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Climate Vulnerability Background Review
for
the Quirimbas National Park, Mozambique

Final Report

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Climate Vulnerability Background Review for the Quirimbas National Park, Mozambique

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AUTHORS:

Anabela Paula

Boris Atanassov

Carlos Litulo

Hugo Costa

Marcos A M Pereira

Mayra Pereira

Raquel S Fernandes

Susana Moreira

EXECUTIVE SUMMARY

Mozambique is recognized as one of the most vulnerable countries in Africa to climate change impacts due to its geographic location. Mozambique has a coastline of about 2470 km with more than 60% of the population (approximately 20.5 million) living in coastal areas. The northern coast of Mozambique is susceptible to seawater rise and a marked reduction in water availability on the mainland, as well as a substantial reduction of available agricultural land and the increase of forest fires risk. Marine and coastal conservation areas, like the Quirimbas National Park (QNP) in Cabo Delgado Province is prone to be affected by climate change negative impacts. Both people and QPN ecosystems and species, are vulnerable to climate change impacts, namely extreme events like floods and sea level raise.

This review is included in the WWF CEAGI Climate change adaptation programme and intends to summarize the relevant available information and references to assess climate vulnerability in the QNP. From all the available references for this review, 143 were considered relevant and analysed and relevant stakeholders, including the Provincial Directorates and Delegations were contacted. The main results obtained are:

- The numbers of fishermen, fishing gear, fishing vessels and fishing centres have been increasing since 1995, and from 2005 to 2012 these 4 parameters have increased between 14,2% and 34,7%. Globally there is a positive trend in terms of total catches with the four most representative fishing gears (beach seine, handline, surface gillnet and bottom gillnet). Beach seine is the fishing gear with the highest catches in the four main fishing districts of QNP (Meluco, Macomia, Quissanga and Ibo). Most of the families that were caught by the four fishing gears mentioned before are declining in terms of % of occurrence. Currently there are no active processing units in the districts overlapped by the QNP (Metuge, Meluco, Macomia, Quissanga, Ibo and Ancuabe), nor under a licensing process. Regarding aquaculture, although some studies have been made in the past, currently, Cabo Delgado's Provincial Directorate for Fisheries does not have any aquaculture projects in operation or at the licensing stage.
- No trends were possible to analyse relative to agricultural land, crops & livestock but the loss of forest is associated to slash and burn agriculture, which seems to have been increasing.
- Currently there are no reliable estimates of the area covered by coral reefs in the QNP. No regular reef monitoring has been conducted in the QNP. Apart from storms, the reef benthos does not seem to be under high stress from anthropogenic action, although fishing (hand-lining, spearfishing and traps) is a common practice.
- Despite the socio-economic importance of seagrass beds, no monitoring has been conducted on the species abundance, distribution and total area, therefore trends and current status is unknown.
- No monitoring has been conducted on the biodiversity and goods provided by the intertidal areas and therefore data are not available on the status and trends of these resources. However, there is a perception that a general decline has occurred.
- Regarding freshwater resources data is still scarce but the most relevant available information (annual flows of the Montepuez and Messalo rivers from 1964/65 till

2013/14 with some gaps), shows lower discharge levels for Messalo river in more recent years (from 1997 to 2013).

- According to a recent study the mangrove forest area in QNP increased 1 568 ha between 1991 and 2002 (a growth of 1.27 % per year), followed by a decrease of 464 ha in 2013 (a decline of 0.33% per year). Despite the negative tendency of the last decade, there was an overall increase in mangrove cover from 1991 till 2013.
- Using the Global Forest Change webtool it was possible to identify that deforestation occurs all over the Park, focusing mostly along the main roads, especially in the northern section (Tanguia Region). It also seems to have a higher concentration in the eastern zone. Forest cover gain also occurs in Tanguia region and QNP east area, which may be compensating part of the recorded deforestation.
- There are no time-series data that would allow status trends of High-profile species to be drawn, and the current state of conservation of these species is largely unknown.
- There is no consistent data for the calculation of growth rate regarding the QNP population. The growth rate projected by INE for Cabo Delgado Province is approximately 2% a year. Assuming that the QNP population will grow in conformity with the growth rate of the Cabo Delgado Province, we can infer that this growth may be associated with the development of the oil and gas industry.
- According to the Agriculture Census done in 2007, less than 5% of the people interviewed in Cabo Delgado Province have stated that they have experienced conflicts regarding land use. These conflicts mentioned are associated with zoning of the land and land being sold to different people.
- In the last decade the Provincial Directorate for the Coordination of Environmental Affairs (DPCA) has issued at least 31 licenses for the following infrastructures in the main districts that are included in the QNP: 14 concerning tourist accommodations, seven electrification projects, four fuel stations, one water bottling project, three mining projects and one oil & gas project. The main existing/planned infrastructure concerns tourism, oil & gas and mining development.
- The data for regions within the QNP area shows that 70% of households in Ancuabe use charcoal as a cooking fuel and 35% use firewood; the data for Metuge shows that 63% of households use charcoal as a cooking fuel and 47% use firewood; while in Bilibiza and Mahate 35% of households use charcoal as a cooking fuel and as much as 71% use charcoal.
- The entire offshore area of Cabo Delgado (Rovuma basin) is devoted to gas exploration. A new bidding process for new oil & gas concessions is undergoing by the Mozambican Government so it is expected that the number of projects increase. Considering the cumulative effect of the impacts of the oil & gas industry and whole associated infrastructure, it is expected that the pressure on local ecosystems will increase significantly as well as the risk of hazards.
- There are currently 20 areas associated with mining activities. Graphite, vanadium and ruby have been found in Cabo Delgado, near the QNP, and the first mines are now starting to operate. Three of these areas are inside the QNP. It is expected that the impacts will focus mainly inland with terrestrial forest loss and habitat fragmentation, which will have consequences on several fauna species.

- The number of hotel units has increased over the last decade, rising from 32 in 2004 to 127 in 2014 (a four-fold increase), as well as the number of beds that rose from 800 to almost 2500 (a three-fold growth). Although dominated by national tourists, foreign tourists are increasing in recent years, with the number of nights by foreigners in 2014 quite similar to those by nationals.

The most relevant information about the trends and projections in climate and related physical and environment parameters is:

- Considering a time series from 1960 to 2005 for the northern region of Mozambique there is an increase of approximately 1.1˚ C for the months March-April-May (MAM) and September-October-November (SON) for the average maximum annual temperature. INGC study also indicates that the average maximum annual temperature was usually bellow 30° C before 1990 but afterwards, higher temperatures became common. The increase in average maximum annual temperatures from 1960 to 2005 was also a result of longer period of extreme hot days, representing approximately an increase of 25% of the number of hot nights during the months DJF and 17% for SON in the northern region of Mozambique.
- Data suggest a reduction of precipitation in December and an increase to a peak in March (rain may exceed 6 mm/day), showing a delay of the wet season and an increase of total number of dry days and extension of the dry season from September to November. Almost all the model projections for 2050-2200 indicate that November will become drier in northern Mozambique. From January to March, most of the models give indications of an increase in average monthly precipitation.
- Cyclones seem to have become more frequent, leading to devastating flood events.
- Flooding is one of the main hazards in QNP. Flooding is known to occur along the banks of the Montepuez and Messalo rivers and affects the two main sectors that provide cash income for local communities, namely: fishing and agriculture. Total artisanal annual catch seems to be significantly correlated to the coastal rainfall lagged two years. Coral reefs and seagrass beds are able to cope with increased rainfall to a certain extent. Heavy floods usually result in massive amounts of nutrients, reduced salinity, light penetration and sedimentation.
- Available information reports a SST rise of ca. 0.010° C/year over 50 years (1957-2007) for "northern Mozambique". Recent models predicted that globally averaged SSTs will increase by 0.3°C–0.6°C. An increase in SST is expected to have deleterious effects on both fish and invertebrate fisheries both directly and indirectly. With the predicted increase in SST, it is expected that coral reefs will suffer, further degradation, shift in distribution and composition, loss of biodiversity, productivity and ecological function.
- Recent estimates show that, globally mean sea level has risen at an average rate of between 1.4 to 2.0 mm/year over the 20th Century and between 2.7 and 3.7 mm/year since 1993. Looking at data from the tidal station network of Mozambique, including Pemba and Mocímboa da Praia, a 2002 study concluded that "No clear evidence has been found with regard to the variation of the mean sea levels particularly as an impact of global climate changes". Several impacts on mangroves are expected from sea level rise: decline of species diversity, change in species composition and distribution. This will result on loss of biodiversity, productivity, as well as coastal protection. INGC (2009) suggests that the region of the QNP (especially the islands) is susceptible to sea level rise. The great majority coastal communities would be left without potable water due to the

increases salinity of ground water. Sea level rise will certainly have deleterious effects on tourism infrastructures as well as other coastal settlements, which are located very close to the shoreline.

- An increase in storm frequency and intensity will certainly have deleterious effects on tourism infrastructures as well as other coastal settlements, which are located very close to the shoreline. Increased winds and surge can potentially cause erosion and risk turtle nesting sites.
- It is expected that changes in the wind patterns (direction and strength) will strongly affect the local fishing communities. It will also have serious effects on the socio-economy of the region in general as trade and long distance travelling along the coast relies heavily on the large dhows.
- Globally coral reefs are undergoing increasing physiological stress from ocean warming and acidification, both of which are gradually reducing their habitat. Negative direct impacts on small-scale fisheries and mollusc mariculture can be anticipated based on scenarios of decreasing pH by 0.5. The ecological and socio-economic consequences for the QNP would thus be devastating, giving the dependency of the local communities as well as the tourism industry on marine resources such as intertidal invertebrates and coral reefs.
- Dramatic impacts on fish production due to climate changes are expected, which can affect the protein supply and fish oils derived for local people. Several of the global climate-related changes and impacts are already being experienced or are expected to occur in the North of Mozambique.
- Regarding high profile species, the loss of nesting habitat as well as productive feeding areas can potentially be conduct marine turtles towards local extinction if current anthropogenic stressors are not dealt with.
- In a public health perspective the frequency and intensity of extreme weather events, flooding or drought may also play an important role on population health. This impact will be determined by the future health status of the population (including the prevalence of cardiovascular diseases, HIV and TB, malnutrition or stunting especially in young children) and the capacity of communities to adapt to health threats as well as to cope with climate events and public health governance measures.

Several gaps in the current knowledge have been identified and they are summarized in this review.

LIST OF ACRONYMS AND UNITS

AQUA – Agência para o Controlo da Qualidade Ambiental

ARA – Administração Regional de Águas

CARE – Cooperative for Assistance and Relief Everywhere

CVCA – Climate Vulnerability and Capacity Analysis

DAS – Departamento de Águas e Saneamento

DNAIA – Direcção Nacional de Avaliação de Impacto Ambiental

DPOPH – Direcção Provincial de Obras Públicas e Habitação

DPCA – Direcção Provincial para Coordenação da Acção Ambiental

DPP – Direcção Provincial das Pescas

DPREME – Direcção Provincial dos Recursos Minerais e Energia

DPS – Direcção Provincial de Saúde

DPTUR – Direcção Provincial do Turismo

ha - hectare

IDPPE – Instituto Nacional de Desenvolvimento da Pesca de Pequena Escala

INAM – Instituto Nacional de Meteorologia

INGC – Instituto Nacional de Gestão de Calamidades

IIP – Instituto Nacional de Investigação Pesqueira

IPCC – Intergovernmental Panel on Climate Change

km - kilometer

MICOA – Ministério para a Coordenação da Acção Ambiental

MITUR - Ministério do Turismo

MSc – Master of Science

PhD – Doctor of Philosophy

QNP – Quirimbas National Park

t – Metric tonne

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1. Background

Climate change is defined as "any change in climate over time, whether due to natural variability or as a result of human activity" (IPCC, 2007), and is increasingly recognized as a serious, ongoing threat to human development (IPCC, 2001 and 2007) and ecosystems conservation (Parmesan & Yohe, 2003). It represents a classic multi-scale global problem characterized by diverse actors, numerous causes and multiple time scales (Adger, 2006), that must be addressed to achieve equitable and sustainable development. The impacts of climate change manifest in floods, droughts, unseasonal rains and extreme events. Those events create additional challenges for developing countries and the poorest communities that are more vulnerable due to their limited economic, technological and human capacities and their dependence on climate sensitive economic sectors (IPCC, 2001).

- Vulnerability to climate change is one of the crucial components of the problem, and is defined as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (Dazé et al., 2009; IPCC, 2001). Other relevant key concepts are:
- Adaptive Capacity is the "ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC, 2001);
- Resilience is "the ability of a community to resist, absorb, and recover from the effects of hazards in a timely and efficient manner, preserving or restoring its essential basic structures, functions and identity (UNISDR, 2009);
- Hazard is "a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (UNISDR, 2009);
- Adaptation to Climate Change is the "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities".

It should be noted that hazard does not translate directly into risk but it is qualified by the degree of vulnerability of the individual or system in question to a specific hazard and the factors causing vulnerability are what determines the risk. Poverty is often considered one of the main risk drivers but there are other causes like geographical location, gender, age, access to resources and wealth, etc. (Bohle et al., 1994; Adger, 1996; Cannon, 2000).

Sub-Saharan Africa is regarded as the region where there are most people vulnerable to climate change impacts. The continent is already prone to erratic rainfall, droughts, floods and cyclones and climate change is exacerbating these continuing challenges. At the same time, Africa fights poverty, environmental degradation, heavy dependence on natural resources for subsistence and occurrence of epidemic diseases (HIV-AIDS, malaria, etc). These factors increase vulnerably and limit the ability of people and institutions to adapt to climate change (CARE, 2010).

Regionally, Mozambique is recognized as one of the most vulnerable countries in Africa to climate change impacts due to its geographic location (INGC, 2009a). Mozambique has a coastline of about 2470 km (CIA, 2013) with more than 60% of the population (approximately 20.5 million) living in coastal areas. Survival and daily living in these areas depend largely on local resources, such as rain-fed agriculture and fishing, while the infrastructure is weak or non-existent (INGC, 2009a). Additionally, the Mozambican coastline consists of recent geological formations with great natural variability and has in general physically unconsolidated ecosystems, namely sandy beaches, estuaries and mangroves (Maueua et al., 2007). These fragility features coupled with the increasing resource consumption and the predicted impacts of climate changes result in a high vulnerability of both people and landscape to drastic events such tropical cyclones and sea level rise. Moreover, it is expected that exposure of Mozambique to the risk of natural disasters will increase significantly over the next 20 years and beyond, as a result of climate change (INGC, 2009a,b).

Worst-case scenarios in existing climate models point out different levels risks in different areas of the coast. The northern coast of Mozambique is susceptible to seawater rise and a marked reduction in water availability on the mainland, as well as a substantial reduction of available agricultural land and the increase of forest fires risk. Climate change is also a major threat to conservation areas and although very few evidence has been produced on conservation impacts, the likelihood of species extinctions is been increasingly accepted (Parmesan & Yohe, 2003). Consequently, marine and coastal conservation areas, like the Quirimbas National Park (QNP) in Cabo Delgado Province, which includes the 11 southern islands of the vast Quirimbas Archipelago (a chain of 28 islands stretching over almost 400 km), is prone to be affected by climate change negative impacts.

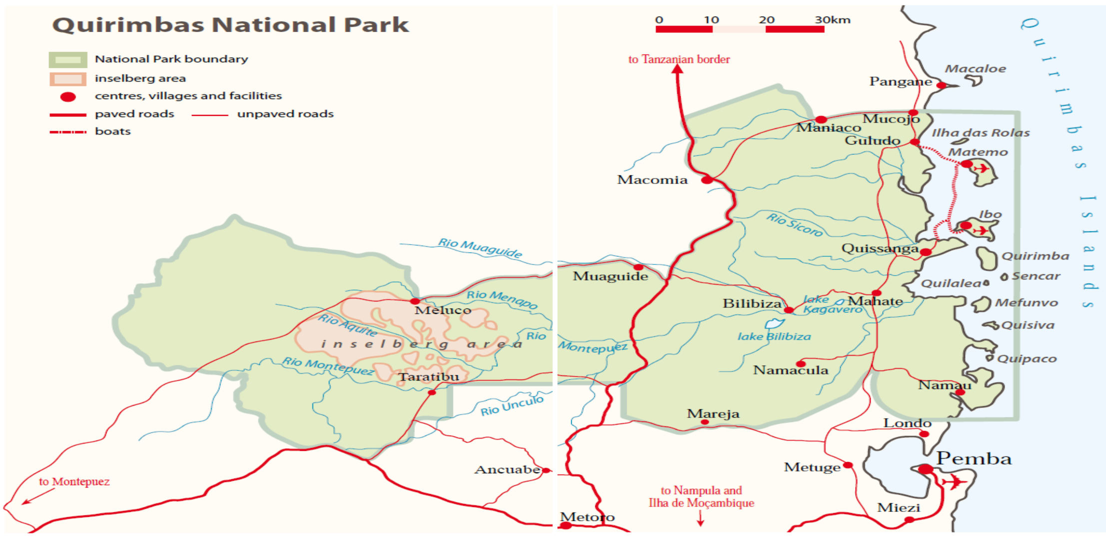


Figure 1.1– Quirimbas National Park (QNP) (from Marques & Tomasinelli, 2012)

The QNP is a global priority conservation area that was created with the support of WWF on 6 June 2002 (Decree 14/2002). The park partially covers 4 districts (Meluco, Pemba-Metuge, Ancuabe and Macomia) and totally includes the districts of Ibo and Quissanga. With a total area of 7 506 km², it includes both terrestrial (5 984 km²) and marine habitats (1 522 Km²; Figure 1.1). QNP is a globally outstanding biodiversity area, with its magnificent inland ecosystems (miombo, coastal forests, granite inselbergs holding many endemic plants, among others), and also sensitive marine ecosystems, namely mangroves, seagrass beds and some of the best kept coral reefs in the southern African region, as well as endangered marine species (e.g. five species of marine turtles, whales and dolphins). With about 135 000 people living permanently within the park boundaries and buffer zone, the population is mainly concentrated along the coast (20% of the QNP's population) and the main roads that cross the park. As elsewhere in the province, the education level is low (illiteracy rates average 83%) and 95% of the economically-active population works in small-scale agriculture on family-run farms, and in fisheries (MITUR, 2011). Considering these characteristics, both people and QPN ecosystems and species, are vulnerable to climate change impacts, namely extreme events like floods and sea level raise.

Therefore, the objective of this assignment is to prepare a review, summarizing relevant available information and references to assess climate vulnerability in the QNP. This initiative is included in the WWF CEAGI Climate change adaptation programme. This programme was initiated in early 2011 and aims to ensure that WWF's conservation programme in coastal Eastern Africa recognizes and addresses the impacts of global climate change on priority ecosystems and on communities that depend on them. The QNP is one of the five priority landscapes selected by the programme to undertake climate change vulnerability assessments and to develop and implement climate change adaptation strategies, to ensure that climate adaptation is incorporated into natural resources management strategies. This review addressed the Step I of the Vulnerability Assessment process supported by WWF, covering the following main topics:

- Trends in status of key ecosystems, natural resources and natural resource-based livelihoods;
- Major development trends and pressures affecting the above;
- Trends and projection in climate and related physical environment parameters;
- Vulnerability and resilience of ecosystems, species, livelihoods and infrastructures to climate variability and change;
- Relevant management policies and strategies that address climate change.

2. Approach

This assessment is a literature review on climate vulnerability in the QNP that aims to summarize available information and identify the main knowledge gaps. For this purpose, the project team searched available data, both in electronic and print formats and grey and scientific literature, namely: national and regional official reports, development strategy plans, the QNP management plan, MSc and PhD thesis, peer reviewed papers, technical reports, among other documents. From all the available references for this review, 143 were considered relevant and analysed.

Additionally, to address the identified knowledge gaps (mostly data on trends in the QNP), relevant stakeholders (regional and national governmental institutions) were contacted. All requests were made officially. Provincial Directorates and Delegations of the relevant stakeholders were visited as many times as needed to gather the information. A few national level institutions were also visited. The work timeline is presented in Figure 2.1.

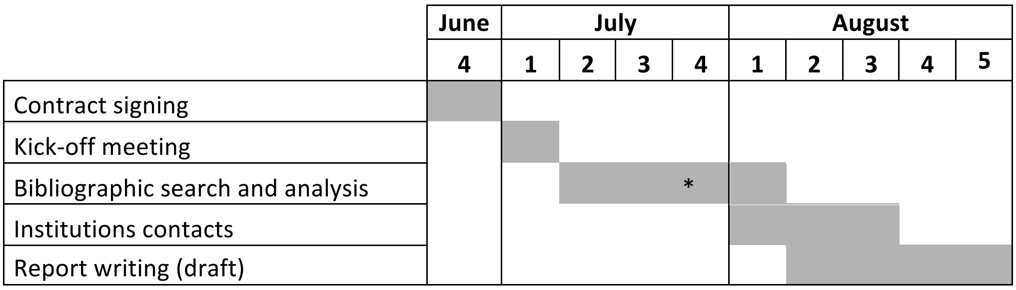


Figure 2.1 – Work timeline (* week when WWF's bibliography was received)

Table 2.1 summarizes the Governmental institutions contacted and the requested versus the obtained information. Information obtained was provided to the District or Provincial level. It was assumed that this information is representative of the QNP situation.

Table 2.1 – Governmental institutions contacted, requested and obtained information

Institution	Requested Information	Obtained Information
INAM (Provincial Delegation and Central)	Annual average, in the last 30 years, of the following parameters: 1. rainfall; 2. temperatures; seawater temperature, wind patterns, mean sea level.	Rainfall (total) and average temperatures (from 1985 till present)
ARA Norte	For the last 30 years: surface and underground water resources (rivers, tributaries, estuaries, permanent and temporary freshwater lakes) and their average flows. Number and type of water supplies to the populations (boreholes, wells, etc.)	Average flows from Messala and Montepuez rivers and maximum flood flows for a return period of 20 years in Meluco, Quissanga and Macomia districts
Water and sanitation Department (DPS) of the DPOPH	Number and types of water supplies to the population (boreholes, wells, etc.) For the past 30 years	All requested information
DPTUR	Number of touristic projects submitted and approved; guest occupancy numbers (National and abroad). For the last 10 years	All requested information
INGC provincial Delegation	Disaster events (including cyclones, floods and others) for the past 30 years.	All requested information

Institution	Requested Information	Obtained Information
DPP	Projects and development plans related with fish processing and landing (type and size) as well as the level of aquaculture, for the last 10 years	All requested information
IDPPE provincial delegation	Artisanal fishing reports	2012 Artisanal fishing reports
IIP provincial delegation	Annual report of artisanal fisheries	Annual reports from 2001 till 2013 (except 2007)
DPCA	Project category type A, B and C that have had environmental permit, for the last 10 years	Type B and C approved projects and some A type projects
DPRMEM	Type and number of mining concessions for the last 10 years	All requested information;
DPS	Data on diseases prevalence and human well-being over the last 10 years.	All requested information;
AQUA	Project category type A that have had environmental permit, for the last 10 years	No information was provided

3. Trends in Status of key ecosystems, natural resources and natural resource-based livelihoods

3.1. Fisheries and aquaculture

The data to assess artisanal and semi-industrial fisheries was obtained from several references, especially IIP's annual reports (from 2001 to 2013), IDPPE's 2007 and 2012 artisanal fisheries census and the QNP Biodiversity Baseline (Sitoe et al., 2010). The data presented in the IDDPE's 2012 is provided at provincial level. This is something that should be improved in the next census. Therefore, it was not possible to compare the trends relatively to 2007 per district but only for the whole province. Sitoe et al. (2010) also presented data from the 1995 and 2002 census for Cabo Delgado, which are summarized in Table 3.1.

Table 3.1 – Number of fishermen, fishing gears, fishing vessels and fishing centres registered in 1995, 2002, 2007 and 2012 and trends in % between the survey years (Sources: Sitoe et al. , 2010; Ministério das Pescas / IDPPE,2013).

Items/Year	1995	2002		2007		2012	
Nr of fishermen	4469	15875	↑ 255,2	14261	↓ -10,2	19097	↑ 33,9
Nr of fishing gears	475	4359	↑ 817,7	4764	↑ 9,3	6417	↑ 34,7
Nr of fishing vessels	1885	4124	↑ 118,8	4439	↑ 7,6	5615	↑ 26,5
Nr of fishing centres	114	141	↑ 23,7	197	↑ 39,7	225	↑ 14,2

In 2012, Cabo Delgado had 225 fishing centres (most of them permanent), 167 (74.2%) in maritime waters and 58 (25.8%) in inland waters. This represents an increase of 14.2% of the number of fishing centres compared to 2007, with an increase of 22.8% for those located along the coast (in 2007 there were 197 fishing centres, 36 in maritime waters and 61 inland). The number of fishing centres has been steadily increasing since 1995, as it can be seen in Table 3.1.

The number of fishermen increased over 250% between 1995 and 2002 and decreased 10.2% between 2002 and 2007 (Table 3.1). In 2012 there were 40794 fishermen: 21 697 fishermen without vessel and 19 097 with vessels (although not clearly explained in the 2012 report it was assumed that these were fishermen with vessels). Additionally, there were 6 108 other people indirectly involved with fisheries. The trend is therefore positive with an increase of 23.8% (in 2007 there was a total of 32 960 fishermen, 14 261 of them with vessels). With regards to people indirectly involved in fisheries the trend is also positive with an increase of 63% (in 2007 the total number of people indirectly involved was 3 747).

Within the QNP, in 2007 (Sitoe et al., 2010), there were five fishing centers in Macomia, 10 in Quissanga, 14 in Ibo and one in Malema, with a total of 30 artisanal fishing centres along the coast (representing 23.1% of all fishing centres in the province). Also in 2007, the number of fishermen from Quissanga, Ibo, Macomia and Pemba-Metuge totaled just over 4 756, which corresponds to just under 30% of fishermen recorded in the province. Because the 2012 census does not present information at district level, it is not possible to compare the trends of fishing centres within the QNP.

In 2012 Cabo Delgado had a total of 5 615 fishing vessels and 6 417 fishing gear. The trend is therefore positive: an increase of 26.5% in fishing vessels and 34.7% in number of fishing gear number compared to 2007. Both parameters had already increased very significantly between 1995 and 2002 and had a smaller positive trend between 2002 and 2007 (Table 3.1)

Regarding the type of vessel, in 2012, 88.3% were dugout canoes, 8.1% dhows ("lanchas"), 2.6% "Moma" type canoes, 0.9% flat tenders "chata" and 0.1% were classified as "others". The following table shows the trends (in %) per comparable types (Table 3.2). No previous data was obtained about the type of vessel. Between 2007 and 2012 significant increases in "Moma" type canoes, flat tenders and dugout canoes were registered and also a significant reduction in the use of dhows.

Table 3.2 – Number of vessels of each type in 2007 and 2012 and trend in %.

Year	"Moma" type canoes	Dugout canoes	Flat tenders	Skiboat	Raft	Dhows	Others	Total
2007	4	3684	6	2	2	737	4	4439
2012	146	4958	49	1	0	457	4	5615
Trend	↑ 3550,0	↑ 34,6	↑ 716,7	↓ -50,0	↓ -100,0	↓ -38,0	→ 0,0	↑ 26,5

Regarding the type of fishing gear, in 2012, 47% were hand lines, 21.2% gillnets, 12.1% spears, 10.7% beach seine, 6.9% traps and 2.3% others. Table 3.3 shows the trends per comparable fishing gear. No previous data was obtained about the type of fishing gear.

Table 3.3 – Number of fishing gears in 2007 and 2012 and trend in %.

Year	Beach seine	Gillnet	Trap	Hand Line	Longline	Purse seine	Others	Total
2007	683	1379	312	2115	13	29	233	4764
2012	684	1358	440	3017	24	108	786	6417
Trend	↑ 0,1	↓ -1,5	↑ 41,0	↑ 42,6	↑ 84,6	↑ 272,4	↑ 237,3	↑ 34,7

As it can be seen only gillnets decreased and all other gear types have increased, in particular purse seine, longline and others (although this category was not considered in 2007, it is assumed that spear, was the fishing gear responsible for such an increase in the "others" category).

Relevant information about fishing gear was found in IIP's Annual Reports (2001 to 2013). Data collection in Cabo Delgado was initiated in 2006, therefore it was possible to analyse the data from 2006 till 2013. Because the type of fishing gear registered was variable among years, trends among years were compared using four of the five most representative fishing gears (beach seine, handline, surface gillnet and bottom gillnet) that were continuously monitored during this eight-year period. Purse seine has not been included because it was only recorded from 2011 to 2013. Table 3.4 shows the yearly trends for the whole Cabo Delgado province, both for total catches (TC) and for catch per unit effort (CPUE). As it can be seen, globally there is a positive trend in terms of total catches. Beach seine and surface gillnet have been increasing except for the 2011-2012 period. Handline has been variable, increasing or decreasing between years and bottom gillnet catches have been increasing continuously since 2011. In terms of CPUE, in the periods of 2006-2007, 2008-2009 and 2009-2010 the trends were negative for almost all the types of fishing gear. The period of 2007-2008 was variable between fishing gear types, whereas 2011 to 2013 was practically always positive to all fishing gear types.

Table 3.4 – Trends in Total Catches (TC) and Catches per Unit Effort (CPUE) for the whole Cabo Delgado Province between 2006 and 2013.

Fishing gear	2006-2007		2007-2008		2008-2009		2009-2010		2010-2011		2011-2012		2012-2013	
	TC	CPUE	TC	CPUE	TC	CPUE	TC	CPUE	TC	CPUE	TC	CPUE	TC	CPUE
Beach seine	40,5	-48,0	111,4	198,1	7,8	-58,2	2,5	-9,1	16,1	45,0	-9,3	-5,7	15,3	4,9
Hand line	32,0	-12,5	-31,1	-38,1	150,8	-7,7	-0,7	-8,3	-4,4	18,2	0,7	38,5	-6,5	5,6
Surface gillnet	-58,0	-54,5	52,8	10,9	92,7	-45,1	2,4	-7,1	35,6	61,5	-24,3	7,1	11,4	6,7
Bottom gillnet	-3,0	-4,7	182,7	-14,8	-52,4	-84,6	28,1	287,5	-1,6	61,3	86,0	32,0	15,3	7,6
Total	-2,2		67,7		29,3		3,0		15,1		-6,8		10,3	

Table 3.5 and Table 3.6 show the trends for the 4 districts overlapped by the QNP: Meluco, Macomia, Quissanga and Ibo. The data is highly variable within districts so a direct comparison between them is not possible. Information regarding several fishing gears is missing in several years and the 2011 data creates some doubts regarding the CPUE. For this reason, 2013 was compared to 2010 only. Of the four fishing gears analysed, beach seine is the one with the higher catches in the four districts (Table 3.5), ranging from 34.5% of the total catches in Macomia to 64.3% in Meluco. Surface gillnet is the second most representative, except for Meluco (values ranging from 11.7 to 35.5% within the four districts). Handline is, in general, the third most representative (range 8.1% to 27.3%) and bottom gillnet the less representative (ranging from 2.7% to 16.9%).

Table 3.5 – Percentage of each of the four analysed fishing gears in terms of total catches per each of the fours districts

Fishing gear	Meluco	Macomia	Quissanga	Ibo
Beach seine	64,3	34,5	49,3	59,9
Hand line	20,9	27,3	8,1	10,5
Surface gillnet	11,7	35,5	25,6	19,5
Bottom gillnet	3,1	2,7	16,9	10,1
Total	100,0	100,0	100,0	100,0

In Meluco, total catches and CPUE seem to have declined from 2009 for most of the fishing gears. Surface gillnet total catches and CPUE have increased between 2011-2013 and 2010-2013, respectively. Nevertheless, globally the total catches have declined in this period (Table 3.6).

The situation is different for Macomia, where beach seine has generally declined over the years but the CPUE has increased since 2010. Handline and surface gillnet seem to be increasing recently, both for total catches and CPUE. Bottom gillnet has also increased between 2012 and 2013 but the CPUE has declined (Table 3.6).

In Quissanga the situation is similar and the total catches and CPUE have been increasing for almost all fishing gears analysed. The only significant difference is the decline by -68.2% of the CPUE for the handline between 2012 and 2013 (Table 3.6).

Ibo has different results. Total catches increased between 2008 and 2010 for all fishing gears where data is available, but since 2011 the trends are variable. For each of the four fishing gears, the trend is the opposite between 2011-2012 and 2012-2013. For example, the trend of the beach seine is negative (-11.2%) in the 2011-2012 period and positive (59.9%) between 2012 and 2013 as showed on Table 3.6. The CPUE was positive for all the fishing gear between 2011 and 2012 but it as negative in 2012-2013 for all fishing gears except for beach seine (increase of 35.1%).

Table 3.6 – Trends in Total Catches (TC) and Catches per Unit Effort (CPUE) for the Meluco, Macomia, Quissanga and Ibo Districts between 2006 and 2013 (* no data available for comparison).

	Fishing gear	2006-2007		2007-2008		2008-2009		2009-2010		2010-2011		2011-2012		2011-13	2010-13
		TC	CPUE	TC	CPUE	TC	CPUE	TC	CPUE	TC	CPUE	TC	CPUE	TC	CPUE
Meluco	Beach seine	*	*	↑ 49,3	↑ 144,0	↑ 18,9	↓ -47,5	↑ 153,0	↑ 6,3	↓ -60,6	*	*	*	↓ -78,4	↓ -41,2
	Hand line	*	*	↑ 59,6	↑ 66,7	↑ 73,3	↓ -55,0	↑ 72,3	↓ -22,2	↓ -78,1	*	*	*	↓ -70,5	↓ -28,6
	Surface gillnet	*	*	↑ 512,0	↑ 661,5	↓ -58,8	↓ -80,8	↓ -33,3	↓ -68,4	↓ -95,2	*	*	*	↑ 712,5	↑ 83,3
	Bottom gillnet	*	*	↓ -2,6	↑ 25,0	↓ -89,5	↓ -96,7	*	*	*	*	*	*	*	*
	Total	*		*		*		*		*		*		↓ -70,8	
Macomia	Beach seine	↓ -32,9	↑ 34,4	↓ -9,2	↓ -52,9	↓ -46,5	↓ -59,6	↑ 125,6	↑ 100,0	↑ 5,7	*	↓ -6,8	↑ 46,0	↓ -31,7	↑ 6,5
	Hand line	↓ -49,8	↑ 329,2	↓ -10,9	↓ -88,3	↑ 85,6	↑ 8,3	↑ 7,2	↓ -30,8	↑ 20,6	*	↓ -40,3	↑ 10,0	↑ 2,4	↑ 77,8
	Surface gillnet	↓ -96,4	↓ -79,5	↑ 1504,3	↑ 54,8	↑ 83,5	↓ -6,2	↑ 13,9	↓ -21,3	↑ 96,0	*	↓ -78,4	↑ 47,0	↑ 18,3	↑ 62,5
	Bottom gillnet	↓ -86,8	↓ -36,7	↑ 396,3	↓ -50,0	*	*	*	*	*	*	*	↑ 55,0	↑ 96,7	↓ -3,2
	Total	*		*		*		*		*		↓ -55,8		↑ 13,8	
Quissanga	Beach seine	↑ 61,6	↑ 112,5	↓ -34,2	↓ -35,3	↑ 262,3	↑ 22,7	↑ 102,0	↓ -19,8	↓ -43,1	*	↓ -16,5	↑ 51,0	↑ 65,3	↑ 5,9
	Hand line	↑ 4411,1	↑ 300,0	↓ -83,7	↑ 120,8	*	*	*	*	↑ 95,8	*	↑ 170,2	↑ 44,0	↑ 10,3	↓ -68,2
	Surface gillnet	↑ 2200,0	↑ 775,0	↑ 23,4	→ 0,0	↑ 6,2	↓ -45,7	*	↑ 5,3	*	*	↓ -1,6	↑ 17,0	↑ 40,3	↑ 182,4
	Bottom gillnet	↓ -14,6	↑ 403,3	↑ 1763,4	↓ -80,8	↓ -59,9	↑ 34,5	*	↓ -25,6	*	*	↑ 187,1	↑ 70,0	↑ 0,1	↑ 11,4
	Total	*		*		*		*		*		↑ 20,4		↑ 5,2	
Ibo	Beach seine	*	*	↓ -31,7	→ 0,0	↑ 505,4	→ 0,0	↑ 236,6	↑ 172,7	↓ -12,4	*	↓ -19,4	↑ 77,0	↑ 59,9	↑ 35,1
	Hand line	*	*	↑ 45,5	↑ 150,0	↑ 100,0	↓ -13,3	↑ 498,4	→ 0,0	↓ -81,2	*	↑ 145,8	↑ 28,0	↓ -56,3	↓ -42,9
	Surface gillnet	*	*	↓ -98,1	→ 0,0	↑ 6350,0	↓ -64,3	↑ 354,3	*	↓ -56,5	*	↓ -38,8	↑ 55,0	↑ 90,1	↓ -23,6
	Bottom gillnet	*	*	*	*	*	*	*	*	↓ -64,4	*	↑ 275,7	↑ 79,0	↓ -71,0	↓ -43,0
	Total	*		*		*		*		*		↓ -0,9		↑ 33,7	

According to Sitoe et al. (2010), historically there was a low intensity of sampling within the QNP. Many of the fishing centres were excluded because it was a program to cover the entire province. It seems that there might have been irregularities in the collection of field data. This may have reduced the quality of the results obtained to guide the management of the park. The lack of methodological details in the IIP reports somewhat limits the interpretation of the results, particularly variations observed between 2006 and 2007. The explanation is not provided in the reports and the methodology is not explained with enough details, in order to infer the possible causes of catch variability.

IIP's annual reports present information about the fish species caught by each fishing gear (but not for the total) within the Cabo Delgado Province (no data at district level was obtained). Therefore, in order to determine any trends between years several types of analysis were conducted. Because the information presented in the annual IIP's reports is: i) presented at family level; ii) the type of analysis is different from year to year; and iii) the methodology used in each year is not explained in detail, the analysis herein presented should be interpreted cautiously.

Fish families caught by each fishing gear

To analyse the trends of the families caught by each fishing gear the following analysis were conducted:

- The top five fish families caught by each type of fishing gear in each year were chosen and their % of occurrence relatively to the total catch (data obtained from IIP's annual reports);
- Each time a new fish family was recorded, its percentage in the previous years was recorded (in the cases were the species of the family had been caught);
- The trend in % of occurrence between each two consecutive years was calculated;
- In the following step, a trend analysis was performed:
    - The number of times that a fish family showed an increase, decrease or stayed stable, per type of fishing gear during the analysed period with data for Cabo Delgado (2006 to 2013) was counted;

- The trend of each family in the last year with available data (2012 or 2013) was recorded
- Combining the previous data it was determined, on a semi-quantitative basis, a possible trend for each family according to each fishing gear type, using 4 categories: Declining; Stable-Declining; Stable and Increasing;
- Using the trend obtained in the previous step, it was determined, on a semi-quantitative basis, a possible trend for the most representative families among the analysed fishing gear types;
- Also using the same information, it was determined, on a quantitative basis (average of the number of times each trend category was accounted for), the average percentage for each trend category per fishing gear type.

Annex 1 shows the results of the global trend analysis. As it can be seen it was not possible to present the 2007 data because the data was not made accessible. Additionally, the only fishing gear that had data for the whole period on a continuous basis was the beach seine. The 2011 and the 2013 reports only present catch data for families caught with this type of fishing gear. This is the reason why the trends for hand line, surface gillnet and bottom gillnet of 2012 were compared relatively to 2010 and not 2011. As it can be seen on a global view the data presented on Annex 1 is not very informative and there is not a pattern per species and/or per fishing gear. However, analysing each row independently, it is possible to observe the global trend per family per fishing gear and the variability of the trend between years.

Table 3.7, shows the percentage of families for each trend category per fishing gear, and the average percentage of families for each trend category considering all fishing gears.

Table 3.7 – Percentage of fish families for each trend category per fishing gear, and average percentage of Families for each trend category considering all fishing gears. This is relative to the total period 2006-2013.

Fishing gear	Declining	Stable-Declining	Stable	Increasing	Total number of most frequent Families
Beach seine	27,3	18,2	36,4	18,2	11
Hand line	33,3	25,0	16,7	25,0	12
Surface gillnet	35,7	7,1	21,4	35,7	14
Bottom gillnet	53,3	13,3	26,7	6,7	15
Average %	37,4	15,9	25,3	21,4	-

Bottom gillnet seems to be the fishing gear with more families within the “Declining” category, followed by surface gillnet and hand lines. Beach seine is the fishing gear with more families within the “Stable” category and surface gillnet the one with more families within the “Increasing” category. Considering the two negative trends together (“Declining” and “Stable-Declining”), bottom gillnet is the fishing gear with the highest percentage (66.7%), followed by hand line (58.3%). Considering the categories “Stable” and “Increasing” together, surface gillnet accounts for 57.1% and beach seine 54.5%.

The category “Declining” is the one with the highest percentage of occurrence (37.4%). It is followed by “Stable” (25.3%) and “Increasing” (21.4%). “Stable-Declining” has a percentage of occurrence of 15.9%. The two negative trends together (“Declining and Stable-Declining”), account for a total of 53.3% of the families.

Finally, the overall analysis per fish family (Table 3.8) shows that from the 10 most representative caught by the four analysed fishing gears between 2006 and 2013, four (40%) seem to be

"Declining", one (10%) is "Stable-Declining", three (30%) are "Stable" and two (20%) are "Increasing".

Table 3.8 – Trends of the most representative families caught by handline, surface gillnet, bottom gillnet and beach seine, between 2006 and 2013.

Family	Trend	Relevant notes
Siganidae	Stable	Declining in Handline and Increasing in Surface gillnet
Carangidae	Declining	
Scaridae	Increasing	Increasing, Stable in Bottom gillnet and Declining in Beach seine
Lethrinidae	Stable	Increasing in Bottom gillnet
Haemulidae	Stable-Declining	Declining in Bottom gillnet ans Stable-Declining in Hand line
Mullidae	Declining	Stable in Beach seine
Gerreidae	Increasing	
Dasyatidae	Declining	
Lutjanidae	Declining	Stable-Declining in Hand line
Serranidae	Stable	Stable in Bottom gillnet and Stable-Declining in Hand line

3.2. Aquaculture

A study was conducted in the Quirimbas Archipelago between late 2003 and 2004 to determine the potential for aquaculture development at Ibo Island, identify native species of bivalves, especially marine oysters and identify of favourable locations for the development of oyster farming (IIP, 2004). According to the climatic characteristics of the region, it was expected that there were environmental conditions and water quality to the development of bivalve farming in the Quirimbas coastal system.

The main species of shellfish include black mussel (*Choromythilus meridionalis*), mangrove oyster (*Saccostrea cucculata*), ambar (*Atrina pectinata*), and the pearl oyster (*Pinctada capensis*). It was concluded that oysters had a good potential for aquaculture, in particular the pearl oyster. The mangrove oyster has the potential to grow in suspended systems either longline or in fixed parks. The pearl oyster has a rapid growth and potential for cultivation in suspended systems (longline) and bottom parks. The area between Matemo and Quilaluia islands has good conditions for shellfish aquaculture of native species, especially in the western side, covering a total area of 7 000 ha. The suspension systems were recommended. The south-western and northern sides of Ibo and Matemo islands were recommended for the development of fixed parks in sandy bottom, with a total area of 100 ha in the northwest of Ibo and 100 ha southwest between this island and Quirambo. Another area of about 800 ha between north Quissanga to the Ibo channel was also recommended. On Matemo island, the areas between Ponta Ucáio in the north, and Riuéculo in the south, have potential for the development of 120 ha of bottom parks and over 900 ha for suspension systems.

In 2005, according to the IIP (2005), a visit to Messalo in Macomia district was carried out to monitor the water quality of the Indian Ocean Aquaculture (IOA) culture station and to analyse the situation of a seaweed culture project in Cabo Delgado province.

More recently, in 2011 and 2012 an assessment was done in the Centre and North of Mozambique to determine which native species had potential for aquaculture development (IIP, 2011, 2012). According to the data presented in the IIP reports (2011 and 2012), none of the water bodies identified in the provinces of Cabo Delgado have *Oreochromis mossambicus* specimens large enough to be able to be used as a source of breeding (the observed size didn't reach the standard average size for selecting the source of breeding). The data also revealed that there was potential for installing floating cages systems and that would imply assessing the carrying capacity and periodic sampling of sediments for evaluating the oxygen levels.

Currently, the Provincial Directorate for Fisheries does not have any aquaculture projects in operation or at the licensing stage.

3.3. Agricultural land, crops & livestock

The most common form of agriculture in the QNP is traditional subsistence based. Common characteristics include the reliance on rainfall, shift cultivation and low or no inputs. Sitoe et al. (2010) classified the rural communities in the region as being historically "nomadic". The QNP management plan (2011), highlights that fields are usually abandoned by farmers every 3-4 years for new areas.

Major food crops grown in the region include cassava, maize, sorghum and groundnuts amongst other. Commonly produced cash crops include cashew, cotton and sesame. Table 3.9 and Table 3.10 show the total areas harvested for these crops in Cabo Delgado province as well as total production in metric tones.

Livestock commonly owned in the region includes goats, sheep and chickens/ducks. Cattle is less common due to incidence of tsé-tsé fly (QNP management plan, 2011).

Table 3.9 – Food crops common in Cabo Delgado Province.

Crops	Cultivated Area in 2010 (ha)	Production (t)
Maize	260 959	369 199
Sorghum	129 487	109 307
Rice	67 869	80 428
Pearl millet	9 169	6 418
Beans	112 399	141 588
Groundnuts	77 795	63 705
Cassava	326 432	1 281 316
Sweet potato	11 061	24 752
Horticultural products	6 820	6 584

Source: Government of the province of Cabo Delgado, 2010

Table 3.10 – Cash crops common in Cabo Delgado Province

Crops	Cultivated Area in 2010 (ha)	Production (t)
Cashew	1 305 385	10 846
Cotton	35 589	16 453
Sesame	35 019	18 895

Source: Government of the Province of Cabo Delgado, 2010

Development assistance by NGOs to introduce conservation agriculture has been common in the QNP. Organizations such as the Aga Khan foundation, WWF, Helvetas and Kulima have been actively engaging with farmers in the region. Furthermore, the Agrarian Institute based in Bilibiza also trains technicians and farmers to engage in conservation agriculture (Grabowski et al., 2013). No trends we possible to analyse relative to this subject but the loss of forest is associated to slash and burn agriculture, which seems to have been increasing as shown further below in the report.

3.4. Shallow marine habitats

The coastline of northern Mozambique has been classified by Tinley (1971) as a coralline coast, typically characterized by an almost continuous fringe of coralline islands and reefs. Associated habitats include extensive seagrass beds and mangrove formations, not only along estuaries, but also bays and other protected sites. These productive ecosystems provide valuable natural resources that sustain the livelihoods of the local populations (Barnes et al., 1998; 2002; Gell, 2004).

The Quirimbas archipelago (especially the southern islands, which are part of the QNP – proclaimed in 2002) and the area around Pemba are known for their high biodiversity and have captured the interest of marine researchers for a long time (e.g. Harrison & Poole, 1909; Saldanha, 1973). However, it was only in recent years that more thorough research activities took place and publications were produced (Rodrigues, 1996; Loureiro, 1998; Gell & Whittington, 2002; Glassom & Schleyer, 2007; Bandeira et al., 2009; Ferreira et al., 2009). Vamizi island, further north, has also been subjected to interesting scientific studies (e.g. Hill et al., 2009; Garnier et al., 2012). Notwithstanding the number of recent studies and publications arising from the area, much information is still needed in order to provide a sound basis for management and conservation.

Relevant shallow marine habitats of the QNP include coral reefs, seagrass beds and tidal flats, which are further discussed below.

Coral Reefs

Coral reefs are arguably the most iconic marine ecosystems of the QNP. Several reef types have been identified within the QNP (Whittington et al., 1998), including exposed, outer-reef, back-reef, shallow-sloping, coral gardens, vertical rock walls and boomie fields. Exposed reef was identified as the most widespread and occurred along the eastern shores of Matemo, Ibo, Quirimba, Sencar, Mefunvo and Quisiva islands.

Figure 3.1, shows the location of the most important reef areas within the QNP. Currently there are no reliable estimates of the area covered by coral reefs in the QNP. A study using LANDSAT 5 imagery and remote sensing techniques (Ferreira et al., 2009), reported 23.2 km2 in the central islands group (Ibo, Quirimba, Sencar, Quilaluia and Mefunvo). This however, constitutes an overestimation and there is an urgent need for more accurate information.

Figure 3.1 – Location of coral reefs (—) in the QNP (from Whittington et al., 1998) and reefs (■) referred to in the text. Adapted from GoogleEarth.

The reefs in the area are true coral reefs, in the sense that they are originated from biogenic accretion as opposed to the reefs in southern Mozambique and South Africa (cf. Schleyer, 1995; 1999; Pereira, 2003). Table 3.11 shows a general description of the reefs found around the islands. A clear pattern is evident where Porites boomie fields are prevalent on the western (sheltered) side of the islands. This is typical on sites with low energy, high sedimentation and low visibility sites, thus only a handful of species tolerate such conditions. Exposed reefs (eastern side) are typically more diverse in their composition with a larger percentage of branching hard corals (especially *Acropora* spp.) and soft corals.

Table 3.11 – General description of coral reefs around islands currently included in the QNP (Whittington et al., 1998).

Island	Physical description	Biological description
Macaloe	Coral gardens on gentle slopes in the south and east. Occasional large caves (eastern side). Shallow water and boomies in the north and west. Reef areas not well developed.	Hard and soft coral cover similar and up to 50% in the south and east. High species richness and abundance of fish on reef slopes, but lower on boomie fields.
Mogundula	East and southern sites comprised of shallow slopes, coral gardens and "spur and groove" zones. Shallow sand and boomie fields typical of northern and western sites.	Hard coral dominance in the south, with "spur and groove" zones, confirming evidence of a high energy site. Fish richness fair in the south, but lower in boomie areas
Rolas	Poorly developed fringing reefs with shallow slopes and low rugosity.	Hard coral dominance rock areas in shallow waters. Low species richness and abundance of fish, dominated by Acanthuridae.
Matemo	Outer reef (east) with gentle slopes. Southern areas comprised of dramatic walls, and boomie fields in the west.	Diverse and dramatic coral gardens in the east and south (up to 90% cover). Large fish associated with slopes and walls, but species richness highest in the north.
Ibo	Gently sloping coral reefs to the east and south. Short wall in the north-east.	Hard coral dominance on most reef sites with exceptionally high cover. High abundance of fish on outer reef sites.
Quirimba	Extensive fringing reef and steep slope.	Diverse array of hard and soft corals. High abundance of reef and commercial fish.
Sencar	Reef surrounding island with "spur and grove" zones to the east and well developed back reefs to the west.	Mixed forms of hard coral at all sites and all depths surveyed. Reasonable fish species richness.
Quilaluia	Sheltered, steep reef slopes to the west and coral gardens to the south and east.	Reef with patchy cover, up to 75% in some areas. High richness, but low abundance of fish species.
Mefunvo	Platform and short wall in the north-east. Sloping reefs and boomies in the south. Steep reef slope by Montepuez channel, north of the island.	High cover on outer reef sites with mixed coral forms. High species richness and abundance of fish in the east and Montepuez channel.
Quisiva	Outer reef platforms and walls to the east. North east wall spectacular. Sheltered reef and gentle slopes in the west.	High hard and soft coral cover on outer reef. High species richness and abundance of fish on reef walls, notably the Napoleon wrasse (*Cheilinus undulatus*).
Quipaco	Shallow slopes with boomies in the north and west.	Coral development restricted to boomie fields I shallow waters. Fish were sparse and generally associated with boomies.

The above pattern is generally consistent with the findings from the most recent reef survey conducted in the QNP (Pereira & Videira, 2013). Table 3.12 shows the percentage cover of broad benthic categories. In the majority of the reefs, rubble (i.e. broken pieces of dead coral), rock/algae (old and consolidated dead coral covered by algae) and sand were the dominant categories, which were most expressive in Sencar channel, Rolas and Ibo farol. These sites are more exposed to the elements and are thus subjected to the full force of storms. Corals were the second most dominant category with percentage cover being very similar in all sites visited, ranging from 35-40% (Table 3.13). However, the specific location of each reef (sheltered or protected), is clearly characterized by the dominant growth forms of corals, be it massive and submassive forms (especially Porites and Pavona) on reefs subjected to high sedimentation loads and low visibility conditions such as Ibo and Matemo or foliose and branching form (*Echinopora* and *Acropora*) on Rolas.

Table 3.12 – Percentage cover (±SD) of broad benthic categories at five reefs surveyed in the QNP, August 2012 (from Pereira & Videira, 2013).

Category	Ibo inner	Sencar channel	Matemo	Rolas	Ibo farol
Coral	38.0 ± 14.5	38.0 ± 14.5	45.4 ± 8.5	47.0 ± 7.9	39.9 ± 3.9
Macroalgae	18.5 ± 4.7	4.8 ± 1.8	6.8 ± 3.9	1.5 ± 0.8	4.6 ± 1.8
Coralline algae	0.1 ± 0.3	1.6 ± 1.5	1.6 ± 0.9	1.1 ± 2.0	0.1 ± 0.3
Molluscs	0.1 ± 0.3	0.0 ± 0.0	0.5 ± 0.8	0.0 ± 0.0	0.0 ± 0.0
Ascidians	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.2	0.0 ± 0.0	0.0 ± 0.0
Other invertebrates	3.3 ± 5.9	2.5 ± 3.3	10.4 ± 6.8	2.9 ± 0.7	3.6 ± 1.9
Sand, rock/algae rubble	39.9 ± 16.1	53.1 ± 12.6	35.2 ± 5.5	47.3 ± 8.4	51.8 ± 4.4
Shadow	0.6 ± 0.7	0.3 ± 0.3	1.2 ± 1.5	0.3 ± 0.5	0.1 ± 0.2

Table 3.13 – Percentage cover (±SD) of coral categories at five reefs surveyed in the QNP, August 2012 (from Pereira & Videira, 2013). Most represented categories are shown in bold.

Category	Ibo inner	Sencar channel	Matemo	Rolas	Ibo farol
Branching hard coral	0.4 ± 0.8	**2.5 ± 1.2**	4.6 ± 6.0	7.1 ± 5.8	2.5 ± 2.1
Encrusting hard coral	0.4 ± 0.5	1.9 ± 1.4	1.5 ± 1.8	2.2 ± 2.3	1.5 ± 1.8
Foliose hard coral	1.2 ± 2.1	0.1 ± 0.3	**7.5 ± 11.1**	**8.9 ± 6.6**	0.9 ± 1.5
Massive hard coral	**17.0 ± 12.9**	2.0 ± 1.7	**10.7 ± 7.6**	2.1 ± 1.7	**15.8 ± 6.4**
Submassive hard coral	**12.4 ± 6.3**	0.8 ± 1.6	**9.4 ± 5.1**	**7.4 ± 4.4**	**2.9 ± 2.0**
Tabular hard Coral	0.6 ± 0.5	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	1.4 ± 1.8
Free living coral	0.7 ± 0.5	0.1 ± 0.3	0.4 ± 0.5	6.7 ± 3.9	0.4 ± 0.5
Soft coral	**2.5 ± 1.7**	**27.1 ± 12.3**	2.5 ± 3.0	0.1 ± 0.2	**10.2 ± 3.1**
Fire coral	1.2 ± 2.3	0.0 ± 0.0	2.7 ± 5.4	0.0 ± 0.0	0.9 ± 1.8
Gorgonian	0.0 ± 0.0	0.0 ± 0.0	0.4 ± 0.8	0.0 ± 0.0	0.0 ± 0.0
Unidentified Coral	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 0.9	0.7 ± 1.1
Total live coral	36.4 ± 13.7	37.4 ± 14.7	39.8 ± 4.2	35.2 ± 7.9	39.9 ± 3.9
Dead coral with algae	0.7 ± 1.5	**3.0 ± 4.1**	5.5 ± 6.8	**11.0 ± 8.1**	2.6 ± 1.5
Recently dead coral	0.9 ± 0.6	0.4 ± 0.8	0.1 ± 0.2	0.9 ± 0.7	0.0 ± 0.0

The large percentage of soft corals observed in Sencar channel (Table 3.13), is a matter for concern as it may indicate a shift of the dominant reef benthos. This is contrary to what was reported after the 1998 coral bleaching event, where reefs around Quilaluia and Sencar channel which sustained mortalities up to 99%, recovered well, with a dominance of fast growing, mono-specific stands of hard corals such as *Galaxea astreata* and *Echinopora lamellosa* (Schleyer et al., 1999; Costa et al., 2005). No regular reef monitoring has been conducted in the QNP. Data has been collected incidentally (Table 3.14). Given the irregularity of the reef surveys conducted at this reef, it is very difficult to ascertain the trends and causes of coral decline. Therefore, a sustained and representative reef-monitoring programme at the QNP is strongly recommended.

Table 3.14 – Percentage cover of total live coral at Sencar channel, Quirimbas National Park.

Year	Total live coral	Source
1999 (March)	1%	Schleyer *et al*. (1999)
1999 (November)	27.1%	Rodrigues *et al*. (1999)
2002	55.9%	Motta *et al*. (2002)
2012	37.4%	Pereira & Videira (2013)

The diversity of coral fauna has not been studied in detail in the QNP. Benayahu et al. (2003) reported 46 species of soft corals from “northern Mozambique”, which included collection stations in Caldeira island (Primeiras and Segundas), Sete Paus island (near Mozambique Island) and in the Sencar channel (QNP). While certainly not all species were collected in the QNP station (Sencar channel), it is safe to assume that most would occur there and therefore this figure gives a good indication of the soft coral diversity in the area.

The hard coral fauna is also poorly studied in terms of its diversity. Rodrigues (1996) listed 21 genera from Ibo farol and Whittington et al. (1998), reported an astonishing number of hard coral genera from Quilaluia (55), thus reinforcing the notion that the area is a centre of coral diversity within the WIO region as later proposed by Obura (2012). Obura (2012) reported a maximum likelihood of about 300 species of hard corals for the area from Nacala to Vamizi, thus encompassing the QNP.

Apart from storms, the reef benthos does not seem to be under high stress from anthropogenic action, although fishing (hand-lining, spearfishing and traps) is a common practice. Only one specimen of crown-of-thorns starfish (*Acanthaster planci*) was observed at Rolas and no bleached colonies were seen (Pereira & Videira, 2013).

Seagrass Beds

In the QNP, seagrass beds cover an estimated area of about 45 km2 (Bandeira & Gell, 2003). Ten species of seagrass have been identified in the QNP (Bandeira & Gell, 2003; Sitoe et al., 2010): *Cymodocea rotundata*, *Cymodocea serrulata*, *Enhalus acoroides*, *Halodule uninervis*, *Halophila ovalis*, *Halophila stipulacea*, *Holodule wrightii*, *Syringodium isoetifolium*, *Thalassia hemprichii*, *Thalassodendron ciliatum*, *T. hemprichii* dominates the intertidal areas, while subtidally *E. acoroides* and *T. ciliatum* are the most abundant (Bandeira & Gell, 2003). Almost 30 species of seaweed have been identified living on or in association with seagrasses (Carvalho & Bandeira, 2003).

The seagrass beds are extremely productive and support the basis of the local artisanal fishery (Gell & Whitington, 2002; Gell, 2004). A total of 249 species in 62 families are caught, including invertebrates, and a CPUE value of 3.6 kg of fish per man-hour was reported (Bandeira & Gell, 2003). Despite the socio-economic importance of seagrass beds, no monitoring has been conducted on the species abundance, distribution and total area, therefore trends and current status is unknown.

Intertidal areas

There are extensive intertidal areas, which can extend more than one kilometre during spring low tides. Apart from the studies conducted by the Frontier Expedition (Whittington et al., 1998), not much information is available. These areas include sandy flats with sparse seagrass cover, as well as coral rubble fields.

These intertidal areas play an important ecological role as foraging grounds for birds and as a source of shellfish for the local communities (Barnes et al. 1998), which collect up to 22 species of molluscs and five species of decapod crustaceans. The most important include blue swimming crabs (*Portunus pelagicus*), large gastropods (*Chicoreus ramosus* and *Fasciola trapezium*), as well as cowries (*Cypraea moneta* and *C. annulus*), which are exported in large quantities, mainly to Tanzania. The overexploitation of these resources is a matter of concern and a decrease in size of the main species was reported in 1998 (Barnes et al., 1998).

No monitoring has been conducted and therefore data is not available on the status and trends of these resources. However, there is a perception that a general decline has occurred (S. Nazerali, pers. com).

3.5. Freshwater resources

The QNP is crossed by a number of periodic rivers and tributaries watercourses. The main rivers in the park include Montepuez (the most important river in the Park), Muagamula, Muaguide, Mivoroto, Mezingue, Sivuca. Another charismatic hydrological resource is Lake Bilibiza located in the Quissanga district. This lake is a body of standing water that can provide unique opportunities for bird watching and has touristic potential (e.g. canoeing). There is also a smaller lagoon, Kagavero, which water surface diminishes dramatically during the dry season, yet, never to the point of drying up entirely. These water bodies are areas of high concentration of fauna, are part of elephant migration routes, and are also areas with concentration of villages/human settlements, being essential for agricultural activities (Sitoe et al. 2010; Marques & Tomasinelli, 2012).

ARA-Norte provided data on the maximum flood flow, in the last 20 years, for 24 rivers of Macomia, Meluco and Quissanga districts:

- **Meluco**: Montepuez 1 122.2 m3/s, Muaguide 431.0 m3/s, Lalamo 337.2 m3/s, Niquerecue 268.2 m3/s, Aquiti 248.1 m3/s, Rio Chiba 211.8 m3/s;
- **Quissanga**: Rio Namirepue 265.3 m3/s, Rio Tara-Quilate 187.4 m3/s, Rio Nanhomo 115.8 m3/s, Rio Mezingue 152.9 m3/s, Rio Sicoro 173.7 m3/s, Rio Mecubi 154.8 m3/s, Rio Naoda 155.1 m3/s, Rio Sivueo 168.1 m3/s;
- **Macomia**: Rio Muacamula 431.1 m3/s, Rio Micoca 230.8 m3/s, Rio Diquide 179.2 m3/s, Rio Miote 144.5 m3/s, Rio Mapi 188.4 m3/s, Rio Mecutiteche 202.8 m3/s, Rio Licualedi 232.1 m3/s, Rio Chafi 92.02 m3/s, Rio Damangue 155 m3/s, Rio Lingula 118.3 m3/s.

ARA-Norte has also provided average annual flows for the Montepuez and Messalo rivers. Although the latter does not cross the QNP, flowing further north, it provides valuable information about the trends in the region. For the Montepuez river information was gathered from 1964/65 till 2013/14 (with data gaps between 1990/91 till 1999/00 and 2003/04 to 2004/05) and for the Messalo river the data series runs from 1960/61 till 2013/14 (with data gaps in 1962/63 and from 1981 till 1999/00 and from 2001/02 till 2004/2005). The Messalo river had high hydrometric levels (Figure 3.2), especially from the 60's until the 80's, with peaks in the years 1964/65, 1968/69, 1973/73 with a maximum peak flood in 1977/78. The hydrometric levels show lower discharge levels in more recent years (from 1997 to 2013), currently presenting more similar values to Montepuez. As expected, the Montepuez river has always presented lower levels of water flow during the study period, without major flow peaks.

On the other hand, as expected, the largest flows are recorded during the rainy season between January and April (Figure 3.3).

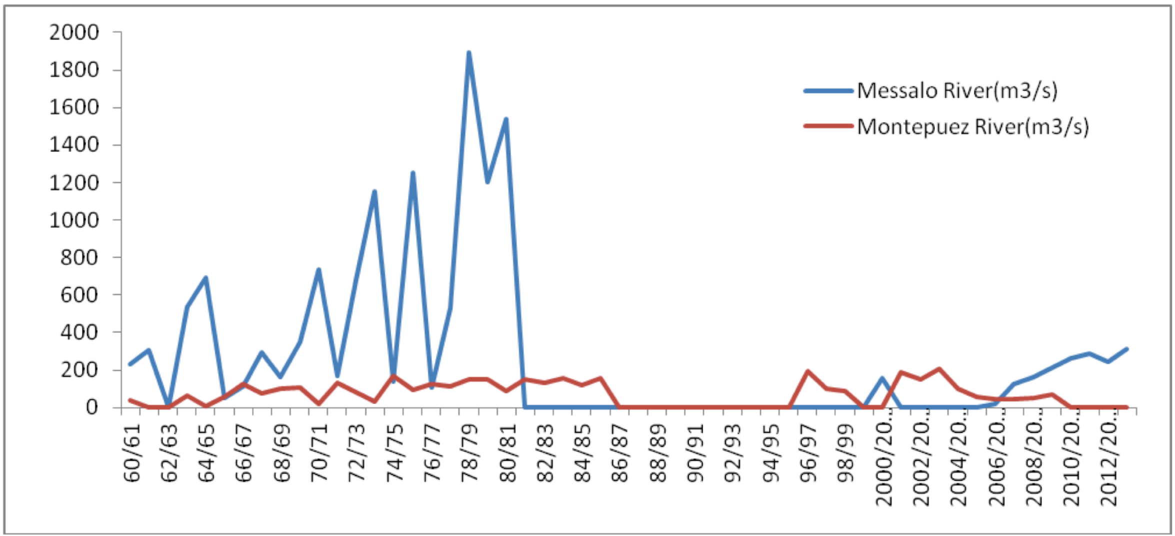


Figure 3.2 – Annual mean flows of Montepuez and Messalo rivers

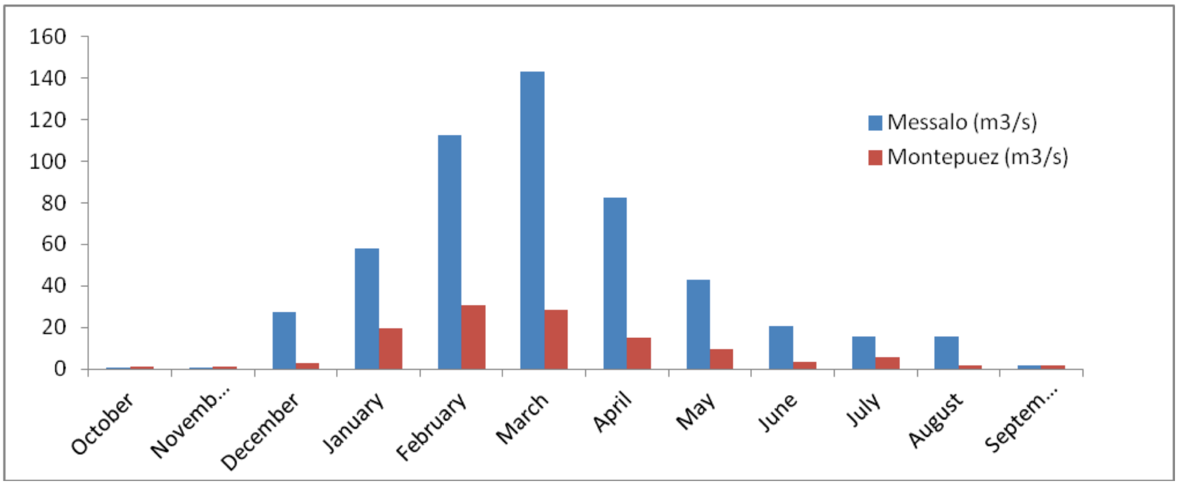


Figure 3.3 – Monthly mean river flows of Montepuez and Messalo rivers

3.6. Mangroves

Extensive mangrove areas occur in the extensive Quirimbas Archipelago and several embayments nearby (e.g. Palma, Ulombi, Mocimboa da Praia and Quiretajo; Sitoe et al., 2010). The QNP mangroves differ in zonation, probably conditioned by factors such as soil type, degree of exposure of the site to tidal action. These influence physical and chemical parameters (salinity and pH), which are important for the development of mangroves. Six mangrove species occur in the QNP, namely: *Avicennia marina*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Rhizophora mucronata*, *Xylocarpus granatum* and *Sonneratia alba*. The species composition differs between the islands depending on the specific characteristics of each site. From these, *Sonneratia alba* is the only species that occurs only in northern and central Mozambique, so its presence in the park is important for conservation (Bandeira et al., 2009).

With regards to tree height, the tallest mangrove trees are found in Mogundula and Sencar, and the shortest at Ibo and Mefunvo Islands. These characteristics are often associated with differences in salinity, pH, topography and soil texture. On the other hand, Sencar and Ibo islands present the highest number of mangrove trees per species, while the largest average diameters and relative density of trees are found in Sencar, Quirimba and Ibo islands. The mangroves at Matemo Island have high basal area. The same study suggests that the major regeneration of *Ceriops tagal*, *Rhizophora mucronata* and *Xylocarpus granatum* takes place in Sencar and *Sonneratia alba* in Mefunvo (Sitoe et al., 2010).

Recently, WWF conducted a study on climate change impact on mangrove ecosystem in QNP, that revealed that between 1991 and 2002, the mangrove forest area showed an increase of 1 568 ha (a growth of 1.27 % per year), followed by a decrease of 464 ha in 2013 (a decline of 0.33% per year; Nicolau et al., 2015; Table 3.15). Despite the negative tendency of the last decade, there was an overall increase in mangrove cover from 1991 till 2013 (of 1 104 ha; Nicolau et al., 2015). Comparing with other studies, namely with Kirui et al., (2012) that estimate a decrease of 0.7 ha per year in Kenya and Giri et al. (2011) that estimated a global degradation rate of 1-2% per year, the rate in QNT is considerably lower.

Table 3.15 – Mangrove change area between 2001 and 2013 in QNP (adapted from Nicolau et al. 2015).

Variables	1991	2002	2013
Area extent (ha)	11 244	12 812	12 348
Cover variation (gain and loss) (ha)		1 568	-464
Annual loss percentage (%)		1.27	-0.33

Structurally, the total density of individuals in the mangrove forest of the QNP has been estimated at 579 stems/ha. Specifically, the density shows some variations with 1 406 stems/ha for *Rhizophora mucronata*, 1 251 stems/ha for *Ceriops tagal*, 393 stems/ha for *Sonneratia alba*, 338 stems/ha for *Avicennia marina*, 80 stems/ha for *Bruguiera gymnorrhiza* and 8 stems/ha for *Xylocarpus granatum*. The analyses of mangrove forest structure reflected a high disturbance, that can be related with multiple factors, such as the increase of human pressure on mangroves (intensive harvesting for boats, construction and firewood, urbanization, etc.) and coastal vulnerability to climate change factors (Nicolau et al., 2015).

However, there was a clear evidence of healthy regeneration in QNP mangrove forests considering the high densities of juveniles namely, *R. mucronata* followed by *C. tagal* and *A. marina*. However *B. gymnorrhiza* and *S. alba* presented very low regeneration rates, which suggests that forest regeneration depends largely on stand dominance species in conjunction with the structural characteristics and environmental conditions across the forest (Nicolau et al., 2015). It is also noteworthy that the natural regeneration observed by Nicolau et al. (2015) in the QPN mangrove forests presented high densities, when compared with the data from Bandeira et al. (2009).

3.7. Terrestrial Forests

Information about specific terrestrial forest trends in the QNP was not obtained. Only qualitative and quantitative information about current status is available, which is presented below. Nevertheless, in order to analyse the general trend of the forests within the QNP, the Global Forest Change website was consulted (Hansen et al., 2013). Hansen and colleagues performed a globally time-series analysis of Landsat images characterizing forest extent and change. ‘Forest Cover Loss’ was defined as a stand-replacement disturbance, or a change from a forest to non-forest state, during the period 2000-2013. 'Forest Cover Gain' was defined as the inverse of loss, or a non-forest to forest change entirely within the period 2000-2012.

The following images from Hansen et al. (2013) show the forest cover loss in the QNP between 2000 and 2013 (Figure 3.4a) and the forest cover gain between 2000 and 2012 (blue area; Figure 3.4b). Deforestation occurs all over the Park, focusing mostly along the main roads, especially in the northern section (Tanguia Region). It also seems to have a higher concentration in the eastern zone (close to the coast), probably related to the highest population density in that area (Nicolau et al., 2015). The most probable causes are related with human impact, namely from agriculture, grazing, logging, fire, use of medicinal plants, etc. The construction of infrastructures and roads may also cause future disturbance (Sitoe et al., 2010). Curiously, forest cover gain also occurs in Tanguia region and QNP east area, which may be compensating part of the recorded reforestation (Nicolau et al., 2015).

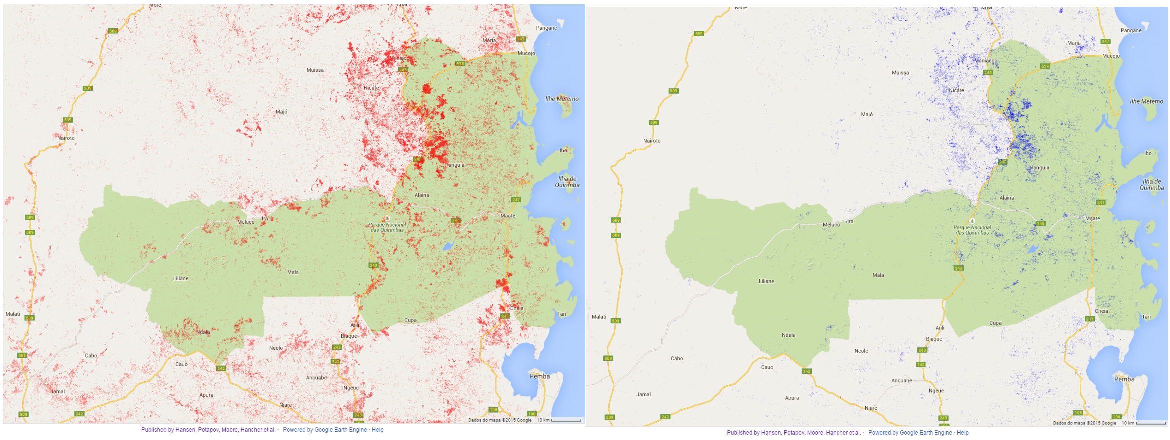


Figure 3.4 – Forest change in QNP, namely: a) Forest cover loss between 2000-2013 (red area) and b) Forest cover gain 2000-2012 (blue area) (from: Hansen et al., 2013 website http://earthenginepartners.appspot.com/science-2013-global-forest)

Considering the current composition, the terrestrial vegetation in the QNP is a mosaic of bamboo, coastal thicket, very dry coastal forest, riverine forest, inselberg forest, miombo woodland, acacia woodland, dambo grassland, palm-savannah/woodland and a succulent-dominated inselberg flora. Mangroves also occur along the coast. There are extensive areas of each vegetation type, both within the park and stretching inland and to the north (Harari, 2005).

In the QNP, the riverine forest along the drainage channels (including rivers and streams) and the forests on the mountain bases are (or nearly) always evergreen during the dry season of the year. The riverine forests along the edges of permanent waters are composed of evergreen trees, dense shrub stratum and sparsely distributed grass stratum. The dominat tree species include *Khaya nyasica*, *Albizia gummifera*, *Adansonia digitata*, *Sterculia appendiculata*, *Bombax rhodognaphalon*, *Pteliopsis myrtifolia*, *Cordyla africana* among others. Some of the accompaning species include *Margaritaria discoidea*, *Cleistochlamys kirkii*, *Vitex payos*. The common herbaceous species are *Achyranthes aspera*, *Panicum maximum*, *Cucumis rehmannii* and *Corchorus trilocularis* (Harari, 2005; Sitoe et al., 2010; Guido, 2012).

On exposed mountain areas (inselbergs), a typical flora composed of succulent species occurs. This flora exhibits as, fundamental characteristics, adaptations to survive extreme temperatures, variations on water availability, tolerance to desiccation on high altitudes, etc. The common species include *Xerophyta retinotii*, *Vellozia* sp. and *Aloe* spp. (Bandeira et al., 2008). The forests on mountains occur on altitudes above 300m. The tallest trees on this vegetation type can reach 8 to 12 meters. The common species include *Brachystegia* spp., Millettia stuhlmannii, *Annona senegalensis*, *Afzelia quanzensis* and *Combretum zeyheri*. On drier areas, away from superficial water tables and watercourses, the vegetation changes according to the edaphic conditions, moisture and perturbation effects. Included in these areas are vegetation types such as bamboo woodlands, miombo woodlands, coastal thickets, and Acacia woodlands. The bamboo woodlands sparsely distributed are dominated by *Oxytenanthera abyssinica*. The accompanying species include *Terminalia sericea*, *Millettia* spp., *Hymenocardia ulmoides*, *Lonchocarpus bussei*, among others, associated or not with other species such as *Baphia* sp., *Acacia nigrescens*, *Hugonia* sp., *Combretum* spp., and *Xeroderris stuhlmannii*. On sandy and brown dark clay soils occur, in a sparse manner, species of *Albizia harvey*, *Acacia nigrescens*, *Acacia polyacantha*, *Vangueria* spp. and *Strychnos* sp.

The miombo woodland in the QNP is semi-deciduous during the whole dry season being dominated by species of *Brachystegia* spp. and *Julbernardia globiflora*. Variations in the species composition do occur at the local level, being justified mainly by difference in moisture content. In humid areas the miombo woodland is more closed with two strata being the arboreal composed of trees which can reach 20 metres of height and more than 20 cm of diameter at breast height (DBH) (Bandeira et al., 2008). The grass stratum is dominated by grass, which can reach about 2 meters of height along valleys. The common trees include *Millettia stuhlmannii*, *Millettia bussei*, *Terminalia* spp., Pteliopsis myrtifolia, *Combretum* spp., Dalbergia melanoxylon, *Diplorhynchus condylocarpon*, *Afzelia quanzensis*, *Pterocarpus angolensis*, *Cordyla africana* among others. As the soil moisture content reduces, the miombo woodlands tend to be less dense and poorer in terms of species composition. The grass stratum is much more abundant and dominated by grass species such as *Heteropogon contortus*, *Heteropogon melanocarpus*, *Urochloa mosambicensis*, *Digitaria eriantha*.

The valleys and depressions with alluvial soils (seasonally inundated areas) are covered with damboos (grasslands) and palm velds. These areas are colonized by abundant grass stratum dominated by grass species and few dispersed trees and/or shrubs. The edges of these areas are dominated by characteristic vegetation type of palm tree savannah with *Hyphaene* sp., *Digitaria* sp., *Corchorus trilocularis*, etc. On inundated areas occur pure grasslands over black cotton soils such as *Typha* sp., *Cyperu*s spp. and *Phagmites autralis* on darker soils (Bandeira & Samussone, 2003; Burguess et al., 2003; Harari, 2005).

According to Bandeira et al. (2008), the distribution of different vegetation types in the QNP follows an altitudinal gradient, which varies from the coast to the interior. In this succession, mangroves are followed by coastal ticket, Acacia-grassland mosaic, miombo woodlands, mixed miombo, and miombo velloziace in the iselbergs. The area covered by each vegetation type in the park, number of species and endemic species are shown in Table 3.16. The mountain and woodland vegetation in the QNP presents highly diverse ecosystems, with considerable endemism. Miombo woodland and the acacia-grassland mosaic are the most dominant forest communities, and the coastal ticket the smallest unit. No other census has been carried out recently that could allow comparisons of the establishment of tends of these communities.

Table 3.16 – Area covered by different types of vegetation in the QNP (Adapted from: Bandeira et al., 2008 and Sitoe et al., 2010).

Vegetation types	Bandeira *et al.* (2008)		Sitoe *et al.* (2010)	
	Total area (km^2)	% cover	N° of species	N° of endemic species
Mangrove	239.4	2.99	6	_
Coastal ticket	52.4	0.56	38	_
Woodland mosaic	1 709.4	21.32	183	6
Miombo woodland	3 275.4	40.84	59	5
Acacia-grassland mosaic	2 655.7	33.12	104	2

Miombo-velloziacea	67.3	0.84	77	7
Other	19.1	0.24	_	_
Total	8 018.4	100	_	_

Considering the main forest disturbances, logging is becoming, in the last decades, a common and widespread practice within the QNP, with species such as *Pterocarpus angolensis*, *Millettia stuhlmannii*, *Afzelia quanzensis*, *Swartia madagascarensi*, *Dalbergia melanoxylon* and *Milicia excels* being favourites among, which has a major effect on the vegetation structure across the park.

Fire is another big threat to forests in Mozambique. In Cabo Delgado, various vegetation types have been exposed to bush fires almost every year, mainly in the dry season (May to October). In the QNP, fires occur commonly between July and October. Further analysis shows a tendency of fires close to residential areas or selected vegetation types. The open vegetation types with dominance of grass stratum are most vulnerable to fire incidences. In eastern Africa, the coastal forests are less susceptible to fires and the frequent occurrence of fires in this ecosystem may lead to species composition changes, allowing colonization of the site by typical miombo species (Sitoe et al., 2010).

3.8. High profile species

High profile species present in the QNP include marine turtles, marine mammals (dolphins and whales) and the whale shark. Although widely recognized for their conservation value as well as for their tourism potential, the knowledge of their status in the QNP is very poor.

Studies have been conducted mainly as part of Environmental Impact Assessments, and mostly provide little more than general descriptions and species occurrence. Unfortunately there are no time-series data that would allow status trends to be drawn, and the current state of conservation of these species is largely unknown.

Three marine turtle species have been reported to nest in the QNP: the green turtle (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and the Olive Ridley (*Lepidochelys olivacea*), although the latter is very rarely seen. Leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) have been observed in the area either feeding on migrating (Hughes, 1971; Louro et al., 2006; Videira et al., 2007). The various attempts to establish a monitoring program in the QNP throughout the years have produced little results and at the moment no reliable data has been collected. Turtle poaching occurs but is seldom reported (Fernandes et al., 2015).

Vamizi island, located about 100 km to the north of the QNP is the best studied site in northern Mozambique, with regards to marine turtles where a monitoring and conservation program has been running since 2004 (Garnier et al., 2012; Trindade, 2012). Vamizi is a key nesting site for the green turtle in Mozambique, with an average of 122 nests per year, with a peak in February-March (Garnier et al., 2012). The area is also used by nesting females and immature hawksbill turtles.

Seven species of whales and dolphins have been recorded within the QNP, and five other species have yet to be confirmed, but the likelihood of their occurrence within the QNP is high (Sitoe et al., 2010). The whale shark also occurs in the QNP (cf. Rowat, 2007; Rohner et al., 2013), but similarly to the other marine megafauna, no published studies have been conducted. It is strongly recommended that monitoring programs as well as specific assessments be conducted in the area.

4. Development trends and pressures

4.1. Population growth

The QNP is comprised of 154 villages, including 102 inside the limits defined for the park and 52 within the buffer zone. Several studies have indicated different numbers regarding the population in the park (Sitoe et al., 2010; QNP Management Plan, 2011). According to the latest Quirimbas Management Plan (2011-2021), there are currently 166000 people, with approximately 95000 people (57%) within the park limits and 71000 (43%) in the buffer zone (Table 4.1)[1].

Table 4.1 – Population inside the QNP and Buffer zone

District	Administrative Post	QNP	BZ	Total
Ancuabe	Ancuabe	2 762	8.376	11 138
	Meza	3 980	17.693	21 673
Ibo	Ibo	7 726	-	7 726
	Quirimba	2 689	-	2 689
Macomia	Chai	-	2.062	2 062
	Macomia	3 142	21.765	24 907
	Mucojo	10 642	7.639	18 281
Meluco	Meluco	12 871	569	13 440
	Muaguide	7 896	2.907	10 803
Montepuez	Nairoto	-	2.615	2 615
	Namanhumbir	-	2.374	2 374
Pemba	Metuge	2 202	2.968	5 170
Quissanga	Bilibiza	16 984	-	16 984
	Mahate	19 066	1.855	20 921
	Quissanga	5 402	-	5 402
Total		**95 362**	**70 823**	**166 185**

Source: Quirimbas Management Plan (2011-2021)

The QNP Management Plan (2011-2021) suggests that in 1997, there were a total of 136338 people, including 77719 inside the park and 58669 in the buffer zone. The updated projections done by National Institute for Statistics (INE) do not include projections for the conservation areas solely as they include projections for the provinces, districts and administrative posts. Since the QNP covers administrative posts (some in full and some only partially), there is no consistent data for the calculation of growth rate regarding the QNP population. The growth rate projected by INE for Cabo Delgado Province (where QNP is located) is approximately 2% a year.

Assuming that the QNP population will grow in conformity with the growth rate of the Cabo Delgado Province, we can infer that this growth may be associated with the development of the oil and gas industry which is likely to alter migration patterns, particularly in terms of the influx of people after the establishment of the projects and associated value chains (Bioglobal, 2015). It is important to note that most of the developments in the Cabo Delgado Province and around QNP are mostly along the coast, where the highest concentrations of local communities are located.

[1] It is assumed that the projections for the year 2011 for the calculation of population inside the park

4.2. Large scale irrigated agriculture

Detailed information could not be sourced for large-scale irrigated agriculture for the QNP. The sugar cane production industry is responsible for most irrigated land area in Mozambique. No sugar-cane projects have been identified in the region. A study done by FAO has identified all irrigation projects in the country, however none can be linked to the QNP (http://www.fao.org/nr/water/aquastat/countries_regions/Profile_segments/MOZ-IrrDr_eng.stm date accessed 12.08.2015).

4.3. Land-use conflict

According to Sitoe et al. (2010), the inland areas of the park are mainly used for subsistence farming while the coastal areas are mainly used by local communities for fishing.

An important conflict arising in the QNP is the human-elephant conflict, which results in negative effects on human social, economic or cultural life, on elephant conservation or on the environment. According to the QNP Management Plan (2014), African elephants (*Loxodonta africana*) are perceived by local communities as one of the biggest threats to subsistence farming. A number of crops are grown on higher grounds with sandy soils while other products are grown in lowland areas near drainage lines and rivers. Elephants elicit the greatest fear from rural communities because they have the potential to damage large areas of crops, destroy property, and cause injury and death. Consequently, human-elephant conflict is a severe concern in elephant conservation in Africa and particularly in the project area. Viable populations of elephants are known to occur in the Quiterajo-Mucojo area inside the park.

Land is available for livestock settlement, however cattle is lacking due to tsé-tsé fly infestation (Harari, 2005). Households in the park often keep livestock that include goats, chickens and ducks. Information is not readily available for land use conflicts in terms of agriculture and livestock settlement inside the QNP.

In terms of coastal areas, the growing population along these areas have increased competition and conflicts over the allocation of land as well as the use of coastal and marine resources, in particular for the fisheries and tourism sectors. The local communities practice small-scale fishing and this constitutes one of the most important activities in terms of household security and cash income. Tourism developments are often located on the islands, on prime beachfront, which restricts fishers' access to the beach. The Quilalea sanctuary is an example of an area, which is restricted to fishers and solely utilized by tourism establishments. Although Harari (2005) has reported that fishermen have agreed to remove their camps from the islands of Quilalea and Sencar, there is no information regarding the potential conflicts that could have arisen between fishers and tourism developers over access to land and to the coastal and marine resources.

According to the Agriculture Census done in 2007, less than 5% of the people interviewed in Cabo Delgado Province have stated that they have experienced conflicts regarding land use. These conflicts mentioned in the Agriculture Census (2007) are associated with zoning of the land and land being sold to different people. A 10-year trend in land-use conflict inside QNP has not been depicted in the available literature for the proposed project.

4.4. Major infrastructure development

In the last decade the Provincial Directorate for the Coordination of Environmental Affairs (DPCA) has issued at least 31 licenses for the following infrastructures in the main districts that are included in the QNP: 14 concerning tourist accommodations, seven electrification projects, four fuel stations, one water bottling project, three mining projects and one oil & gas project. From the 31 projects, two environmental licenses issued were Type A, 10 type B and 19 Type C (Annex 2).

With regards to planned infrastructures for short/medium term, considering the proposed actions for Pemba/Quirimbas priority touristic nodes, the following investments may occur: road improvement and maintenance; traffic management plan; flood control through drainage; electricity improvement and expansion; improvement of waste disposal and Pemba airport upgrade (MITUR, 2014). Since the discovery of large reserves of natural gas in the Rovuma Basin, it is also expected that the implementation of infrastructures to support oil & gas operations in Cabo Delgado Province, namely: the logistic and terminal port of Pemba and Palma (with construction, pipeline installation, ship repair yards, residential, commercial and service facilities, gas processing industries, etc.) and the gas pipeline from north - south Mozambique and its associated infrastructures (e.g. roads improvement, etc.) that will probably cross the QNP (EIA-Anadarko, 2014 http://www.mzlng.com/Environmental-Impact-Assessment/; Mozambique Gas Summit Conference, 2014).

In summary, the main existing/planned infrastructure concerns tourism, oil & gas and mining development. It is known that tourist development may pose some threats to the integrity of natural areas as it cannot happen without bringing changes to the natural environment. It is of particular concern in the QNP as there are es (MITUR, 2004, 2014).

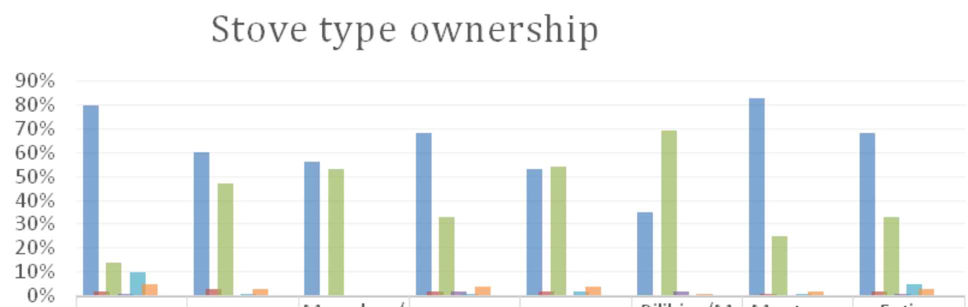
Impacts from oil & gas infrastructures and mining will be presented in Subchapters 4.7 and 4.8, respectively.

4.5. Dam construction

There is no indication of a potential dam construction inside the QNP (AquaGlobal, 2014). Several rivers have been identified in this study and the only Dam, which is known to be under assessment, is the Megaruma River Dam, south of Pemba, significantly far from the QNP. This will be used both for irrigation and water supply to Pemba. The adverse environmental and socioeconomic impacts of the construction of dams are widely known and therefore the development of a dam inside QNP could ultimately be detrimental to either the environment or the surrounding population.

4.6. Charcoal & firewood use

Detailed information on charcoal and firewood use for the QNP was not available in the literature. However, GreenLight projects carried out a household energy baseline study in 2014, which looked at cooking fuel usage in Cabo Delgado region. The data for regions within the QNP area shows that 70% of households in Ancuabe use charcoal as a cooking fuel and 35% use firewood; the data for Metuge shows that 63% of households use charcoal as a cooking fuel and 47% use firewood; while in Bilibiza and Mahate 35% of households use charcoal as a cooking fuel and as much as 71% use charcoal (Figure 4.1). It must be noted however that the data is from households located in the urban centres of each district. It is expected that in the rural areas the use of firewood would dominate much more. The use of charcoal in the urban centres implies a production of charcoal in the regions. The research reveald that bags of charcoal were sold along the national road within the QNP. This may be a concern for deforestation if sustainable charcoal production practices are not implemented by the communities (GreenLight, 2014).



	Pemba	Metuge	Murrebue/ Mecufi	Ancuabe	Chiure	Bilibiza/M ahate	Montepue z	Entire sample
Charcoal	80%	60%	56%	68%	53%	35%	83%	68%
Improved charcoal	2%	3%	0%	2%	2%	0%	1%	2%
Firewood	14%	47%	53%	33%	54%	69%	25%	33%
Improved firewood	1%	0%	0%	2%	0%	2%	0%	1%
LPG	10%	1%	0%	1%	2%	0%	1%	5%
Electric	5%	3%	0%	4%	4%	1%	2%	3%
Ethanol	0%	0%	0%	0%	0%	0%	0%	0%
Kerosene	0.20%	0%	0%	0%	0%	0%	0%	0%

Figure 4.1 – Cooking fuel usage in Cabo Delgado region (Source: GreenLight, 2014).

4.7. Oil & gas extraction in proximity of QNP

Most of the Mozambican exploration and production concessions are located on three provinces: Cabo Delgado, Sofala and Inhambane. In the northern coast the entire offshore area of Cabo Delgado (Rovuma basin) is devoted to gas exploration (currently exploration and future exploitation). The Rovuma basin covers approximately 64000 km^2 and is formed by six offshore blocks. Reserves have been estimated for block 1 (Anadarko) in the range up to 150 tcf and on block 4 (ENI) estimated in up to 75 tcf. The current potential will increase in future from ongoing exploration in blocks and 3 and 6 (Petronas) and in blocks 2 and 5 (Statoil) (Mozambique Mining Cadastre Portal). Statoil blocks are located offshore the QNP area. However, until now, no commercially viable wells have been reported and apparently those blocks were relinquished (Berry, 2015). The QNP buffer zone also includes a small part of the Anadarko Onshore Area 1.

In Mozambique, oil & gas exploration projects are regulated by legislation (Decree 56/2010) and require environmental permits, since exploration methods can be invasive and damage sensitive ecosystems and threatened species. Considering oil & gas offshore projects the following major impacts may occur in QNP and/or its surroundings: the drilling of the offshore production wells may pose potential impacts to water quality and marine ecology. The deep water reef structures and associated organisms may be at risk of enduring acute effects as the recovery of reef structures usually takes time due to the low growth rates of these organisms. Effects of vessel collisions or disturbance on whales may also be problematic due to their conservational importance. Changes in the character of the seabed are also likely to occur due to the addition of hard substrate (subsea infrastructure), which may result in changes to the benthic community structure (e.g. colonization by others organisms) (Abrahamson et al. 2013, EIA-Anadarko, 2014).

In the near-shore project area, where construction activities are focused, disruption of seagrass, coral reefs and/or mangrove are likely to occur. These features play critical roles in ecological interrelationships and directly and indirectly affect productivity and biodiversity due to the increased turbidity in the water column, the deposition of fine sediment on benthos and modifications on the seabed. The installation of near-shore infrastructure across the intertidal beaches and shallow subtidal zone will modify beach structure that may result in a loss of the productivity or allow the establishment of hard substrate communities. It may also facilitate colonisation by alien and potentially invasive species with potential negative effects on marine biodiversity. Impacts to fish, whales, dolphins and turtles from noise associated with pile driving may also occur, although the extent of the effects differs among groups. Discharged solid and liquid wastes from marine vessels during any phase of the project could also cause impacts related with the proliferation of litter and compromised water quality, harming marine organisms, seabirds and biodiversity in Palma Bay (Abrahamson et al. 2013, EIA-Anadarko, 2014).

It should be noted that the implementation of mitigation measures can help to reduce the significance of much of the identify impacts, and as such should be considered in all oil & gas projects, following the principles set out by IFC's Performance Standard 6 (IFC, 2012).

A new bidding process for new oil & gas concessions is undergoing by the Mozambican Government so it is expected that the number of projects will increase in future. Considering the cumulative effect of the impacts of the oil & gas industry and whole associated infrastructure, it is expected that the pressure on local ecosystems will increase significantly as well as the risk of hazards.

4.8. Mining

Mozambique has a large and diverse unexploited mineral resources potential, which has been manifested by a large number of exploration companies. Despite this, commercial mining has played a relatively minor role in the development of the country's economy. This situation is gradually changing mainly due to the production of aluminium and natural gas and development of world-class coal and heavy mineral sand deposits (Lehto & Goncalves, 2008; Callaghan et al., 2011).

Accordingly with the data provided by Provincial Directorate for Mining Resources and Energy from Cabo Delgado and the information available on the Mozambique Mining Cadastre Portal in the QNP and surroundings there are currently 20 areas associated with mining activities (Annex 3), of which: nine are in operation, seven correspond to requests for exploration, one still needs to collect the mining certificate, one is awaiting approval, other has its mining certificate expired and the last one has the extension request pendant. The 20 above mentioned areas comprise an area of 107 262ha, and 10 correspond to mining certificates (1.3% with 1 387 ha in total), nine to exploration licenses (prospecting and exploration operations - 94.5% with 101 395 ha in total) and another area is still undergoing the bidding process (4.2%, with 4 480 ha in total). Three of the twenty areas are inside the QNP.

The most obvious mining physical impacts are related with contamination. Air pollution from the mining industry is of increasing concern, producing pollutants such as dust, SO2, lead, arsenic and other particles and gasses. When unregulated, such pollutants from upcoming large-scale mining projects could present respiratory risks to communities and decrease the tourism potential in certain parts of the country. Pollutants from industrial and artisanal mining can enter the waterways causing environmental damage to areas far from the mining sites and affect agricultural productivity. In addition, pollution from agriculture, industrial mining, and relatively unmonitored practices of artisanal mining, are sources of contamination to the country's pristine marine environments, as chemicals are emptied or washed into waterways leading to the sea. So, mining can affect air quality, water quality (surface water, underground water and rainwater) and, directly or indirectly, sensitive ecosystems and species. Deforestation is also a significant impact linked with mining activities that also cause interference with nature conservation, namely habitat fragmentation and fauna losses. There also impacts associated with soil productivity, noise, landscape quality, etc. (Abrahamson et al., 2013; EPDA-Kenmare, 2012). Considering those impacts, mining companies should incorporate the cost of rehabilitating any ecosystems that are damaged by mining activities. In the case where full rehabilitation is not possible, the company should pay compensation for environmental damage (Abrahamson et al. 2013; IFC, 2012).

Graphite, vanadium and ruby have been found in Cabo Delgado, near the QNP, and the first mines are now starting to operate. It is possible that further projects will happen in the region in the next years. It is expected that the impacts will focus mainly inland with terrestrial forest loss and habitat fragmentation, which will have consequences on several fauna species.

4.9. Mangrove & non-mangrove timber logging

The population living within the QNP exploits mangroves for various purposes including fuel, wood and construction materials, fencing and boat repairing (Sitoe et al., 2010). The most problematic sites in terms of mangrove logging seem to be Mefunvo, Ibo and Matemo Islands. Here, the local population has preference for cutting *Ceriops tagal* and *Bruguiera gymnorrhiza*, which have already been declared endangered (Sitoe et al., 2010). According to Davie (2014), the illegal timber trade occurring in the border between southern Tanzania is plagued by malpractices including: use of fraudulent documents (e.g. registration, permits and license documents) at the border, allowing them to pass through official checkpoints and export timber illegally to the Tanzanian market; informal entry points and false identity.

Conservation measures to minimize mangrove logging within the QNP may include: allowing cutting of mangroves near the upper limit or the mangrove or not less than 10 meters from the coastline, avoid disruption of protective barrier formed by the trees near the shoreline, promote use of other trees as source of energy and construction materials and promote reforestation of mangroves in heavily damaged habitats (MITUR, 2011; Nicolau et al., 2015).

Activities need to be carried out to ensure sustainable use of mangroves such as raise awareness of mangrove importance for marine habitats, ecosystem services assessment, protection of vulnerable areas, harvesting control, policy enforcement for illegal logging and promotion of a restoration programme involving the main stakeholders and local communities (Nicolau et al., 2015).

4.10. Increased investment in fisheries processing & landing sites

According to the information provided by the Provincial Directorate for Fisheries of Cabo Delgado (DPP – Cabo Delgado), currently there are no active processing units in the districts overlapped by the QNP (Metuge, Meluco, Macomia, Quissanga, Ibo and Ancuabe), nor under a licensing process. Table 4.2 shows the processing units that are registered in the area but are currently inactive due to several reasons: breakdown of freezers, high price of products, management issues, etc. When active these units used to buy the products to the artisanal fishers (fish, squid, shrimp and lobster), process, preserve and sell it in the local markets. None of them used to send the products abroad.

Table 4.2 – Name and location of registered processing units in the districts of the study area (DPP – Cabo Delgado, 2015)

District	Location	Project name
Meluco	---	---
Macomia	Quitarejo	Quitarejo, Lda.
	Pangane	Mar Fresco
	Pangane	Pangamar

District	Location	Project name
	Ingoane	Latifo Ismael Latif
Quissanga	Ilha de Mefunvo	Mefunvo, Lda.
Ibo	Ibo	Galopescas Ibo

4.11. Aquaculture development

DPP does not have any record of aquaculture projects within these four districts nor any under a licensing process. There is however an intention for an Aquaculture project in Ancuabe.

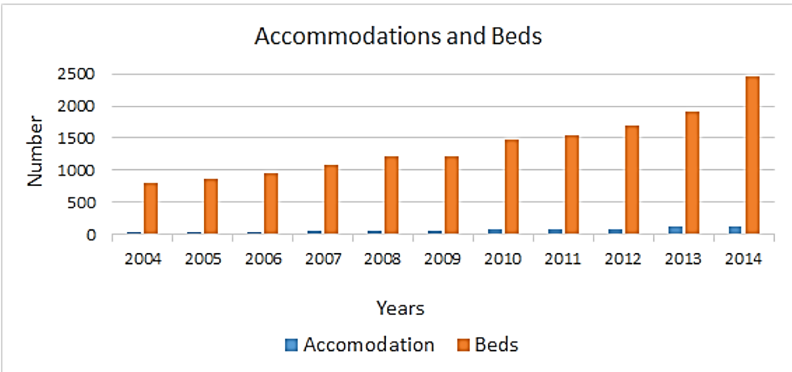
4.12. Coastal tourism

Mozambique is a very young and emerging touristic destination and is at the early stages of development (MITUR, 2014). Cabo Delgado province has a great potential for tourism, but the degree of current development activity is low and is limited to the region of Pemba (Pemba axis - Murrébuè - Ibo) and the QNP (Machava et al., 2010). Both areas are defined as primary investment nodes in northern tourism region (MITUR, 2014).

Tourism is one of the greatest economic resources in the QNP that is actually seen as a new ecotourism destination, remote and not deteriorated, which offers a remarkable variety combining three major tourism products experiences: a) sea and beaches; b) wildlife in the continent; c) places of great historical and cultural value (Tapper 2007, MITUR 2009). The strategy proposed for the QNP aims at sustainable tourism, that should maintain the characteristics of an exclusive destination by developing medium/high quality tourism with low volume/density that must be consistent with the QNP conservation objectives (Gabrie et al., 2008, MITUR 2009, 2011).

The followings charts (Figure 4.2 and

Figure 4.3) show the trends in tourism numbers in Cabo Delgado Province over the past 10 years (from 2004 till 2014), namely the number of available touristic accommodation and beds as well



as the total overnight stays in each year (data provided by DPTUR of Cabo Delgado).

Figure 4.2 – Trends in the number of accommodation resorts and beds in the last 10 years, in Cabo Delgado Province

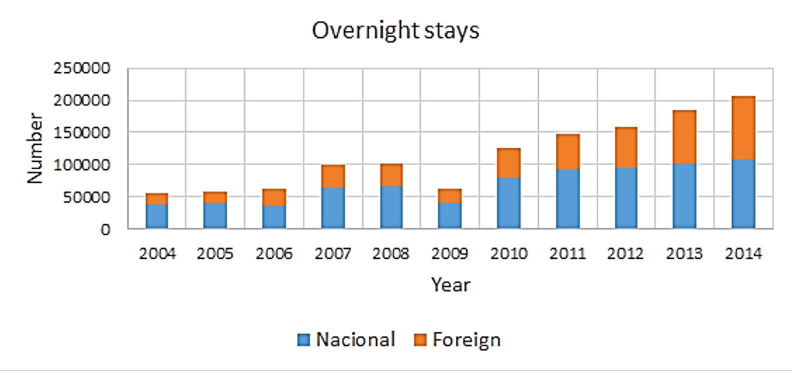


Figure 4.3 – Trends in the number of overnight stays (national and foreign) in the last 10 years, in Cabo Delgado Province

The number of hotel units has increased over the last decade, rising from 32 in 2004 to 127 in 2014 (a 4-fold increase), as well as the number of beds that rose from 800 to almost 2500 (a 3-fold growth). The total of overnight stays has also followed this trend, raised from about 55 800 to 206 600 (representing 3.7x). It stands out the fall recorded in 2009, after the global crisis of 2008. Although dominated by national tourists, foreign tourists are increasing in recent years, with the number of nights by foreigners in 2014 quite similar to those by nationals. In fact, QNP is beginning to gain international reputation (Gabrie et al., 2008; Junior, 2010) and together with the Bazaruto and Niassa National Parks, between 2009 and 2013, the conservation revenue of those parks increased from 8% to 27% (MITUR, 2014).

Some efforts to increase the tourism potential in the QNP are being taken, namely by OIKOS foundation, which intends to identify QNP's best areas for tourism and define strategies for maximizing its potential, creating value to local communities. The project includes QNP's communities capacity-building in sustainable tourism and in sustainable practices for using local resources.

5. Trends and projections in climate and related physical environment parameters

5.1. Surface air temperature (including extreme high temperature events)

30 year trends & 30 year projections for air temperature patterns

Cabo Delgado's climate is rainy and hot from October/November to April/May and dry from June to September.

Records of atmospheric temperatures from 1985 to 2013 observed at the Pemba meteorological station show an average annual temperature of 25.6˚ C (SD = 1.6˚ C). There was an increase of the average temperature for the hot and the cold seasons, of 0.03 and 0.04 ˚C per year for December-January-February (DJF) and June-July-August (JJA), respectively (Figure 5.1). The INGC (2009) analysed the average maximum annual temperatures on a time series from 1960 to 2005 for the northern region of Mozambique and detected an increase of approximately 1.1˚ C for the months March-April-May (MAM) and September-October-November (SON). The INGC study also indicates that the average maximum annual temperature was usually bellow 30° C before 1990 but afterwards, higher temperatures became common.

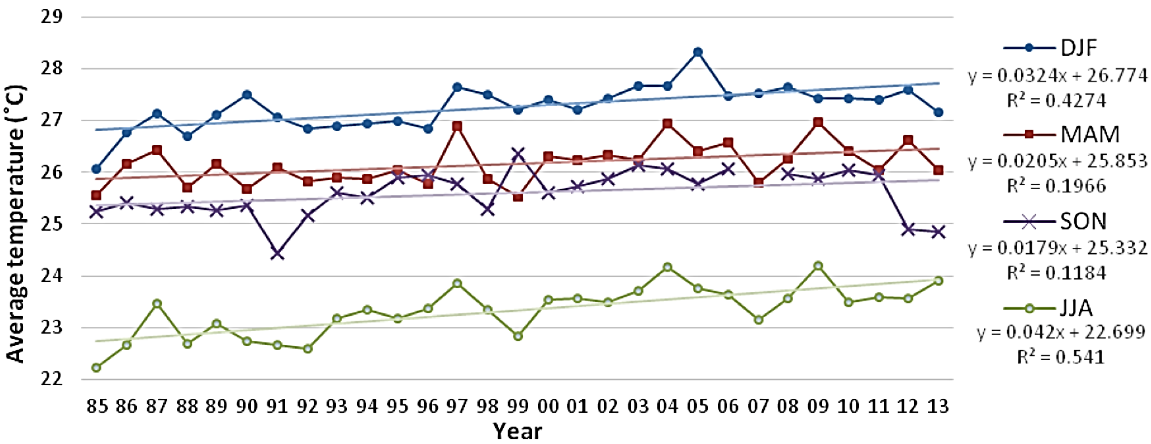


Figure 5.1 – Average daily temperatures for the hottest months – DJF (blue) and for coldest months – JJA (green), and intermediate months – MAM (red) and SON (purple), observed at the Meteorological station of Pemba

Frequency of extreme high temperature events

The increase in average maximum annual temperatures from 1960 to 2005 was also a result of longer period of extreme hot days, representing approximately an increase of 25% of the number of hot nights during the months DJF and 17% for SON in the northern region of Mozambique (INGC, 2009).

Existing research on impacts of extreme high temperature events on agriculture, livestock, human health, wildlife, turtle hatching

No data is readily available on the impacts of extreme high temperature on agriculture, livestock, human health or wildlife in Mozambique, or the QNP. Literature from abroad was consulted and relevant examples are presented here. As pointed out by Adams (1997), much of the literature on extreme heat impacts combines heat and drought into one climatological event and it is often unclear if the effects are from a short duration heat wave or a longer-term drought. In the area of health impacts, the focus has been on the temperature as a causal agent of health impacts. Several studies have reported that extreme high temperatures were associated with increased mortality (especially in large cities), after a short lag period, when temperatures exceeded obvious threshold levels (e.g. Adams, 1997; WHO, 2013; Gao et al., 2015). Those at greatest risk of death in heat waves are the urban-dwelling elderly without access to an air-conditioned environment for at least part of the day. Thus the issues of prevention and mitigation combine issues of the aging and of public health (Adams, 1997).

Extreme heat has severe impacts on agriculture and livestock, including rabbits, poultry, and cattle especially with regards to milk production and reproduction (Adams, 1997). Crops yields are also affected. This poses a high risk for food-security for the QNP communities.

Wildlife is also affected by heat waves and cases of widespread mortality have been reported for flying-foxes (a bat species) in Australia (Welbergen et al., 2008). Reproduction and fitness of marine animals such as marine turtles will certainly be affected as the viability and development of the embryos is very temperature sensitive (e.g. Godley et al., 2001; Wood et al., 2014).

5.2. Rainfall trends & variability (including drought and extreme high rainfall events)

30 year trends & 30 year projections for rainfall temperature patterns

The average annual precipitation in Pemba from 1987 to 2013 (excluding missing years) was 1 061.7 mm (SD=398.7 mm) with an average of 162.1 mm (SD = 45.4 mm) per month from December to March, to 18.1 mm (SD=13.1 mm) per month from April to November. Precipitation variation does not show a clear pattern Figure 5.2a), and the total precipitation differences between the years may be due to inter-annual variability. Figure 5.2b suggests a reduction of precipitation in December and an increase to a peak in March (rain may exceed 6 mm/day), showing a delay of the wet season. INGC (2009) and Tadross et al. (2009) also reported a delay of the wet season, as well as an increase of total number of dry days and extension of the dry season from September to November.

Almost all the model projections for 2050-2200 indicate that November will become drier in northern Mozambique (zone 13) while for December there is less consensus. From January to March, most of the models give indications of an increase in average monthly precipitation (KNMI, 2007), although there is no clear evidence for changes in wet extremes. This is probably because the models do not simulate the southwest Indian Ocean tropical cyclones, which are one of the major sources of torrential rainfall in southern Africa.

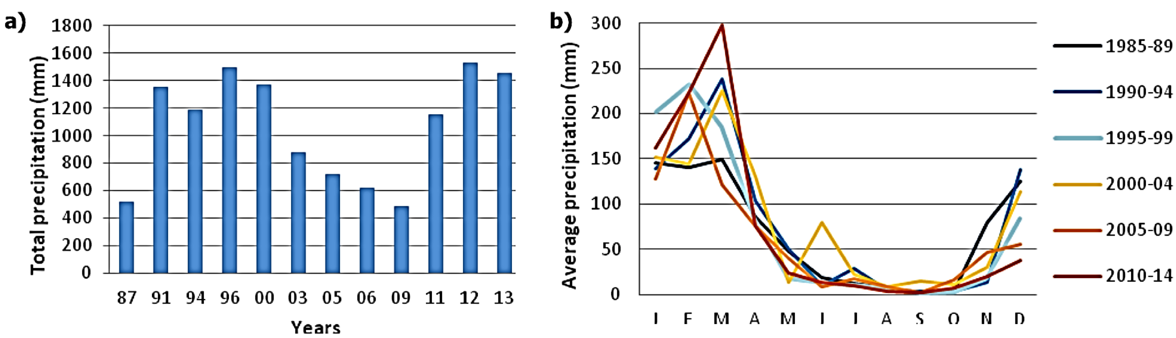


Figure 5.2 – a) Total rainfall observed at the Meteorological Station of Pemba from 1987 to 2013. Note that absent years were excluded due to data gaps. b) Intra-annual variation between annual series.

Frequency of drought and extreme high rainfall events

Northern Mozambique is the region in the country with less tropical cyclones (approximately 25%; INGC, 2009). In recent years, from 2008 to 2014, four tropical cyclones were reported in Cabo Delgado, against five that occurred from 1956 to 2007 (Guha-Sapir et al., 2015). These events became more frequent, leading to devastating flood events (Tadross & Johnston, 2012; Hellmuth et al., 2007) (Figure 5.3).

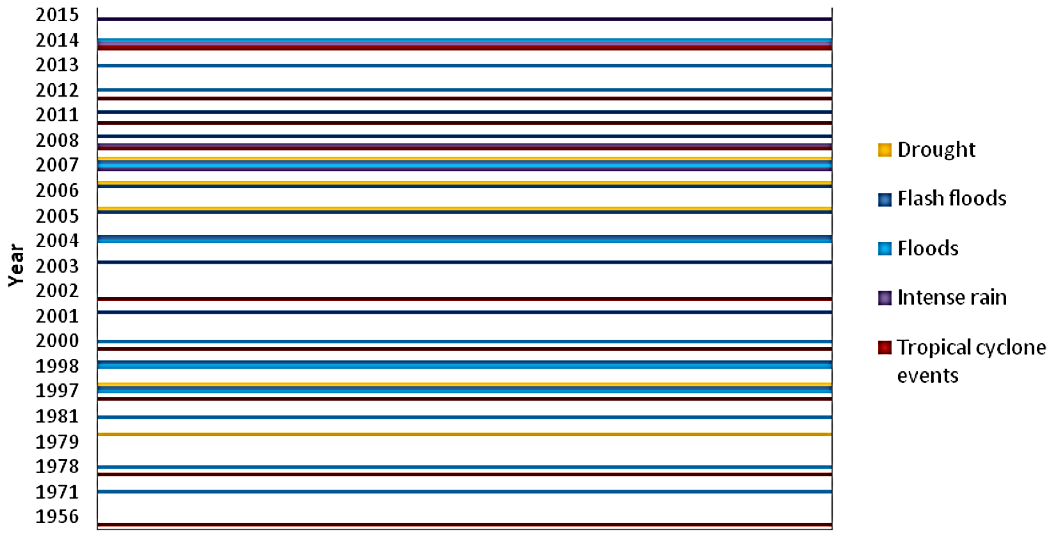


Figure 5.3 – Extreme events in Cabo Delgado from 1956 to early 2015 (Source: INGC, 2009; Guha-Sapir et al., 2015; DesInventar, 2011).

Historic river flow data

The QNP has two national seasonal rivers, the Messalo and the Montepuez. According to Carmo Vaz (2000), the Messalo and Montepuez rivers do not have a history of major floods. However, against the annual average discharge of 526.8 m^3/s (SD = 489.0 m^3/s), the maximum annual discharge of 1 891 m^3/s for the Messalo River in 1978/79 is considerably high and coincides with a tropical cyclone that hit the northern part of the country in December 1978 (Guha-Sapir et al., 2015). Notwithstanding the missing data between 1981 and 2004, there appears to have been a reduction in the maximum annual discharge of the Messalo River. The average annual discharge pre-1981 was 636.3 m^3/s (SD = 532.7 m^3/s), whereas post-2004 it was 181.1 m^3/s (SD = 111.8m^3/s).

The cyclones of 1978 and 2000 (Guha-Sapir et al., 2015) coincided with the highest annual discharge for the Montepuez River. Mean annual discharge, from 1964 to 2013, was 99.2 m^3/s (SD = 54.9 m^3/s), with a minimum of 0.91 m^3/s in 1965/66 and a maximum of 206.87 m^3/s 2007/08 (Figure 5.4).

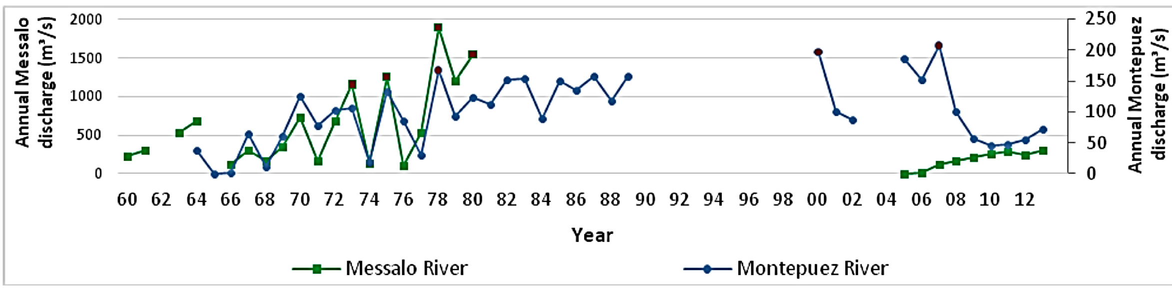


Figure 5.4 – Annual discharge (m3/s) for Messalo (left axis) and Montepuez (right axis) rivers. Data provided by ARA-Norte.

Information on coastal livelihood resilience and coping strategies in response to rainfall extremes (drought & flooding)

Droughts are not frequent in northern Mozambique. According to the National Adaptation Action Plan (2007), water is available for crops for a full growing season, with drought conditions possibly occurring only twice every ten years.

Flooding is one of the main hazards in QNP. Flooding is known to occur along the banks of the Montepuez and Messalo rivers. Flooding affects the two main sectors that provide cash income for local communities, namely: fishing and agriculture.

In terms of fishing, during flood events, fishers are often faced with loss of income and a decrease in their dietary protein. In the QNP, fishers swap to other income-generating activities such as engaging more intensely in agricultural production of crops resistant to extreme events, selling of wood and non-timber forest product, employment in the tourism industry and selling of goods such as alcoholic beverages and cooking products. In Quiterajo and Mucojo areas, the dietary intake during intense rainfall events is often restricted to cassava and watermelon.

In terms of agriculture, during flood events, farmers are faced with loss of crops and associated loss of income. In the QNP, farmers utilize a number of crop varieties that are planted in different seasons and in different areas (highland and lowland). This is mainly based on the farmers' experience. Cassava and cucumber are two crops that are mainly utilized during extreme events.

Common strategies that local communities in QNP are using to ensure their income and subsistence during extreme events such are flooding include food storage, charcoal production, hunting, casual labour and informal trade. Flood control measures are not implemented in Mozambique and therefore local communities are recurrently faced with adverse effects caused by extreme events such as flooding.

Information on the effect of rainfall variability on nearshore fish and fisheries

Hoguane et al. (2012) analysed the effect of the freshwater input into the coastal zones through rainfall from 1995 to 2008 on the landing of artisanal catches 1998-2008 in northern Mozambique. The results showed that the total artisanal annual catch was significantly correlated to the coastal rainfall lagged two years. The two-year lag matched the longevity of three fish families (Engraulididae, Clupeidae and Leiognathidae), and the maturity age of Carangidea, the top four dominant fish families in the catches. The results emphasise the role of freshwater in the productivity of coastal waters and in the survival and growth rate of the fish population during the earlier stage of their life cycle.

Impacts of rainfall (run off) variabilities and coral reefs, sea grasses

Coral reefs and seagrass beds are able to cope with increased rainfall to a certain extent. Heavy floods usually result in massive amounts of nutrients, reduced salinity, light penetration and sedimentation. This results in physiological stress, bleaching and ultimately coral death (Hoegh-Guldberg, 1999). Although in the south of Mozambique, a study conducted at Xai-Xai after the 2000 floods, showed almost 60% mortality of corals due to the reduced salinity, light penetration and smothering of corals (Pereira & Gonçalves, 2004).

Impact of rainfall variability on patterns of sediment deposition and/or erosion, especially around river outlets

Coastal habitats and ecosystems in the QNP are heavily dependent on the input of nutrients and sediments. Estuaries, bays, mangroves and seagrass beds depend on these for their normal functioning. Rainfall variability will have consequences on sediment dynamics and probably exacerbate coastal erosion and the productivity of these ecosystems and habitats. According to the INGC (2009) assessment, an increase of between 10-25% of precipitation is expected within the next 50 years with higher variability.

Impacts of increased incidence of flooding/drought on mangroves

Increased floods or drought would have deleterious effects on mangroves due to their counter-effects over salinity. The influx of fresh water from flooding would reduce salinity to very low levels and droughts would cause the contrary effect. This causes physiological stress, which impairs growth and reproduction and can ultimately cause a reduction of the mangrove area as reported for the Zambezi Delta (Davies et al., 2000).

5.3. Sea temperature

20 year trends & 30 year projections for sea surface temperature patterns

Data on SST are not readily available in Mozambique. However, McClanahan et al. (2007), reported for "northern Mozambique", a SST rise of ca. 0.010° C/year over 50 years (1957-2007). This contrasts with the global average, which as increased by 0.5°C since 1961 (IPCC, 2007). According to the IPCC (2007), tropical oceans are projected to experience the greatest increases. Recent models predicted that globally averaged SSTs will increase by 0.3°C–0.6°C over the near term relative to 1986-2005 (IPCC 2013).

Effects of increasing SST on finfish, invertebrate fisheries and aquaculture

An increase in SST is expected to have deleterious effects on both fish and invertebrate fisheries both directly and indirectly. Indirectly it will have dramatic effects on the habitats of these species (see below). The sensitivity of fish stocks to these changes will determine the range of potential impacts to life cycles, species distributions, community structure, productivity, connectivity, organism performance, recruitment dynamics, prevalence of invasive species, and access to marine resources by fishers (Jonhson & Welch, 2010; Bell et al., 2011).

Effects of increasing SST on coral reef status

Sea surface temperature has dramatic effect on corals by causing physiologic stress, bleaching and ultimately death. This was demonstrated during the El Niño Southern Oscillation (ENSO) event of 1998, which caused 99% mortality in certain reefs in the QNP (Sencar channel and Quilaluia; Schleyer et al., 1999). The ecological, social and economic consequences have been widely documented within the Western Indian Ocean region (e.g. Wilkinson et al., 1999; Westmacott et al., 2000; Obura, 2005; McClanahan et al., 2007; Ateweberhan & McClanahan, 2010). With the predicted increase in SST, it is expected that coral reefs will suffer, further degradation, shift in distribution and composition, loss of biodiversity, productivity and ecological function.

5.4. Sea level change

25 year trends & 30 year projections for sea levels

Global average sea level has risen since 1962 at an average rate of 1.8 mm/year and since 1993 at an average rate of 3.1 mm/year (IPCC, 2007). More recent estimates show that, globally mean seal level has risen at an average rate of between 1.4 to 2.0 mm/year over the 20th Century and between 2.7 and 3.7 mm/year since 1993 (IPCC, 2013).

A projected rise of 0.18 to 0.59 m above the 1980-1999 baseline by 2100, with a possible rise up to 1.4 m was reported by IPCC (2007). Under all model scenarios, the rate of sea level rise will very likely exceed that observed during the 191-2010 due to increased ocean warming and increased loss of mass from the glaciers and ice sheets. However, sea level rise will no be uniform.

Despite the global trend, a study by Sete et al. (2002) looking at data from the tidal station network of Mozambique, including Pemba and Mocímboa da Praia, concluded that “No clear evidence has been found with regard to the variation of the mean sea levels particularly as an impact of global climate changes”. A report by the INGC (2009b), suggested that only small areas in northern Mozambique are at risk, specifically the low-lying islands close to the border with Tanzania. However, it was acknowledged that long time series of mean sea levels have been lacking and a permanent sea level monitoring is required.

Impact of sea level rise on mangroves

Sea level rise is arguably the most important threat to mangrove ecosystems (Gillman et al., 2008; Ellison, 2015), mainly through sediment erosion, inundation stress and increased salinity at landward zones. These problems will be exacerbated for mangrove stands that are subjected to ‘coastal squeeze’, i.e. where landward migration is restricted by topography or human developments. The QNP is at risk with the growing human population adding pressure into the mangroves and its resources as well as the fact that large mangrove areas are located on islands (e.g. Ibo).

Several impacts on mangroves are expected from sea level rise: decline of species diversity, change in species composition and distribution. This will result on loss of biodiversity, productivity, as well as coastal protection (Ellison, 2015).

Impact of sea level on availability of ground water

The INGC (2009) suggests that the region of the QNP (especially the islands) is susceptible to sea level rise. In the worst-case scenario of a high increase it is estimated that the coastline may recess as far as 500 m. This would be catastrophic (cities such as Pemba and other in the region would be submerged. The great majority coastal communities would be left without potable water due to the increases salinity of ground water.

Impact of sea level rise on beach or coastline profiles (impacts on tourism, coastal settlements, turtle nesting sites)

Sea level rise will certainly have deleterious effects on tourism infrastructures as well as other coastal settlements, which are located very close to the shoreline. The low-lying islands and coastal zone are potentially at risk (INGC, 2009a). Turtle nesting sites (mainly on selected islands) are at risk.

5.5. Changes in wind patterns & frequency of storm events (cyclones)

Trends in wind patterns over the past 25-30 years

Information was obtained for Palma, which is located about 110 km north of the QNP. From March to September, the wind patterns are predominantly from the south-southeast and from October to February the winds blow from the north-northeast (

Figure 5.5). The average annual wind speed is 4.1 m/s as show on

Table 5.1.

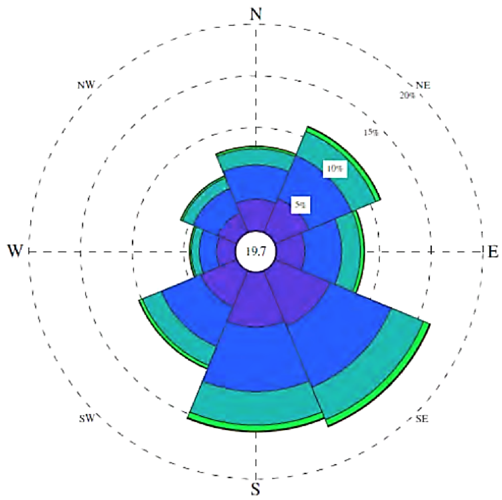


Figure 5.5 – Wind rose for Palma (1960-2009) (from EIA Anadarko, 2014). Data source: INAM.

Table 5.1 – Average wind speed (m/s) for Palma, Cabo Delgado (from EIA Anadarko, 2014)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean	3.7	3.3	3.3	3.8	3.9	4.1	4.3	4.5	4.6	4.8	4.6	4.0	4.1
Max	26.7	12.8	9.2	12.2	11.4	12.2	25.3	13.3	11.9	10.3	11.4	16.7	26.7

Data source: INAM (1960-2009)

Physical damage from increased storms frequency (tourism, coastal settlements, turtle nesting sites, aquaculture ponds)

Although the QNP is not prone to high cyclone and storm activity (INAM, 2009a), an increase in storm frequency and intensity will certainly have deleterious effects on tourism infrastructures as well as other coastal settlements, which are located very close to the shoreline. Increased winds and surge can potentially cause erosion and risk turtle nesting sites. Nests have been relocated at the QNP in the past due to the risk of inundation (A. Costa, pers. com.) and 14 were lost at Vamizi Island last season (Fernandes et al., 2015).

Impact of changes in wind patterns on fishing activities

The great majority of artisanal fishers in Mozambique and within the QNP use non-motorized traditional vessels and rely on manpower or sailing to travel to and from the fishing grounds. These are consequently very dependent on wind and current patterns. Fishing and sailing has a long tradition in the area and the well-established weather patterns of the region are well known by the local communities. It is expected that changes in the wind patterns (direction and strength) will strongly affect the local fishing communities. It will also have serious effects on the socio-economy of the region in general as trade and long distance travelling along the coast relies heavily on the large dhows.

Impact of storms on mangroves

Mangroves reduce coastal damage from storms by reducing wind, height and power of waves, and by reducing coastal flooding during tropical cyclones (McIvor et al., 2012a,b). However, the reverse is fewer documents and understanding, ie. the impact of storms on mangroves. Smith et al. (2009) reported damages via wind damage, storm surges and sediment deposition. Immediate effects included changes to stem size-frequency distributions and to species relative abundance and density. Despite the frequency and severity of tropical storms and cyclones, virtually no study has been published on the effects of these extreme events on mangroves.

5.6. Ocean acidification

Trends in ocean acidification

No research or monitoring on ocean acidification has been conducted in Mozambique. Globally, oceanic pH is estimated to have decreased 0.1 units since pre-industrial times (IPCC, 2013). There is very high confidence that oceanic uptake of anthropogenic CO_2 results in gradual acidification of seawater and decreasing pH in surface waters. The observed trends range between -0.0015 and 0.0024 units per year (IPCC, 2013). It was predicted that pH would fall 0.14 to 0.35 units by 2100 (IPCC, 2007).

Impact of acidification on coral reef communities

Corals are extremely sensitive to ocean acidification (Hoegh-Guldberg et al., 2007; Veron et al., 2009; Veron, 2011). The reduced pH lowers the solubility product of aragonite-calcium carbonate in sea water, which impairs reef-building by corals through inhibition of their skeletal deposition. As corals derive calcium directly from seawater, they are vulnerable to changes in the surrounding aquatic carbonate chemistry (Silvermann et al., 2007). Left unchecked, this process would ultimately dissolve existing coral reefs, by decreased growth rates and skeletal strength (Veron et al., 2009). Globally coral reefs are thus undergoing increasing physiological stress from ocean warming and acidification, both of which are gradually reducing their habitat. Veron (2011) concluded in his review that most impacts of ocean acidification on coral reefs will be synergistic and that the primary outcome will be a progressive reduction of species diversity correlated with habitat loss and widespread extinctions.

Impact of acidification on fish & calcareous invertebrates

Acidification has been shown to be deleterious to both fish and calcareous invertebrates throughout several phases of the life cycle with direct effect on the cellular physiology, which then affects the organisms' biology and ultimately population and ecosystem processes with socio-economic repercussions (Le Quesne & Pinnegar, 2012; Hilmi et al., 2015). It has been shown that acidification has negative impacts on fish egg and larvae survival and development (e.g. Kikkawa et al., 2004; Bignami, 2013), it decreases calcification of calcareous animals (e.g. Andersson et al., 2011; Riebesell & Tortell, 2011). This suggests that highly calcium-carbonate-dependent ecosystems, such as coral reefs and oyster and mussel beds - could be particularly vulnerable. Physiological effects on these calcified organisms can result in decreases in their abundance and shifts in the composition of communities and ecosystems (Hilmi et al., 2015).

The socioeconomic impacts of ocean acidification arise through direct effects on species, and through indirect effects on food or habitat resources, which in turn alter the availability or quality of species or natural resources of interest. Negative direct impacts on small-scale fisheries and mollusc mariculture can be anticipated based on scenarios of decreasing pH by 0.5 (Sumaila et al., 2015). The ecological and socio-economic consequences for the QNP would thus be devastating, giving the dependency of the local communities as well as the tourism industry on marine resources such as intertidal invertebrates and coral reefs.

Studies (e.g. Lam et al., 2014), have shown that the impacts of ocean acidification on the different species taxa are likely to vary substantially so there is still much research to be done in this field.

Impact of pH on macro algae

Koch et al. (2013) review the impacts of climate change and ocean acidification (OA) on seagrasses and macroalgae. Examining more than 100 species, they showed that the majority (≥ 85%) of them have C3 photosynthesis and that photosynthetic and growth rates of marine macro-autotrophs are likely to increase under elevated CO_2 similarly to terrestrial C3 species.

Fundamental linkages between elevated CO_2 and temperature on photorespiration, enzyme systems, carbohydrate production, and calcification dictate the need to consider these two parameters simultaneously. Relevant to calcifiers, elevated CO_2 lowers net calcification and this effect is amplified by high temperature. Calcareous macroalgae are highly vulnerable to OA, and it is likely that fleshy macroalgae will dominate in a higher CO_2 ocean (Koch et al., 2013). However, recent work by Cornwall (2013), showed that OA could be ameliorated at slow flows for calcareous organisms that are capable of photosynthesizing, where the pH micro-environment is altered favouring higher calcification rates during the day. However, recent work by Cornwall (2013), showed that macroalgae are capable of acting as ecosystem engineers, altering both their chemical and physical environment. Also, their ability to alter their physical micro-environment has flow on effects for their chemical micro-environment. This alteration of their micro-environment has implications for both coralline macroalgae, and potentially other species that live within macroalgal beds.

6. Vulnerability and resilience of ecosystems, species, livelihoods and infrastructure to climate variability and change

6.1. Fisheries and aquaculture-based livelihoods

According to Wilkinson & Buddemeier (1994), Maueua (2007), Nicholls et al. (2007) and USAID (2013) several direct impacts on fisheries and aquaculture sectors in coastal zones are expected to happen due to the climate-related changes:

- Temperature sector rise (air and seawater)
- Changes in precipitation (reduce water flow to estuaries, increase salinity and runnof – sedimentation and pollution)
- Extreme events (storms, waves)
- Floods (sea level, runoff)
- Rising water tables (sea level)
- Erosion (sea level, storms, waves)
- Salt water intrusion (sea level, runoff)
- Biological effects (all climate drivers)

Dramatic impacts on fish production are expected, which can affect the protein supply and fish oils derived for local people (Mauea, 2007). The expected consequences of some of these impacts on fisheries are described below.

<u>Temperature rise (Maueua, 2007; Bell et al. 2011):</u>

Changes in water temperature have a major influence on most tropical marine and coastal fish and invertebrates, as they are sensitive to variations in SST because temperature regulates metabolism and development, and limits activity and distribution. As sea surface temperature (SST) increases due to global warming, significant consequences are expected on the distribution and abundance of key fish and invertebrate species, as well as productivity and composition of coastal fisheries. Projected increases in SST within shallow coastal environments of up to 2.5–3°C by 2100 are expected to have limited direct effects on survival of adults for most fisheries species, but may still interfere with reproduction, recruitment and juvenile growth. Even temperature increases of 1–2°C can affect the reproductive performance of some reef fish and are likely to lead to shifts in the timing of spawning, and possibly falling egg production, in some populations. Where reproductive development and spawning synchrony are cued to temperature, seasonal changes in SST may lead to alterations in the timing of breeding.

Increases in ambient temperature, and corresponding increases in food demands, are also expected to affect the survival of offspring, especially during pelagic dispersive phases.

Productivity of coastal fisheries is also likely to be reduced as a result of the effects of higher SST on metabolic rates. Overall fisheries production is expected to decline with increasing SST, except in locations of local nutrient enrichment.

Increased intensity of disease outbreaks frequencies and may result in frequent algae bloom in the coastal zone.

Ocean acidification (Bell et al., 2011):

Ocean acidification is expected to compound the negative effects of increasing SST for fish and invertebrates. Impaired larval behavior caused by elevated CO_2 could also affect the replenishment of populations, increasing the risks of decline in the stocks that support coastal fisheries.

Habitat degradation and loss (Bell et al., 2011):

Reef-associated fish and invertebrates are likely to become less abundant following extensive degradation and loss of the coastal habitats on which they depend, especially coral reefs. The demersal fish commonly associated with coral reefs that are expected to be affected include emperors, snappers, groupers, surgeonfish, parrotfish and rabbitfish. There may also be some replacement of specialist reef-associated species with more generalist species (e.g. Mugilidae).

Extreme weather events (Maueua, 2007):

Any increase in the intensity and frequency of extreme weather events such as cyclones, floods and droughts will bring negative impacts on aquaculture production and result in significant destruction of infrastructure. The rising sea level is expected to bring negative effects on the walls and aquaculture tanks.

Sea level rise (Davis, 2011):

Sea level rise may also affect coastal ecosystems, such as mangroves and coral reefs, with consequences for fisheries and tourism. Several of the aforementioned impacts are already being experienced in the North of the country, namely in Nampula, by the local coastal fishing communities (Østergaard, 2008).

Analysing the previous information, it can be seen that several of the global climate-related changes and impacts are already being experienced or are expected to occur in the North of Mozambique. As explained earlier in this document, most of the data relatively to fisheries was obtained at the Province level and not at the District level. Therefore the considerations we can do are limited to this fact. We assume that the trends within QNP are similar to the whole Cabo Delgado Province.

Although methodological issues might have biased data analysed in the previous sections, and therefore it is not completely reliable, it allows detecting a few trends and relations that together with climate-related effects may cause changes in local ecosystems and, consequently, may have impacts in local livelihoods:

- There seems to be a relation for the hand line, in this case negative. Total Catches have been declining since 2009 and the representativeness of the Families most caught by this type of fishing gear has also been declining for the same period (33,3% or 58,3% if we also consider the category "Stable-Declining"). On the other hand, CPUE has been increasing since 2010, whereas the number of fishing gears has grown 42,6% between 2007 and 2012. It seems that this type of fishing gear is causing a huge pressure in the marine ecosystems.

- Most of the Families caught by Beach seine from 2006 to 2013 are stable in terms of the percentage of occurrence relatively to the total number of species caught. Although the number of fishing gears has also maintained stable in Cabo Delgado between 2007 and 2012, the Total Catches from 2006 to 2013 have been increasing and the CPUE has been variable. In this case there seems to be certain equilibrium.

- Regarding Bottom gillnet the representativeness of most Families caught by this type of fishing gear has declined between 2006 and 2013, whereas for Surface gillnet there has been a positive trend. Generally, since 2007, total catches and CPUE have been increasing using surface gillnets. For Bottom gillnets the trend is similar but since 2009 only. The number of fishing gears relative to gillnets in Cabo Delgado has decreased slightly between 2007 and 2012. It was not possible to distinguish between Surface and Bottom gillnet for this parameter, because the data are presented as one. As it can be seen, it is not possible to infer much about these types of fishing gears because the data is variable.

Further data collection and analysis is needed to establish a relation between the information that has been collected over the years and the climate-related changes and impacts.

6.2. Agriculture and livestock-based livelihoods

Data from INGC (2009) suggests that the region of the QNP is susceptible to the rise in sea level (and possible increase in salinity to ground-water in coastal regions); reduction in the availability of fresh water on the continental zone; substantial reduction of land for agriculture and an increased risk of wild fires.

Data from the 2007 agricultural census shows the percentage of farmers, which experienced crop loss on the fields during 2006. Table 6.1 shows the results for the different crop types in Cabo Delgado Province.

Table 6.1 – Experienced crop loss in Cabo Delgado

Crop type	% experienced crop loss on fields
Maize	60.4%
Rice	63.8%
Sorghum	59.7%
Peanuts	54%

Source: MAG, 2007

The reasons for loss of crops on the fields can be varied. Table 6.2 highlights the reasons stated by farmers in Cabo Delgado province. Climate variations (floods, excess rain and lack of rain) are responsible for the largest loss in crops registered. Crop loss due to plagues and diseases is also considerable. It is not clear whether these are associated to climate change. Crop loss due to wild animals is also significant.

Table 6.2 – Reasons for crop losses according to local farmers.

Reasons for crop loss	Maize	Rice	Sorghum	Peanuts
Floods	9.7%	8.1%	1.6%	10%
Plague	18.3%	28.5%	28.5%	26.3%
Wild animals	23.1%	14.5%	25.3%	19.2%
Domestic animals	0.5%	-	-	-
Disease	3.7%	3%	8%	5%
Excess rain	17%	10.1%	9.9%	16.4%
Lack of rain	19.9%	35.9%	22.3%	15.6%
Wild fires	0.2%	-	0.8%	-
Other	10.3%	-	3.7%	4.9%

Source: MAG, 2007

6.3. Shallow marine habitats (coral reefs and seagrasses)

Coral reefs within the QNP are usually located relatively far from the mainland and thus would be relative protected from flooding events. Seagrasses on the other hand are located much closer and would be potentially subjected to increased sedimentation and run off. Other important climate change stressors include SST rise as well as extreme events such as cyclones. In addition, both coral reefs and seagrass beds are under permanent anthropogenic stress, which is probably going to have deleterious effects on their natural recovery. Therefore there is a need to strengthen and consolidate the management and enforcement within the QNP in order to facilitate their natural recovery as it is highly unlikely in the near future, that active habitat restoration will be pursued by the park management due to the high costs involved.

6.4. Freshwater

According with the information provided by the Water and Sanitation Department of the Provincial Delegation of Public Works, Housing and Water Resources (DAS, DPOBH Cabo Delgado), presently in the six districts where QNP is located, there are a total of 683 available and operational water sources (359 were active boreholes, 316 operational wells and nine water supply and sanitation systems) covering 62% of the community living in those districts. Ibo, Meluco and Quissanga are the best-covered districts (with 100%, 99% and 90% of the population with water supply, respectively) followed by Matube (63%), Macomia (51%) and Ancuabe (48%; Table 6.3). Regarding this topic, it was not possible to source the trends on water availability for community use, as only information on current situation was provided.

Table 6.3 – Number of Operational and Inactive Boreholes, Wells, and water supply and sanitation system, and % of people with access to that Water Sources

	Macomia	Meluco	Quissanga	Ibo	Metuge	Ancuabe	Total
Total Population	89 807	26 135	40 348	11 429	79 939	120 205	367 863
Operational Boreholes (N)	94	43	45	1	80	96	**359**
Inactive boreholes (N)	40	0	4	0	1	15	**60**
% of people with access to operational boreholes	**31.40%**	**49.36%**	**33.46%**	**2.62%**	**30.02%**	**23.96%**	**29.28%**
Operational wells (N)	43	33	59	50	73	58	**316**
Inactive wells (N)	39	0	7	0	2	27	**75**
% of people with access to well	**14.36%**	**37.88%**	**43.87%**	**97.38%**	**27.40%**	**14.48%**	**24.72%**
Operational water supply and sanitation system (N)	3	3	0	0	1	2	**9**
Inactive water supply and sanitation system (N)	1	1	1	0	0	0	**3**
% of people with access to water supply and sanitation system	5.57%	19.13%	0.00%	0.00%	5.63%	9.98%	**8.02%**

	Macomia	Meluco	Quissanga	Ibo	Metuge	Ancuabe	Total
Total Operational water sources	**140**	**79**	**104**	**51**	**154**	**156**	**684**
% of people with access to water sources	**51.33%**	**98.72%**	**89.72%**	**100.00%**	**63.05%**	**48.42%**	**62.01%**

Regarding water quality, according to ARA-Norte, in 2007 there were only two stations (1 hydrometric and another for rainfall) in Cabo Delgado and Niassa provinces. Currently there are 73 stations in operation, and in some places water quality parameters are being measured. Unfortunately the study area is not cover yet, but it is expected that those districts will be covered in the near future.

6.5. Mangroves

Mangroves are sensitive to projected climate change. The primary impact likely to be rising sea level, affecting inundation period, productivity and sediment budgets to cause dieback from the seaward edge and migration landward, subject to topography, and human modifications. Climate warming is likely to have little negative impact, even increasing mangrove productivity and biodiversity at higher latitudes (McLeod & Salm, 2006)

Rainfall changes are of greater significance to mangroves, particularly reduced rainfall, with drier coastal areas showing lower tree stature and biodiversity relative to humid coastlines. Reduced rainfall may change sediment inputs and salinity to affect productivity. However, the effects of relative sea level rise are the primary climate change impact of concern, giving a range of severely detrimental effects on mangroves (Gilman et al., 2006).

Sedimentation in mangroves allows the mangrove substrate to keep-up with sea level rise, and so reduce impacts of increased inundation stress, as a natural adaptation process in mangrove systems. Different contributions to mangrove sediment accretion are organic detritus from the mangroves, mineral sediment from river discharge, and soil volume change/compaction (Alongi, 2008).

Mozambique is predicted to experience among the most direct consequences of global climate change, particularly low lying deltas in countries with low GDP limiting adaptive capacity. It is expected that many communities living around the QNP may experience floods every year due to sea level rise and Mozambique has been shown to have particular vulnerability to sea level rise (Ostergaard, 2008; WWF, 2015). On these coastlines sedimentary sheltered areas are dominated by mangroves, which provide coastal accretion, stability and protection values, as well as a food resource for local communities. Direct human pressure has resulted in significant mangrove losses in the past few years, to which sea-level rise impacts will add further pressure (WWF, 2015; Bandeira et al., 2009).

Mangroves in the QNP have lower resilience to climate change due to heavy human usage of the resource adding pressures to the ecosystem. However, detailed studies addressing forest assessment of mangroves, recent spatial changes of mangroves, ground elevations in and behind mangroves, relative sea level trends, sedimentation rates under mangroves, adjacent ecosystem resilience, climate (temperature rainfall) modelling and compilation of local community knowledge are need for better understanding of this phenomenon.

6.6. High profile species

Within the QNP, apart from marine turtles, which are relatively resident to the feeding grounds, as well as very sensitive in terms of the nesting beaches and embryological development, the other high profile species (ie. marine mammals, whale shark) are relatively resilient to climate change at local level. Given their ability to migrate long distances and the fact that they spend their whole life cycle at sea, whales and dolphins as well as the whale shark can seek refuge and find other foraging grounds elsewhere in case of a major catastrophic event. The loss of nesting habitat as well as productive feeding areas can potentially be conduct marine turtles towards local extinction if current anthropogenic stressors are not dealt with.

This includes not only coastal and island development, the oil & gas industry, but also direct poaching of turtles as well as habitat degradation.

6.7. Infrastructure

River flooding often occurs when a river cannot cope with the amount of water draining into it from the surrounding land. Whenever it rains heavily, and particularly during summer, rivers can flood and this event can last weeks or longer. The Messalo River and the Montepuez River, both located inside the QNP, were two examples of rivers that have been flooded due to the heavy rains in Cabo Delgado in 2014. The Messalo and the Montepuez bridges were damaged due to intense rainfall events. The bridge over the Messalo River carries national highway 423, which is the only reliable road along which supplies can reach the northern districts of Cabo Delgado.

6.8. Human Health

As a result of climate changes several phenomena like the accelerating sea level and the increasing of flood peaks are expected in the north of Mozambique. The region will be more prone to severe cyclones placing several coastal areas and nearby islands at risk (INGC, 2009).

In a public health perspective the frequency and intensity of extreme weather events, flooding or drought may also play an important role on population health (with population displacements outcome). Sea level rise is expected to exacerbate intrusion of saline water into the fresh groundwater aquifers in the coastal zone limiting the access to safe water (Matyas & Silva, unknown year).

Increasing temperature enhances soil evaporation, increasing soil salinization. This will cause the deterioration of crop quality and lower productivity with significant socioeconomic consequences and serious implications for food security (resulting in malnutrition and micro-nutrient deficiencies). Since in Mozambique communities coping strategies rely on women, inducing women over-burden is expected (Matyas & Silva, unknown year). Impairment of food quality with marine bacteria proliferation, shellfish poisoning and ciguatera will have particular impact on people living in coastal areas (Nicholls et al., 2007).

The scenario for the re-emerging and expanding of several diseases related with changing temperatures, rainfall patterns and environmental changes it is also cause of concern (Davis, 2011).

Warmer temperatures may prolong the seasonality and extend the range of transmission of vector-borne diseases such as malaria, dengue, chicungunya fever as well as favouring the expansion of the meningitis belt and the incidence of rodent borne diseases (Davis, 2011; INGC, 2009).

Water borne diseases such as diarrhoeal diseases (giardia, cholera), hepatitis, and enteric fevers have its peaks following flooding and warm temperatures. Worth mention the cholera epidemics seen in Mozambique and Tanzania in 1998 during 1997/98 El Niño event (Nicholls et al., 2007; INGC, 2009).

The official data (2005-2015) supplied by DPS of Cabo Delgado (2015) only presents information from the year 2007 and beyond. The data were analysed and a similar methodology to the one applied in topic 3.1 was used (Annex 4). In what regards the prevalence of diseases and well being in the last 10 years in Ibo, Macomia, Meluco and Quissanga, the results reveal that there is a tendency to an increasing of: dysentery in Ibo; malaria and diarrhoea in Macomia; malaria, diarrhoea and dysentery in Meluco and malaria and diarrhoea in Quissanga. However there are no studies relating this data with climate change.

The outlined above highlights the potential impacts of climate change on populations in coastal regions. This impact will be determined by the future health status of the population (including the prevalence of cardiovascular diseases, HIV and TB, malnutrition or stunting especially in young children) and the capacity of communities to adapt to health threats as well as to cope with climate events and public health governance measures (Nicholls et al., 2007).

7. Relevant policies & strategies

7.1. National Strategy on Climate Change

The National Strategy on Climate Change (2013-2025) of 2012, aims at establishing guidelines for action to build resilience, including the reduction of climate risks on communities and the national economy, and promote the development of low carbon and green economy by integration of these principles in the sectorial and local planning process. This is expected to be achieved by:

- Increasing resilience to climate change impacts, while minimizing risks to people and property, restoring and ensuring the rational use and protection of natural resources;
- Identifying and implementing opportunities to reduce greenhouse gases emissions that contribute to sustainable use of natural resources and low-carbon emission development;
- Creating institutional and human capacity, and explore opportunities for accessing technological and financial resources to implement the strategy.

Over the time scale of the Strategy, the priority will be to increase local resilience, combating poverty and identifying opportunities for adaptation and low carbon development at community level, to be included in district planning (2013-2015), provincial planning (2015-2019) and at national planning (2020-2025).

Areas of Intervention

<u>Climate Risk</u>

The aim is to strengthen the early warning system in order to protect people and assets from extreme events, such as floods, drought, and uncontrolled fires. The lack of an efficient national system is contributing to negative impacts often resulting in loss of lives. Here, the access to meteorological data is critically important, tailored to sector specific needs and with accurate forecast of extreme events.

Allied to this, the strengthening of preparedness and response to climate risks is of paramount importance to mitigate the impact of climate disasters. In this regard the strategy stresses the need to boost the coordination capacity of the INGC and that of the Multiple Use Resource Centres (CERUM) to assist the communities.

<u>Water Resources</u>

Water is becoming a major asset both in terms of human needs, storage for drought impact and in regards to flood management.

There is the need to manage shared river catchments and to boost dam discharge in order to limit flush flooding and water management to support agriculture and other human socio economic developments.

<u>Agriculture, Fisheries, Food Security and Nutrition</u>

The aim is to increase agriculture and livestock resilience by:

- Crop diversification and introduction of crops more resistant to variations in climate parameters;
- Improve agricultural productivity with appropriate technology and inputs adapted to climate change;
- Combat and control pests and diseases in crops;

- Strengthen the agro-ecological zoning and land use planning;
- Develop conservation programs and soil nutrition (conservation agriculture);
- Improve animal nutrition through pastures and forage production management techniques;
- Improve epidemiological surveillance and control of animal diseases;
- Improve and expand technical assistance to producers in terms of intervention quality.

On fisheries, emphasis is to increase resilience by:

- Aquaculture development as an alternative means to reduce fishing effort and sustain fish demand;
- Regenerate mangroves and implement protective measures on seaweed, seagrass, coral reefs and other critical ecosystems;
- Improve small-scale fisheries;
- Reinforce fisheries management by applying clean fisheries technology to ensure the renewal and maintenance of stocks.

Adequate levels of food safety and nutrition are expected to be achieved by:

- Improved mechanisms for marketing of food products;
- Improve food stocks;
- Enhance nutrition by improving education and access to food;
- Develop community-based processing and value-adding;
- Promote agro-processing;
- Promote the use and value-adding of indigenous foods.

Social Protection

It is expected that climate change and extreme events have a more pronounced consequence on the most vulnerable groups, including women, children, elderly, disabled, displaced and climate chronically ill. These are expected to contribute to impoverishment and increased vulnerability of the population in general. The resilience can be increase by:

- Increase adaptive capacity of vulnerable people by applying innovative approaches to community-based adaptation, and improving the effectiveness of programs on social protection; and
- Strengthening the links between social protection systems and response to natural disasters systems, including coordination with early warning systems.

Health

Direct health risks are of physical safety and increased risk of disease spreading, particularly during extreme events:

- To increase resilience to transmission it is vital to strengthen the capacity to prevent and control the spread of vector-borne diseases;
- Expand and improve the operation of systems for collecting and treating solid waste and wastewater;

- Promoting and using clean technologies and create forest and recreation areas, and buffer zones in cities, including mangrove conservation in coastal areas.

Biodiversity

The overall objective of the country's Conservation Policy is "to develop and consolidate a national system of biological resources conservation and its aquatic and terrestrial biodiversity contributing to sustaining life, economic growth and poverty eradication". In turn, the policy and strategy on Forestry and Wildlife recognizes the social, ecological and economic measurements as the basis for a harmonious development of the sector.

In order to improve resilience on biodiversity conservation and protection the following actions are:

- Identify adaptation actions to ensure that wildlife does not go extinct;
- Establish trans-frontier conservation areas to maintain ecosystem functions and allow migration of wildlife;
- Implement management practices that increase the adaptive capacity of ecosystems, maximizing the use of habitats and biodiversity conservation;
- Reclassify and resize conservation areas, identifying biodiversity loss risk areas.

Forests

The impact of climate change on forests are not well known, but direct effects of extreme events such as spread of fires in dry scenarios and temperature rise, leads to loss of biomass and possible endangered species.

The National Strategy of Forestry operationalize this vision aligning intervention measures that can either be used as mechanisms of adaptation as well as mitigation to climate change. However, deforestation and increased exposure of soil are highly adverse, affecting subsistence of rural communities. Thus, the strategic actions proposed include:

- Increasing the adaptive capacity of forests involves:
- Develop planting multi-purpose trees and economic value of programs to meet the needs of products to local communities, seeking to enhance local initiatives, combating deforestation and preventing fire and its spread;
- Explore agro-forestry-pastoral systems, allowing diversification of livelihoods and incomes.

Infrastructure

According to the Medium Term Expenditure Framework (2012-2014) (MTEF) most of the investments in Mozambique will be made in the construction or maintenance of infrastructure.

The integration of climate aspects in the urban planning process allows cities to develop their capacity to adapt effectively to current and future climate impacts, but also take the opportunity to develop, experiment and innovate in their urban planning policies.

Develop resilience mechanisms in urban areas and other settlements by:

- Draw up and update the planning tools and climatically robust territory planning and strengthen its implementation;

- Map the infrastructure vulnerable or at risk, depending on the type of weather phenomena (floods, cyclones, rising sea level);
- Revamp the building codes of transport infrastructure, telecommunications, power distribution, buildings, water infrastructure and wastewater treatment in order to make them resilient to climate;
- Ensure that investments, particularly public, in hazardous areas are climate-proof;
- Promote the design and implementation of potential insurance mechanisms against climate risks in built heritage.

Tourist and coastal infrastructure may be vulnerable. Therefore actions are needed to:

- Evaluate the main climate risks on the resources and tourist interest zones;
- Advise operators about the appropriate building codes;
- Promote best practice amongst operators and tourists, through public-private partnerships aimed at the resilience of the sector and the conservation of ecosystems;
- Develop conservation and coastal protection practices;
- Promote the adoption of climate insurance for activities and tourism infrastructure.

8. Conclusion and Recommendations

The fundamental starting point for the production of a climate vulnerability assessment is the acquisition of basic data on a number of important parameters that characterise the area. Relevant information relative to the QNP includes the following:

- Natural resources, ecosystems and biodiversity (condition, trends and threats);
- Socio-economic situation (human settlements and livelihoods, fisheries, agriculture, tourism, infra-structure and other coastal development)
- Climatic and weather parameters and trends (including climate stressors);
- Oceanography of the region;
- Hydrological/water resources
- Coastal geomorphology/topography (including erosion/accretion patterns);
- Legal and institutional framework

Based on the literature review several gaps in the current knowledge have been identified and are summarized below:

- Biodiversity assessments, monitoring programs and status assessments for high profile species and important ecosystems are urgently needed, not only to allow proper vulnerability assessments to be produced but also to support management and conservation (as a matter of priority the following ecosystems should be addressed: mangroves, coastal forests, coral reefs, seagrass beds and tidal flats, as well as marine megafauna ie. marine turtles, marine mammals and the whale shark and manta rays);
- Quantification of natural resource use is also a long felt need within the QNP, and should include both extractive and non-extractive uses (eg. fishing and invertebrates collection, charcoal and firewood, tourism);
- Monitoring of climate stressors within the QNP need to be implemented as a matter of priority as well as the acquisition of time-series data (such as satellite and modelling oceanographic and climate parameters);
- There's no consistent data of human population and its trend of growth within the QNP and within the buffer zone, limiting the assessment of human vulnerability to climate change;
- Additionally, an inventory of land use and crop regime at the QNP is needed, in order to foresee improved local based technologies to adapt to climate change.
- A comprehensive monitoring and evaluation framework to track major issues such as land use and agriculture vulnerability and resilience to climate change, and extent to which climate change adaptation is addressed in reducing climate change impacts and boosting sustainability, is required.

The National Strategy on Climate Change defines the actions to be taken to adapt and mitigate the impact of climate change and that of extreme events. These principles should be taken in light of climate vulnerability assessment and when reviewing priority areas of vulnerability and adaptation options to implement at the QNP.

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10. Annexes

10.1. Annex 1 – Trend analysis for fish species (family) caught by different type of fishing gear between 2006 and 2013

The comparison unit is the % of occurrence of the Family, per fishing gear per year. Grey cells refer to the comparison between 2012 and 2010 and not 2011 (no data was available for this year for three of the fishing gears). The remaining colours represent the trend according to the classes identified in the column "Possible trend". Red arrows mean "Declining", Yellow arrows mean "Stable" and Green Arrows mean "Increasing".

Fishing gear	Family	2006		2008		2009		2010		2011		2012		2013		Trend analysis				
		%	Trend	%	Trend	%	Trend	%	Trend	%	Trend	%	Trend	%	Trend	Stable	Up	Down	Last year	Possible trend
Beach seine	Siganidae	24	-	13	↓ -11	24	↑ 11	7	↓ -17	19	↑ 12	20	↑ 1	19	↓ -1	0	3	3	Declining	Stable
	Carangidae	21	-	11	↓ -10	6	↓ -5	16	↑ 10	6	↓ -10	12	↑ 6	3	↓ -9	0	3	4	Declining	Declining
	Scaridae	11	-	9	↓ -2	8	↓ -1	4	↓ -4	13	↑ 9	6	↓ -7	0	↓ -6	0	1	5	Declining	Declining
	Lethrinidae	10	-	8	↓ -2	7	↓ -1	8	↑ 1	14	↑ 6	11	↓ -3	25	↑ 14	0	3	3	Increasing	Stable
	Haemulidae	9	-	3	↓ -6	11	↑ 8	4	↓ -7	7	↑ 3	7	→ 0	7	→ 0	2	2	2	Stable	Stable
	Caesionidae	5	-	28	↑ 23	4	↓ -24	11	↑ 7	4	↓ -7	4	→ 0	0	↓ -4	1	2	3	Declining	Stable-Declining
	Mullidae	0	-	2	↑ 2	7	↑ 5	4	↓ -3	8	↑ 4	3	↓ -5	2	↓ -1	0	3	3	Declining	Stable
	Hemiramphidae	0	-	3	↑ 3	6	↑ 3	6	→ 0	0	↓ -6	7	↑ 7	9	↑ 2	1	4	1	Increasing	Increasing
	Scombridae	0	-	2	↑ 2	2	→ 0	10	↑ 8	0	↓ -10	0	→ 0	0	→ 0	3	2	1	Stable (0)	Stable-Declining
	Clupeidae	0	-	4	↑ 4	5	↑ 1	7	↑ 2	3	↓ -4	0	↓ -3	0	→ 0	1	3	2	Stable (0)	Declining
	Gerreidae	7	-	0	↓ -7	0	→ 0	5	↑ 5	10	↑ 5	11	↑ 1	16	↑ 5	1	4	1	Increasing	Increasing
Hand line	Siganidae	36	-	25	↓ -11	24	↓ -1	9	↓ -15	-	-	6	↓ -3	-	-	0	0	4	Declining	Declining
	Lethrinidae	17	-	22	↑ 5	12	↓ -10	35	↑ 23	-	-	25	↓ -10	-	-	0	2	2	Declining	Stable
	Dasyatidae	10	-	0	↓ -10	0	→ 0	0	→ 0	-	-	0	→ 0	-	-	3	0	1	Stable (0)	Declining
	Labridae	7	-	0	↓ -7	0	→ 0	0	→ 0	-	-	0	→ 0	-	-	3	0	1	Stable (0)	Declining
	Lutjanidae	7	-	11	↑ 4	14	↑ 3	4	↓ -10	-	-	4	→ 0	-	-	1	2	1	Stable	Stable-Declining
	Haemulidae	6	-	3	↓ -3	5	↑ 2	12	↑ 7	-	-	4	↓ -8	-	-	0	2	2	Declining	Stable-Declining
	Carangidae	4	-	24	↑ 20	7	↓ -17	7	→ 0	-	-	5	↓ -2	-	-	1	1	2	Declining	Declining
	Serranidae	4	-	4	→ 0	2	↓ -2	4	↑ 2	-	-	2	↓ -2	-	-	1	1	2	Declining	Stable-Declining
	Sillanginidae	0	-	0	→ 0	19	↑ 19	0	↓ -19	-	-	2	↑ 2	-	-	1	1	2	Increasing	Stable
	Scombridae	0	-	3	↑ 3	4	↑ 1	13	↑ 9	-	-	23	↑ 10	-	-	0	4	0	Increasing	Increasing
	Istiophoridae	0	-	0	→ 0	0	→ 0	5	↑ 5	-	-	13	↑ 8	-	-	2	2	0	Increasing	Increasing
	Scaridae	0	-	3	↑ 3	8	↑ 5	0	↓ -8	-	-	5	↑ 5	-	-	0	3	1	Increasing	Increasing
Surface gillnet	Siganidae	26	-	3	↓ -23	6	↑ 3	8	↑ 2	-	-	9	↑ 1	-	-	0	3	1	Increasing	Increasing
	Carangidae	15	-	7	↓ -8	0	↓ -7	10	↑ 10	-	-	6	↓ -4	-	-	0	1	3	Declining	Stable-Declining
	Lethrinidae	13	-	14	↑ 1	6	↓ -8	16	↑ 10	-	-	15	↓ -1	-	-	0	2	2	Declining	Stable
	Haemulidae	11	-	3	↓ -8	0	↓ -3	3	↑ 3	-	-	3	→ 0	-	-	1	1	2	Stable	Stable
	Hemiramphidae	10	-	5	↓ -5	4	↓ -1	0	↓ -4	-	-	0	→ 0	-	-	1	0	3	Stable (0)	Declining
	Leignathidae	0	-	15	↑ 15	0	↓ -15	0	→ 0	-	-	0	→ 0	-	-	2	1	1	Stable (0)	Declining
	Caesionidae	9	-	7	↓ -2	8	↑ 1	15	↑ 7	-	-	7	↓ -8	-	-	0	2	2	Declining	Stable
	Gerreidae	0	-	6	↑ 6	2	↓ -4	3	↑ 1	-	-	7	↑ 4	-	-	0	3	1	Increasing	Increasing
	Nemipteridae	0	-	5	↑ 5	0	↓ -5	0	→ 0	-	-	0	→ 0	-	-	2	1	1	Stable (0)	Declining
	Mugilidae	0	-	3	↑ 3	25	↑ 22	3	↓ -22	-	-	7	↑ 4	-	-	0	3	1	Increasing	Increasing
	Clupeidae	0	-	0	→ 0	22	↑ 22	10	↓ -12	-	-	24	↑ 14	-	-	1	2	1	Increasing	Increasing
	Mullidae	0	-	0	→ 0	7	↑ 7	4	↓ -3	-	-	0	↓ -4	-	-	1	1	2	Declining	Declining
	Scaridae	3	-	2	↓ -1	4	↑ 2	5	↑ 1	-	-	7	↑ 2	-	-	0	3	1	Increasing	Increasing
	Lutjanidae	5	-	2	↓ -3	0	↓ -2	9	↑ 9			2	↓ -7			0	1	3	Declining	Declining
Bottom gillnet	Dasyatidae	44	-	42	↓ -2	29	↓ -13	25	↓ -4	-	-	23	↓ -2	-	-	0	0	4	Declining	Declining
	Myliobatidae	12	-	5	↓ -7	5	→ 0	7	↑ 2	-	-	7	→ 0	-	-	2	1	1	Stable	Stable
	Mugilidae	11	-	5	↓ -6	0	↓ -5	0	→ 0	-	-	3	↑ 3	-	-	1	1	2	Increasing	Stable-Declining
	Rajidae	10	-	0	↓ -10	0	→ 0	0	→ 0	-	-	0	→ 0	-	-	3	0	1	Stable (0)	Declining
	Pristidae	10	-	0	↓ -10	0	→ 0	0	→ 0	-	-	0	→ 0	-	-	3	0	1	Stable (0)	Declining
	Sphyraenidae	7	-	0	↓ -7	6	↑ 6	0	↓ -6	-	-	0	→ 0	-	-	1	1	2	Stable (0)	Declining
	Scaridae	3	-	10	↑ 7	6	↓ -4	8	↑ 2	-	-	8	→ 0	-	-	1	2	1	Stable	Stable
	Carangidae	0	-	9	↑ 9	0	↓ -9	6	↑ 6	-	-	4	↓ -2	-	-	0	2	2	Declining	Stable-Declining
	Mullidae	0	-	5	↑ 5	0	↓ -5	0	→ 0	-	-	0	→ 0	-	-	2	1	1	Stable (0)	Declining
	Lutjanidae	0	-	4	↑ 4	0	↓ -4	0	→ 0	-	-	0	→ 0	-	-	2	1	1	Stable (0)	Declining
	Haemulidae	0	-	0	→ 0	17	↑ 17	10	↓ -7	-	-	7	↓ -3	-	-	1	1	2	Declining	Declining
	Siganidae	0	-	2	↑ 2	9	↑ 7	10	↑ 1	-	-	9	↓ -1	-	-	0	3	1	Declining	Stable
	Serranidae	0	-	0	→ 0	8	↑ 8	0	↓ -8	-	-	4	↑ 4	-	-	1	2	1	Increasing	Stable
	Sparidae	3	-	0	↓ -3	8	↑ 8	0	↓ -8	-	-	0	→ 0	-	-	1	1	2	Stable (0)	Declining
	Lethrinidae	0	-	0	→ 0	2	↑ 2	21	↑ 19	-	-	21	→ 0	-	-	2	2	0	Stable	Increasing

10.2. Annex 2 – Licenses Issued by Provincial Delegation for the Coordination of Environmental Affairs (DPCA) in the last decade

Projects	District	Category	Proponent	License (year)	Validity (Year)	License number
Tourism Project Cinco Portas	Ibo	B	Projecto Cinco Portas	2006	2011	Jan/06
Tourism Project Arimba	Quissanga	B	Projecto Turistico de Arimba	2008	2013	15/2008
Água de Macomia	Macomia	B	Captação e engarrafamento de água mineral (arbi mussa)	2008	2013	17/2008
Tourism Complex Rural Flor de Messano	Macomia	B	Complexo turísticos Rural Flor de Messano	2008	2013	23/2008
Electrification of administrative posts of Quissanga	Quissanga	C	FUNAE	2008	2013	28/2008-C
Electrification of administrative posts of Macomia	Macomia	C	FUNAE	2008	2013	29/2008-C
Electrification School - Photovoltaic System Macomia	Macomia	C	FUNAE	2008	2013	46/2008-C
Electrification School - Photovoltaic System IBO	Ibo	C	FUNAE	2008	2013	47/2008-C
Electrification of administrative posts of Muaguide	Meluco	C	FUNAE	2008	2013	51/2008-C
Tourism Complex Casa Hospedes Caminho-Norte	Macomia	C	Samuel Machude	2007	2012	13/2007-C
Construction of a gas station	Macomia	C	António Fernandes Sergio	2007	2012	23/2007-C
Construction of a gas station Lojas exito - Macomia	Macomia	C	African Petroleum, Lda	2009	2014	22/2009-C
Construction of a gas station Meluco	meluco	C	FUNAE	2009	2014	24/2009-C
Construction of a gas stationQuissanga	Quissanga	C	FUNAE	2009	2014	26/2009-C
Electrification project Macomia	Macomia	C	FUNAE	2009	2014	5/2009-C
Tourism Complex Casa Hospedes Café do Ibo	Ibo	C	Abdul Satar Abubacar	2010	2015	11/2010-C
Botanical Garden	Ibo	C	Isabel Martins Cort-Fundación Ibo	2010	2015	15/2010-C-Rep
Exploration and Geological Research of Iron and Associate Minerals - Macomia	Macomia	C	Eugenio William Telfer	2010	2015	4/2010-C

Projects	District	Category	Proponent	License (year)	Validity (Year)	License number
Tourism Complex Macomia Lodge	Macomia	B	Complexo turístico Macomia Lodge	2011	2016	Dez/11
Electrification based on Generator Set	Ibo	C	FUNAE	2011	2016	14/2011-C
Ecotourism - Bapbibo de hospedes	Ibo	C	Luma Lda	2011	2016	16/2011-C
Miti Miwiri	Ibo	C	Joeg Salzer	2011	2016	20/2011-C
Tourism Project Pousada Venture 2005, LDA	Ibo	B	Sociedade turistica Venture 2005, Lda	2015	2020	Jan/15
Tourism Project Sakata Lodge	Ibo	C	Mozimbo, Lda	2015	2020	02/2015-C
Tourism Project Messano Flower Lodge	Macomia	B	Messano flower lodge	2014	2019	Jul/14
Tourism Project Eco-vidas Erimbas - Mefuvo LDA	Quissanga	B	Eco-vidas, arimbas mefuvo, Lda	2013	2018	24/2013
Heavy sand exploitation	Quissanga	B	Pemba Combustível Lda	2013	2018	28/2013
Tourism Project Pensão Residencial Caminhos do Norte	Macomia	C	Samuel Machude	2013	2018	29/2013-C
Stone quarry exploration	Quissanga	B	Pemba Combustível Lda	2013	2018	69/2015
Tourism Project Guludo Experience	Macomia	A				
Hydrocarbon exploration and search Area 2 - Rovuma Basin	Ibo/Quissanga	A				

10.3. Annex 3 - Licenses Issued by Provincial Delegation of Mining resources and Energy from Cabo Delgado (* references those inside the QNP)

District	Bidder	License No.	License type	Area (ha)	Covered minerals	Issuance date	Validity	Current status
Moja / Quissanga	Moja Inertes Lda	15/CM/2011	Mining certificate	300	Granitic gneisses	27/08/13	27/08/15	Active
Songueia / Quissanga	Grupo Silda-SECARP Industrial, Lda.	15/CM/2012	Mining certificate	30	Gnaisses	21/12/12	21/12/14	Expired
Songueia / Quissanga	Pedreiras de Cabo Delgado	25/CM/2013	Mining certificate	30	Gnaisses	22/11/13	22/11/15	Active
Quissanga / Bilibiza	Exito Combustíveis, Lda	18/CM/2013	Mining certificate	100	Gnaisses	24/12/13	24/12/15	Active
Quissanga	Exito Combustíveis, Lda	18/CM/2013	Mining certificate	100	Gnaisses	28/08/13	27/08/15	Active
Moja / Quissanga	Pemba Constrution, Lda	31/CM/2013	Mining certificate	152	Granitic and Lgneisses	02/11/13	27/11/15	Active
Quissanga / Oalma	Mapiko, Consultores e Serviços	20/CM/2015	Mining certificate	120,26	imestone s	08/01/15	08/01/25	Certificate to lift
Quissanga / Bilibiza	Manuel Bernardo Gondola		Mining certificate	128,65	Granitic and gneisses			Requested
Quissanga	Manuel Alfredo Brito Gamito		Mining certificate	114,35	Granitic and gneisses			Requested
Ancuabe	Margarita Adamugi Talapa	4638 L	Research and Exploratio n	22780	GEM	20/12/11	20/12/16	Active
Quissanga / Meluco*	Momad Bachir Abú Bacar*	1288 L	Research and Exploratio n	300	STO	28/12/05	28/12/10	Active
Ancuabe	PRODEMO, LDA	7270CM	Mining certificate	312	STO			Pending approval
Meluco	Mwiriti Lda	7499 L	Research and Exploratio n	11419	BME, GRP, MI			Requested

District	Bidder	License No.	License type	Area (ha)	Covered minerals	Issuance date	Validity	Current status
Meluco	Mwiriti Lda	7501 L	Research and Exploration	16672	BME, GRP, MI			Requested
Meluco	Mwiriti Lda	7494 L	Research and Exploration	23189	BME, GRP, MI			Requested
Meluco	Mwiriti Lda	7500 L	Research and Exploration	22371	BME, GRP, MI			Requested
Meluco*	Minas de Meluco, S.A.*	3695 L	Research and Exploration	720	AQU, QTZ, TOU	02/06/10	02/06/15	Active
Meluco*	Guillermina Ernesto Langa*	2504 L	Research and Exploration	2504	MI, TOU			Requested
Meluco	Abú	3667 L	Research and Exploration	1440	AQU, RUB, TOU	12/07/10	12/07/17	Pending extension
Meluco	MIREM	5167 AC	Bidding process	4480	MBME, PME	06/04/11	18/11/13	Active

10.4. Annex 4 – Trend analysis of the most prevalent diseases in Ibo, Macomia, Meluco and Quissanga from 2007 to 2014

District	Most prevalent diseases	2007		2008		2009		2010		2011		2012		2013		2014		Trend analysis				
		Prev.	Trend	Prev.	Trend	Prev.	Trend	Prev.	Trend	Prev.	Trend	Prev.	Trend	Prev.	Trend	Prev.	Trend	Stable	Up	Down	Last year	Possible trend
Ibo	Malaria	0,8	-	34	↑ 33	67,5	↑ 34	42,8	↓ -25	18,8	↓ -24	18,3	↓ -1	16,4	↓ -2	32,9	↑ 17	0	3	4	Increasing	Declining
	Diarrhea	2,2	-	1,9	↓ -0	14,4	↑ 13	13,1	↓ -1	12,9	↓ -0	15,3	↑ 2,4	15,4	↑ 0,1	11,5	↓ -4	0	3	4	Declining	Declining
	Dysentery	4,1	-	3,4	↓ -1	3,6	↑ 0,2	3,9	↑ 0,3	3,5	↓ -0	4,1	↑ 0,6	4,8	↑ 0,7	4,7	↓ -0	0	4	3	Declining	Increasing
	Cholera	0	-	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	0	0	Stable (0)	Stable
	Tuberculosis	0,1	-	0,1	→ 0	0,2	↑ 0,1	0,4	↑ 0,2	0,2	↓ -0	0	↓ -0	0	→ 0	0,5	↑ 0,5	2	3	2	Increasing	Stable-Increasing
Macomia	Malaria	1	-	33,5	↑ 33	61,4	↑ 28	5,4	↓ -56	43	↑ 38	40,6	↓ -2	37,7	↓ -3	51,9	↑ 14	0	4	3	Increasing	Increasing
	Diarrhea	5,5	-	5,8	↑ 0,3	8,1	↑ 2,3	10,5	↑ 2,4	11,2	↑ 0,7	11,8	↑ 0,6	10,8	↓ -1	8	↓ -3	0	5	2	Declining	Increasing
	Dysentery	3	-	2,8	↓ -0	2,6	↓ -0	2,9	↑ 0,3	3,6	↑ 0,7	3,5	↓ -0	2,9	↓ -1	2,7	↓ -0	0	2	5	Declining	Declining
	Cholera	0	-	0	→ 0	0,1	↑ 0,1	0,2	↑ 0,1	0	↓ -0	0	→ 0	0	→ 0	0	→ 0	4	2	1	Stable	Stable-Declining
	Tuberculosis	0,2	-	0,3	↑ 0,1	0,3	→ 0	0,2	↓ -0	0,2	→ 0	0	↓ -0	0	→ 0	0,3	↑ 0,3	3	2	2	Increasing	Stable-Increasing
Meluco	Malaria	1,1	-	38,9	↑ 38	84,7	↑ 46	94,8	↑ 10	86,1	↓ -9	77,2	↓ -9	84,8	↑ 7,6	119,2	↑ 34	0	5	2	Increasing	Increasing
	Diarrhea	10,9	-	12,1	↑ 1,2	14,9	↑ 2,8	15,1	↑ 0,2	12,8	↓ -2	13	↑ 0,2	14,1	↑ 1,1	9,1	↓ -5	0	5	2	Declining	Increasing
	Dysentery	4,1	-	4,3	↑ 0,2	5,2	↑ 0,9	6	↑ 0,8	6,5	↑ 0,5	6,8	↑ 0,3	6,5	↓ -0	5,5	↓ -1	0	5	2	Declining	Increasing
	Cholera	0	-	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	0	0	Stable (0)	Stable
	Tuberculosis	0,2	-	0,2	→ 0	0,3	↑ 0,1	0,4	↑ 0,1	0,4	→ 0	0	↓ -0	0	→ 0	0,4	↑ 0,4	1	0	3	Increasing	Declining
Quissanga	Malaria	2,2	-	24	↑ 22	48,5	↑ 25	52,1	↑ 3,6	53,6	↑ 1,5	48,4	↓ -5	48,5	↑ 0,1	82,4	↑ 34	0	6	1	Increasing	Increasing
	Diarrhea	8,33	-	9,98	↑ 1,7	10,44	↑ 0,5	10,79	↑ 0,4	11,07	↑ 0,3	12,01	↑ 0,9	12,71	↑ 0,7	10,06	↓ -3	0	6	1	Declining	Increasing
	Dysentery	3,2	-	3,2	→ 0	2,9	↓ -0	3,4	↑ 0,5	3,3	↓ -0	3,4	↑ 0,1	3,4	→ 0	3,4	→ 0	3	2	2	Stable	Stable-Declining
	Cholera	0	-	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	→ 0	0	0	0	Stable (0)	Stable
	Tuberculosis	0,1		0,2	↑ 0,1	0,2	→ 0	0,2	→ 0	0,2	→ 0	0	↓ -0	0	→ 0	0,3	↑ 0,3	4	2	1	Increasing	Stable-Increasing