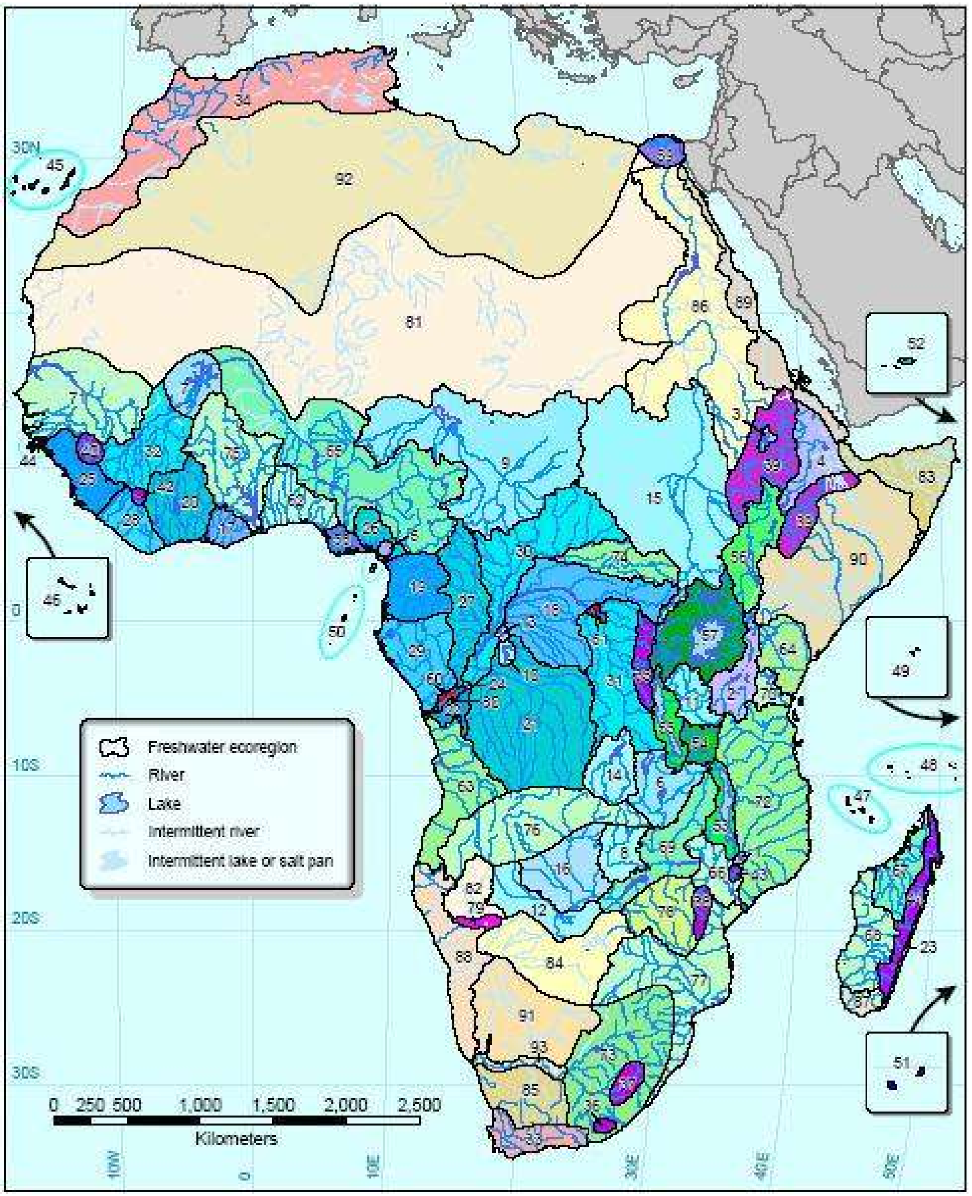


Figure 4.2 Freshwater ecoregions of Africa (WWF).
Niassa Reserve is located in the east African coastal region defined by Ecoregion 72.

The Eastern Coastal Basin ecoregion extends along the east African coast from the northern Wami River in Tanzania to the Luala River basin in Mozambique, just above the lower reaches of the Zambezi basin. The ECB ecoregion is dominated by the Ruaha/Rufiji, Ruvuma, Lugenda and Lúrio river systems and includes a number of smaller coastal basins. Rivers in this region are typical of those in the Niassa Reserve, characterised by relatively low gradients, high sediment yields traversing dry miombo forest. The WWF classification considers these “continentally outstanding” and “vulnerable”, meaning that the region is characterised by unique features relative to the rest of the continent.

Within the ECB ecoregion there is a diverse array of habitats. These include forested headwater streams, medium-sized rivers and their tributaries, mangrove forests, estuaries, small lakes, permanent swamps, dambos, deltas, and seasonal floodplains. The freshwater environments of the Niassa Reserve are representative of these including large permanent rivers – the Rovuma and Lugenda, along with a large number of smaller ephemeral rivers and streams. The inselbergs and mountain ranges to the west provide high altitude, canopied mountain streams while the low lying flat plateau is scattered by dambos, small grass covered seepage areas, and other wetlands.

About thirty percent of the nearly 100 described fish species within this ecoregion are considered endemic. Among these, there is a radiation of the Aplocheilidae genus *Nothobranchius*, with nine endemics known from this ecoregion (Lévêque 1997). A survey of the fishes of the Niassa Reserve has recorded 39 species within the RdN, with at least one of the endemic *Nothobranchius* species, *N. kirki*, recorded as common from within the Rovuma River (Bills, 2004). The most speciose groups within this region are the characins, anguillid eels, rivulins, cyprinids, gobies, and mochokids. The fish fauna is considered relatively depauperate, with rivers in this region considered to have dried out during the last interpluvial (Roberts 1975). Affinities with the Zambezian fauna are considered to be the result of convergence in coastal rivers during sea level changes (Lévêque 1997).

The mountain headwaters of this ecoregion are less well known and the same can be said for the high altitude regions of the RdN. Over sixty species of aquatic-dependent frogs are known from the mountainous region in southern Tanzania alone (includes the Kipengere, Livingstone and Udzungwa mountain ranges), seven of which are endemic. Limited investigation has also shown that some of the mountains of southern Tanzania contain an important assemblage of Odonata (dragonflies and damselflies: Clausnitzer 2001).

4.3 Hydro-ecological Characteristics

The Niassa Reserve is characterised by a number of different aquatic habitats. It has been estimated that 55% of the reserve is wetland habitat (WHO? REF). The Lugenda and Rovuma rivers are both large, braided sand bed rivers with origins outside the reserve (Figure 4.3). North flowing tributaries to the Rovuma and south flowing tributaries to Lugenda are completely contained within the RdN. South flowing tributaries to the Rovuma River drain areas of Tanzania while the north flowing tributaries to the Lugenda drain areas within the reserves buffer zones and beyond. These rivers in turn have numerous smaller tributaries. These are typically small, sand channels with little riparian vegetation. In contrast, many of the upper reaches have well established riparian vegetation forming thick canopies fed via sub-surface waters (Figure 4.4).

This section will briefly consider the characteristics of the rivers in general. Three different river types are differentiated herein; the main boundary rivers, secondary internal rivers with catchment contained within the reserve and smaller tertiary rivers. In addition the reserve has numerous dambos (Figure 4.5). These are important seepage areas covered with sedges and grass. The following section looks more specifically at the individual catchments with a view to providing information for the development of the management framework.

Figure 4.3 The meandering, sand-bed channels of the Lugenda and Rovuma rivers, Niassa Reserve.

Figure 4.4 Streams within the Niassa Reserve display various characteristics, from open, sand-bed streams to heavily canopied, bedrock streams.

Figure 4.5 Grassed dambos within the Niassa Reserve act as important watering holes within the Niassa Reserve.

The main channels of the Lugenda and Rovuma rivers are braided, characterized by multiple channels flowing around alluvial islands (Figure 4.6). This creates a diverse array of lotic, semi-lotic, and lentic environments formed by fluvial action. These environments include side channels, dead arms connected with the main channel at one end, abandoned meander loops, abandoned braids, backswamps, and marshes, in addition to tributary streams, and alluvial springbrooks. Such rivers are highly unstable, with islands typically consisting of transient sand and less frequently, gravel bars. The establishment of vegetation cover during lower flow periods increases island stability under certain conditions (Schumm, 1985). Temporal changes in flow, combined with the wide, braided channel creates a diverse mosaic of habitat patches, ecotones, and successional stages. These are typically characterized by different biotic communities (Castella *et al.,* 1984; Copp, 1989; Mitsch and Gosselink, 1993).

Figure 4.6 Examples of the braided channels characteristic of the Lugenda and Rovuma rivers.

In addition to these habitats, subsurface, hyporheic waters below the stream provide an important refuge during periods of low and no flow. Sandy substrata, typical of the rivers in the Niassa Reserve, have low levels of available oxygen and suitable sub-surface habitats are typically confined to coarser gravel beds. None the less, these provide an important refuge in the otherwise harsh habitats of shifting sands and limited availability of water.

In certain areas rocky outcrops emerge from the river increasing habitat diversity. These outcrops typically occur where the river is constricted by changes in the underlying geology. Under such conditions erosional forces cut into the bedrock, resulting in pronounced drops in altitude, often with spectacular results as seen at the Mapanda Falls (Figure 4.7).

Figure 4.7 The geological constriction and change in altitude at the Mapanda Falls creates a diversity of habitats.

These outcrops provide important, stable habitats and create a diversity of flow related microhabitats. These are important refugia in an otherwise barren, sand-bed, riverine landscape but are susceptible to increases sedimentation. This may result from clearing of riparian vegetation and subsequent destabilisation of unconsolidated bank slopes accentuated through bank cultivation. Increases in sediments and nutrient levels will result in blanketing of rocky areas, destroying breeding areas for a diverse array of aquatic species and habitats.

The movement of sediments through these systems is dependent upon their characteristics and certain flow related variables. These can be used to estimate the rivers discharge and flow characteristics (Hick, 1968; Woodyer, 1968). These are “steps” in the channel profile corresponding to different discharges with a certain recurring frequency. Examples from the Lugenda River are presented below (Figure 4.8).

Insert hand drawings of benches and profiles

Figure 4.8 Cross section of the Lugenda River illustration the formation of benches or river terraces.

Vegetation mapping within the reserve has identified limited areas of riparian vegetation. This is largely confined to areas along the main channel of the Rovuma and Lugenda rivers, with patches occurring along certain tributaries. The rare occurrence and limited distribution of riparian vegetation within the reserve increases its importance. Riparian vegetation exhibits distinct zonation patterns from the main channels to the uplands. The margins of the larger rivers support a relatively thin strip of riparian vegetation which is notably absent from the majority of smaller streams within the reserve, although see Figure 4.4 and accompanying text. Headwater streams, particularly those higher altitude streams toward the west and north-west, exhibit thick stands of riparian vegetation. This will translate into broad-scale spatial segregation of species along the rivers elevation gradient. At finer scales, species will segregate according to microsite. Gregory *et al.* (1991) attribute the high biodiversity of riparian plant communities to habitat diversity and disturbance regimes. Riparian vegetation is also important in regulating stream temperature and provides additional refuge and succulence for fauna during dry periods. Riparian vegetation along the Zambezi River has been found to support higher densities of wildlife during the dry season than the wet.

The profile of the main channels of the Rovuma and Lugenda rivers combined with the lack of extensive riparian vegetation may help explain the apparent paucity of crocodiles within the reserve. Although accounts of crocodile numbers differ, it is possible that the suitable habitat observed along the banks of the Rovuma and Lugenda rivers during periods of low flow is not available during high-flow, summer breeding months. In the absence of extensive riparian vegetation the habitat above bank full capacity is characterised by hard, sun-baked soils, high temperatures and evaporation rates with little vegetation and shade cover.

Dambos

The Niassa reserve has a number of seasonally inundated wetland areas or dambos. These are common at the headwaters of many southern and central Africa's streams and are considered important stores of water. Although the volume of water stored is insufficient to maintain dry season flows, dambos none the less provide an invaluable source of moisture during the dry season. As such, they represent a valuable agricultural resource, particularly for small scale farmers during the dry season.

Dambos are found throughout the Niassa Reserve, although greater concentrations are observed in the north-western and central parts of the reserve's core areas. These are typically higher altitude headwaters regions. They provide an important source of water, particularly during dry periods and as a result of extensive utilisation display characteristic piosphere effects, where land is degraded around the watering point from animals coming to the water to drink.

Figure 4.9 Dry dambo illustrating piosphere effect caused by animals coming in to drink.

4.4 Catchment Descriptions

This section provides a preliminary description of each of the secondary catchments within the reserve. The term secondary catchment is derived in relation to the rivers of the reserve and does not reflect stream order. As such, the Rovuma and Lugenda rivers are considered to be the reserve's primary rivers, with those indicated in Figure 4.1 above described as secondary rivers. There also exist a large number of small ephemeral drainages. These are not considered in detail but are acknowledged at the end of this section.

The information presented herein draws on existing and available information, which includes the results from the aerial wildlife surveys (Gibson, 2000), biodiversity surveys, interviews with senior management, experiences of geologists working in area and field verification of some sites. While aerial verification of landscape scale processes followed by ground-truthing and biological sampling would prove useful, there was limited opportunity due to availability and access to aircraft, vehicles and time. The field visit was undertaken during one week at the end of the dry season. This afforded the opportunity to document the driest conditions and determine the seasonality of flows. It would be beneficial to undertake similar investigations toward the end of the wet season to verify findings and compare conditions.

We have attempted to present a standard reporting format for each of the rivers within the reserve boundaries. These rivers are grouped according to their being in the Rovuma or Lugenda catchments. This format first provides a brief summary of characteristics, such as river length, gradient and catchment area, an estimate of the total annual run-off and the size and distribution of human settlements within the catchment. This information is contextualised with a brief description of the vegetation according to the Flora Zambeziana. This is a broad classification system and is obviously limited in its application. The intention is provide an overview and example of the approach. This can be used to identify priority areas for further refinement.

Similarly, the wildlife maps are prepared from results of the SRN aerial survey (Gibson, 2000). This information is obviously for a single period and includes species capable of movement between catchments. The survey has been carried out toward the end of the dry season and from that perspective affords an indication of those catchments that might provide important refugia for species during periods of drought. The base maps were cut according to the catchment files. This enabled calculation of density estimates or the percentage of the total distribution for a species represented by the individual catchment being considered. A summary of this information is presented in Annex 3. Again, the intention is to provide a broad overview and indication of the application of the catchment based framework for conservation and management.

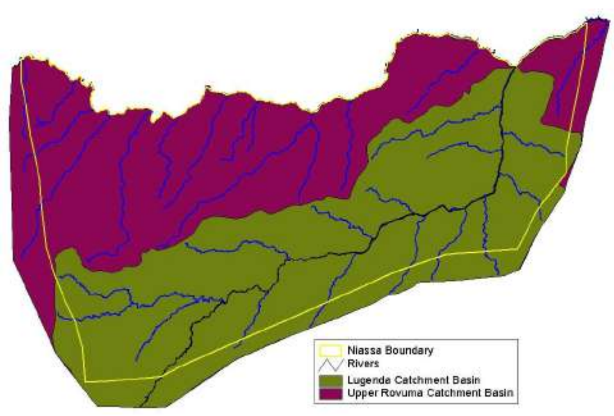


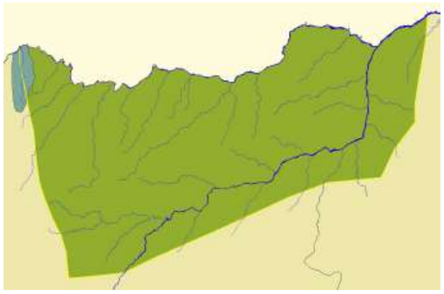
Figure 4.10 Rovuma (red) and Lugenda (green) sub-catchments of the Niassa Reserve.

4.4.1 Rovuma Sub-Catchment

The Rovuma River runs for 400km along the northern boundary of the Niassa Reserve and forms the border between Moçambique and Tanzania. The river has a relatively low gradient (0.0010) and is characterised by alluvial sandy substrata interspersed with rocky outcrops. The northern part of the Rovuma catchment is situated in Tanzania. Given the catchment traverses two countries information pertaining to the hydrological characteristics is limited.

The following descriptions include only those catchments on the southern side of the Rovuma catchment within the Niassa Reserve.

Luguluzia River



Catchment Characteristics

Length (km)	55
Gradient	0.0031
Area (km^2)	840
Run-Off (Mm^3 / year)	420
Population	0

The Luguluzia River is situated on the eastern boundary of the reserve and drains north into the Rovuma River. The river has a relatively small catchment with average gradient for the rivers of the reserve. Catchment vegetation is dominated by deciduous miombo (95%) with the remaining 5% covered by tardily deciduous miombo. Situated on the edge of the reserve boundary, wildlife data is limited. Relatively high concentrations of sable are observed within the centre of the catchment with eland observed over 30km2 of the catchment, representing 1% of the total distribution. Kudu were observed over 70km2 of the lower part of the catchment toward the confluence with the Rovuma River accounting for 1% of the total species distribution in the reserve. Reedbuck is common, covering 170km2 of the lower and upper reaches accounting for 5% of the species distribution. There is no recorded population within the Luguluzia River catchment.

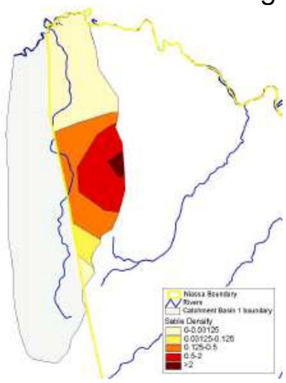


Figure 4.11 Distribution of Sable within the Luguluzia River catchment.

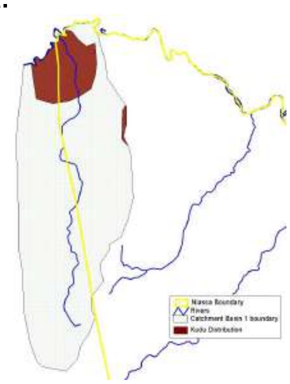


Figure 4.13 Distribution of Kudu within the Luguluzia River catchment.

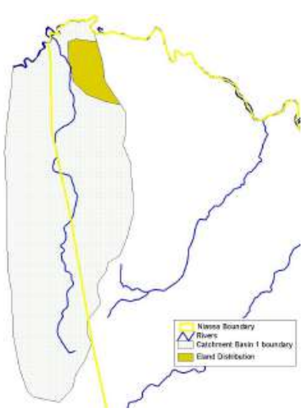


Figure 4.12 Distribution of Eland within the Luguluzia River catchment.

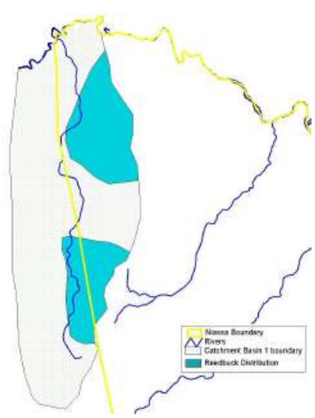
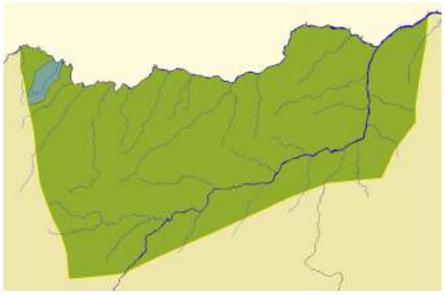


Figure 4.14 Distribution of Reedbuck within the Luguluzia River catchment.

Lutiambila River



Catchment Characteristics

River Length (km)	42
Gradient	0.0043
Area (km^2)	460
Run-off (Mm^3 / year)	230
Population	0

The Lutiambila River is situated on the eastern side of the reserve and drains north into the Rovuma River. The river has one of the smallest catchment with a relatively steep gradient for the rivers of the reserve. Catchment vegetation is dominated by deciduous miombo (95%) with the remaining 5% covered by tardily deciduous miombo. Relatively little wildlife was recorded during aerial surveys with reedbuck found over 170km2 of the lower and upper reaches of the catchment accounting for 4% of the species distribution. Kudu is found over 80km2, representing 1% of the total species distribution, in the north-western part of the catchment adjacent to the Rovuma River. There is no recorded population within the Lutiambila River catchment.

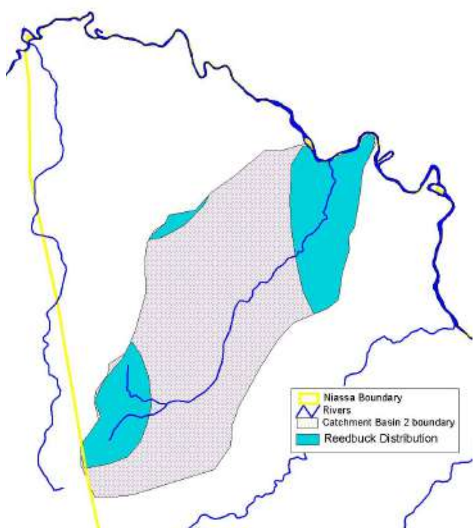


Figure 4.15 Distribution of Reedbuck within the Lutiambila River catchment.

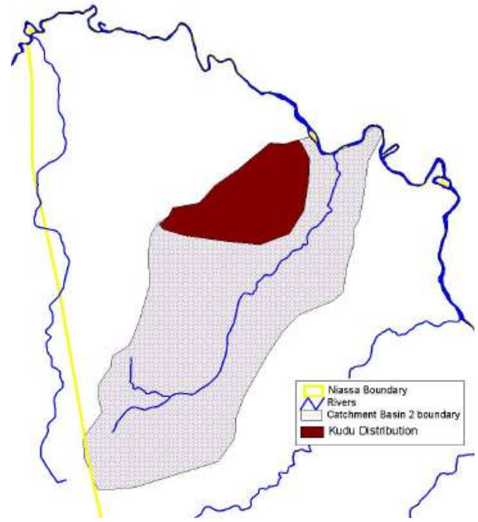
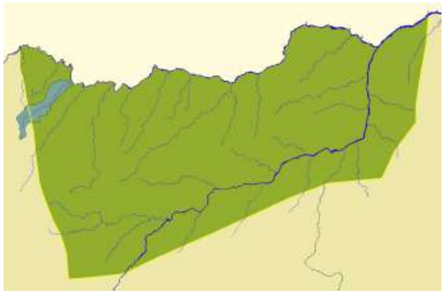


Figure 4.16 Distribution of Kudu within the Lutiambila River catchment.

Lualece River



Catchment Characteristics

River Length (km)	70
Gradient	0.0043
Area (km^2)	520
Run-off (Mm^3 / year)	260
Population	0

The Lualece River is situated on the eastern boundary of the reserve and drains north into the Rovuma River with the upper reaches originating outside the reserve. The river has a relatively small catchment with relatively steep gradient for the rivers of the reserve. Catchment vegetation is dominated by deciduous miombo (90%) with the remaining 10% covered by tardily deciduous miombo. With the upper reaches outside of the reserve boundary, wildlife data is limited. Relatively high concentrations of zebra and sable are observed within the centre of the catchment with eland observed over 60km2 of the upper reaches equivalent to 2% of the species distribution. Kudu and reedbuck are found in the lower reaches (70km2 and 90km2) representing 1% and 3% of the species distribution, with waterbuck (2% of species distribution) and some reedbuck (3% of species distribution) observed in the middle of the catchment area. There is no recorded population within the Lualece River catchment.

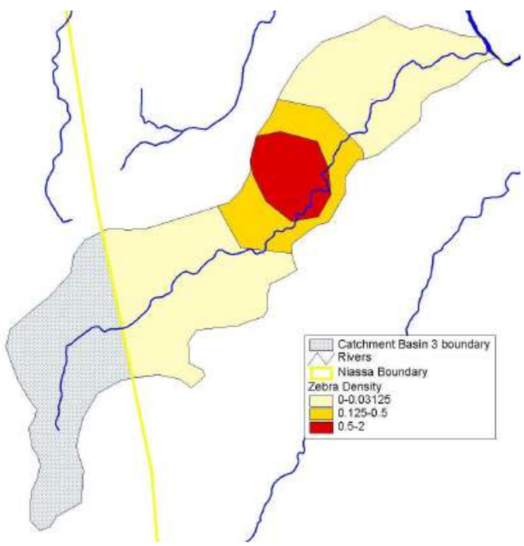


Figure 4.17 Density of Zebra in the Lualece River catchment.

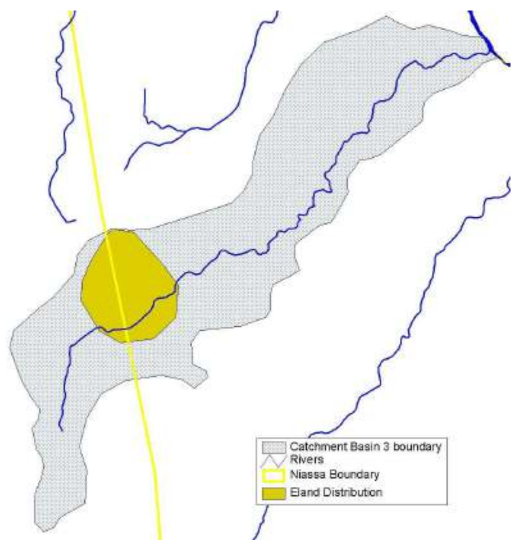


Figure 4.18 Distribution of Eland in the Lualece River catchment.

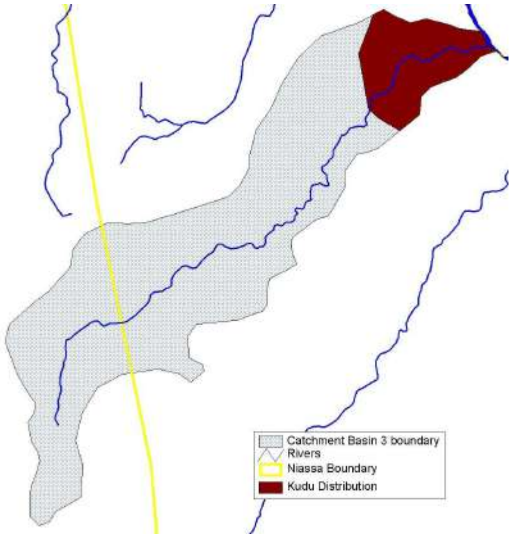


Figure 4.19 Distribution of Kudu in the Lualece River catchment.

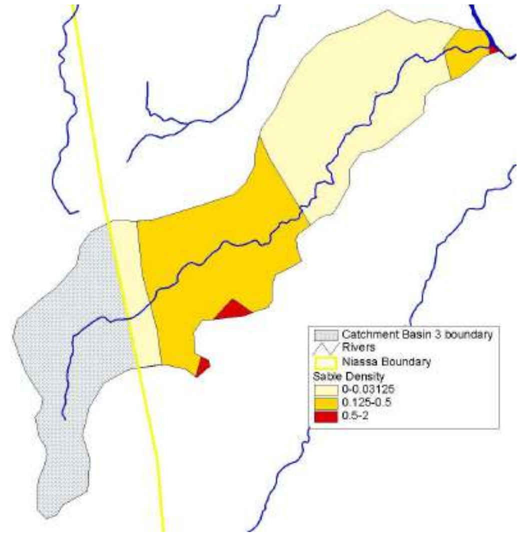


Figure 4.21 Density of Sable in the Lualece River catchment.

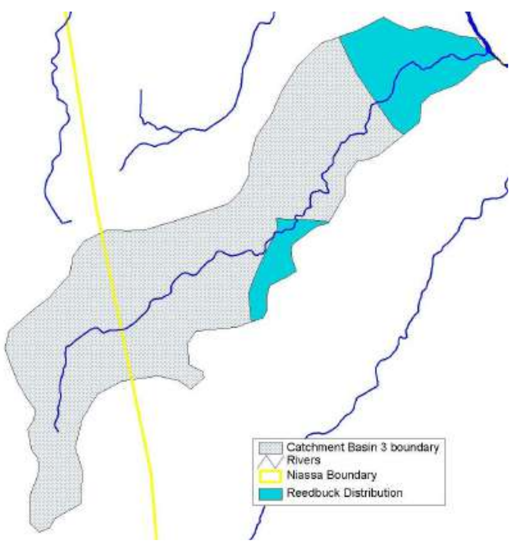


Figure 4.20 Distribution of Reedbuck in the Lualece River catchment.

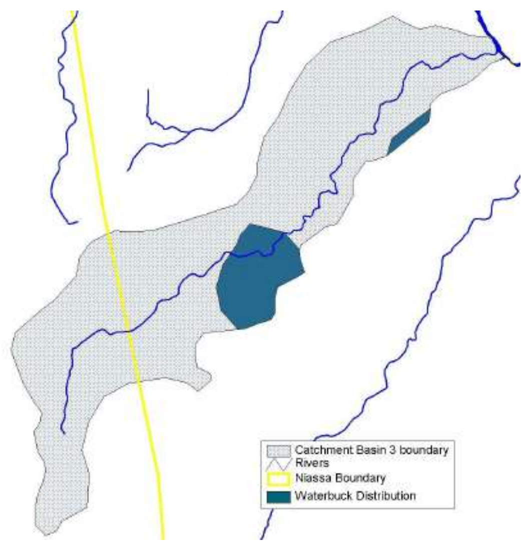
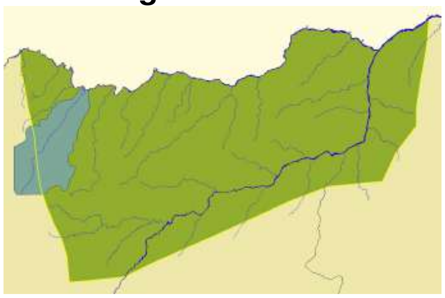


Figure 4.22 Distribution of Waterbuck in the Lualece River catchment.

Lucheringo River



Catchment Characteristics

River Length (km)	120
Gradient	0.0041
Area (km^2)	2670
Run-off (Mm^3 / year)	1335
Population	188 (Milepa)

The Lucheringo River is the largest of the catchments in the reserve. Situated on the eastern boundary of the reserve its drains north-west into the Rovuma River with the upper reaches originate outside the reserve. The river is one of the largest of the rivers in the reserve with relatively steep gradient. Catchment vegetation is dominated by deciduous miombo (80%) with the remaining 20% covered by tardily deciduous miombo. With the upper reaches outside of the reserve boundary, wildlife data is limited. Relatively low concentrations of zebra and elephant are observed within the centre of the catchment with higher concentrations of sable scattered throughout the catchment. Kudu were observed over 70km2 representing 1% of the species distribution, with waterbuck showing similar distribution in the lower reaches of the catchment. Hartebeest are observed on the south-eastern part of the catchment representing 1% of the total distribution with reedbuck displaying similar distribution. Wildebeest are only observed within a small area of the central part of the catchment. One settlement is recorded within this catchment, having 188 people.

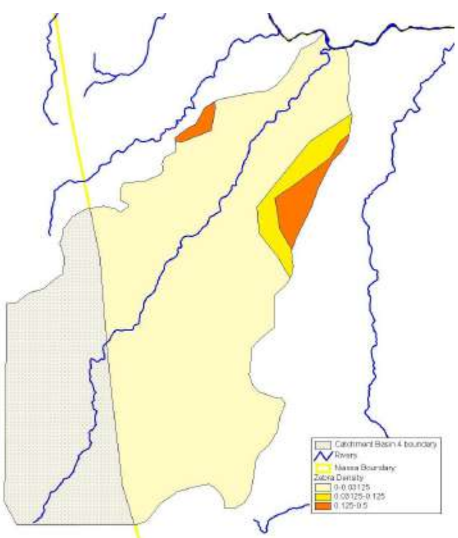


Figure 4.23 Density of Zebra in the Lucheringo River catchment.

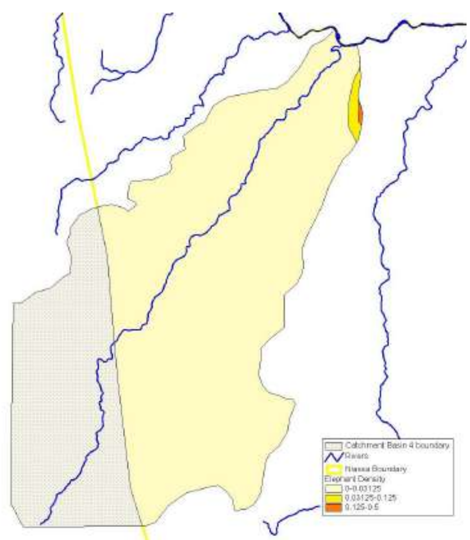


Figure 4.24 Density of Elephant in the Lucheringo River catchment.

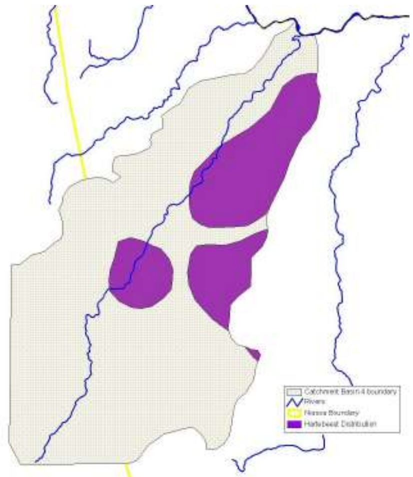


Figure 4.25 Distribution of Hartebeest in the Lucheringo River catchment.

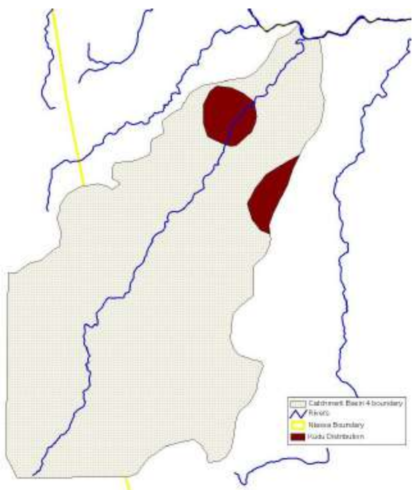


Figure 4.26 Distribution of Kudu in the Lucheringo River catchment.

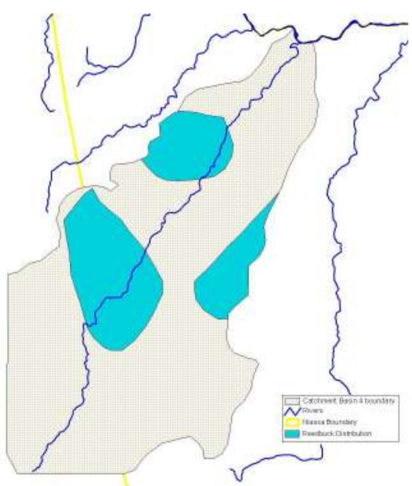


Figure 4.27 Distribution of Reedbuck in the Lucheringo River catchment.

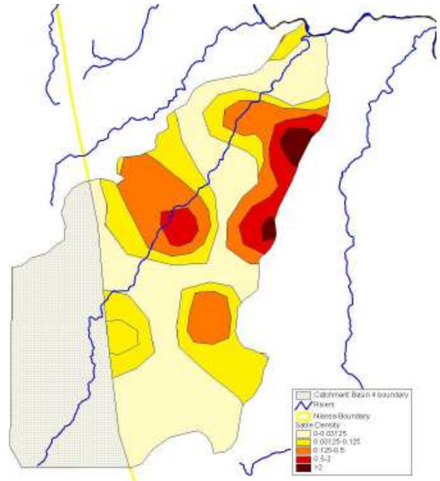


Figure 4.28 Density of Sable in the Lucheringo River catchment.

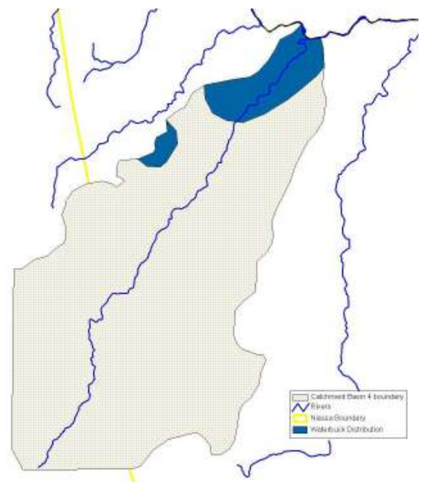


Figure 4.29 Distribution of Waterbuck in the Lucheringo River catchment.

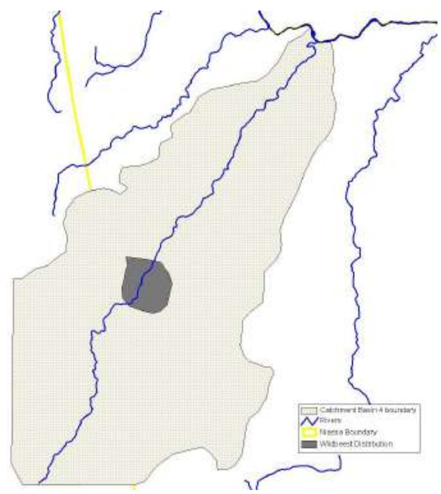
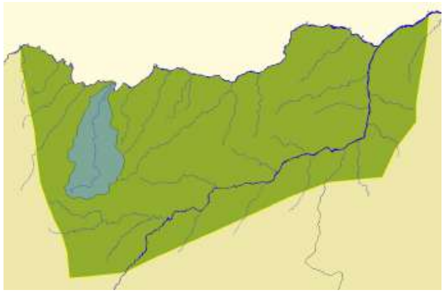


Figure 4.30 Distribution of Wildebeest in the Lucheringo River catchment.

Lussanando River



Catchment Characteristics

River Length (km)	133
Gradient	0.0024
Area (km^2)	2330
Run-off (Mm^3 / year)	1165
Population	0

The Lussanando River is the second largest of the catchments within the reserve, situated centrally on the eastern side of the reserve and draining north into the Rovuma River. The upper reaches originate high on the escarpment. The river is one of the largest of the rivers in the reserve with relatively low average gradient, although including steep headwater streams. Catchment vegetation is dominated by deciduous miombo (80%) with the remaining 20% covered by tardily deciduous miombo. The catchment is one of the more diverse, with zebra and elephant present and high concentrations of sable scattered throughout. The distribution of reedbuck accounts for 17% of the total observed distribution, including 14% of the total observed distribution of hartebeest, 7% of the kudu distribution, and 1% of the eland distribution. No settlements are recorded within the Lussanando catchment.

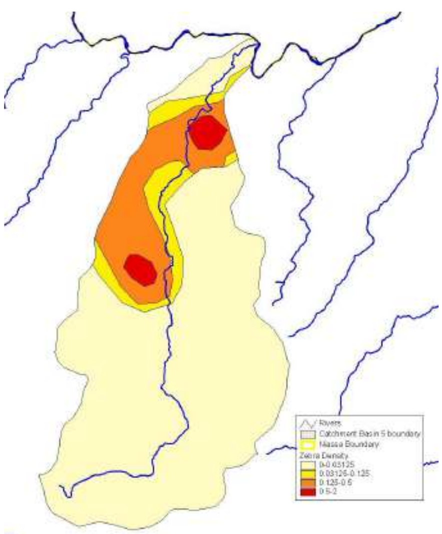


Figure 4.31 Density of Zebra in the Lussanando River catchment.

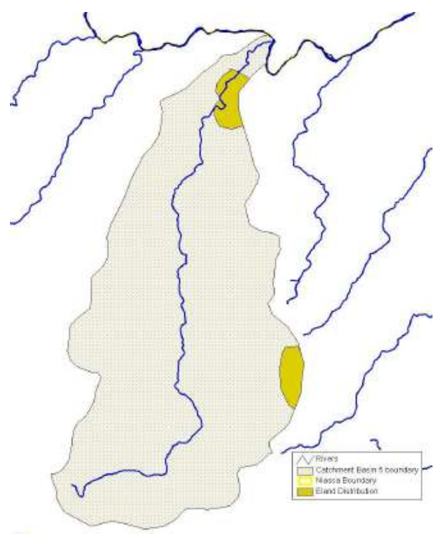


Figure 4.32 Distribution of Eland in the Lussanando River catchment.

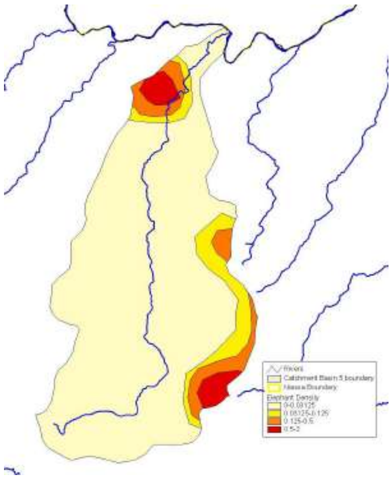


Figure 4.33 Density of Elephant in the Lussanando River catchment.

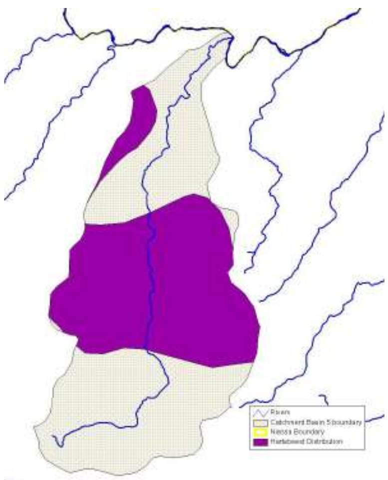


Figure 4.34 Distribution of Hartebeest in the Lussanando River catchment.

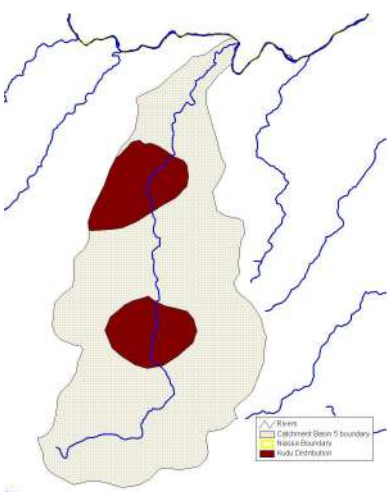


Figure 4.35 Distribution of Kudu in the Lussanando River catchment.

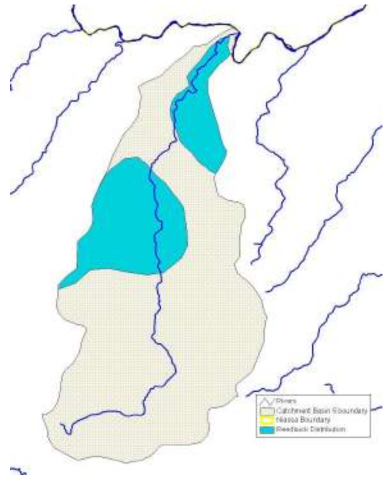


Figure 4.36 Distribution of Reedbuck in the Lussanando River catchment.

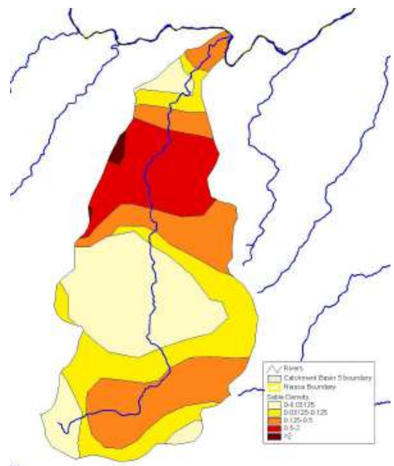
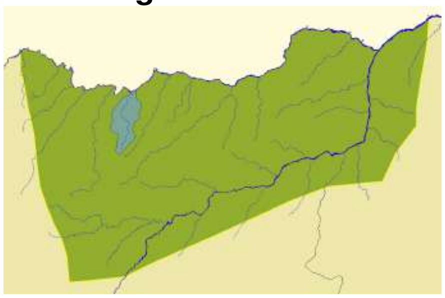


Figure 4.37 Density of Sable in the Lussanando River catchment.

Lucabanga River



Catchment Characteristics

River Length (km)	67
Gradient	0.0034
Area (km^2)	640
Run-off (Mm^3 / year)	320
Population	0

The Lucabanga River is a relatively small catchment situated centrally within the reserve and draining north into the Rovuma River. The river is one of the smallest rivers in the reserve with an average gradient for rivers of the reserve. Catchment vegetation is mixed with deciduous (67%) and tardily deciduous (28%) miombo dominating. The remaining 5% is made up of dry tall mixed thicket. Despite its relatively small size the Lucabanga River catchment includes diversity of wildlife, with observations of reedbuck accounting for 18% of the total distribution, 3% of the distribution of hartebeest and 1% of the wildebeest distribution. Zebra concentrations are high toward the lower reaches with elephant observed in relatively low densities in the upper reaches and sable observed throughout. No settlements are recorded within the Lucabanga River catchment.

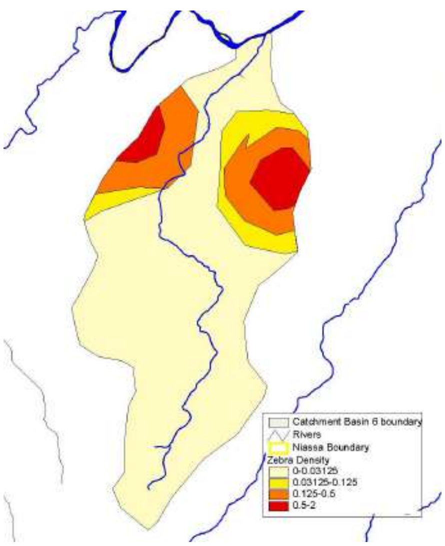


Figure 4.38 Density of Zebra in the Lucabanga River catchment.

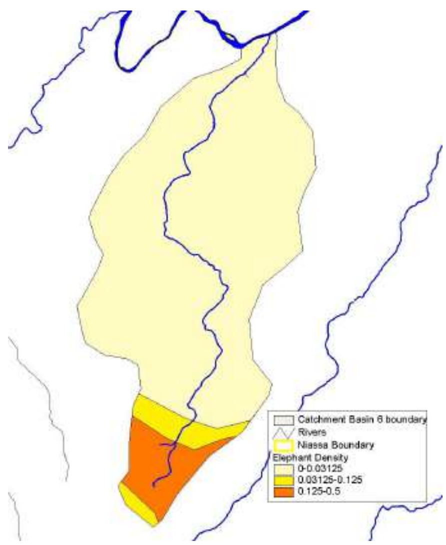


Figure 4.39 Density of Elephant in the Lucabanga River catchment.

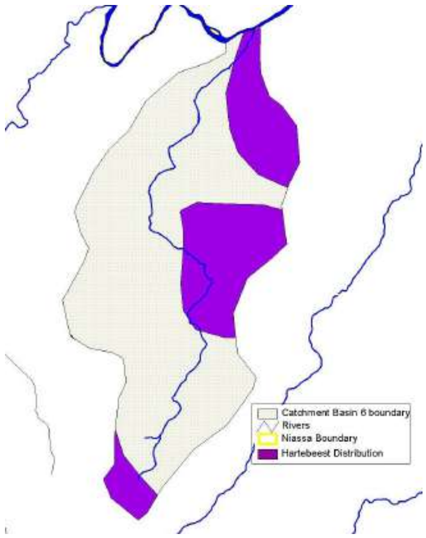


Figure 4.40 Distribution of Hartebeest in the Lucabanga River catchment.

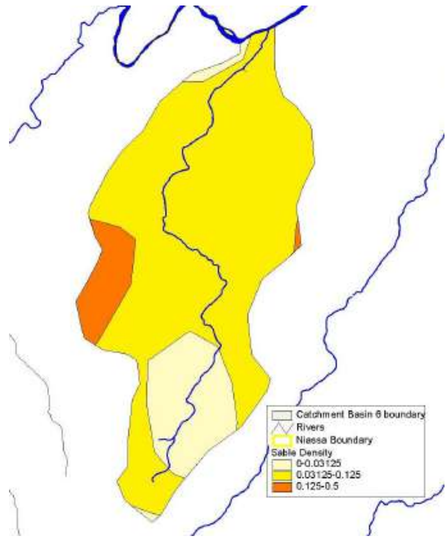


Figure 4.42 Density of Sable in the Lucabanga River catchment.

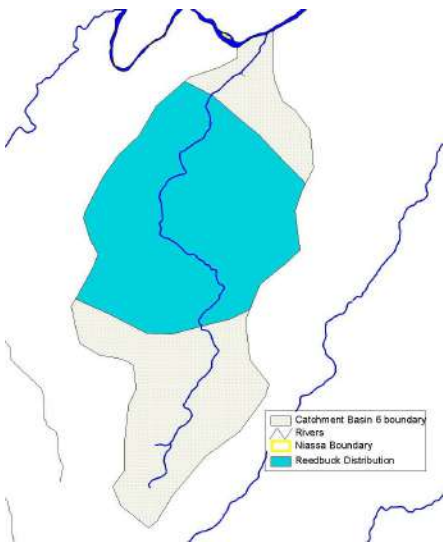


Figure 4.41 Distribution of Reedbuck in the Lucabanga River catchment.

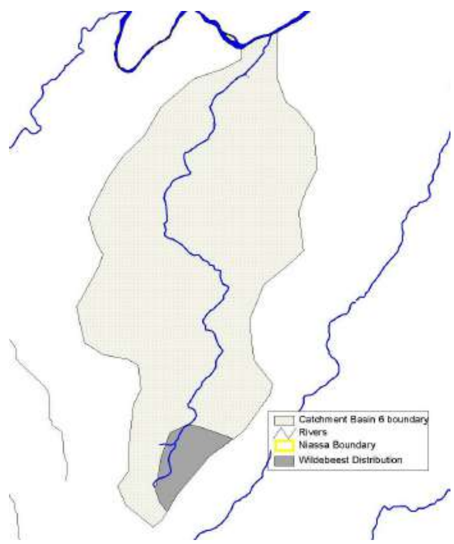
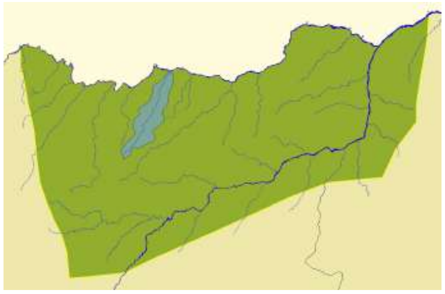


Figure 4.43 Distribution of Wildebeest in the Lucabanga River catchment.

Ludmule River



Catchment Characteristics

River Length (km)	87
Gradient	0.0025
Area (km^2)	900
Run-off (Mm^3 / year)	450
Population	143 (Chamba)

The Ludmule River is a relatively small catchment situated centrally within the reserve and draining north into the Rovuma River. The river is one of the smallest rivers in the reserve with an average gradient for rivers of the reserve. Catchment vegetation is mixed with deciduous (80%) miombo dominating. Tardily deciduous miombo (15%) and dry tall mixed thicket (5%) make up the rest of the catchment vegetation. Despite its relatively small size the Ludmule River catchment includes a diversity of wildlife. Observations of waterbuck and wildebeest account for 4% and 3%, respectively, of the distribution of these species with both observed in the upper reaches of the catchment. The catchment includes 3% of the eland distribution and 3% of that for hartebeest, with 1% of the distribution for reedbuck and kudu. Sable exhibit increasing concentrations toward the confluence with the Rovuma River, with elephant highly concentrated in two locations and a low concentration of zebra throughout. Zebra The settlement of Chamba, with 143 people, is situated at the confluence of the Ludmule and Rovuma rivers.

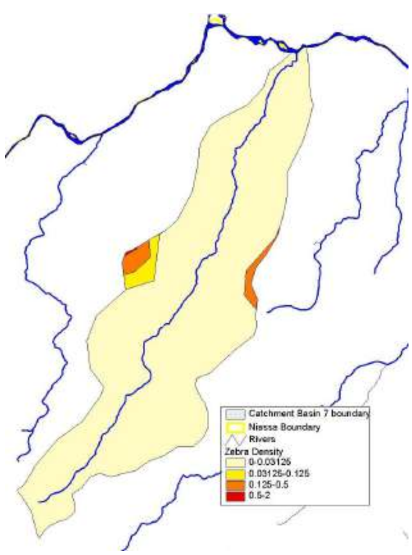


Figure 4.44 Density of Zebra in the Ludmule River catchment.

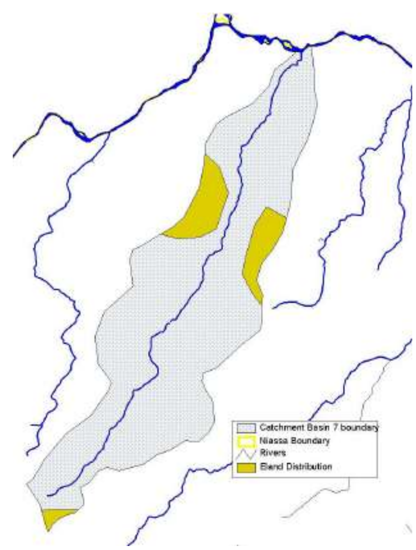


Figure 4.45 Distribution of Eland in the Ludmule River catchment.

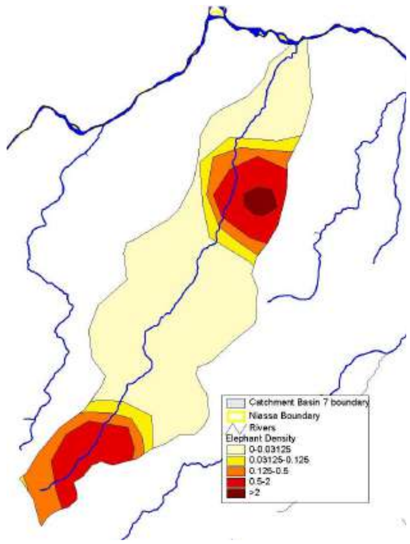


Figure 4.46 Density of Elephant in the Ludmule River catchment.

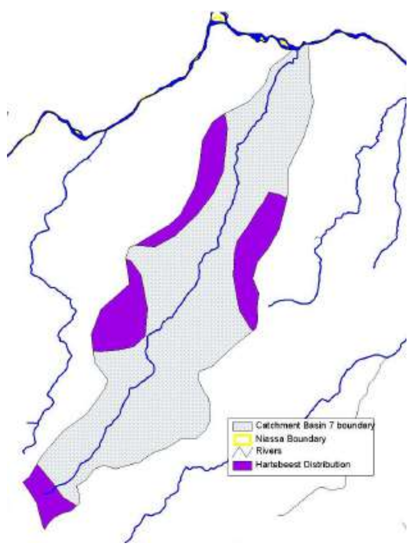


Figure 4.47 Distribution of Hartebeest in the Ludmule River catchment.

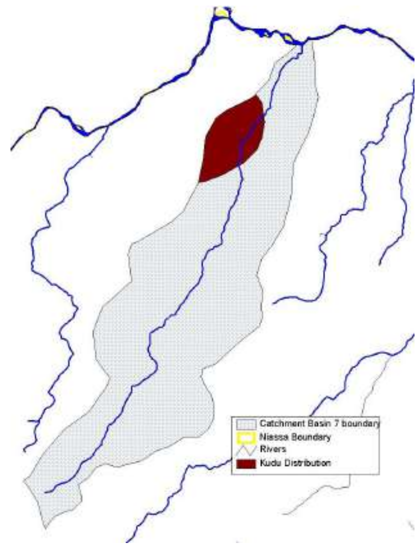


Figure 4.48 Distribution of Kudu in the Ludmule River catchment.

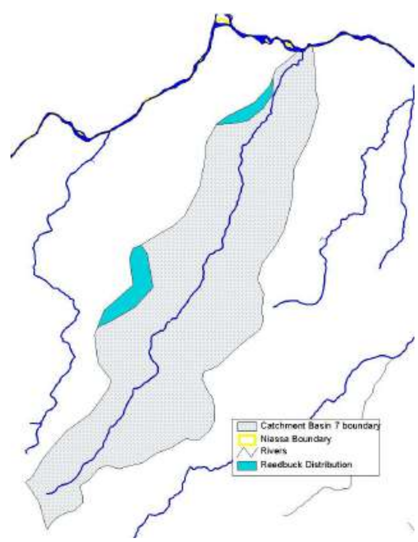


Figure 4.49 Distribution of Reedbuck in the Ludmule River catchment.

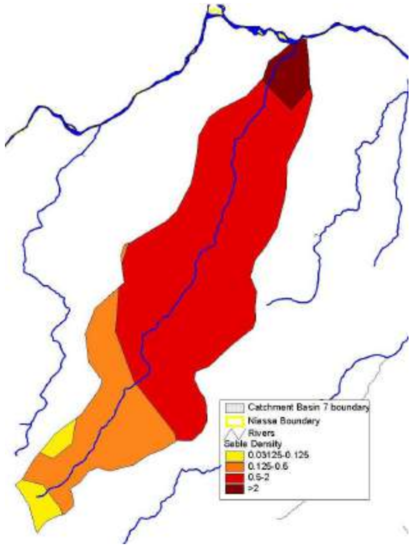


Figure 4.50 Density of Sable in the Ludmule River catchment.

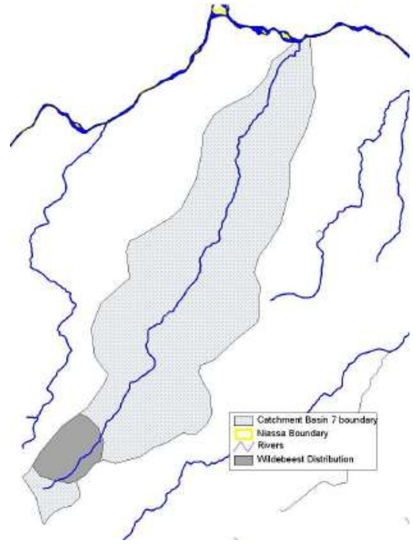


Figure 4.52 Distribution of Wildebeest in the Ludmule River catchment.

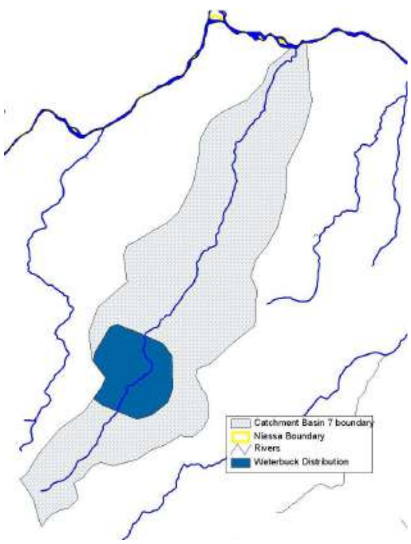
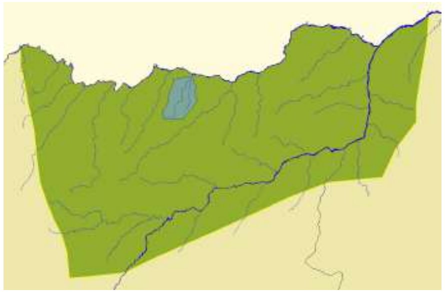


Figure 4.51 Distribution of Waterbuck in the Ludmule River catchment.

Mazeze River



Catchment Characteristics

River Length (km)	55
Gradient	0.0036
Area (km^2)	590
Run-off (Mm^3 / year)	295
Population	0

The Mazeze River is one of the reserve's smaller catchments. Situated centrally within the reserve and draining north into the Rovuma River, the river is has an average gradient for rivers of the reserve. Catchment vegetation is dominated by deciduous miombo (95%) with the remaining 5% dry tall mixed thicket. There is a high concentration of zebra and elephant toward the upper reaches of the catchment with high densities of sable observed throughout. The distribution of eland is confined to the upper reaches and accounts for 5% of the species total distribution within the reserve. A small number of impala were recorded toward the confluence with the Rovuma River, 1% of total distribution with 5% of the total hartebeest distribution observed in the middle and upper reaches of the catchment. No settlements are recorded within the Mazeze River catchment.

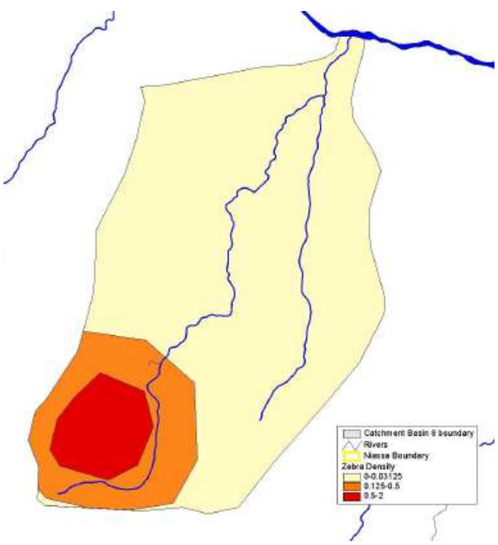


Figure 4.53 Density of Zebra in the Mazeze River catchment.

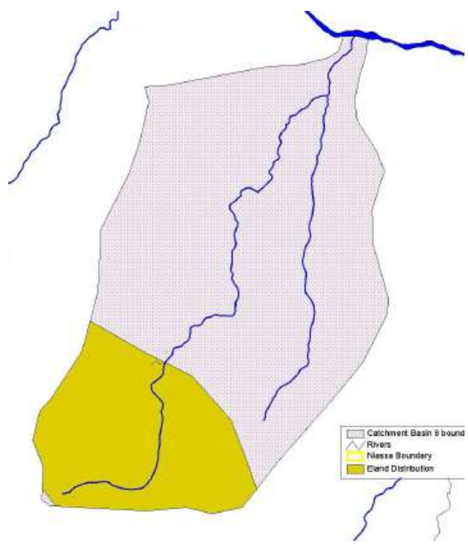


Figure 4.54 Distribution of Eland in the Mazeze River catchment.

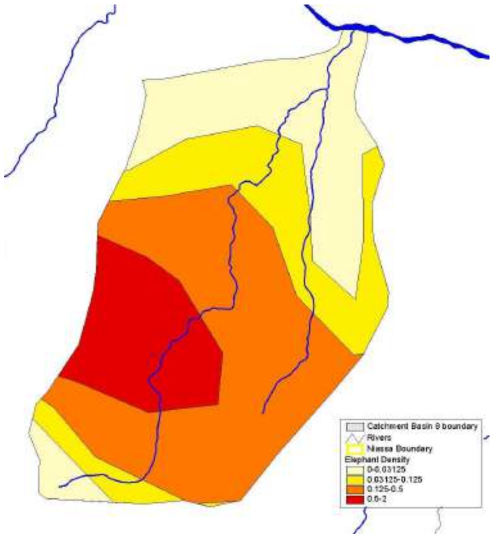


Figure 4.55 Density of Elephant in the Mazeze River catchment.

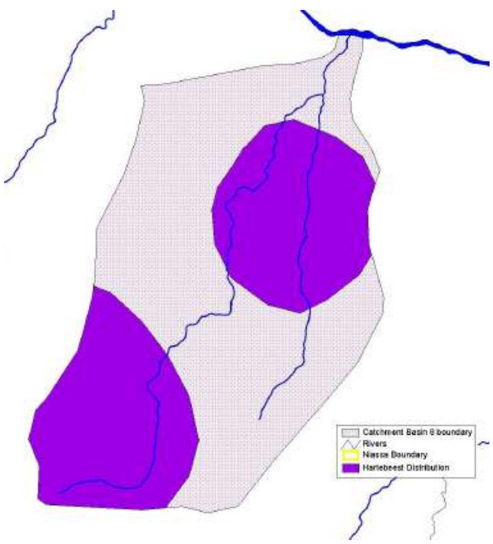


Figure 4.56 Distribution of Hartebeest in the Mazeze River catchment.

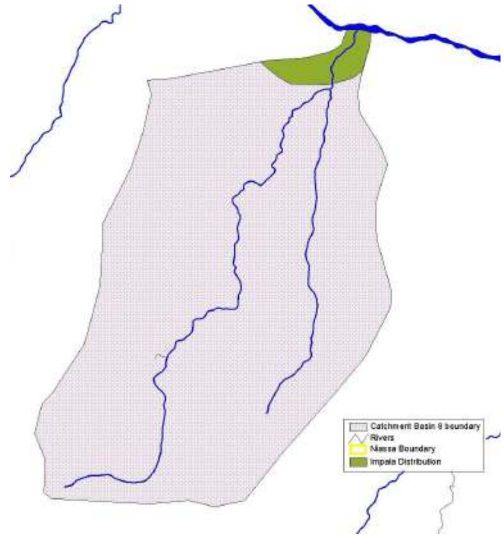


Figure 4.57 Distribution of Impala in the Mazeze River catchment.

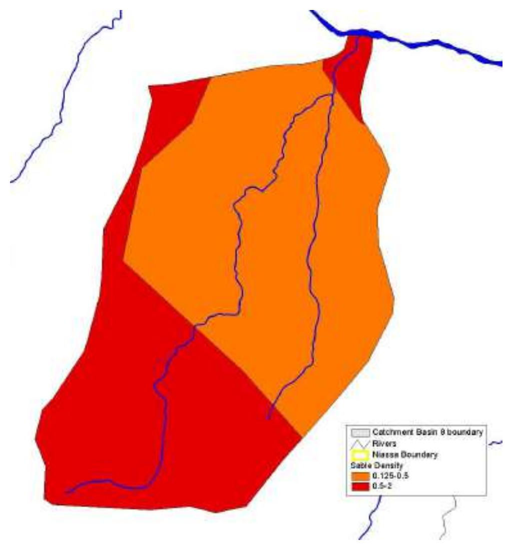
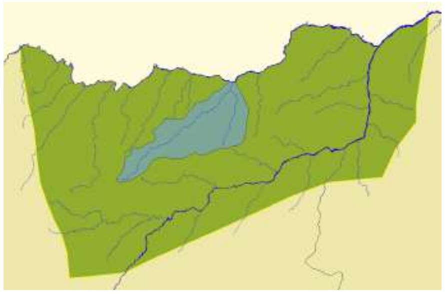


Figure 4.58 Density of Sable in the Mazeze River catchment.

Chiuwexi River



Catchment Characteristics

River Length (km)	148
Gradient	0.0037
Area (km^2)	3000
Run-off (Mm^3 / year)	1500
Population	437 (Matondovela)

The Chiuwexi River is one of the largest in the reserve. Situated centrally within the reserve it drains north-east into the Rovuma River and for a river of its size has a relatively steep gradient for those in the reserve. Catchment vegetation is mixed with deciduous (76%) and tardily deciduous (17%) miombo dominating. The remaining 7% is comprised dry tall mixed thicket. Given its size, the Chiuwexi River catchment includes diversity of wildlife and accounts for large percentages of the total distribution of numerous species. Of the total distribution of eland, 25% is accounted for by observations in the Chiuwexi catchment. These are scattered throughout the catchment. Zebra, elephant and sable are found in relatively high concentrations throughout the catchment, while kudu and waterbuck are limited to small patches in the lower reaches. Given the catchment size these still account for roughly 5% of the total distribution of these species. The Chiuwexi catchment accounts for 40% of wildebeest distribution, 11% of buffalo and 13% of the hartebeest distribution making it one of the most diverse and concentrated areas of game within the reserve. No settlements are recorded within the Chiuwexi River catchment.

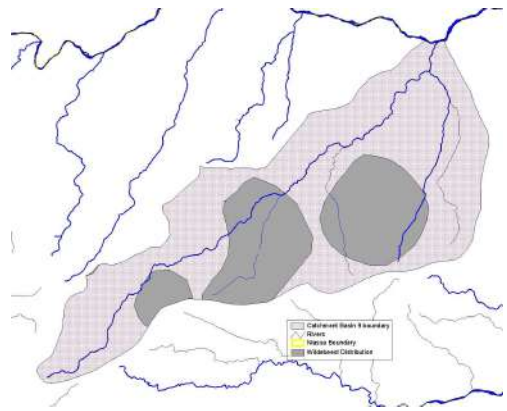


Figure 4.59 Distribution of Wildebeest in the Chiuwexi River catchment.

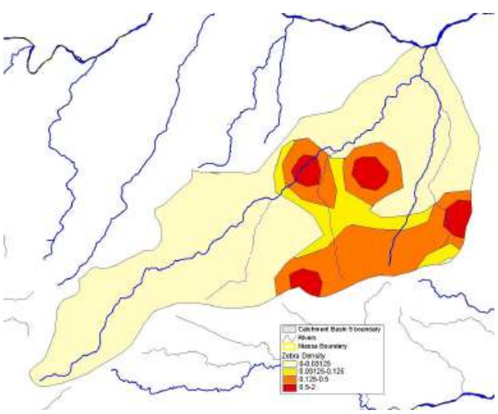


Figure 4.60 Density of Zebra in the Chiuwexi River catchment.

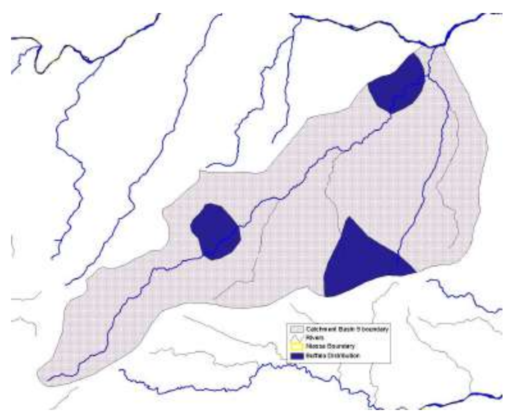


Figure 4.61 Distribution of Buffalo in the Chiuwexi River catchment.

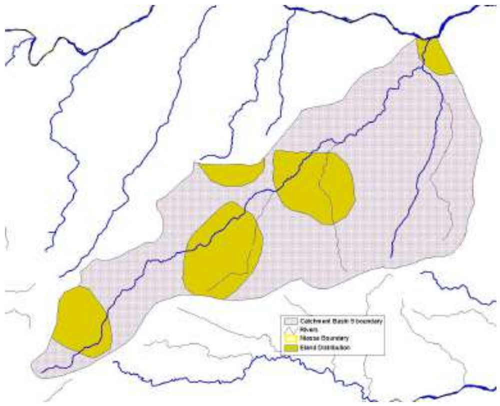


Figure 4.62 Distribution of Eland in the Chiuwexi River catchment.

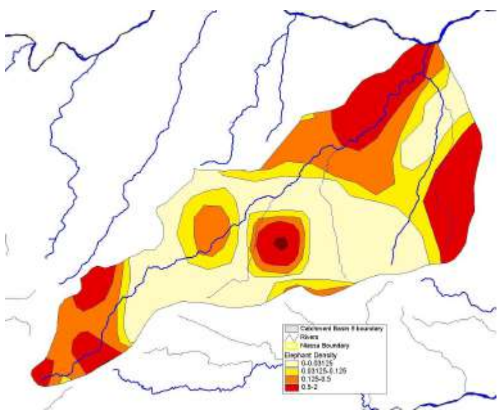


Figure 4.63 Density of Elephant in the Chiuwexi River catchment.

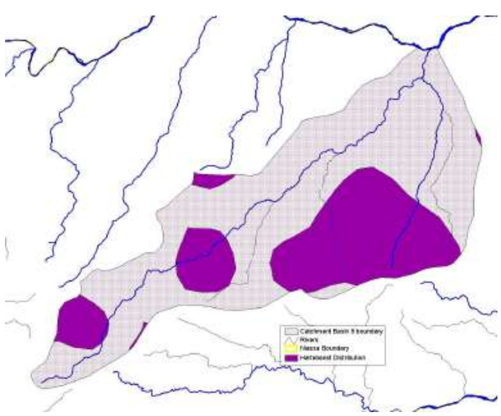


Figure 4.64 Distribution of Hartebeest in the Chiuwexi River catchment.

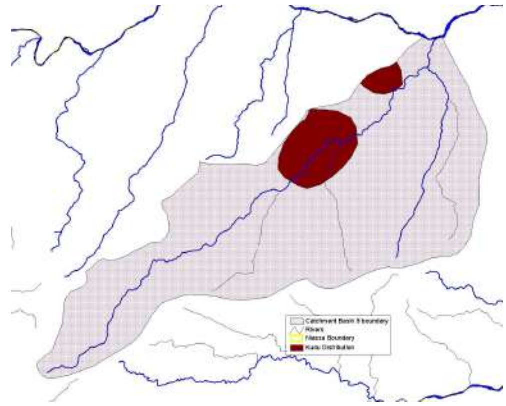


Figure 4.65 Distribution of Kudu in the Chiuwexi River catchment.

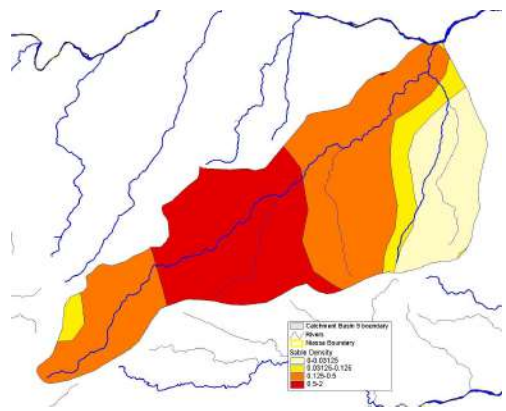


Figure 4.66 Distribution of Sable in the Chiuwexi River catchment.

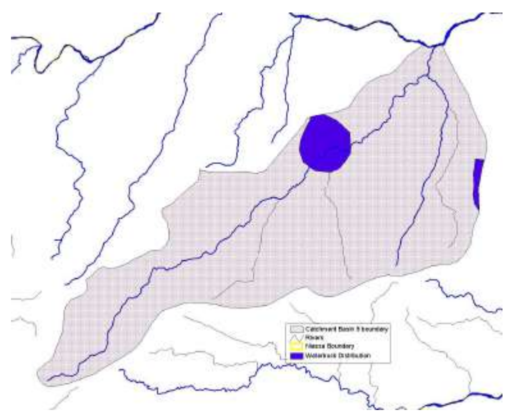
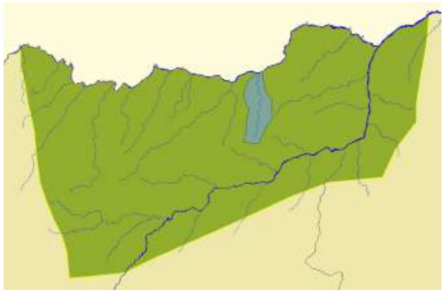


Figure 4.67 Distribution of Waterbuck in the Chiuwexi River catchment.

Licombe River



Catchment Characteristics

River Length (km)	65
Gradient	0.0015
Area (km^2)	800
Run-off (Mm^3 / year)	400
Population	0

The Licombe River is a relatively small catchment draining north into the Rovuma River in the centre of the reserve. It has a gentle gradient with relatively diverse catchment vegetation. This is dominated by deciduous (77%) and tardily deciduous (10%) miombo but includes deciduous dry miombo savanna woodland (8%) and moist evergreen forest (3%). The Licombe River catchment includes diversity of wildlife and accounts for relatively large percentages of the total distribution of numerous species given its size. Waterbuck and distributed in the upper reaches of the catchment and account for 6% of the species total distribution, while eland are observed only in the lower reaches, accounting for 3% of the total distribution. Hartebeest, impala and kudu are all found throughout the catchment and account for 4%, 7% and 7% of the respective species distributions within the reserve. Elephant show high concentrations throughout the catchment, while zebra and concentrated in the upper reaches and sable are observed in low numbers throughout. No settlements are recorded within the Licombe River catchment.

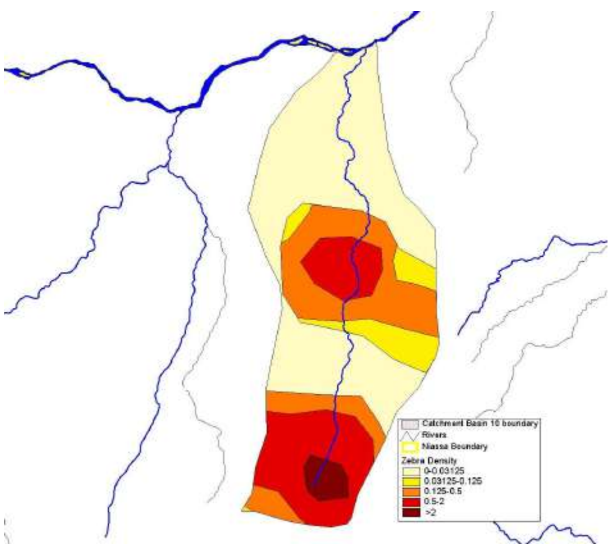


Figure 4.68 Density of Zebra in the Licombe River catchment.

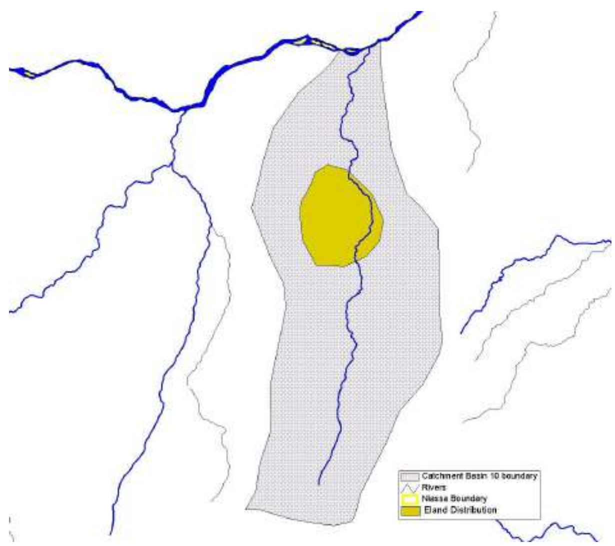


Figure 4.69 Distribution of Eland in the Licombe River catchment.

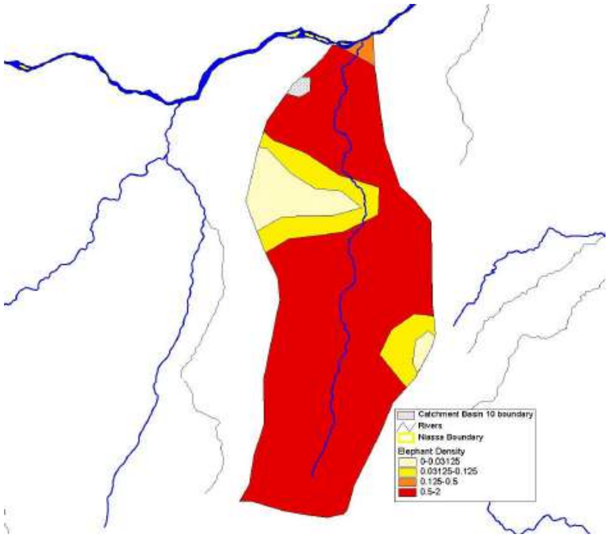


Figure 4.70 Density of Elephant in the Licombe River catchment.

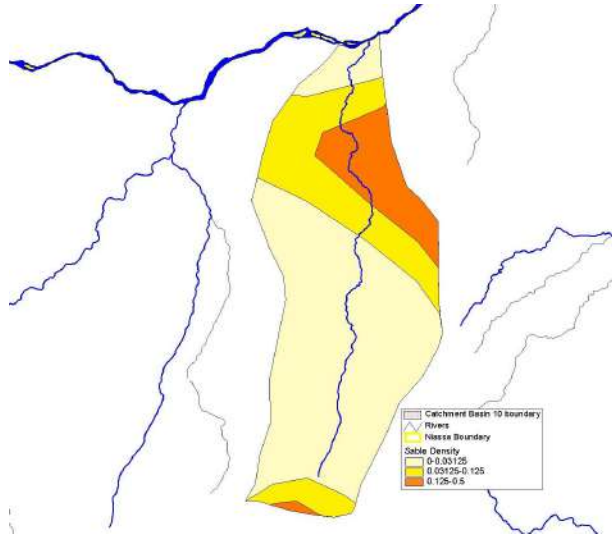


Figure 4.72 Density of Sable in the Licombe River catchment.

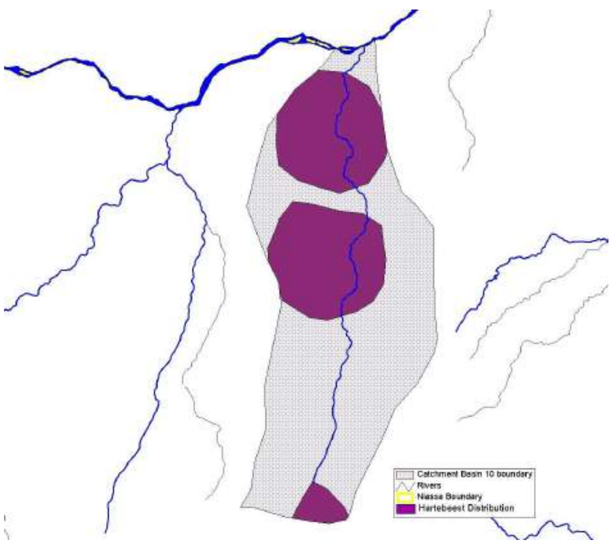


Figure 4.71 Distribution of Hartebeest in the Licombe River catchment.

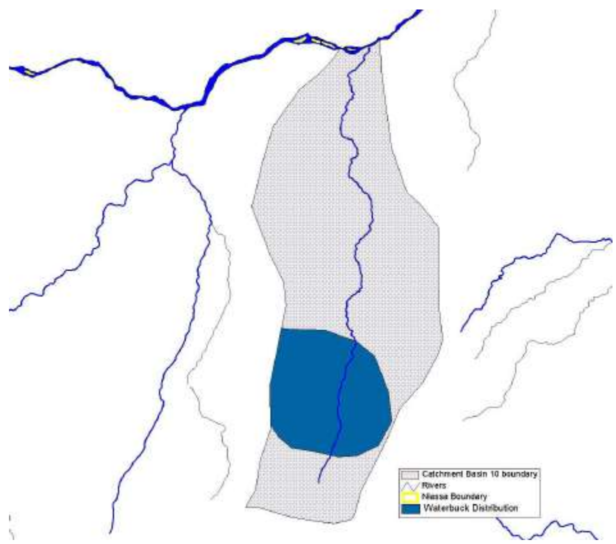
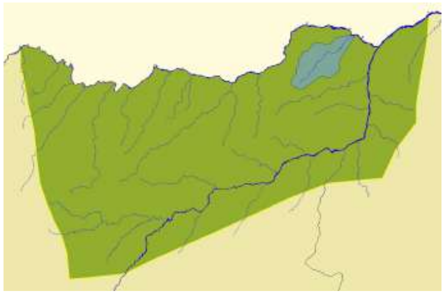


Figure 4.73 Distribution of Waterbuck in the Licombe River catchment.

Misangese River



Catchment Characteristics

River Length (km)	73
Gradient	0.0027
Area (km^2)	960
Run-off (Mm^3 / year)	480
Population	645 (Gomba)

The Misangese River is a relatively small catchment draining the reserve north-east into the Rovuma River. It has a relatively steep gradient give its size and location in the reserve. Catchment vegetation is comprised 58% and 42% deciduous miombo and deciduous dry miombo savanna woodland. Given its relatively small size, the Misangese River catchment includes diversity of wildlife although with the exception of eland and buffalo, accounts for little of the total distribution of individual species. Impala, hartebeest, eland and buffalo have all been observed within the central part of the catchment. Kudu is observed throughout the catchment with high concentrations of elephant and relatively low concentrations of zebra and sable throughout. The settlement of Gomba, with 645 people, is situated toward the confluence of the Misangese and Rovuma rivers.

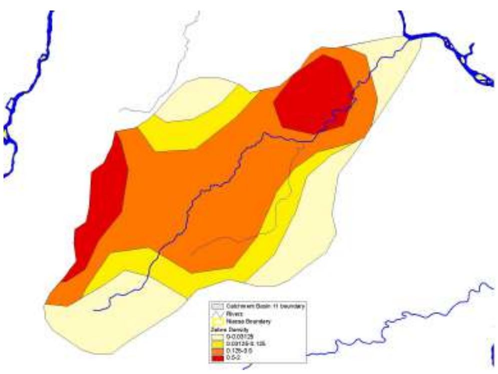


Figure 4.74 Density of Zebra in the Misangese River catchment.

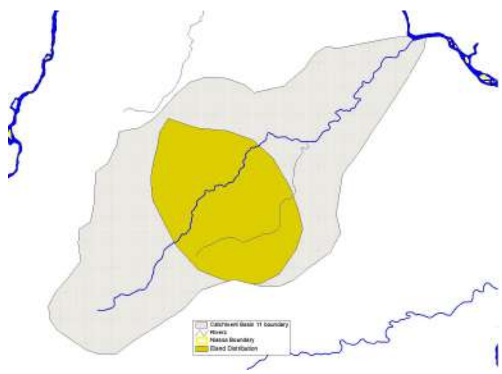


Figure 4.76 Distribution of Eland in the Misangese River catchment.

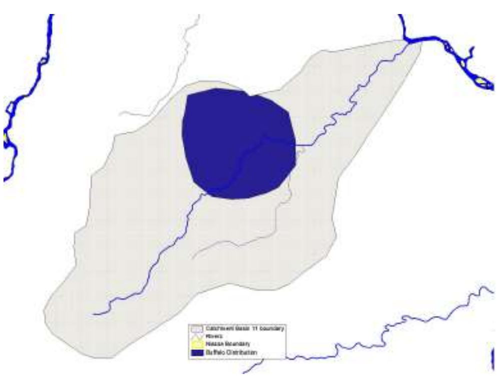


Figure 4.75 Distribution of Buffalo in the Misangese River catchment.

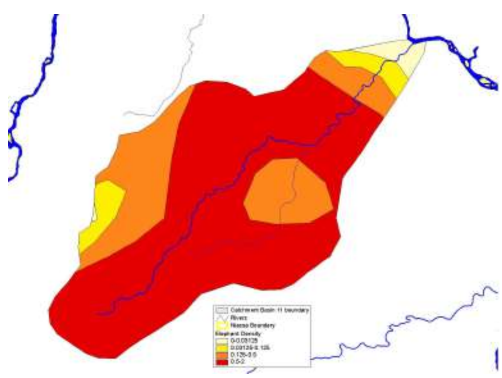


Figure 4.77 Density of Elephant in the Misangese River catchment.

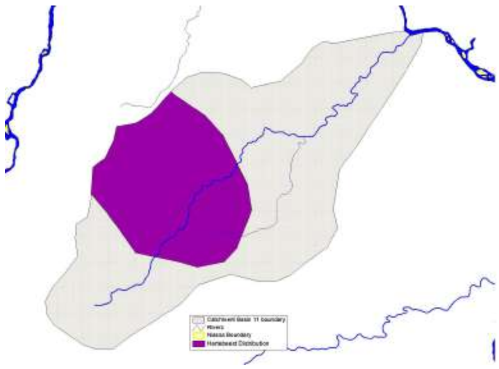


Figure 4.78 Distribution of Hartebeest in the Misangese River catchment.

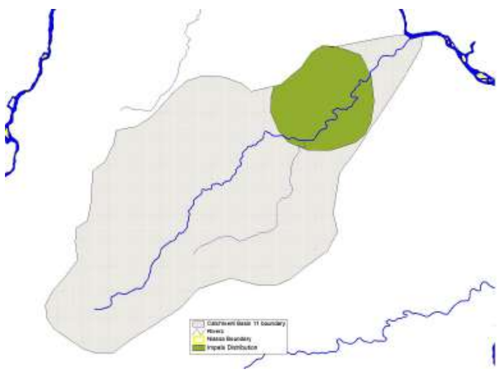


Figure 4.79 Distribution of Impala in the Misangese River catchment.

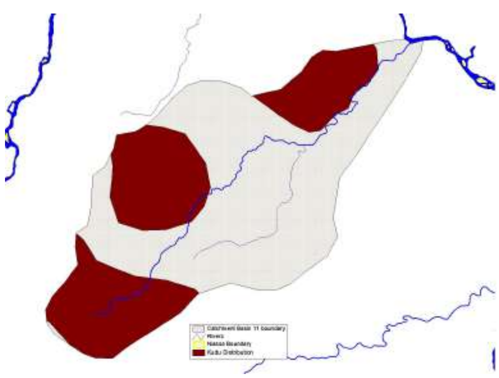


Figure 4.80 Distribution of Kudu in the Misangese River catchment.

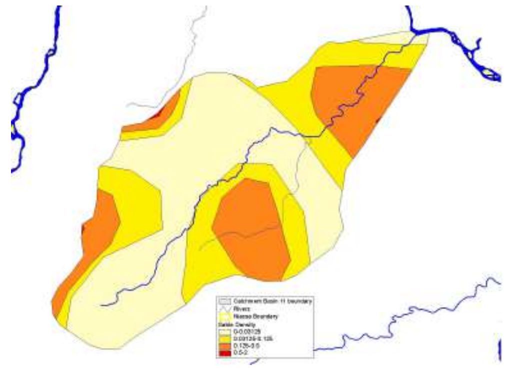


Figure 4.81 Density of Sable in the Misangese River catchment.

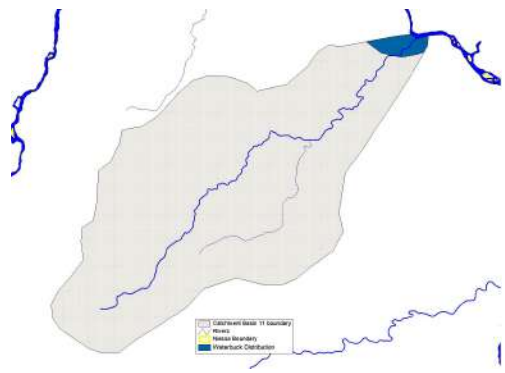


Figure 4.82 Distribution of Waterbuck in the Misangese River catchment.

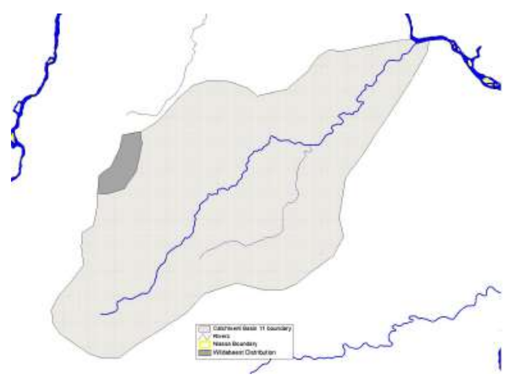
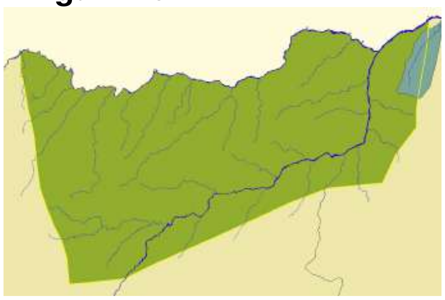


Figure 4.83 Distribution of Wildebeest in the Misangese River catchment.

Ninga River



Catchment Characteristics

River Length (km)	82
Gradient	0.0012
Area (km^2)	1060
Run-off (Mm^3 / year)	530
Population	0

The Ninga River is a low gradient river situated on the western most boundary of the reserve. According to the map the confluence of the river with the Rovuma falls outside the reserves boundaries. The catchment area is relatively large but falling outside the reserve means that counts do not cover the entire catchment. The vegetation is comprised deciduous dry miombo savanna woodland with a dry tall mixed thicket representing the remainder of the catchment. Observations of wildlife are limited, with low densities of zebra and elephant recorded and the distribution of eland observed accounting for 3% of the total species distribution. No settlements are recorded for the Ninga River catchment within the reserve.

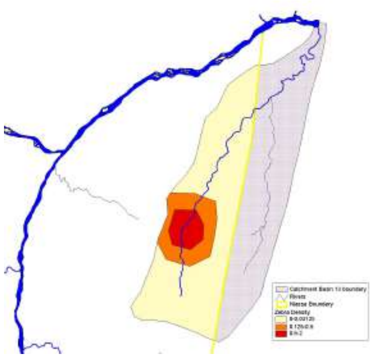


Figure 4.84 Density of Zebra in the Ninga River catchment.

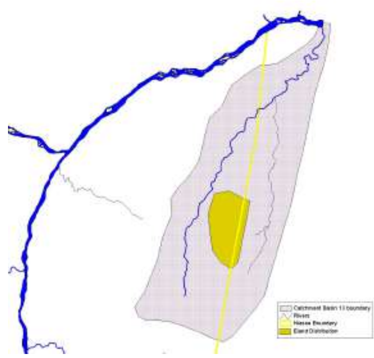


Figure 4.85 Distribution of Eland in the Ninga River catchment.

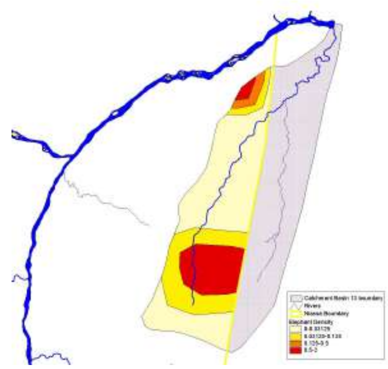
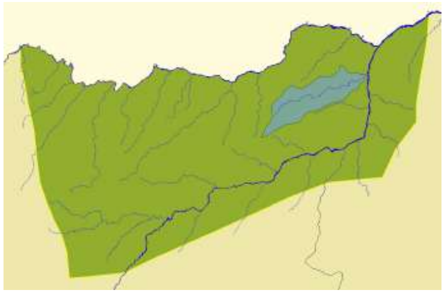


Figure 4.86 Density of Elephant in the Ninga River catchment.

4.4.2 Lugenda Sub-Catchment

The Lugenda River runs along 369 km of the Niassa Reserves southern boundary. The river is characterised by its relatively low gradient (0.0011) and predominantly alluvial sandy substrata.

Jurege River



Catchment Characteristics

River Length (km)	108
Gradient	0.0021
Area (km^2)	1530
Run-off (Mm^3 / year)	765
Population	1335 (various)

The Jurege River is a relatively large catchment draining east into the Lugenda River. It has a relatively gentle gradient with a diversity of vegetation types occurring in the catchment. This vegetation is dominated by deciduous (40%) and deciduous dry miombo savanna woodland (35%) but includes moist evergreen forest (10%), tardily deciduous miombo (10%) and a small amount of submontane grassland (1%). An important catchment with respect to density of elephant observed little other game has been recorded during the aerial counts. Zebra have present in low densities with some sable concentrated in the upper reaches of the catchment. Buffalo, eland and kudu are present in the middle to lower reaches, accounting for 3%, 5% and 3% of their respective total distributions within the reserve. Impala at the confluence account for 1% of the total distribution for this species. Despite the high density of elephants this catchment also contains a number of settlements, namely Mitope (66), Nalama (150), Eruvuka (200), Naulala (111) and Macalange (808).

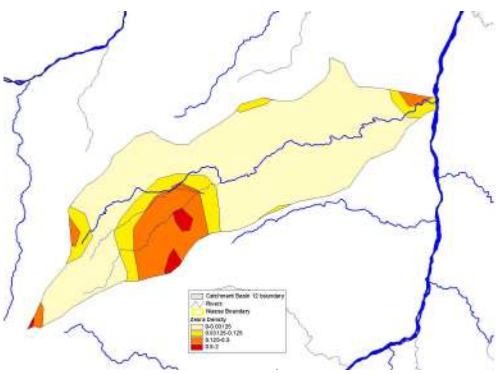


Figure 4.87 Density of Zebra in the Jurege River catchment.

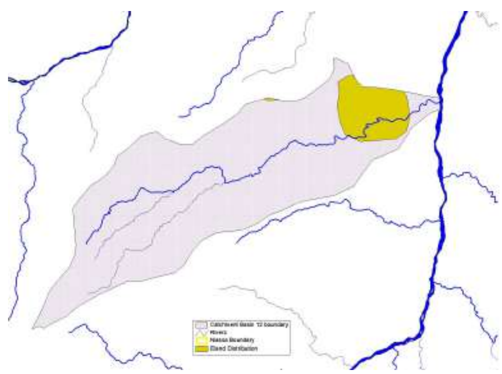


Figure 4.89 Distribution of Eland in the Jurege River catchment.

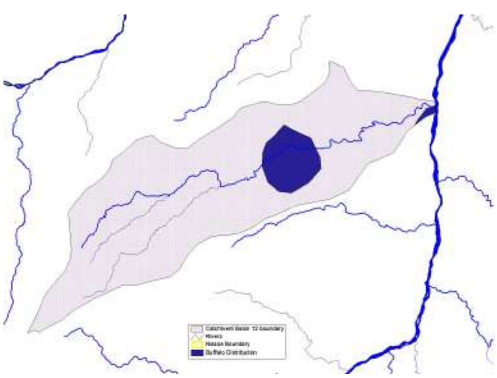


Figure 4.88 Distribution of Buffalo in the Jurege River catchment.

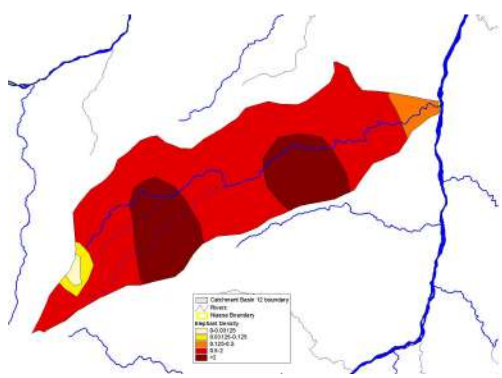


Figure 4.90 Density of Elephant in the Jurege River catchment.

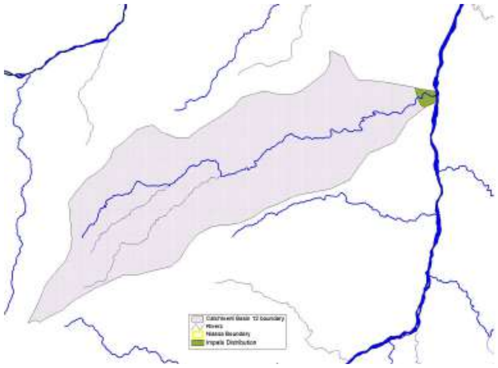


Figure 4.91 Distribution of Impala in the Jurege River catchment.

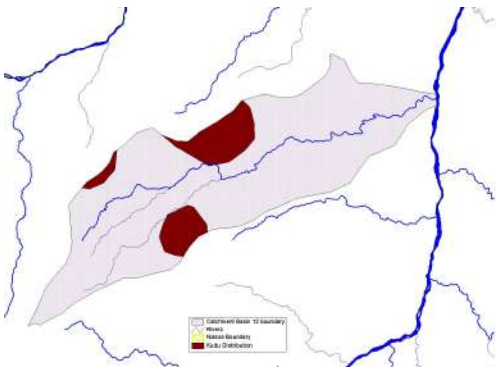


Figure 4.92 Distribution of Kudu in the Jurege River catchment.

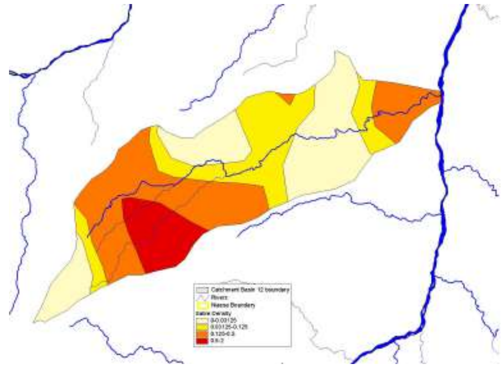
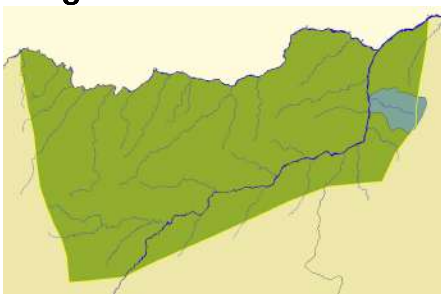


Figure 4.93 Density of Sable in the Jurege River catchment.

Irangwe River



Catchment Characteristics

River Length (km)	51
Gradient	0.0032
Area (km^2)	960
Run-off (Mm^3 / year)	480
Population	0

The Irangwe River is one of the few west flowing rivers almost completely contained within the reserve. A smaller catchment with a relatively steep gradient the river drains west into the Lugenda River and is comprised completely of deciduous dry miombo savanna woodland. The aerial survey recoded numerous species within this catchment including – buffalo, wildebeest, kudu and impala. These observations accounted for 1% 12% 2% and 2% of the total distribution of these species within the reserve. Relatively low densities of zebra, elephants and sable were recorded. No human settlements are recorded within this catchment.

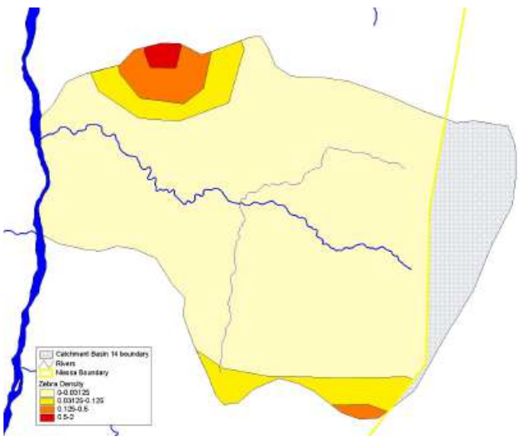


Figure 4.94 Density of Zebra in the Irangwe River catchment.

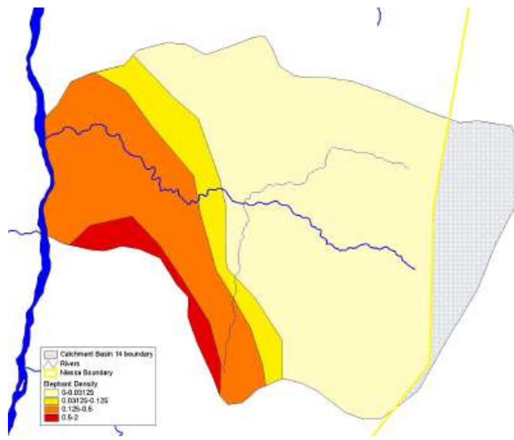


Figure 4.96 Density of Elephant in the Irangwe River catchment.

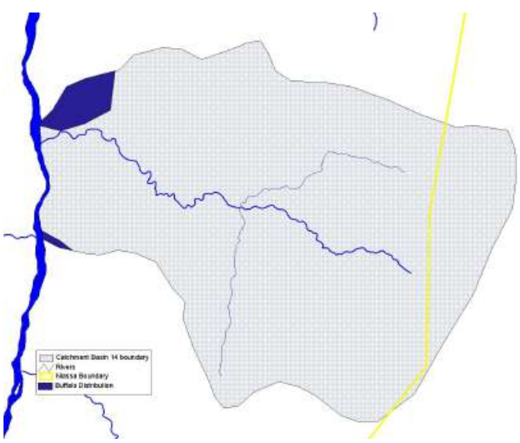


Figure 4.95 Distribution of Buffalo in the Irangwe River catchment.

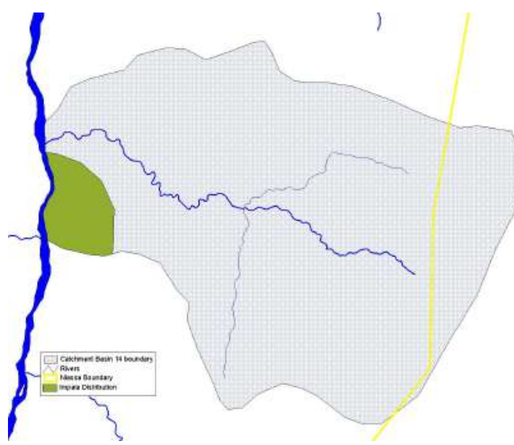


Figure 4.97 Distribution of Impala in the Irangwe River catchment.

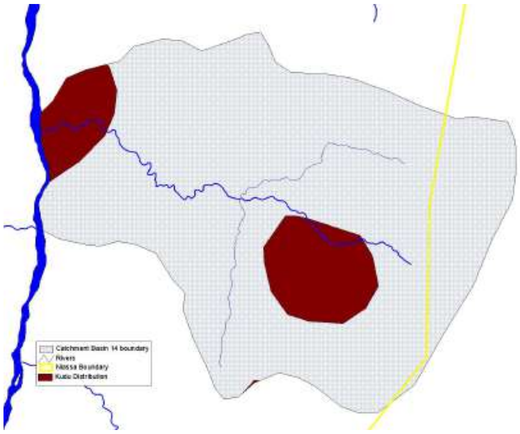


Figure 4.98 Distribution of Kudu in the Irangwe River catchment.

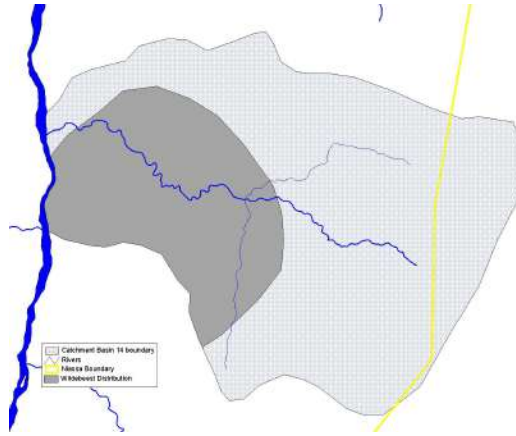


Figure 4.100 Distribution of Wildebeest in the Irangwe River catchment.

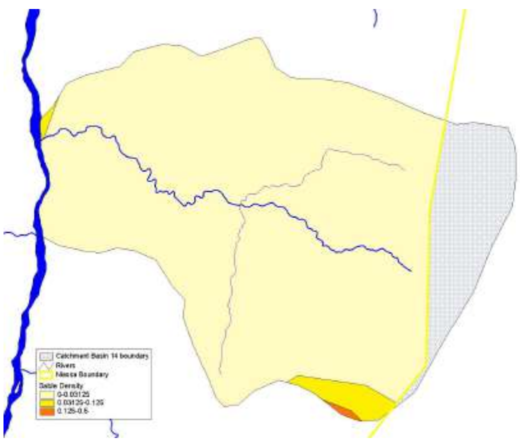
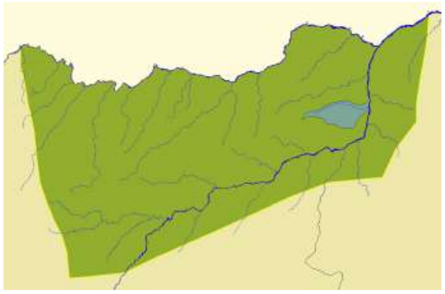


Figure 4.99 Density of Sable in the Irangwe River catchment.

Miuro River



Catchment Characteristics

River Length (km)	55
Gradient	0.0029
Area (km^2)	580
Run-off (Mm^3 / year)	290
Population	0

The Miuro River is a relatively small catchment draining east into the Lugenda River. It has an average gradient for rivers of its size within the reserve with the catchment vegetation dominated by deciduous dry miombo savanna woodland (88%) with some deciduous miombo (12%). The catchment has a high density of elephant observed throughout with intermediate densities of zebra and sable toward the upper part of the catchment. Buffalo, impala and kudu are all found in the lower reaches accounting for 4%, 2% and 1% of the total distribution of these species within the reserve. No human settlements are recorded within this catchment.

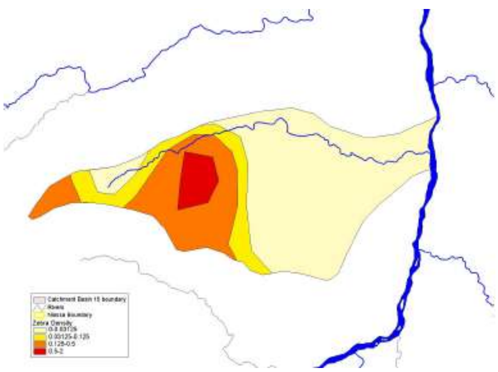


Figure 4.101 Density of Zebra in the Miuro River catchment.

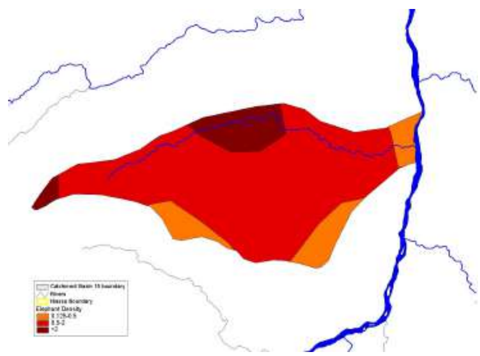


Figure 4.103 Density of Elephant in the Miuro River catchment.

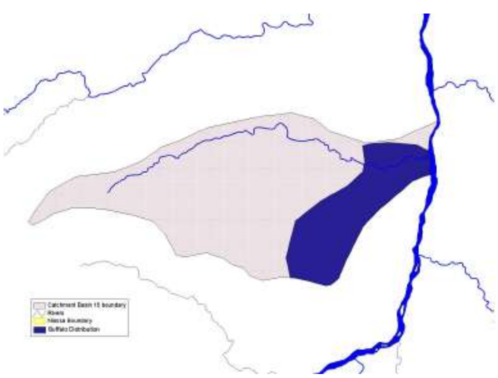


Figure 4.102 Distribution of Buffalo in the Miuro River catchment.

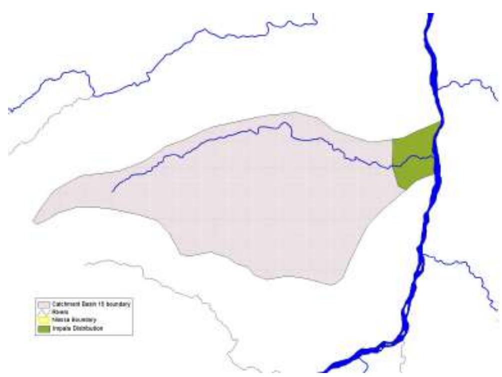


Figure 4.104 Distribution of Impala in the Miuro River catchment.

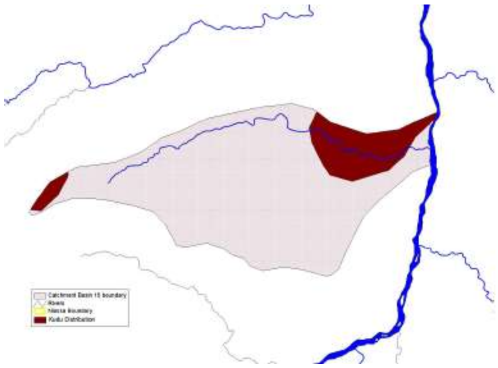


Figure 4.105 Distribution of Kudu in the Miuro River catchment.

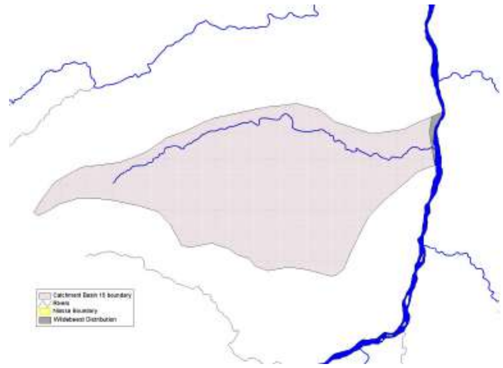


Figure 4.107 Distribution of Wildebeest in the Miuro River catchment.

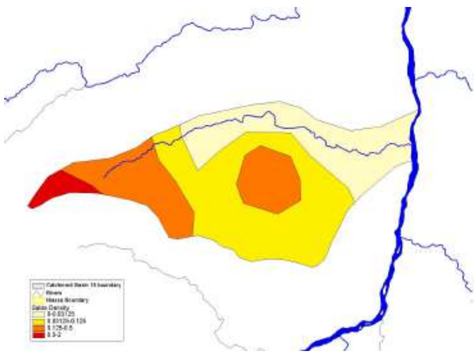
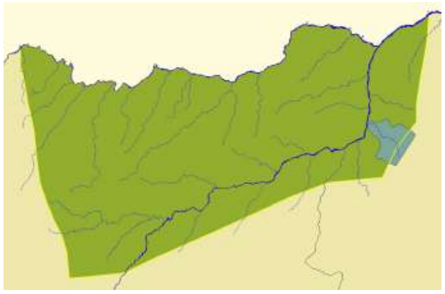


Figure 4.106 Density of Sable in the Miuro River catchment.

Namaho River



Catchment Characteristics

River Length (km)	52
Gradient	0.0044
Area (km^2)	720
Run-off (Mm^3 / year)	360
Population	0

One of the few west draining rivers in the reserve the Namaho River is a relatively small catchment with its upper reaches outside of the reserve boundaries. The river has a relatively steep gradient and drains north-west into the Lugenda River. Catchment vegetation is dominated by deciduous dry miombo savanna woodland (80%) with the remaining 5% in the reserve dry tall mixed thicket. The catchment has relatively high density of elephant and zebra with high densities of sable observed in the middle reaches. The distribution of buffalo, kudu and wildebeest accounts for 4%, 2% and 4% of the total observed distributions for these species in the reserve. No human settlements are recorded within this catchment.

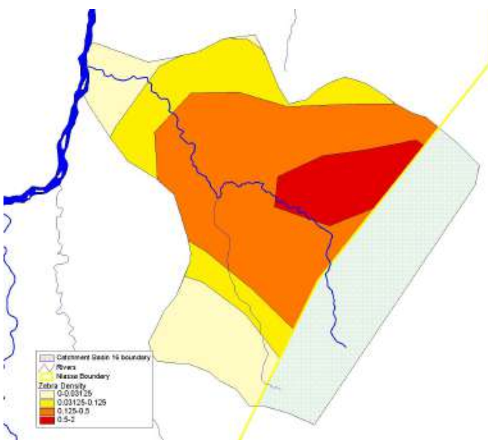


Figure 4.108 Density of Zebra in the Namaho River catchment.

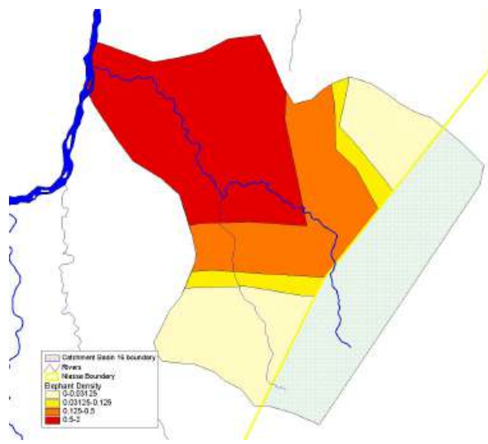


Figure 4.110 Density of Elephant in the Namaho River catchment.

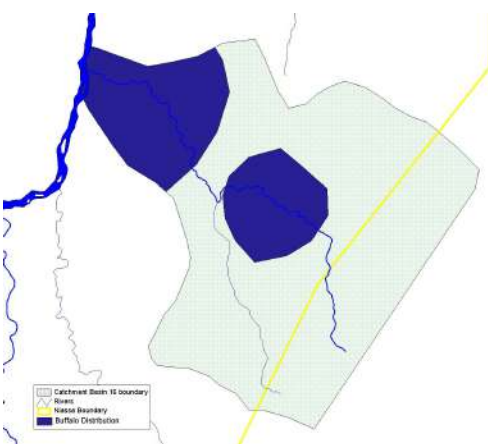


Figure 4.109 Distribution of Buffalo in the Namaho River catchment.

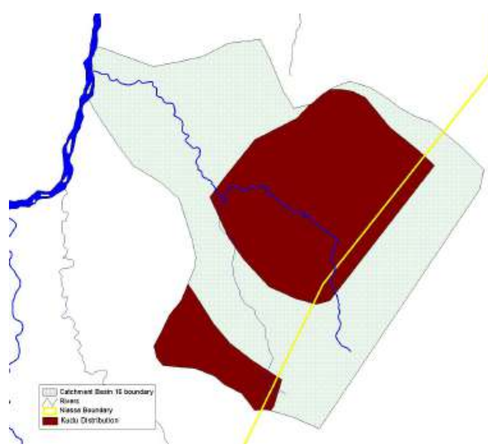


Figure 4.111 Distribution of Kudu in the Namaho River catchment.

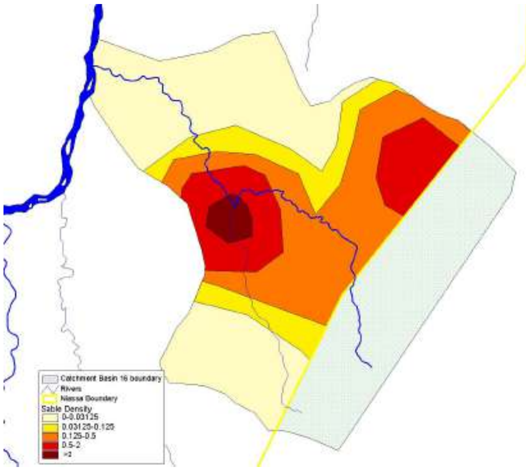


Figure 4.112 Density of Sable in the Namaho River catchment.

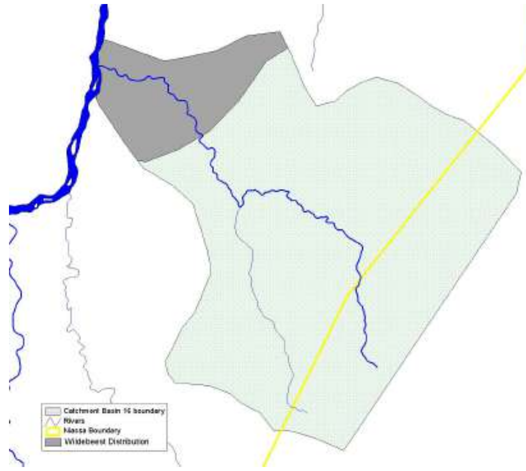
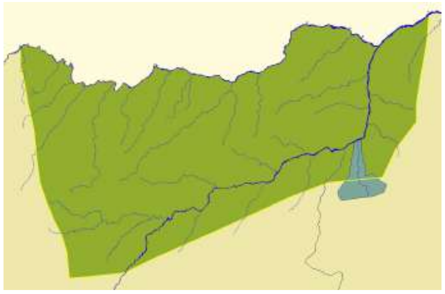


Figure 4.113 Distribution of Wildebeest in the Namaho River catchment.

Nichandocha River



Catchment Characteristics

River Length (km)	65
Gradient	0.0024
Area (km^2)	730
Run-off (Mm^3 / year)	365
Population	0

The Nichandocha River is another of those rivers on the southern boundary of the reserve. Draining to the north into the Lugenda River almost 50-% of the catchment area falls beyond the reserve boundaries. The relatively low gradient catchment area is characterised by the dominance of deciduous dry miombo savanna woodland although includes a small percentage cover of deciduous miombo. Sable and elephant have been recorded at relatively high densities during the aerial survey, with waterbuck and eland observed at the confluence with the Lugenda River. The distribution of these within the catchment account for 1% of their respective total distributions in the reserve. Buffalo distribution accounts for 4% of the total with observations recorded within the middle of the catchment. No human settlements are recorded within this catchment.

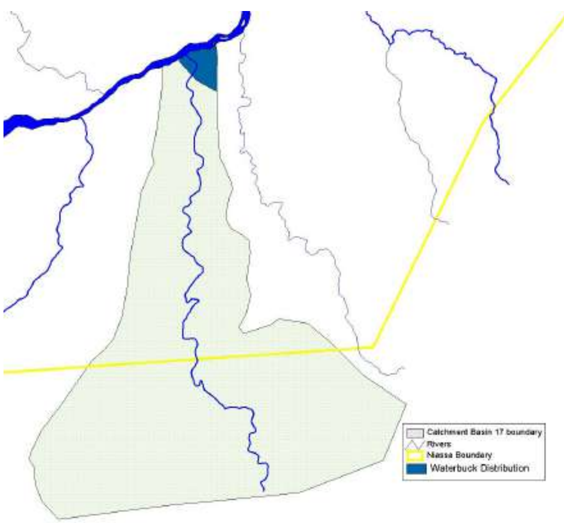


Figure 4.114 Distribution of Waterbuck in the Nichandocha River catchment.

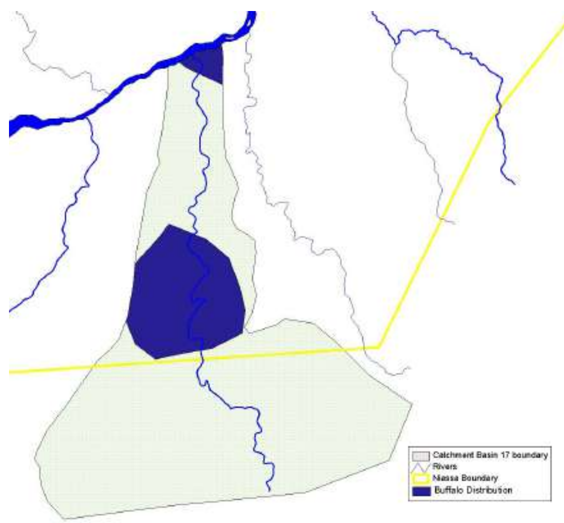


Figure 4.115 Distribution of Buffalo in the Nichandocha River catchment.

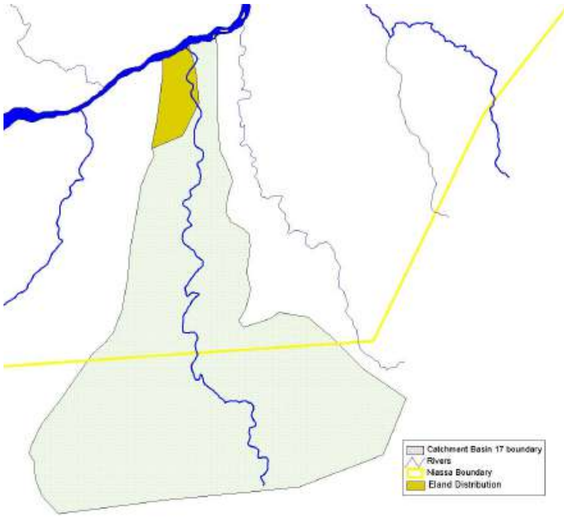


Figure 4.116 Distribution of Eland in the Nichandocha River catchment.

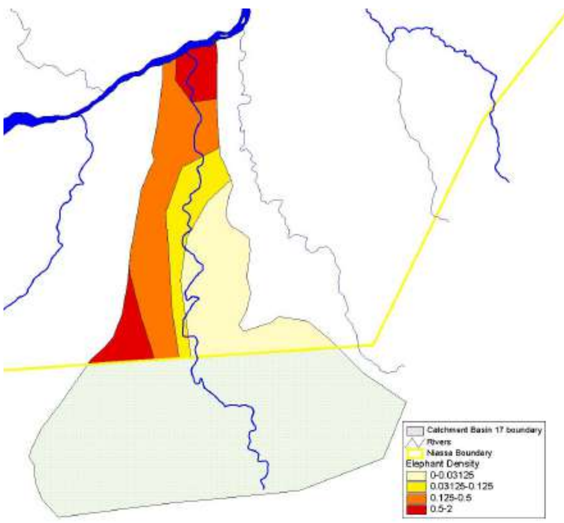


Figure 4.117 Density of Elephant in the Nichandocha River catchment.

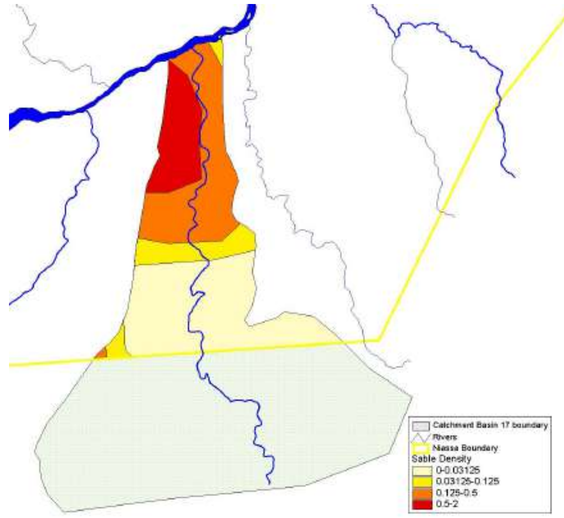
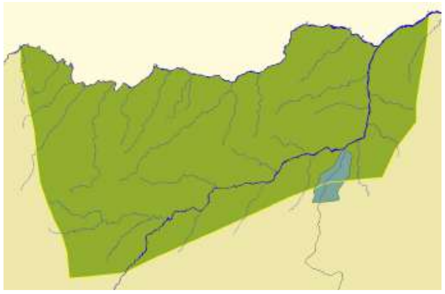


Figure 4.118 Density of Sable in the Nichandocha River catchment.

Luambezi River



Catchment Characteristics

River Length (km)	55
Gradient	0.0018
Area (km^2)	610
Run-off (Mm^3 / year)	305
Population	0

The Luambezi River drains to the north and into the Lugenda River and is another of those southern boundary rivers with catchments falling outside of the reserve. Roughly 25% of the total catchment area is outside the formal reserve boundaries. The relatively low gradient catchment area is characterised by the dominance of deciduous miombo and deciduous dry miombo savanna woodland although. High densities of sable and elephant have been recorded with zebra showing high densities along the north-western boundary. Small distributions of eland, impala, kudu, waterbuck and wildebeest within the catchment account for 5%, 11%, 8%, 7% and 3% of the total distribution of these species. No human settlements are recorded within this catchment.

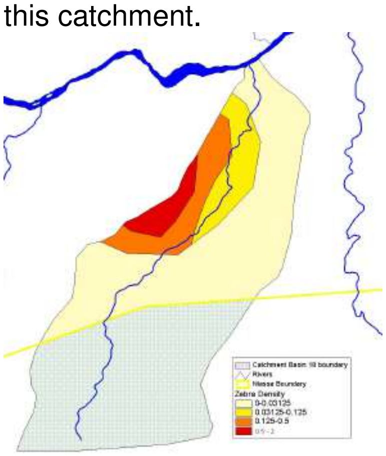


Figure 4.119 Density of Zebra in the Luambezi River catchment.

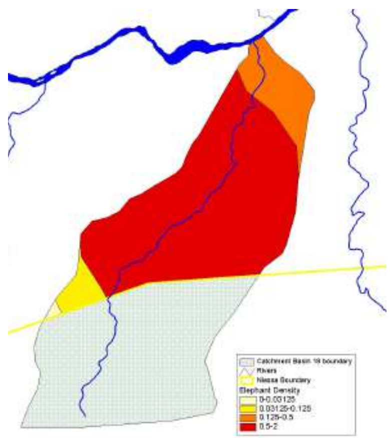


Figure 4.121 Density of Elephant in the Luambezi River catchment.

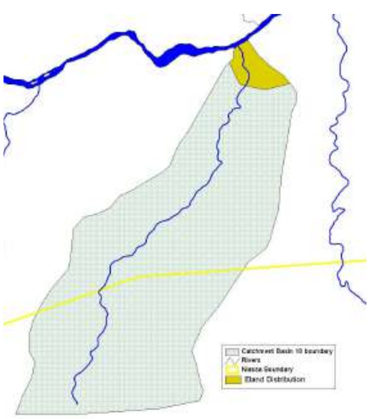


Figure 4.120 Distribution of Eland in the Luambezi River catchment.

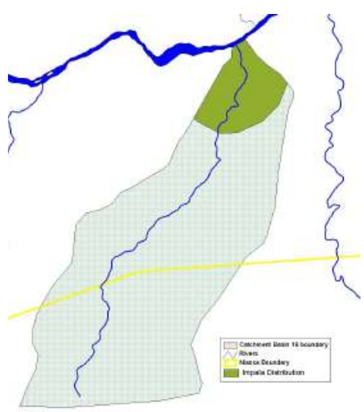


Figure 4.122 Density of Impala in the Luambezi River catchment.

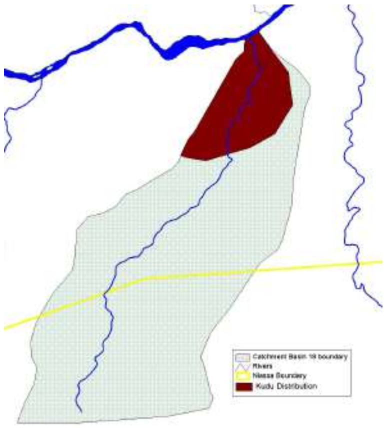


Figure 4.123 Distribution of Kudu in the Luambezi River catchment.

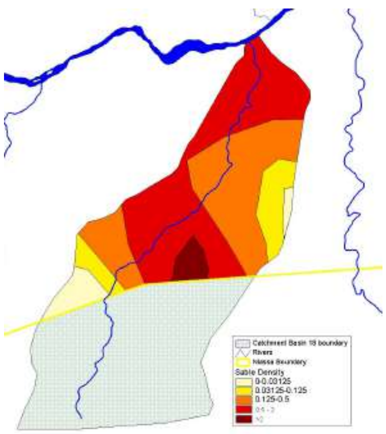


Figure 4.124 Density of Sable in the Luambezi River catchment.

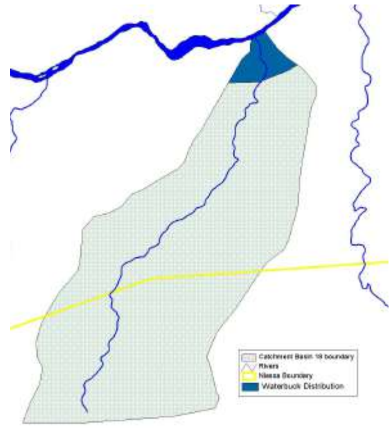


Figure 4.125 Distribution of Waterbuck in the Luambezi River catchment.

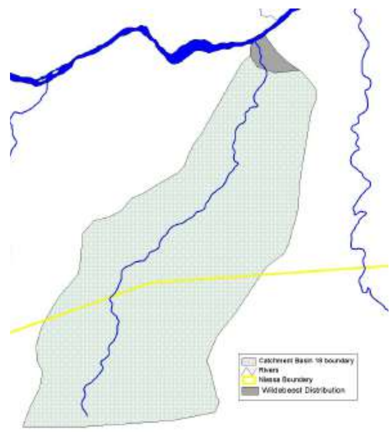
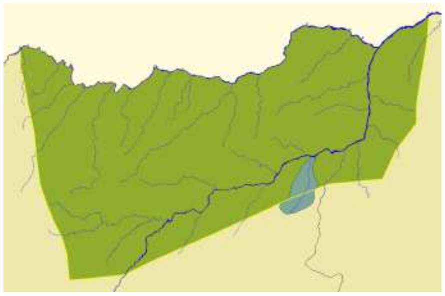


Figure 4.126 Distribution of Wildebeest in the Luambezi River catchment.

Luchinge River



Catchment Characteristics

River Length (km)	59
Gradient	0.0017
Area (km^2)	620
Run-off (Mm^3 / year)	310
Population	0

The Luchinge River drains north into the Lugenda River and is another of those southern boundary rivers with catchments falling outside of the reserve. Roughly 10% of the total catchment area is outside the formal reserve boundaries. The relatively low gradient catchment area is characterised by the dominance of deciduous miombo and deciduous dry miombo savanna woodland although. High densities of sable and elephant have been recorded in the lower reaches of the catchment toward the confluence with the Lugenda River. Hartebeest and kudu have been observed within the middle reaches of the catchment with some impala toward the confluence. These distributions account for 1%, 2% and 2% of the total for these species. No human settlements are recorded within this catchment.

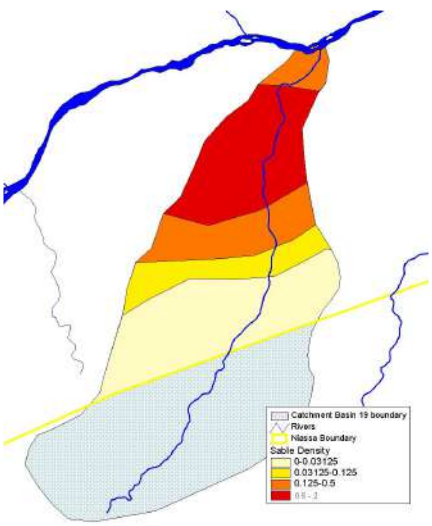


Figure 4.127 Density of Sable in the Luchinge River catchment.

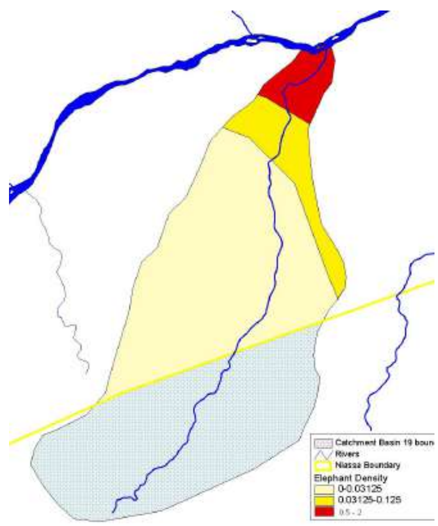


Figure 4.128 Density of Elephant in the Luchinge River catchment.

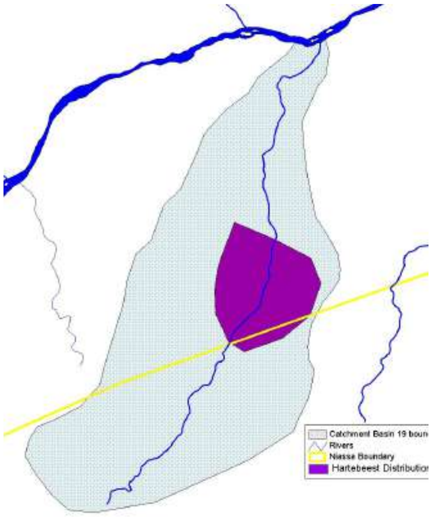


Figure 4.129 Distribution of Hartebeest in the Luchinge River catchment.

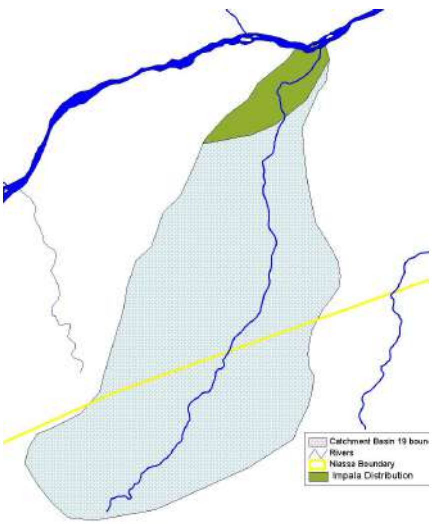


Figure 4.130 Distribution of Impala in the Luchinge River catchment.

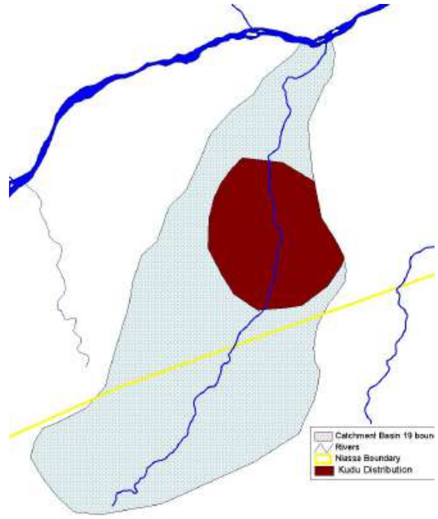
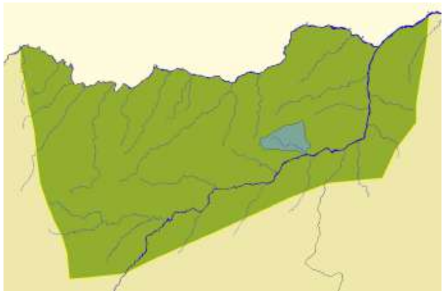


Figure 4.131 Distribution of Kudu in the Luchinge River catchment.

Ncuti River



Catchment Characteristics

River Length (km)	41
Gradient	0.0024
Area (km^2)	570
Run-off (Mm^3 / year)	285
Population	4981

The Ncuti River drains off the Mecula Mountain in south-east direction to the Lugenda River. The average gradient belies the steep gradients found in the upper reaches on the inselbergs. Reflecting its origins the catchment includes some montane and submontane grassland (2%) along with moist evergreen forest (5%), although the catchment is dominated by deciduous miombo (65%) with some deciduous dry miombo savanna woodland (18%) and tardily deciduous miombo (10%). The catchment would appear important with respect to the high densities of elephant, zebra and sable found throughout. Hartebeest, impala and waterbuck are all found near the confluence with the Lugenda River and account for 1%, 5%2% of the total distribution of these species. Despite the high density of elephants and other wildlife in this catchment, there are two settlements including the large settlement of Mecula, with 4570 people, with the other being Ncuti (411).

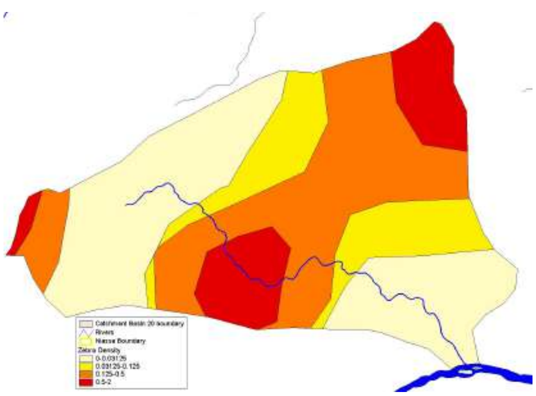


Figure 4.132 Density of Zebra in the Ncuti River catchment.

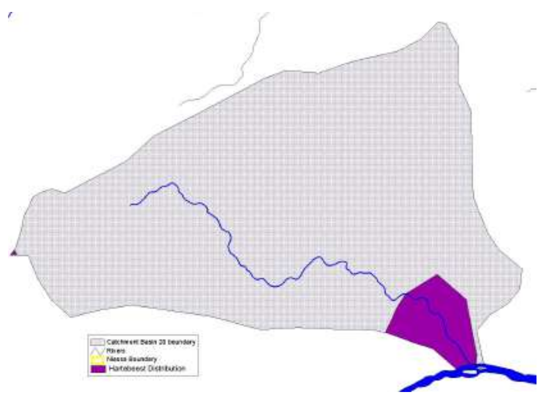


Figure 4.134 Distribution of Hartebeest in the Ncuti River catchment.

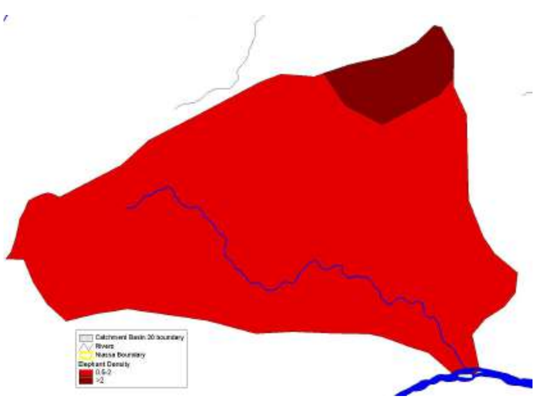


Figure 4.133 Density of Elephant in the Ncuti River catchment.

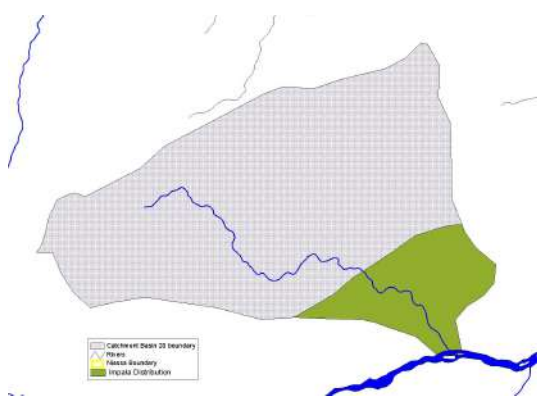


Figure 4.135 Distribution of Impala in the Ncuti River catchment.

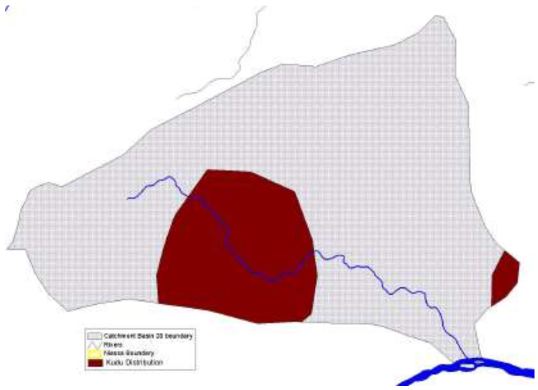


Figure 4.136 Distribution of Kudu in the Ncuti River catchment.

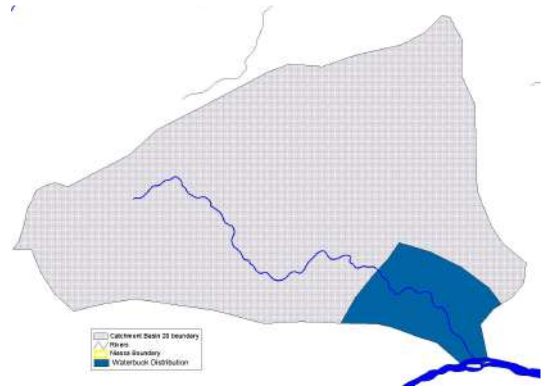


Figure 4.138 Distribution of Waterbuck in the Ncuti River catchment.

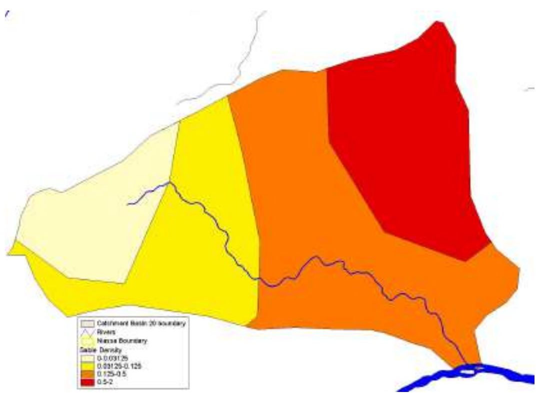
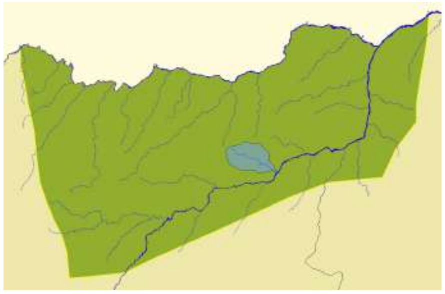


Figure 4.137 Density of Sable in the Ncuti River catchment.

Incalaue River



Catchment Characteristics

River Length (km)	55
Gradient	0.0039
Area (km^2)	600
Run-off (Mm^3 / year)	300
Population	451

The Incalaue River drains off the side of Mecula Mountain in south-east direction to the Lugenda River. A relatively small river with a steep gradient the catchment vegetation is dominated almost completely by deciduous miombo (95%). Again there is a high density of elephant observations within this catchment with zebra observed around the upper reaches and low densities of sable throughout. Eland are found within the middle reaches of the catchment, accounting for 7% of the species total distribution within the reserve. Buffalo are observedin the upper south-western part of the catchment, accounting for 2% of total distribution. Hartebeest are similarly observed in the upper reaches, accounting for 3% of total distribution, while wildebeest and kudu are observed in the middle and lower reaches of the catchment area accounting for 5% and 2% of total distribution within the reserve for these species. This catchment includes three settlements, namely Mbatamila (50), N'timbo (315) and Lissongole (86).

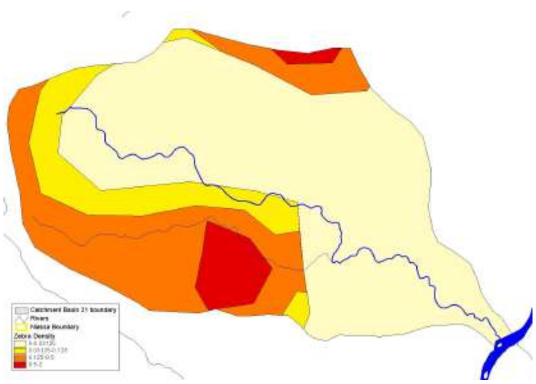


Figure 4.139 Density of Zebra in the Incalaue River catchment.

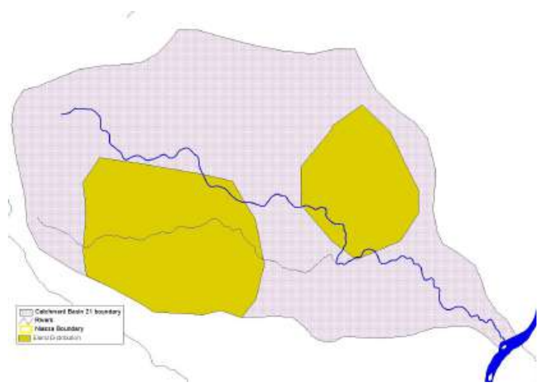


Figure 4.141 Distribution of Eland in the Incalaue River catchment.

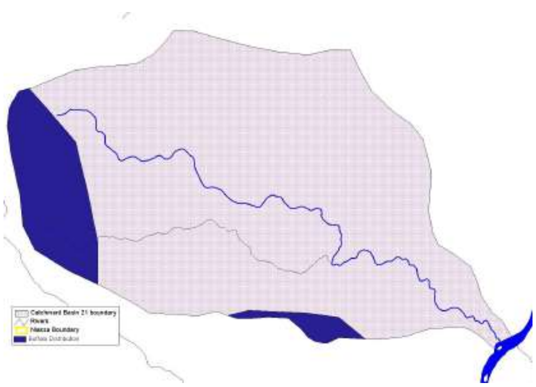


Figure 4.140 Distribution of Buffalo in the Incalaue River catchment.

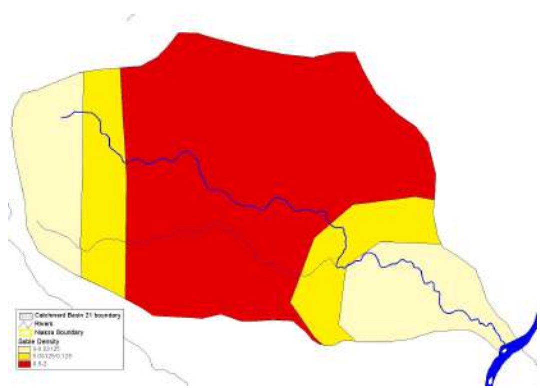


Figure 4.142 Density of Elephant in the Incalaue River catchment.

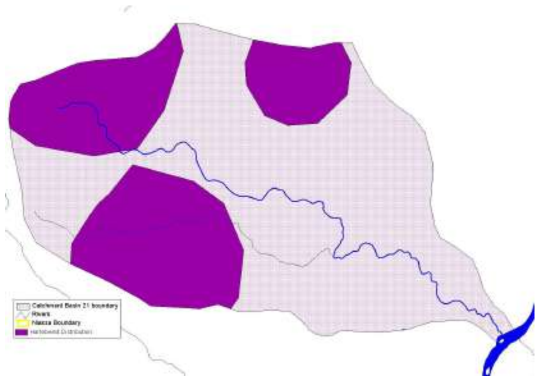


Figure 4.143 Distribution of Hartebeest in the Incalaue River catchment.

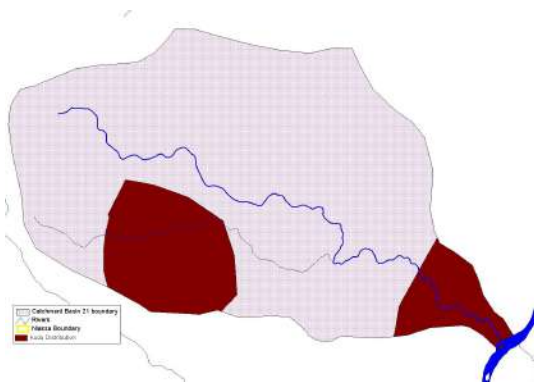


Figure 4.144 Distribution of Kudu in the Incalaue River catchment.

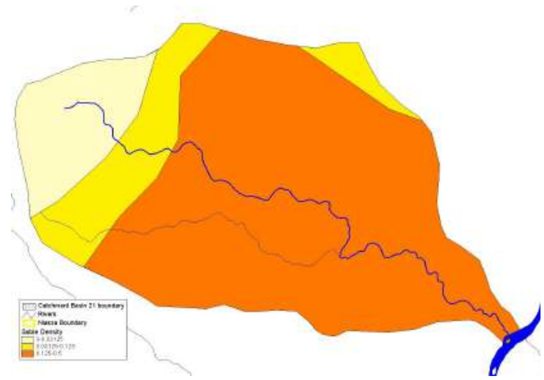


Figure 4.145 Density of Sable in the Incalaue River catchment.

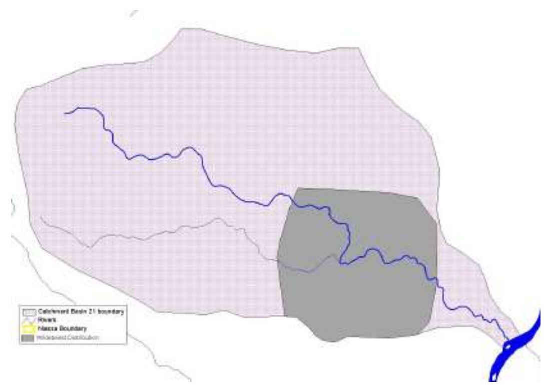
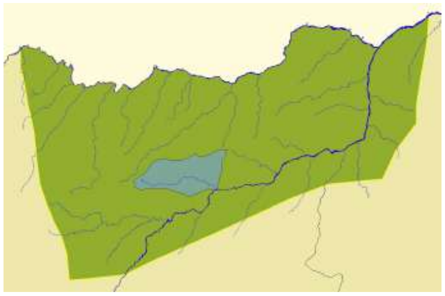


Figure 4.146 Distribution of Wildebeest in the Incalaue River catchment.

Metapiri River



Catchment Characteristics

River Length (km)	89
Gradient	0.0034
Area (km^2)	1480
Run-off (Mm^3 / year)	740
Population	0

The Metapiri River drains off the western escarpment in a south-easterly direction to the Lugenda River. The average gradient belies the steep gradients found in the upper reaches of the escarpment where well vegetated and canopied streams create diversity of habitats. Despite these origins the vegetation is dominated by deciduous (40%) and tardily deciduous (59%) miombo with a small percentage of the catchment covered by deciduous dry miombo savanna woodland (1%). The Metapiri catchment accounts for 16% of the total buffalo distribution and 8% of the hartebeest distribution. Other important species observed include 5% of the wildebeest and 4% of the reedbuck distributions. Kudu are also found in the lower reaches of the catchment while the presence of reedbuck was recorded in the middle reaches and wildebeest in the upper most reaches. Elephant and sable are both recorded in high densities with zebra found throughout. No settlements are recorded within this catchment.

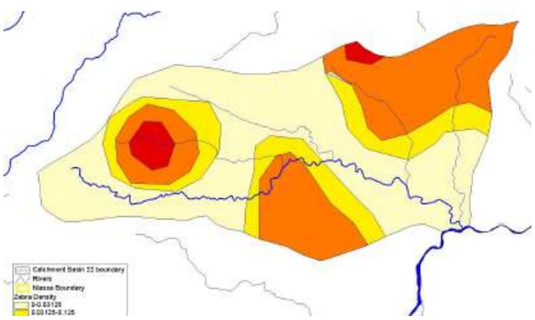


Figure 4.147 Density of Zebra in the Metapiri River catchment.

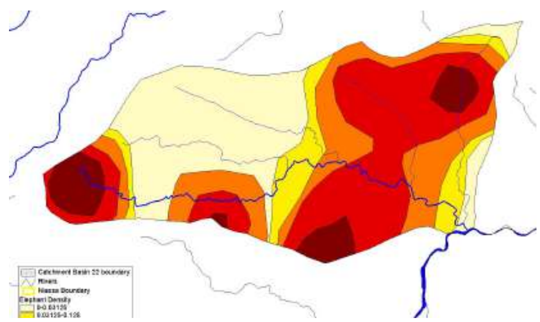


Figure 4.149 Density of Elephant in the Metapiri River catchment.

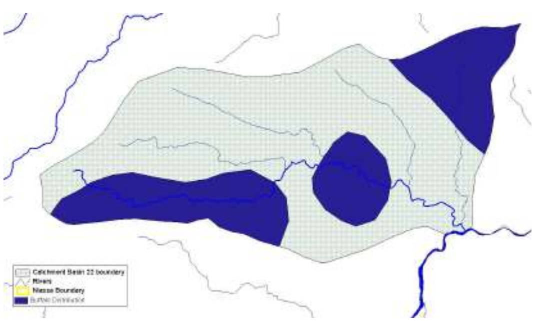


Figure 4.148 Distribution of Buffalo in the Metapiri River catchment.

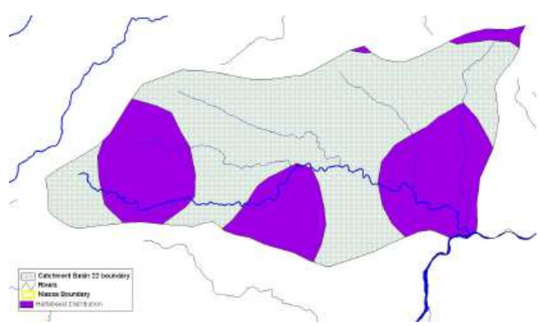


Figure 4.150 Distribution of Hartebeest in the Metapiri River catchment.

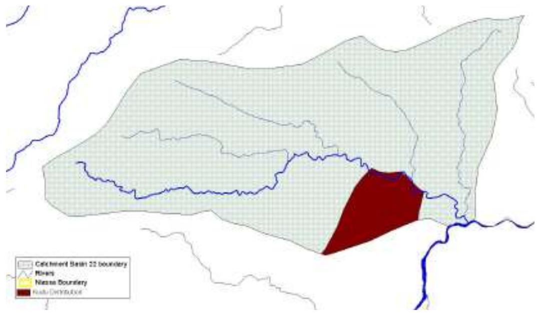


Figure 4.151 Distribution of Kudu in the Metapiri River catchment.

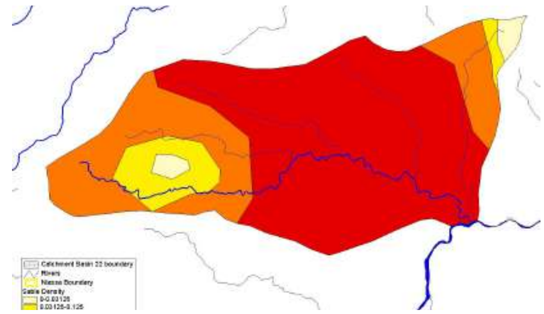


Figure 4.153 Density of Sable in the Metapiri River catchment.

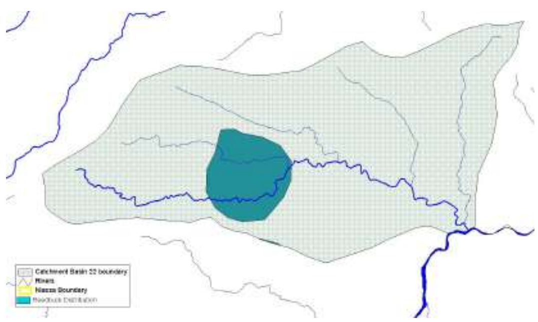


Figure 4.152 Distribution of Reedbuck in the Metapiri River catchment.

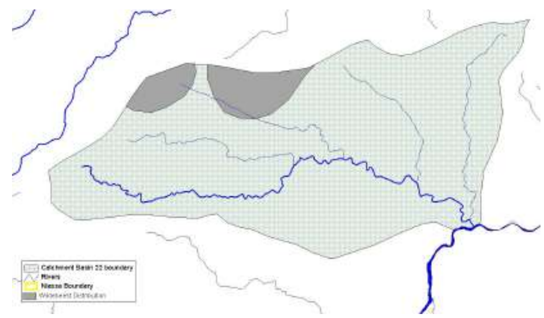
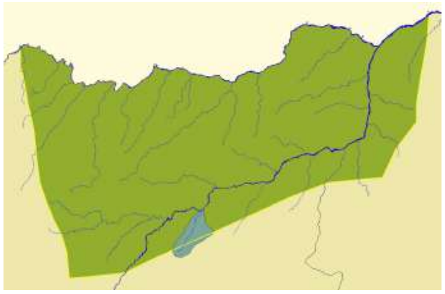


Figure 4.154 Distribution of Wildebeest in the Metapiri River catchment.

Lumbuisse River



Catchment Characteristics

River Length (km)	47
Gradient	0.0043
Area (km^2)	500
Run-off (Mm^3 / year)	250
Population	0

The Lumbuisse River drains the southern boundary of the reserve north into the Lugenda River. The river has a relatively steep gradient with approximately 20% of the upper reaches of the catchment falling outside of the formal reserve boundaries. The vegetation is almost completely dominated by deciduous miombo (70%) with the remaining part of the catchment in the reserve characterised by deciduous dry miombo savanna woodland (10%). Distribution of wildlife is concentrated toward the confluence with low densities of zebra and sable recorded. Elephant densities are high toward the confluence with the Lugenda River while eland were recorded in a small part of the eastern part of the catchment. Impala, hartebeest, waterbuck and wildebeest are also observed from the lower reaches toward the confluence. These distributions account for 2%, 1%, 1% and <1% of the total. No settlements are recorded within this catchment.

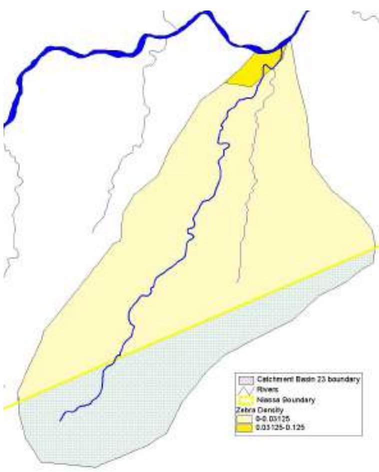


Figure 4.155 Density of Zebra in Lumbuisse River catchment.

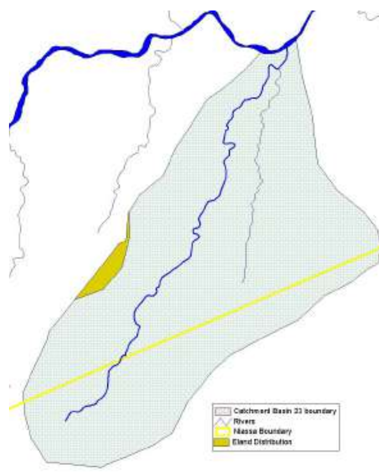


Figure 4.156 Distribution of Eland in Lumbuisse River catchment.

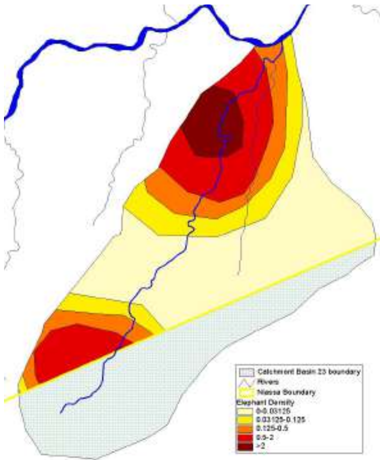


Figure 4.157 Density of Elephant in Lumbuisse River catchment.

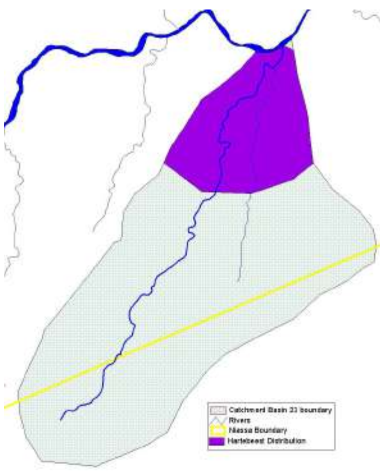


Figure 4.158 Distribution of Hartebeest in Lumbuisse River catchment.

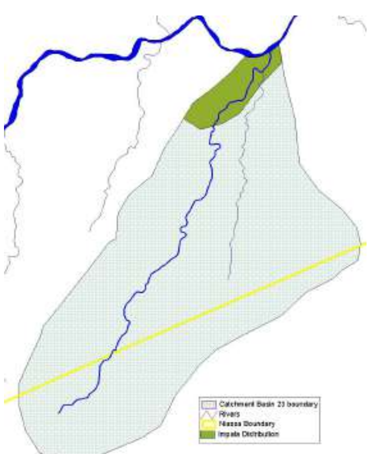


Figure 4.159 Distribution of Impala in Lumbuisse River catchment.

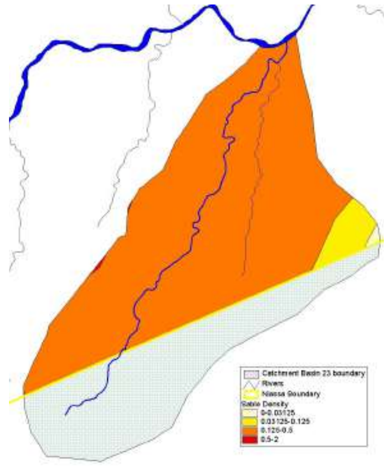


Figure 4.160 Density of Sable in Lumbuisse River catchment.

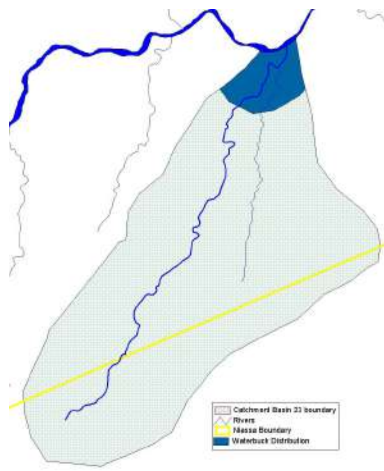


Figure 4.161 Distribution of Waterbuck in Lumbuisse River catchment.

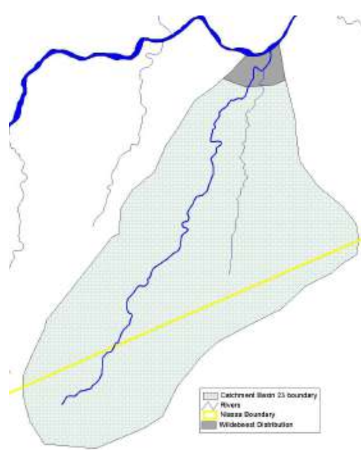
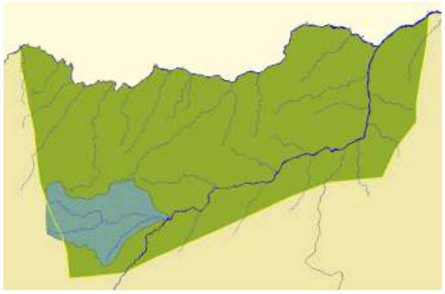


Figure 4.162 Distribution of Wildebeest in Lumbuisse River catchment.

Luatize River



Catchment Characteristics

River Length (km)	144
Gradient	0.0099
Area (km^2)	3350
Run-off (Mm^3 / year)	1675
Population	4000 (Msawise)

The Luatize River is the largest catchment in the reserve. The high average stream gradient reflects its origins in the western escarpment from where it drains in an easterly direction into the Lugenda River. Catchment vegetation is dominated by tardily deciduous (89%) and deciduous (10%) miombo with a small percentage of the catchment covered by deciduous dry miombo savanna woodland (1%). The Luatize catchment has a notable absence of elephant observations accounts with observations of waterbuck, eland, buffalo, kudu and reedbuck confined to the central part of the catchment. These account for 6%, 8%, 6% and 9% of the total distribution of observations within the reserve during the aerial survey. Hartebeest observations are from the lower reaches with the confluence, accounting for 1% of total distribution. A single settlement is recorded within the catchment, namely Msawise (4000).

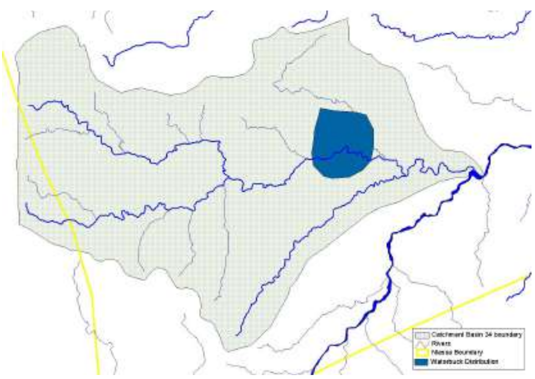


Figure 4.163 Distribution of Waterbuck in the Luatize River catchment.

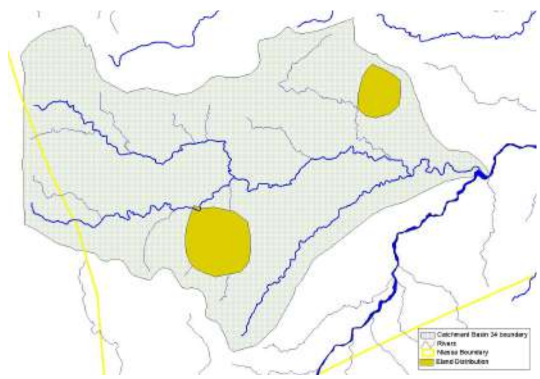


Figure 4.165 Distribution of Eland in the Luatize River catchment.

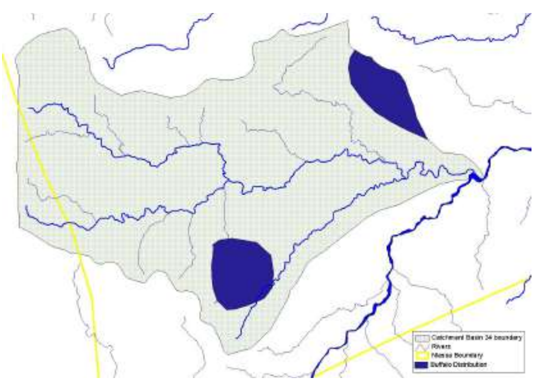


Figure 4.164 Distribution of Buffalo in the Luatize River catchment.

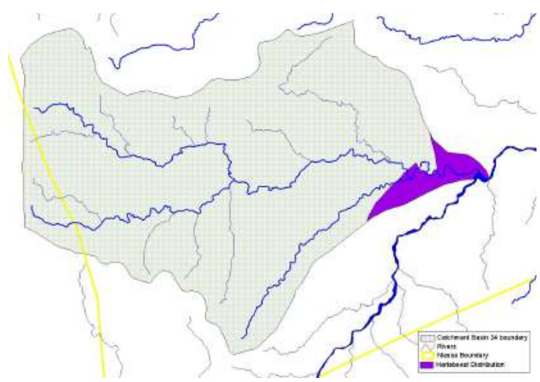


Figure 4.166 Distribution of Hartebeest in the Luatize River catchment.

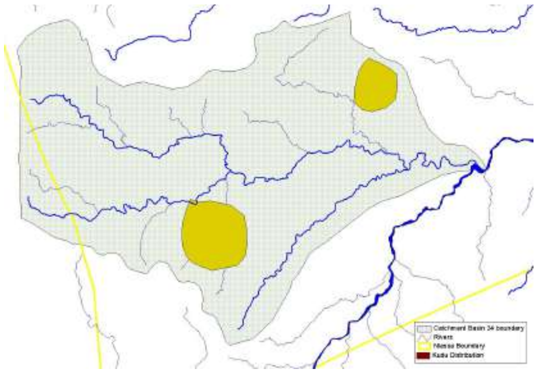


Figure 4.167 Distribution of Kudu in the Luatize River catchment.

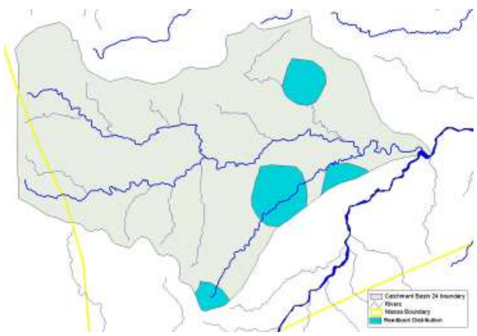


Figure 4.168 Distribution of Reedbuck in the Luatize River catchment.

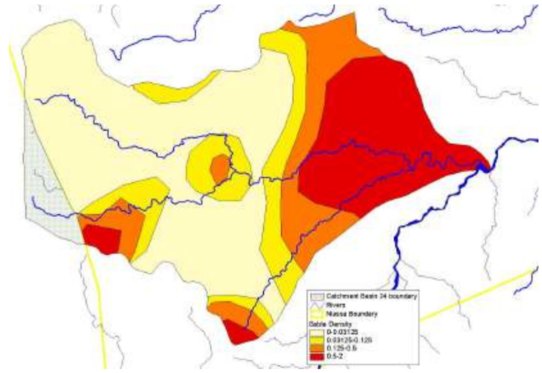
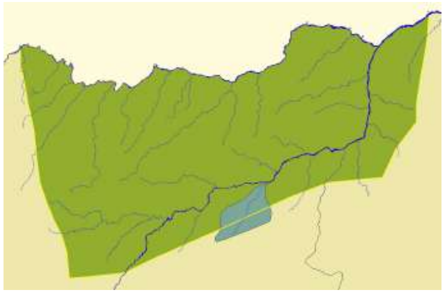


Figure 4.169 Density of Sable in the Luatize River catchment.

Lureco River



Catchment Characteristics

River Length (km)	57
Gradient	0.0037
Area (km^2)	960
Run-off (Mm^3 / year)	480
Population	609 (various)

The Lureco River drains the southern boundary of the reserve north into the Lugenda River. The river has a relatively steep gradient with approximately 30% of the upper reaches of the catchment falling outside of the formal reserve boundaries. The vegetation is almost completely dominated by deciduous miombo (60%) with the remaining part of the catchment in the reserve characterised by deciduous dry miombo savanna woodland (10%). While densities of sable and zebra are relatively low there is a high density of elephant toward the confluence with the Lugenda River. The only other observations of impala and kudu in the lower reaches of the catchment account for 3% and 5% of their total distribution within the reserve. Two settlements are recorded within this catchment, namely Mpamanda (411) and Mucovia (198).No settlements are recorded within this catchment.

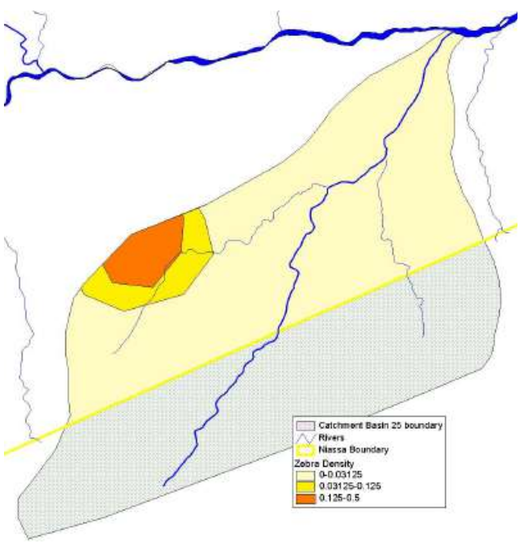


Figure 4.170 Density of Zebra in the Lureco River catchment.

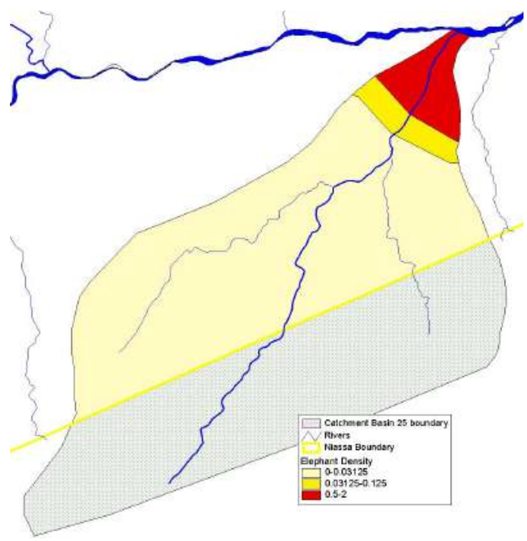


Figure 4.171 Density of Elephant in the Lureco River catchment.

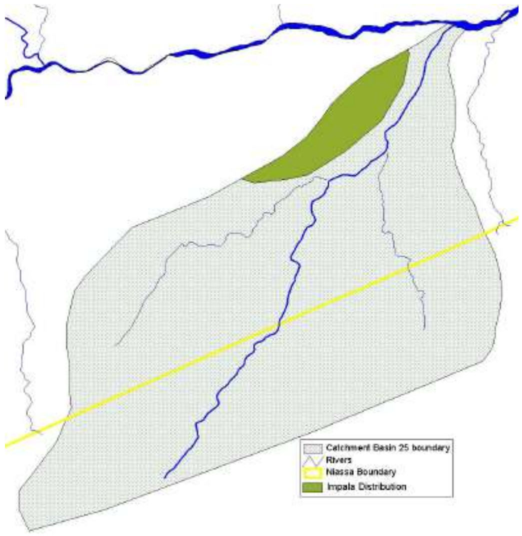


Figure 4.172 Distribution of Impala in the Lureco River catchment.

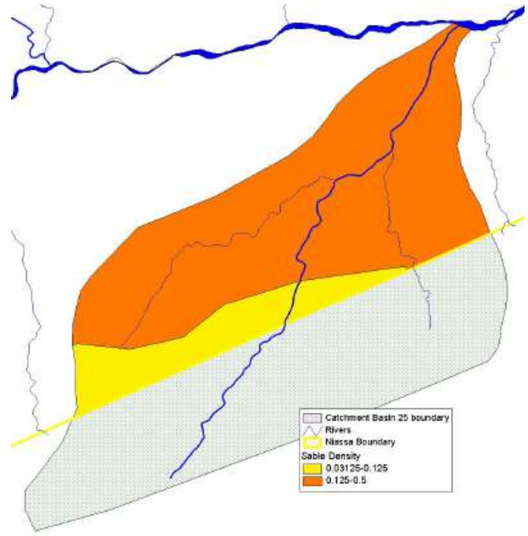


Figure 4.174 Density of Sable in the Lureco River catchment.

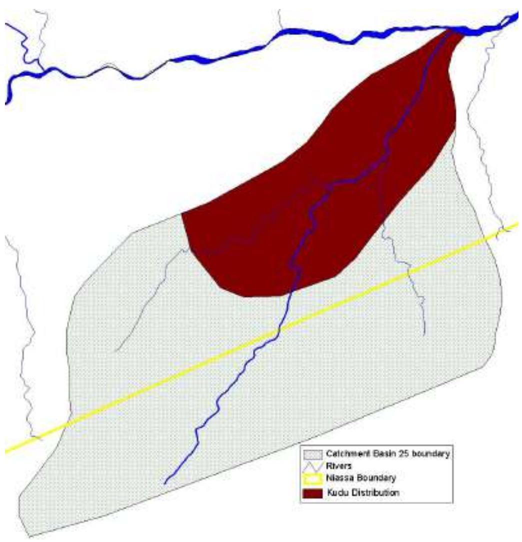


Figure 4.173 Distribution of Kudu in the Lureco River catchment.

4.4.3 Tertiary Rivers

There are large number of these smaller drainages and while these are important in the landscape process and functioning of the rivers they are to numerous to considered individually. These rivers typically experience highly variable flow, will be flashy in nature and responds to localised rainfall events. They differ in characteristics depending upon local geology and soil properties but all cease to flow during the dry cool months over winter.

It appears in the east the lower rainfall and sandy soils results greater infiltration and more ephemeral streams with less predictable stream flow. These streams have less canopy and greater percentage of sandy bed with outcrops of exposed bedrock. To the west the higher altitude, greater rainfall and shallower soils means that water persists in the streams for longer, although typically cease to flow for part of the year. These streams are better canopied with a well established riparian strip.

4.5 Threats to River Integrity

The rivers of the Niassa Reserve face a number of threats. These stem largely from increased populations pressures. Although the regional has a long history of humans habitation, with communities inhabiting the coast of eastern Africa continuously since the late Pleistocene (Clarke and Karoma 2000), communities within the reserve present a complex history of migration in and out of the reserves core areas. Increasingly sophisticated technology combined with growing population densities places increasing pressures upon the natural resource base. These aspects are being considered by the Niassa Reserve under a separate initiative. Irrespective of the historical considerations however, there is an urgent need to manage human pressures within the reserve, specifically those on the reserve's rivers.

Main threats include the effects from deforestation and increased, uncontrolled agricultural production, overfishing and pollution, with potential future threats stemming from the effects of an increasing human population and the need to secure potable water supplies through new impoundments on the Rovuma and Lugenda rivers, water diversions for irrigation schemes and an increase in the development of groundwater abstraction through boreholes.

Deforestation and Agricultural Production

It has been estimated that as much as 90% of the reserve burnt prior to the 1998 and 2000 aerial surveys. Impacts associated with deforestation and reduce bank stability include a reduced water supply from forested regions, increased turbidity, greater light exposure of riverine habitats, and increased flash flooding. The high pressure on riparian forests is generated primarily by the need to open up new agricultural areas, provide fuel but also by the need for construction material. As of 1989, wood made up over 90% of rural east African energy consumption (Clarke and Karoma

2000).

Agricultural production is evident along the margins of most of the rivers within the reserve. These areas provide more fertile alluvial soils and reliable access to water with moist soils and extensive plantations are observed along the relatively rich alluvial soils of the rivers margins. These result in increased bank stability during growth periods, and accentuated instability following harvest. Increased human activity associated with cultivation also has negative impacts upon the bank stability, increasing erosion and undermining the geomorphological integrity.

Fishing

A separate detailed study has been carried out on the fish of the Niassa reserve which also examined issues surrounding commercial and subsistence fisheries within the reserve (Bills, 2004). The aim herein is to briefly review with a focus on the impacts upon rivers and wetlands of the Niassa Reserve.

Numerous methods are employed in the reserve fisheries, including barrier fences, traps, nets, hook and line with evidence of poisons being used. Poisoned water supplies have reportedly resulted in mortality among larger wildlife and the contamination of human supplies.The size and permanent flow of the Rovuma and Lugenda rivers means that they are subject to intense fishing pressure, with extensive barrier trapping evident along both rivers. Such evidence is also apparent on smaller ephemeral tributaries within the reserve, such as the tributary to the Rovuma River shown above.

Human Pollution

The rivers of the RdN provide a wide range of valuable services in support of local livelihoods, primary of which is supply of potable water for domestic uses.

Limited human use within the reserve is not a problem in itself, although increased human consumption and more sophisticated water supply and sanitation services should be examined thoroughly before implementation. Development of boreholes is likely to result in lowering of the water table and a reduction in base flows. Such developments are also likely to impact upon the riparian vegetation.

Of more immediate concern is the washing of clothes in the rivers and pools of the reserve, particularly during the dry season when base flows are reduced. Chemical contamination impacts significantly upon the aquatic fauna, destroying food webs and result in direct death of many species. During low flows the chemical concentrations in the isolated pools are higher and there is no flow to dissipate the chemicals.

Pollution from mining by-products is a often cited as a problem within the region. High mercury levels have been recorded in soils near gold mining and processing centres in Tanzania, although studies show low mercury concentrations in fish and aquatic plants (Ikingura *et al*. 1997). Local community members asked about mining activities produced small samples of gold reportedly collected from the Lugenda River. There were also numerous reports of more intensive mining activities further upstream, although these could not be confirmed.

Small scale mining activities often rely on mercury-gold amalgamation extraction methods, resulting in heavy metal contamination. This is highly toxic to aquatic organisms and detrimental to human health. In addition, larger mining operations will use significant amounts of water reducing base flows. Such flow reductions during the dry season may result in the elimination of isolated dry season pools and a complete absence of water from the river. These pools may be further impacted through increased sedimentation as a result of mining activities. These pools are important refugia during low flow periods and need to be maintained.

5 Catchment Based Conservation & Management of the Niassa Reserve

5.1 Background

According to the WWF (Dinerstein et al., 2000), landscape level planning and action is rapidly emerging as a necessary strategy for achieving significant conservation results and for linking human development opportunities to biological diversity. Increasingly organisations such as WWF and the Nature Conservancy are advocating strategies that are formulated at the ecoregion scale. Ecoregion-based conservation (ERBC) is a rigorous approach at a spatial and temporal scale that allows allocation of efforts for safeguarding biodiversity over the long term. In doing so such scales effectively address the fundamental goals of biodiversity conservation, namely:

1. Represent all distinct natural communities within conservation landscapes and protected areas networks;
2. Maintain ecological and evolutionary processes that create and sustain biodiversity;
3. Maintain viable populations of species;
4. Conserve blocks of natural habitat that are large enough to be resilient to large-scale stochastic and deterministic disturbances as well as to long-term changes;
5. Prevent the introduction of invasive species and eradicate or control established invasive species.

While ecoregions typically represent large areas of land, the same functional landscape approach can be developed for smaller units, such as catchments. The aim of this section is to provide an holistic framework for integrated catchment based conservation management planning of the Niassa Reserve. This will inform the development of a decision-support system to aid the delivery of landscape scale strategies for conservation at the catchment scale. The development of a catchment based decision-support system, facilitating delivery of landscape scale strategies for conservation, is built upon the synthesis of information presented in the preceding chapters, with the delineation of catchment units and the analysis of bio-physical features.

The SGDRN is currently identifying options for zoning and development of the Niassa Reserve. According to ??? (in prep), the objectives of the zonation is to;

1. Increase the management effectiveness of SGDRN within the bounds of foreseen financing;
2. Identify the most appropriate land use for increasing management effectiveness, revenues, and sustainability and health of he natural resource base, including especially wildlife;
3. Ensure the maximum degree of benefit to, and involvement of, resident communities through SGDRN management and Reserve utilisation; and
4. Use the principle of adaptive management whereby management approaches are reviewed and adapted where necessary

A number of different zones have been identified with various proposed management options. These clearly defined zones provide a broad overlay of the reserve based on the assumption that the reserve constitutes one landscape management unit. The reserve is actually comprised of numerous smaller ecological management units that encompass landscape processes, namely catchment units. The proposed zonation currently transects different catchment units - effectively dividing the contiguous river systems. While there are other reasons behind the delineation of these zones, the development of a management framework based on the delineation and categorisation of catchment units provides an approach that encompasses landscape processes and provides a mosaic for phased management interventions. It should be acknowledged that these two approaches are not mutually exclusive. The catchment units defined here could be incorporated into the existing zones with some minor adjustments.

A set of categories are proposed to classify each of the catchments according to predefined management objectives. These objectives are guided by the overall objectives of the RdN, taking into account the challenges of balancing the presence of communities with those of conservation. While the aim of this exercise is to provide a framework and not to define the management objectives we have attempted to align the following discussion with the specific management areas proposed in the zoning of the RdN.

5.2 Stakeholder Consultation

This process has been developed on limited information, time and consultation. Ideally such a process should be developed through extensive involvement and consultation with stakeholders. The management objectives of the RdN need to be clearly articulated and incorporated into defined and measurable objectives. Through this process of consultation a classification, of the sort defined below, should be developed. The consultation should then be used to facilitate the delineation and prioritisation of the different catchments. Similarly, a process of community consultation should facilitate the same process of delineation and zonation. Communities and government administration should be engaged to ensure that there is consensus on the categorisation and delineation of each of the catchment units. This is important in ensuring such a framework is successful.

Involvement thus far has been limited and as such the following should be viewed as a proposed framework, which needs to be engaged further. If properly developed and implemented the catchment based framework will provide a structured framework that will enable the RdN to meet its conservation objectives and assist in developing a community based co-management approach within the reserve. The framework should be seen as adaptive one that enables the RdN to respond to changes in priorities and in accordance with the success of the various interventions.

This flexibility and adaptive cycle is particularly important when considering strategies to engage local communities. Outcomes from such interventions are difficult to pre-determine and define. As such, there is a need to develop flexible mechanisms and frameworks that can respond to the outcomes and needs of both the communities and the RdN.

5.3 Classification System

The basic premise of the approach is the delineation of catchment units and the definition of conservation classes. These classes acknowledge the existing condition but should be modified as conditions within the reserve change. This might be the movement or relocation of communities outside of the reserve, or it may be an increased in communities into certain key areas of the reserve engaged cultural and co-management initiatives. As tourism develops and the infrastructure increase there will be a need to re-assess and adjust the definition and management approaches for individual catchments.

The following categories are proposed herein to facilitate discussion and provide the outline for the framework. These should be taken as indicative and subject to further refinement through a consultative process as outlined above. It should also be acknowledged that this provides a spatial framework for conservation. Many species require specific management interventions to ensure their conservation. Individuals of different species exhibit different territorial and migratory behaviours. Other species and habitats will also require specific measures to ensure protection. Mount Mecula exhibits unique biological diversity, with a number of endemic species such as the cordylid lizard, while other habitats such as dambos, need special protection measures. Larger mammals obviously roam between catchments are will need protection through continued anti-poaching activities. However, this spatial framework provides a readily accessible tool for structuring and focussing the limited resources of the reserves management in key areas as well as providing a focus for focussed community programmes.

5.1.1 Core Conservation Areas (CCA)

Given the central objective of the RdN is conservation, core areas need to be defined, allocated and protected in a pristine, or near to, state. Within these areas any interventions should be aimed at minimising unnatural activities and ensuring a true wilderness state. These areas should be free of any roads or infrastructure other than minimal impact walking trails and are comparable to the Wilderness Areas defined by ??? (in prep).

These will be areas dedicated to core conservation values. Human settlement and development programmes will be excluded and the focus of management interventions will be to ensure conservation of wildlife. By proclaiming core conservation areas where it is agreed with the communities that no person shall enter rangers will soon be able to determine the presence of illegal poachers and be mandated to take the appropriate actions. To facilitate this, these areas should preferably be bordered by Tourism Conservation Areas which would serve as a buffer.

5.1.2 Tourism Conservation Areas (TCA)

These would serve as buffers to the core areas. The central objective of these areas would again be conservation focussed with revenue generating activities. As such they lend themselves to a variety of activities including the Eco-tourism, hunting, private investment and public tourism areas proposed in the draft zonation plan. There should be limited road access confined to ridges dividing the catchments with access and trails developed along the rivers and within the catchment. These areas would be managed according to ecological objectives to ensure protection of the essential wilderness qualities.

The spatial orientation and designation of these areas would depend upon the overall objectives and more detailed zoning considerations being developed by the RdN. The spatial arrangement should be given careful consideration to orientate in such a way that core areas are protected by buffers of tourism related areas. Interspersed catchments with different designated activities would enable core areas to repopulate hunting areas, and private and eco-tourism areas to be developed as refugia for wildlife.

5.1.3 Co-management Conservation Areas (CMCA)

The presence of communities with the RdN is currently a reality. Community co-management areas promote integrated use, recognising the existence and entitlement of local communities. It also acknowledges that certain activities can impact upon the conservation objectives of the RdN. In the absence of a negotiated agreement and decisive strategy for resolving the current situation the catchment framework provides an ecological based approach to ensuring minimal impact upon the conservation objectives.

These will in effect be Community Based Natural Resource Management Areas, where communities will be permitted to pursue certain activities. However, it acknowledges that interventions are required to develop these areas toward more of a wilderness state. Emphasis should be placed on integrating activities within the conservation objectives of the reserve, through focussing on the promotion of indigenous knowledge systems, cultural practices etc. These could in turn be developed into more detailed income generating programmes within the tourism framework. These are equivalent to the multiple-use and open access areas in the detailed zonation plan for the reserve.

Designating specific Community Co-Management Areas will enable the RdN to limit the impact of human settlement on the natural condition. It will also provide the reserve management, the local administration and NGOs with a focussed spatial framework for ensuring a coordinated approach to the implementation of development initiatives that minimises the impact take upon the reserves natural condition.

Not only will these areas become the focus of development initiatives, but these can be structured and implemented in such a manner that they integrated principles of sustainable CBNRM. The communities, the SGRDN, government structures and NGOs can actively encourage initiatives that fit within a spatially contained, coordinated framework. This framework should have as it goal the conservation of the reserve and be aimed at creating appropriate development orientated incentives to encourage prosperity outside the reserves boundaries. The evidence from a review of case studies has shown that co-management approaches to conservation of wildlife have increased, stabilised numbers previously in decline or to maintained populations (Roe et al. 2000).

The acronym, CCMA, is deliberately similar to the Core Conservation Areas. This is because the focus should be the same, with the only difference being a certain level of community co-existence. In order to ensure this is effective communities need to be empowered with responsibility and a stake in determining activities through co-management structures.

Unlike the core conservation areas, it becomes more difficult to differentiate local community members and illegal trespassers in integrate use areas. However, empowering communities to take responsibility for their own natural resources in these areas will result in them being more inclined to identify trespassers and self regulate.

Similar initiatives have been implemented in the empowerment of fishers in the Kosi Bay area. These have resulted in improved sustainability of fish stocks, better returns for local communities and less conflict with administrative structures (Kyle, 1986).

5.1.4 Special Conservation Areas

Catchment units will invariably encompass most areas. However there is a need to afford discretionary power to designate special protection worthy areas, referred to as Special Protection Zones by ?? (??). These may cover several catchments and lie on the watershed between two or more catchments and represent areas with unique or high biodiversity value. The most obvious of these is Mt Mecula. In addition to its apparent unique biodiversity Mt Mecula provides an important drainage area for the secondary rivers in that region. It is also reported to include the six most important elephant populations, which inhabit a circle around Mecula in proximity to an estimated 4,000 people. Given the unique features of such areas they represent prime tourism destination and a valuable resource. As such they should be governed by special measures and subject to limit impact.

5.2 Conservation Management Framework

The following maps show how such an approach may be developed. Based on the catchment descriptions the following catchments have been identified as being of high conservation importance. This is based simply on the density and distribution of wildlife and so should be taken as indicative of the process, not necessarily reflecting true ecological importance. This would require further verification through more detailed research.

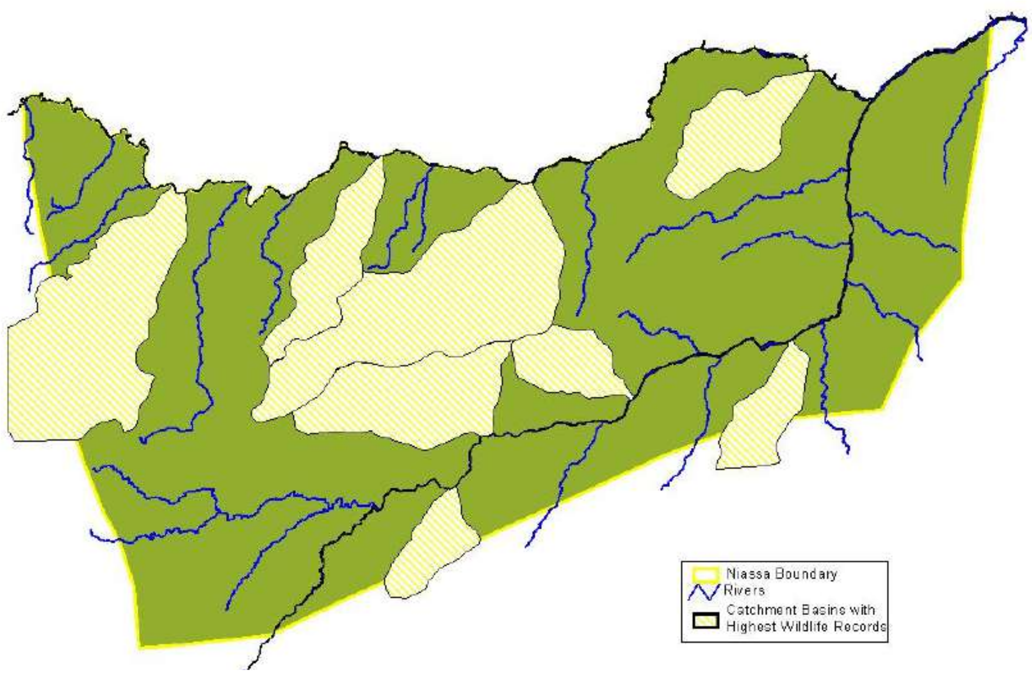


Figure 5.1 Example of delineation of Core Conservation Areas based on distribution and density of wildlife.

Based on wildlife alone these areas fail to encompass and ensure a representation of the different vegetation units within the reserve. Given this, the following map incorporates an additional two catchments into the Core Conservation Area classification network based on the inclusion of under represented vegetation types.

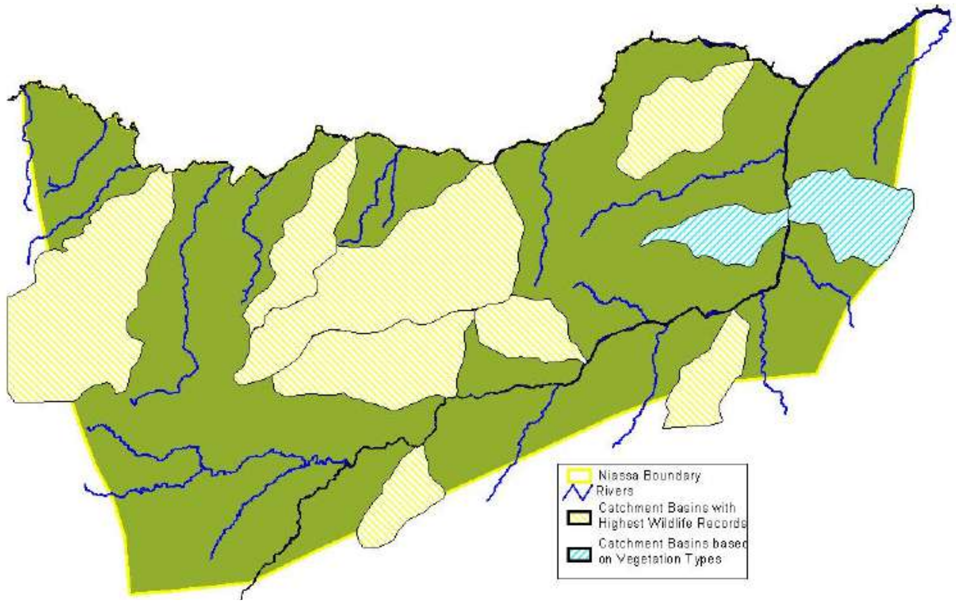


Figure 5.2 Example of delineation of Core Conservation Areas based on distribution and density of wildlife and representation of vegetation types within the Niassa reserve.

In addition to the ecosystem processes approach there are unique features within the reserve that require special protection measures. Acknowledging these the inselbergs of Mecula and Matondavela are also added to the Core Conservation Areas.

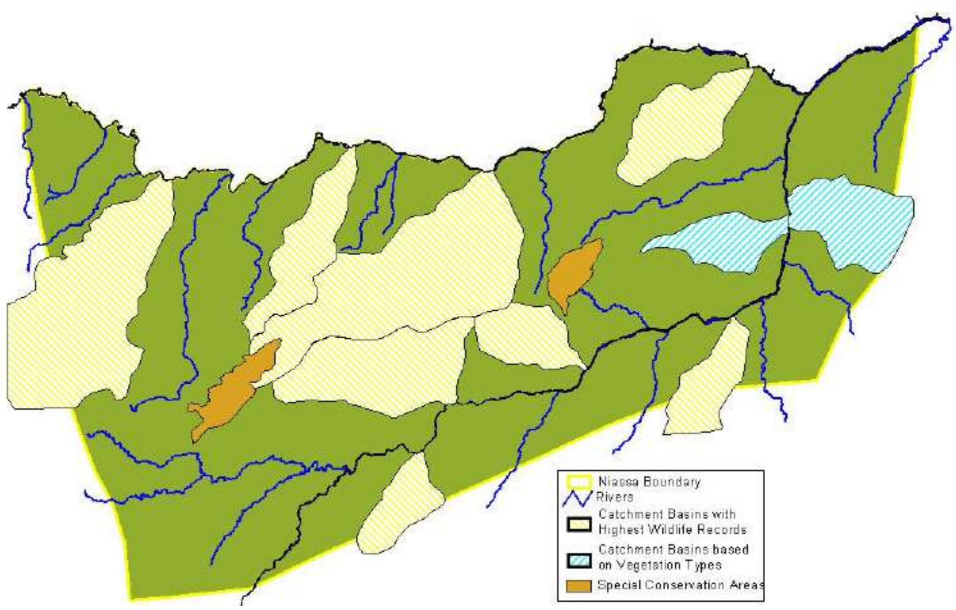


Figure 5.3 Example of delineation of Core Conservation Areas based on distribution and density of wildlife and representation of vegetation types within the Niassa reserve.

From this cumulative process a network of Core Conservation Areas begins to emerge. Given the presence of settlements within the reserve, any conservation framework needs to be cognisant of the distribution and size of human populations. The following map looks at the proposed framework with respect to the size and distribution of human settlements.

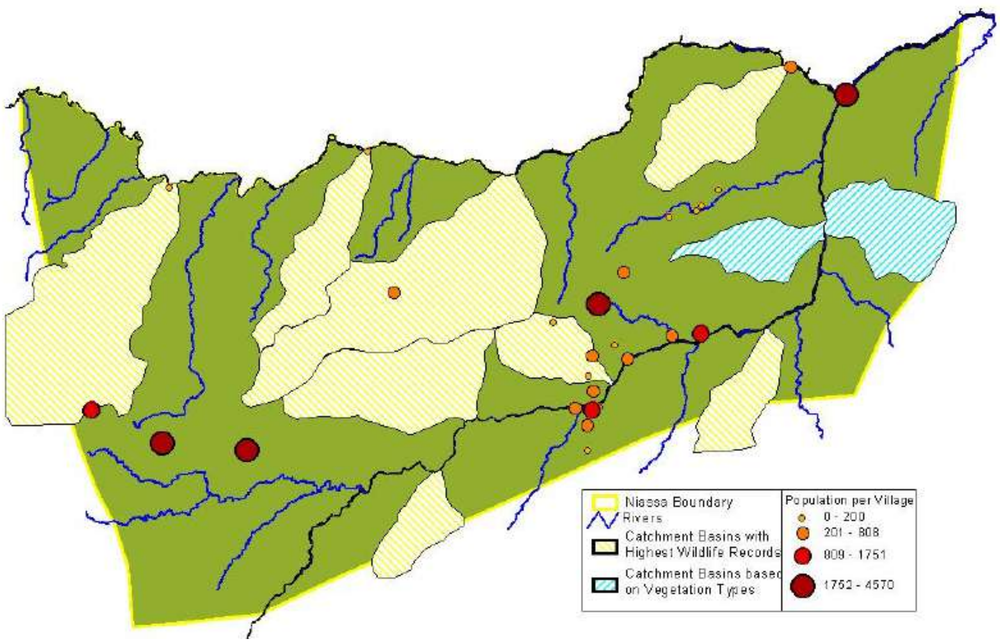


Figure 5.4 Distribution and size of human settlements in relation to the catchment based Core Conservation Areas in the Niassa Reserve.

This map clearly identifies areas of potential conflict with the reserves primary objectives of conservation. As such it facilitates the spatial prioritisation of interventions required to ensure these objectives are met and maintained. From this preliminary approach the village of Matonodovela is clearly a key area that needs necessary interventions. This may be to encourage relocation to other areas, through appropriate incentives. Alternatively, it may be possible to include this settlement in the reserves infrastructure planning by making this central area the research and monitoring station. This would establish an official presence and allow the reserve to monitor and regulate activities. It could also provide the opportunity for co-management partnerships. Such decisions need to be based on the long-term decisions made by the RdN management and are beyond further consideration within the context of this report.

In a similar manner, the mapping and prioritisation of these catchment units provides a spatial framework for facilitating development of the reserves infrastructure, most importantly the road network (see Figure 5.5). In order to protect the integrity of catchment landscape units, roads should be built along the watershed, that divide between catchments. Again, the maps reveal the road to Matondovela as being one of concern, traversing the Core Conservation Area. Based on such an approach this should be a priority intervention area. The re-alignment of this road along the watershed to the south would move human traffic from within the Core Conservation Area. Similarly, the road through the Misangese River catchment should also be a priority for re-alignment. As can be seen from the map most of the other roads can be easily maintained without compromising the integrity of the various prioritised catchments.

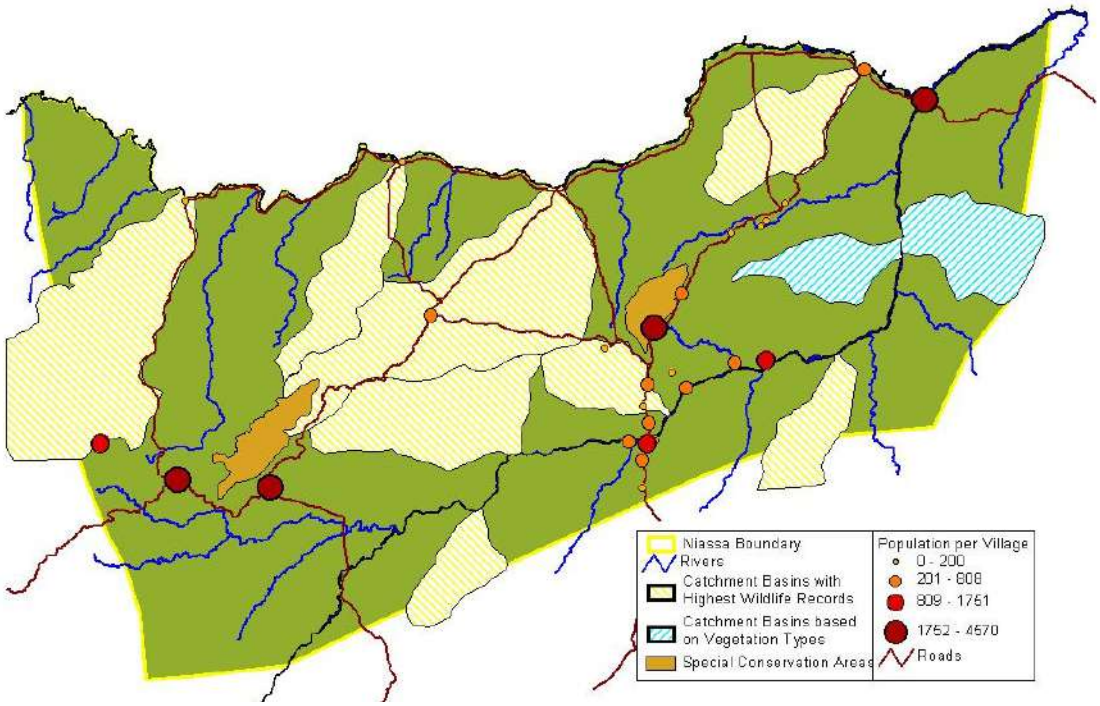
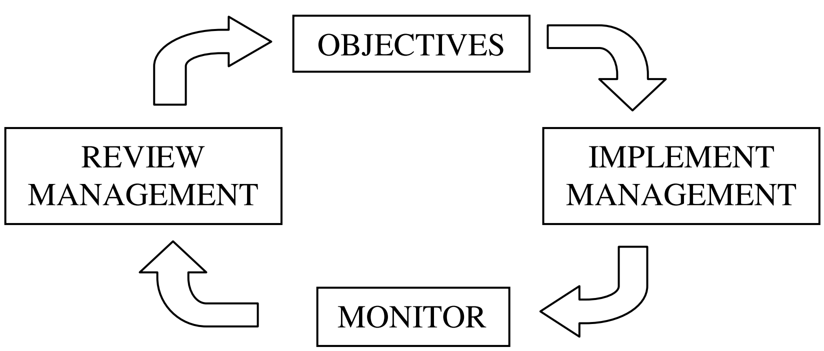


Figure 5.5 Distribution of the road network within the Niassa reserve in relation to size of human settlements and catchment based Core Conservation Areas.

The final planning step is to identify and prioritise the tourism and community co-management areas. Ideally these should be delineated through a consultative process. It is important to situate Tourism Conservation Areas around those Core Conservation Areas and in doing so provide a buffer. This is may not always be possible however.

Based on this preliminary exercise, Tourism Conservation Areas would be best situated toward the north-western side of the reserve, within the Lussanando and Lucabanga catchments, and the Licombe catchment to the north-east. This would provide a corridor among Core Conservation Areas and provide the foundations for further development under the Niassa-Selous initiatives.

The delineation and prioritisation should be considered an ongoing, dynamic and adaptive process developed around a list of regular activities or management objectives, based on existing regulations and applied to each of these areas. This not only provides a useful a management tool but, again through a process of consultation, a way in which to reach agreement and self regulation through the co-management with communities.



5.2.1 Summary

The development and implementation of a catchment based spatial management framework for the RdN provides a landscape level approach to ensuring protection of the reserves natural features and processes. Such an approach also enables communities to be engaged in constructive dialogue and, through coordinated programmes, the development of a coordinated co-management framework.

The spatial arrangement provides readily definable and easily recognisable units that can be differentiated in the field. Rangers can therefore quickly determine if certain activities, or individuals, are in violation of the agreed regulations for that particular area. This should help to improve policing functions, anti-poaching activities and regulation of fisheries. An indicative list of activities and how these may relate to the development of regulations in the reserve is presented below.

Activities	Core CAs	Tourism CAs	Co-Mgmt CAs	Special CAs
Settlement	X	Lodges only	✓	x
Agriculture	X	X	✓	x
Anti-poaching	✓	✓	✓✓	✓
Human exclusion	✓	✓	x	✓
Fishing regulations	x	✓	✓✓	X
Fishing ban	✓	X	X	✓
Land use planning	X	✓	✓✓	X
Land care programs	X	✓	✓✓	X
Washing ban	✓	✓		✓
Reforestation	X	✓	✓	X
Boreholes	X	✓	✓	x

The principles in defining this approach can easily be adapted and expanded to match the needs of the reserve. There are a number of reserves in the broader regional setting. Such a framework enables a system to be developed to link these through differentiated catchment unit practices. For example, the Selous Game Reserve lies to the north within the Rufiji basin, covering 55,000 km^2 and containing several important wetlands (Manongi 1993). Further to the south is the Gile Game Reserve, while the Mikumi National Park in Tanzania also covers parts of the Rufiji River and several of its tributaries (Sayer et al. 1992). More realistically, the proposed transboundary peace park between the Niassa and Selous Game Reserves (Iddi 1998) provides an opportunity for the Niassa Reserve to establish the foundations for the development of a catchment based approach to conservation.

The ideas contained herein represent a draft process rather than a prescriptive process. Further development requires an emphasis on consensus between the principal stakeholders. It provides an adaptive framework within which management can change in response to uncertainty and circumstances. It also provides a formalised framework for monitoring and evaluation and for the identification of threats and opportunities. The overall objective is to achieve an acceptable compromise between conservation and development objectives so that the vision of the Niassa Reserve is fully realised.

6 Research and Monitoring

Sound management is based upon a comprehensive understanding of the natural environment and process that structure it. In order to achieve this level of understanding the RdN should continue to develop its focussed strategy to address research needs within the reserve. The limited resources available make this all the more important. Research should be direct through strategic partnerships and focus on requirements of the reserve and focus on short, medium and long-term needs.

The first phase, which is currently being supported, is that of initial inventories. These are providing a solid foundation for further studies and a comprehensive list of species present.

The medium term focus should be toward more detailed temporal monitoring and comparative studies of the biodiversity within the reserve and identification of the process important in maintaining these.

Once the foundations exist, research should be directed and develop toward developing landscape level, process orientated projects.

More specifically, research and monitoring on the rivers of the reserve should initially focus on establishing a monitoring network for the collation of long term data sets. These will assist in forecasting and determining limits of natural variation and should include stream flow, precipitation and evaporation, rapid biomonitoring of aquatic diversity, and fixed point photography of channel form.

Monitoring of water quality is more complicated and expensive. Portable units can be purchased and this should be a long term goal. Spot checks of aspects such as heavy metals should be initiated immediately through partnerships with universities to determine presence and concentrations of heavy metals in the environment as well as tissue samples of fish.

A comprehensive fisheries monitoring and control programme should be developed for immediate implementation. The differentiation of fishing regulations according to different catchments provides a spatial framework to facilitate protected fishing areas. These would not only provide protection for the fish fauna but also a source of recruitment for other rivers.

Monitoring and the collection of data are meaningless unless such information is utilised properly and fed back in to management structures. Within the research and monitoring context, the catchment framework facilitates comparative studies of the different management classes. For example, this will enable quantitative determination of the effects of human settlement on the reserves ecological integrity and the success of co-management in those CCMAs.

As data becomes available there should be a formalised mechanism for incorporating it in to the decision making process. A continual process of re-assessment through review and revision of implementation strategies should be measured against clearly articulated and defined objectives. The results of such implementation strategies should be monitored and the information obtained through this process subsequently evaluated, put back in to the formulation of new objectives and development of implementation strategies. Such a strategy allows flexibility in management and changes to be made in light of improved or new data, issues or objectives.

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Annex 1 Terms of Reference

The consultant will be responsible for achieving the following specific objectives and activities in a consultancy period spread from the 25th of September to the 31st of December 2004.

Objectives:

1. To identify and define the conservation value of individual catchments units in the Niassa Reserve.
2. To provide a management tool to guide the process of prioritisation for conservation areas and the designation of human resource utilization and development areas.

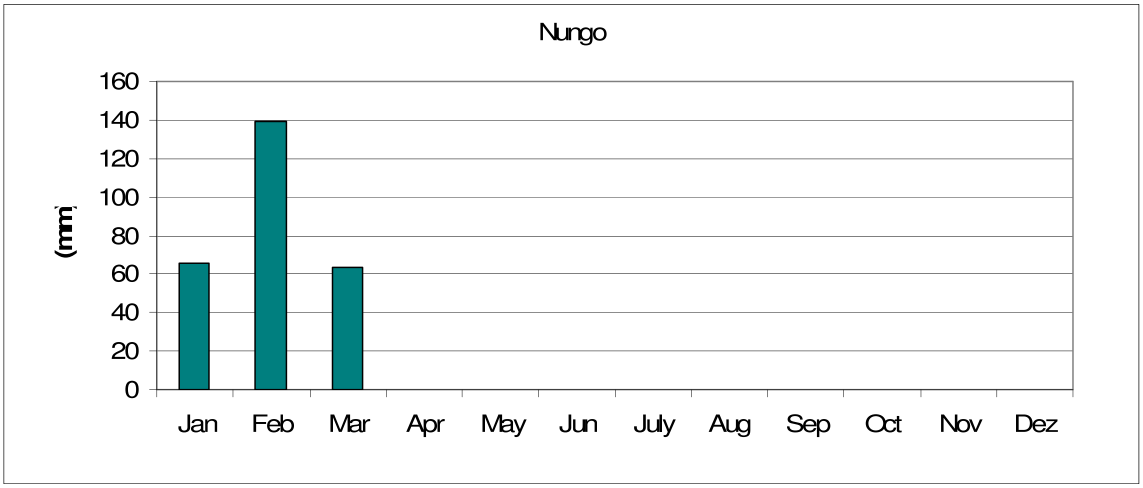
Expected outputs:

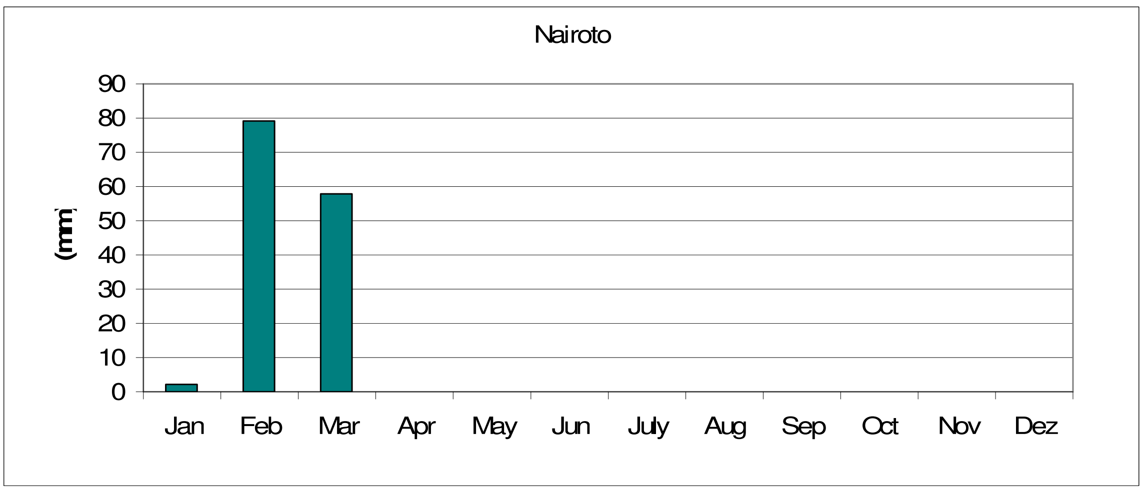
1. Holistic framework for integrated catchment based conservation management planning.
2. Delineation and definition of tertiary and, where possible, quaternary catchment units within the reserve area.
3. GIS shape files for each catchment unit.
4. Preliminary estimates of the inter- and intra-annual variation in the hydrological regime of rivers in the reserve area.
5. Bio-physical description of aquatic environments and ecosystem linkages.
6. Ecological characterisation of rivers and catchments within the reserve.
7. Catchment based conservation zoning of the reserve.

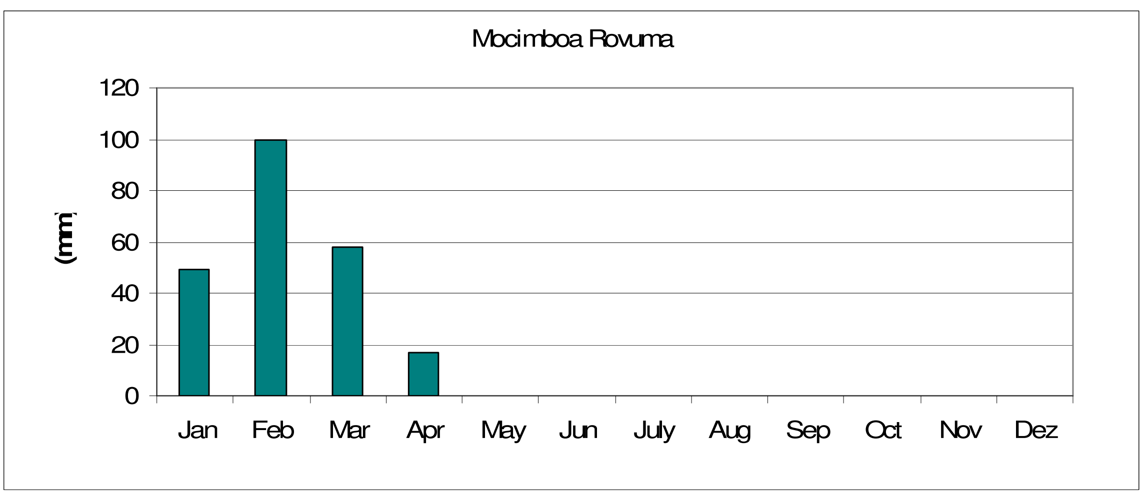
Scope of Work:

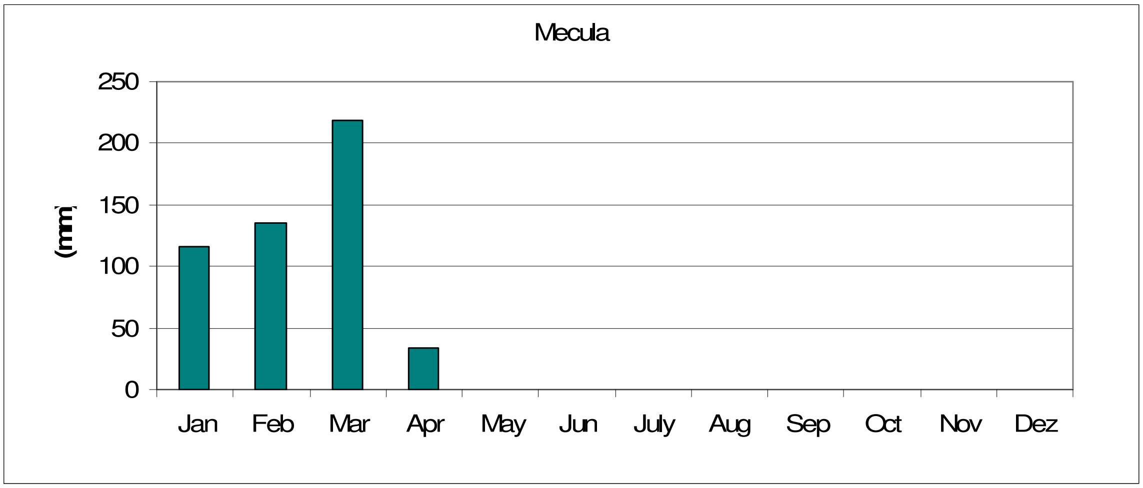
1. Desktop level reconnaissance of the reserve.
2. Definition of catchment units.
3. Categorisation of geological and pedological characteristics.
4. Synthesis of vegetation characteristics.
5. Collection of climatic data; rainfall, evaporation, etc.
6. Elaboration of run-off model, synthesis of hydrological characteristics of rivers, based on climatic, geological and floristic information.
7. Aerial survey to examine landscape ecology, verify the run-off model and hydrology, geomorphological interpretation of hydrological features in rivers of the reserve, and eco-hydrological description.
8. Integration of geological, geomorphological and hydrological information into GIS database.
9. Delineation of catchments according to conservation importance to identify management zones and facilitate planning.

Annex 2 Surplus water at climatic stations in northern Moçambique





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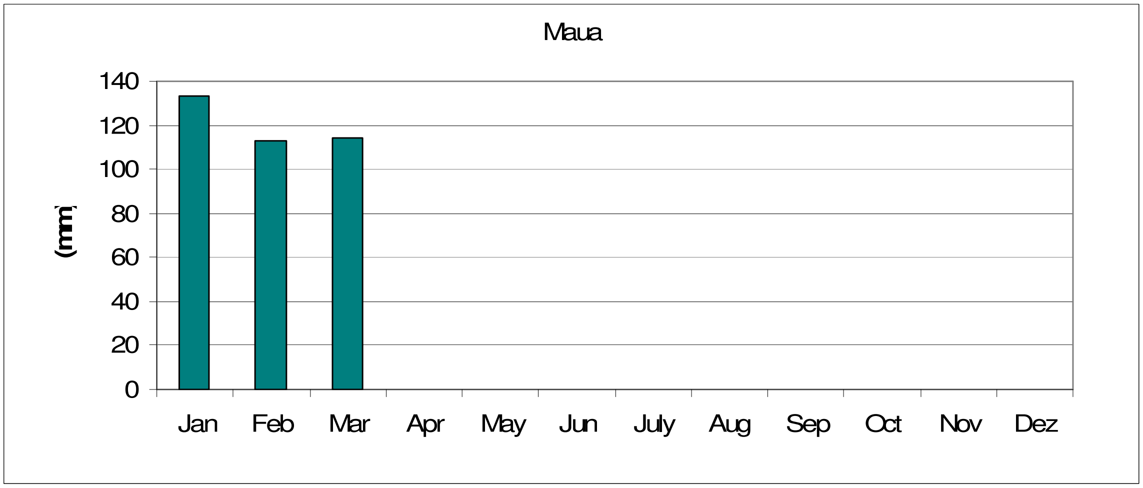
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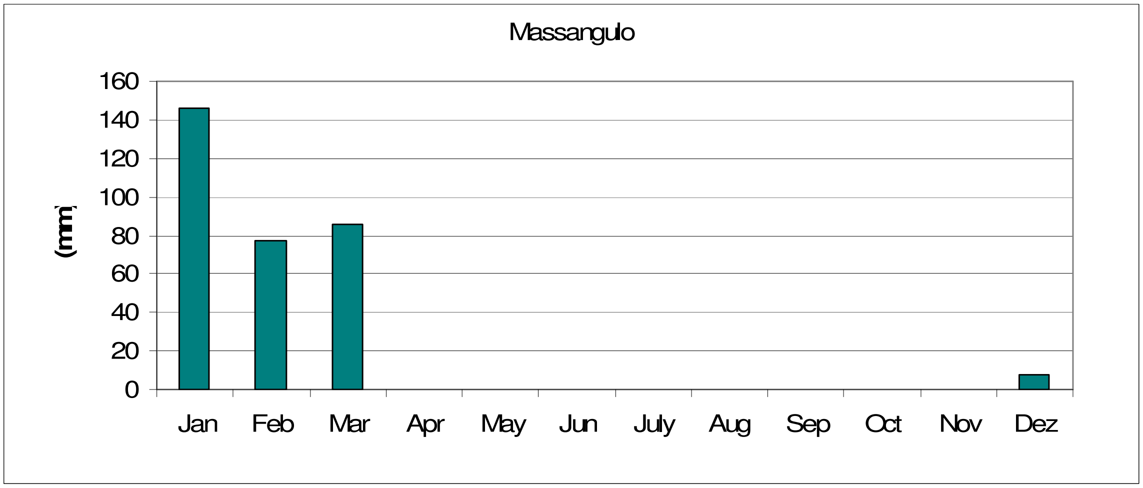
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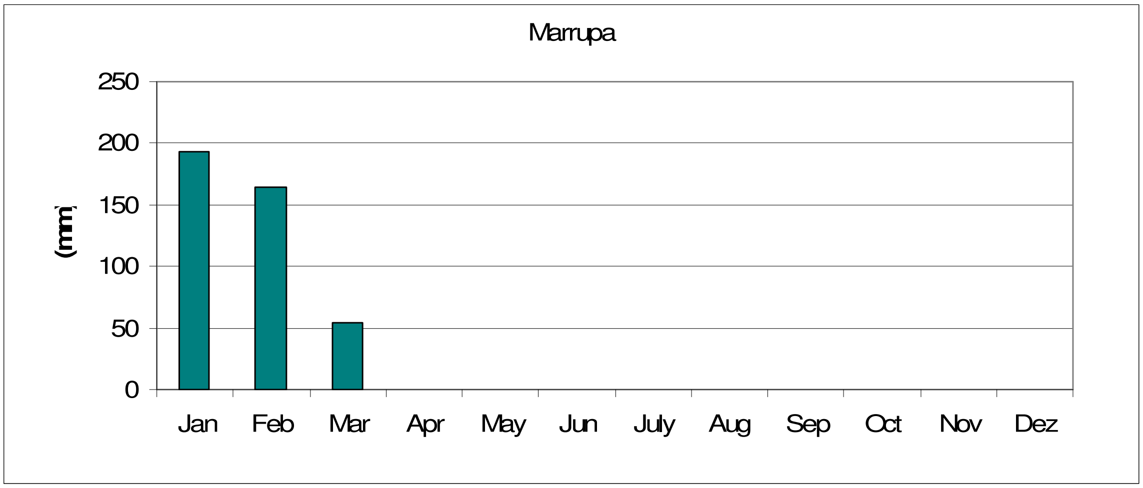
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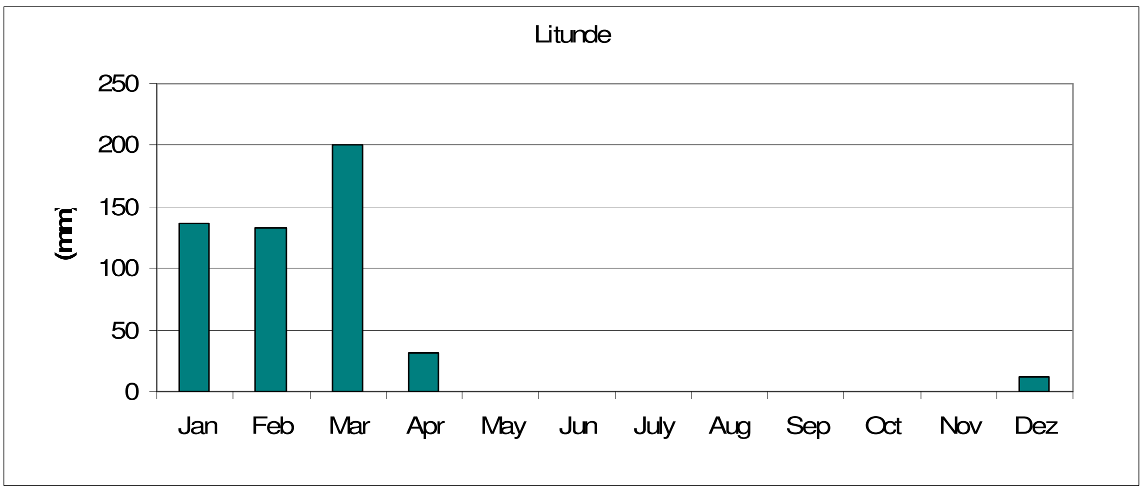
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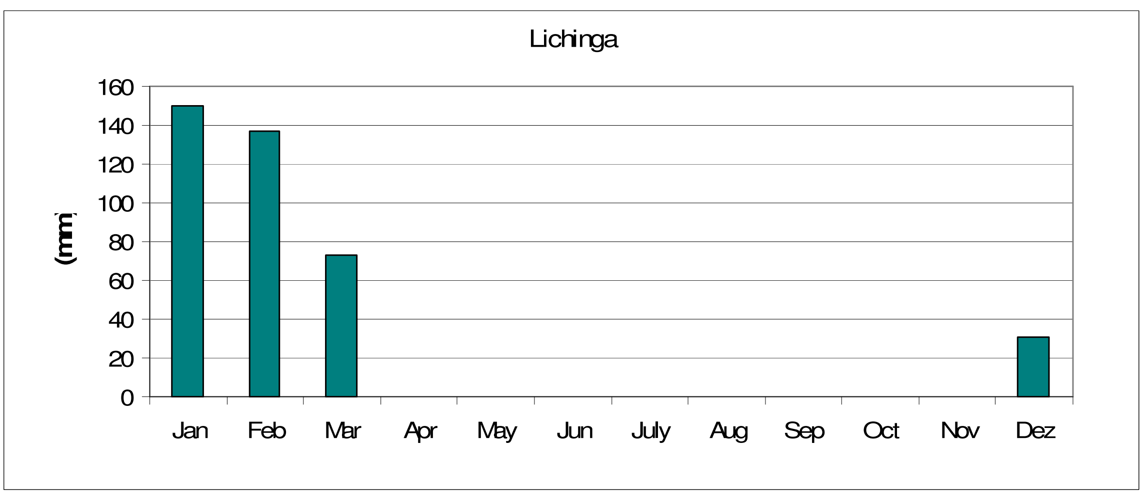
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Annex 3 Summary of Catchment Characteristics

River Name	River Length (Km)	Gradient	Area (Km2)	Population	
				Name	Population Number
Luguluzia	55	0.0031	840		
Lutiambila	42	0.0043	460		
Lualece	70	0.0043	520		
Lucheringo	120	0.0041	2670	Milepa	188
Lussanando	133	0.0024	2330		
Lucabanga	67	0.0034	640		
Ludmule	87	0.0025	900	Chamba	143
Mazeze	55	0.0036	590		
Chiuwexi	148	0.0037	3000	Matondovela	437
Licombe	65	0.0015	800		
Misangese	73	0.0027	960	Gomba	645
Jurege	108	0.0021	1530	Mitope / Nalama / Eruvuka / Naulala / Macalange	66 / 150 / 200 / 111 / 808
Ninga	82	0.0012	1060		
Irangwe	51	0.0032	960		
Miuro	55	0.0029	580		
Namaho	52	0.0044	720		
Nichandocha	65	0.0024	730		
Luambezi	55	0.0018	610		
Luchinge	59	0.0017	620		
Ncuti	41	0.0024	570	Mecula/Ncuti	4570 / 411
Incalaue	55	0.0039	600	Mbatamila/N'timbo/Lissongole	50 / 315 / 86
Metapiri	89	0.0034	1480		
Lumbuisse	47	0.0043	500		
Luatize	144	0.0099	3350	Msawise	4000
Lureco	57	0.0037	960	Mpamanda/Mucovia	411 / 198
Lugenda	369	0.0011	22560		
Rovuma	400	0.001			

River Name	Wildlife															
	Bufalo		Eland		Hartebeest		Impala		Kudu		Reedbuck		Waterbuck		Wildebeest	
	Area (Km^2)	% of Sp. Distribution	Area (Km^2)	% of Sp. Distribution	Area (Km^2)	% of Sp. Distribution	Area (Km^2)	% of Sp. Distribution	Area (Km^2)	% of Sp. Distribution	Area (Km^2)	% of Sp. Distribution	Area (Km^2)	% of Sp. Distribution	Area (Km^2)	% of Sp. Distribu tion
Luguluzia	0	0	30	1	0	0	0	0	70	1	170	5	0	0	0	0
Lutiambila	0	0	0	0	0	0	0	0	80	1	140	4	0	0	0	0
Lualece	0	0	60	2	0	0	0	0	70	1	90	3	40	2	0	0
Lucheringo	0	0	0	0	60	1	0	0	130	2	0	0	0	0	0	0
Lussanando	0	0	40	1	1008	14	0	0	400	7	550	17	0	0	0	0
Lucabanga	0	0	0	0	190	3	0	0	0	0	570	18	0	0	30	1
Ludmule	0	0	90	3	200	3	0	0	60	1	40	1	110	4	60	3
Mazeze	0	0	150	5	350	5	20	1	0	0	0	0	0	0	0	0
Chiuwexi	360	11	740	25	960	13	0	0	260	5	0	0	120	5	940	40
Licombe	0	0	80	3	300	4	130	7	380	7	0	0	160	6	0	0
Misangese	160	5	290	10	300	4	0	0	0	0	0	0	20	1	20	1
Jurege	110	3	140	5	0	0	10	1	180	3	0	0	0	0	0	0
Ninga	0	0	80	3	0	0	0	0	0	0	0	0	0	0	0	0
Irangwe	20	1	0	0	0	0	40	2	130	2	0	0	0	0	290	12
Miuro	140	4	0	0	0	0	30	2	80	1	0	0	0	0	10	0
Namaho	190	6	0	0	0	0	0	0	280	5	0	0	0	0	100	4
Nichandocha	120	4	30	1	0	0	0	0	0	0	0	0	10	0	0	0
Luambezi	0	0	160	5	0	0	210	11	450	8	0	0	170	7	80	3
Luchinge	0	0	0	0	80	1	40	2	130	2	0	0	0	0	0	0
Ncuti	0	0	0	0	30	0	90	5	120	2	0	0	60	2	0	0
Incalaue	70	2	200	7	220	3	0	0	120	2	0	0	0	0	120	5
Metapiri	510	16	0	0	560	8	0	0	100	2	130	4	0	0	120	5
Lumbuisse	0	0	10	0	100	1	30	2	0	0	0	0	30	1	10	0
Luatize	260	8	220	7	110	1	0	0	330	6	290	9	140	6	0	0
Lureco	0	0	0	0	0	0	50	3	270	5	0	0	0	0	0	0

River Name	Flora					
	Moist Evergreen Forest	Dry Tall Mixed Thicket	Tardily Deciduous Miombo	Deciduous Miombo	Deciduous Dry Miombo Savanna Woodland	Submontane and Montane Grassland (68)
	% of Catchment Area	% of Catchment Area	% of Catchment Area	% of Catchment Area	% of Catchment Area	% of Catchment Area
Luguluzia	0	0	5	95	0	0
Lutiambila	0	0	5	95	0	0
Lualece	0	0	10	90	0	0
Lucheringo	0	0	20	80	0	0
Lussanando	0	5	20	80	0	0
Lucabanga	0	5	28	67	0	0
Ludmule	0	5	15	80	0	0
Mazeze	0	5	0	95	0	0
Chiuwexi	0	7	17	76	0	0
Licombe	3	0	10	77	8	2
Misangese	0	0	0	58	42	0
Jurege	10	0	14	40	35	1
Ninga	0	10	0	0	56	0
Irangwe	0	0	0	0	100	0
Miuro	0	0	0	12	88	0
Namaho	0	5	0	0	80	0
Nichandocha	0	0	0	5	60	0
Luambezi	0	0	2	55	20	0
Luchinge	0	0	2	43	46	0
Ncuti	5	0	10	65	18	2
Incalaue	0	0	0	95	5	0
Metapiri	0	0	40	59	1	0
Lumbuisse	0	0	0	70	10	0
Luatize	0	0	89	10	1	0
Lureco	0	0	0	60	10	0