Chapter 8

Environmental Baseline – Onshore

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8 ENVIRONMENTAL BASELINE – ONSHORE

8.1 INTRODUCTION

This chapter provides a description of physical and biological aspects of the Project's onshore environment, and is structured as follows:

- *Section 8.2:* Geology and Terrain;
- *Section 8.3:* Soils and Land Capability;
- *Section 8.4:* Groundwater;
- *Section 8.5:* Hydrology;
- *Section 8.6:* Surface Water Ecology;
- *Section 8.7:* Vegetation;
- *Section 8.8:* Herpetofauna;
- *Section 8.9:* Avifauna;
- *Section 8.10:* Mammals; and
- *Section 8.11:* Summary of Key Environmental Sensitivities.

In order to describe the baseline conditions in the Afungi Project Site (illustrated in *Figure 8.1*), specialists undertook surveys over two seasons and mapped out areas of sensitivity within the Afungi Project Site with respect to their individual disciplines. The terrestrial ecology baseline (*Sections 8.6* to *8.10*) outlines the sensitivities found and identifies habitats that provide important ecological functions or support species of conservation importance [(1)]. It is crucial to note that the sensitive habitats discussed in this chapter indicate sensitivity to change and are not necessarily an indicator of importance relative to other similar habitats that extend for several tens of kilometres south of the Rovuma River. The relative importance of habitats is considered when assessing the degree of significance of potential impacts on those habitats. Together, sensitivity and relative importance are used to provide guidance to the Project with respect to informing site layout mitigation measures.

Reference is made throughout this chapter to the conservation status of species according to the IUCN Red List of Threatened Species (IUCN, 2012), which is further detailed in *Chapter 6*.

(1) The identified habitat types have been characterised as modified or natural and the presence of alien/invasive species have been recorded.

Legend

- Villages / Settlements
- Local Roads
- Regional Roads
- Afungi Project Site

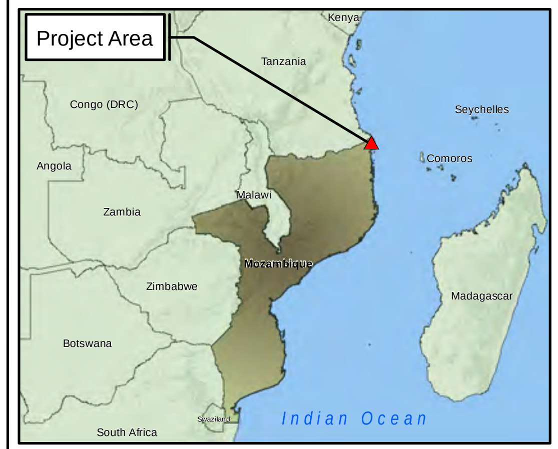

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Figure 8.1: Afungi Project Site

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8.2 GEOLOGY AND TERRAIN

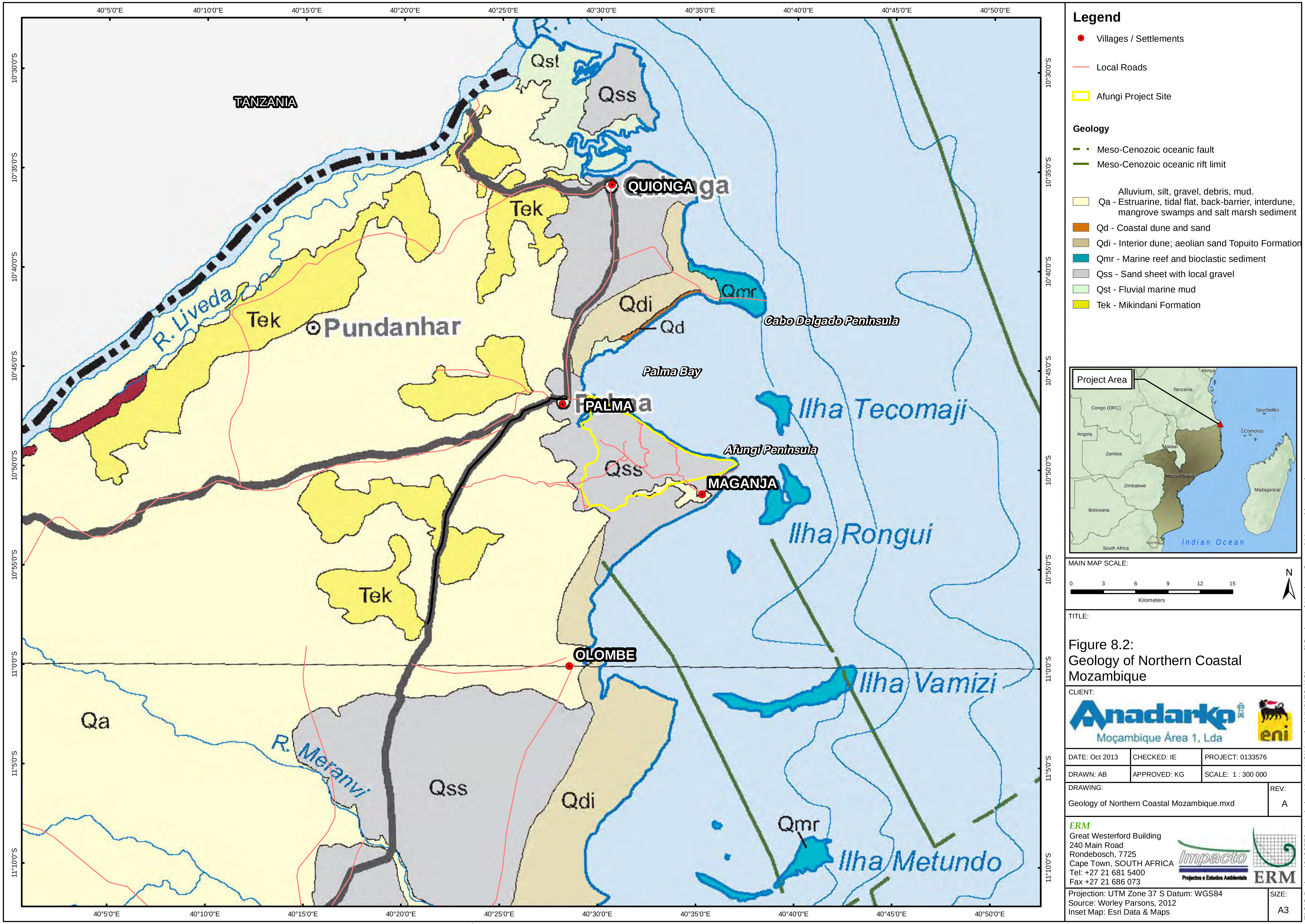
8.2.1 *Regional Geology*

The onshore portion of the Rovuma Basin, consisting of unconsolidated sand deposits, is approximately 120km wide. Broadly, the upper 2,000 to 3,000m of sediments comprises deltaic deposits underlain by Cretaceous age Maconde Sandstone and marlstones, and the upper Cretaceous Pemba Formation Sandstone Member. The regional geology is illustrated in *Figure 8.2*.

Tectonic activity, especially faulting and other displacement over geological time, has created breaks in the continuity of the formations of various ages. Faults are typically oriented north to south and roughly parallel to the coast. These are mostly normal, east side down faults, and are interpreted as listric growth faults through the Tertiary sediments.

The Afungi Peninsula is located in the Rovuma Sedimentary Basin on the coastal plain and consists of undulating topography. The coastal plain was formed by sedimentation and erosion processes active throughout the Neogene geological period and more recent geologic history as extension from the east and uplift in the west contributed to formation of the coastal landforms. Within approximately 5km of the coast, elevations average 30m above sea level. Within 10 to 15km, elevations reach up to 100m. The stratigraphic development is related to the tectonic activity, including offshore rifting as well as uplift and faulting associated with the East Africa Rift System.

The upper 2,000 to 3,000m of sediments formed as an eastern thickening wedge of deltaic deposits—a deltaic progradation (Key et al., 2008). At great depth are the older, Cretaceous age Maconde Sandstone and marlstones, and the upper Cretaceous Pemba Formation Sandstone Member. These older formations are overlaid by fine textured marine sandstones (early Tertiary in age), which are in turn overlaid by the Mikindani Formation, a ferruginous sandstone and conglomerate, the predominant bedrock formation. It is exposed in places through the overlying Quaternary age unconsolidated sediments. Its thickness, according to literature, is variable: 30 to 675m. However, AMA1 reportedly encountered a formation thickness of 1,100m.


TANZANIA
QUIONGA
PALMA
MAGANJA
OLOMBE
Pundanhar
R. Liveda
R. Meranvi
Palma Bay
Cabo Delgado Peninsula
Afungi Peninsula
Ilha Tecomaji
Ilha Rongui
Ilha Vamizi
Ilha Metundo
Qst
Qss
Tek
Qdi
Qd
Qmr
Qa
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40°10'0"E
40°15'0"E
40°20'0"E
40°25'0"E
40°30'0"E
40°35'0"E
40°40'0"E
40°45'0"E
40°50'0"E
10°30'0"S
10°35'0"S
10°40'0"S
10°45'0"S
10°50'0"S
10°55'0"S
11°0'0"S
11°5'0"S
11°10'0"S
Legend
Villages / Settlements
Local Roads
Afungi Project Site
Geology
Meso-Cenozoic oceanic fault
Meso-Cenozoic oceanic rift limit
Qa - Alluvium, silt, gravel, debris, mud. Estruarine, tidal flat, back-barrier, interdune, mangrove swamps and salt marsh sediment
Qd - Coastal dune and sand
Qdi - Interior dune; aeolian sand Topuito Formation
Qmr - Marine reef and bioclastic sediment
Qss - Sand sheet with local gravel
Qst - Fluvial marine mud
Tek - Mikindani Formation
Project Area
Kenya
Tanzania
Congo (DRC)
Seychelles
Angola
Comoros
Malawi
Zambia
Mozambique
Zimbabwe
Madagascar
Botswana
South Africa
Indian Ocean
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8.2.2 *Local Geology*

The Afungi Project Site is located on recent to Tertiary age units with the near-coast areas covered with recent (Quaternary) unconsolidated deposits that include dunes, low coastal deposits and stream sediment deposits, as well as reef and coral formations, lacustrine and tidal zone sediments and surface soils. These deposits are underlaid by the Mikindani Formation; a Miocene–Pliocene age fluvial sandstone and conglomerate formation. Beneath the western portion of the site, the predominately sandy sediments are underlaid by weathered, dark grey, very soft rock siltstone and mudstone at depths varying from approximately 23m to greater than 90m below existing ground level. These sedimentary rocks are probably the Mikindani Formation of Miocene age.

The Mikindani Formation lithology is divided into lower sandstone with basal conglomerate beds overlying an unconformity, and an upper thicker and generally sandier section. The thickness of the formation varies from 30 to 675m (Ferro & Bouman, 1987; Key et al., 2008). The sandstones are described as massive, red-brown and burrow-mottled. The ancient Rovuma River Delta is thought to have deposited much of the Mikindani Formation.

The Afungi Project Site is underlaid by, in descending order, gravel to fine-grained size alluvium, Mikindani Formation sandstone and conglomerate, and deeper Tertiary sandstones and carbonates (AMEC, 2011). Sand dominates 70 percent of the Afungi Project Site and originated from marine alluvial deposits (Insitituto de Investigacao Agronomica de Mocambique, 1972).
A number of faults are present in the area and these are being studied further. These generally trend north-south, roughly parallel to the coast. Most of these are normal, north-striking, east dipping listric faults.

8.3 *Soils and Land Capability*

A soils and land capability study was undertaken within the Afungi Project Site [(1)]. Due to constraints accessing some parts of the site at the time of the fieldwork (due to the risk of UXOs), the baseline surveys were largely restricted to the Onshore Project Footprint Area (ie surrounding areas that had not been declared clear of landmines were avoided). The results were extrapolated for the rest of the Afungi Project Site (Area 2 in *Figure 8.3*), based on specialist interpretation of satellite imagery. These areas are illustrated in *Figure 8.3*.

8.3.1 *Soils and Land Use*

Currently, the main land use within the Afungi Project Site is subsistence agriculture (including cassava, rice and coconut) and minimal livestock

(1) This study was undertaken by Digby Wells Environmental.

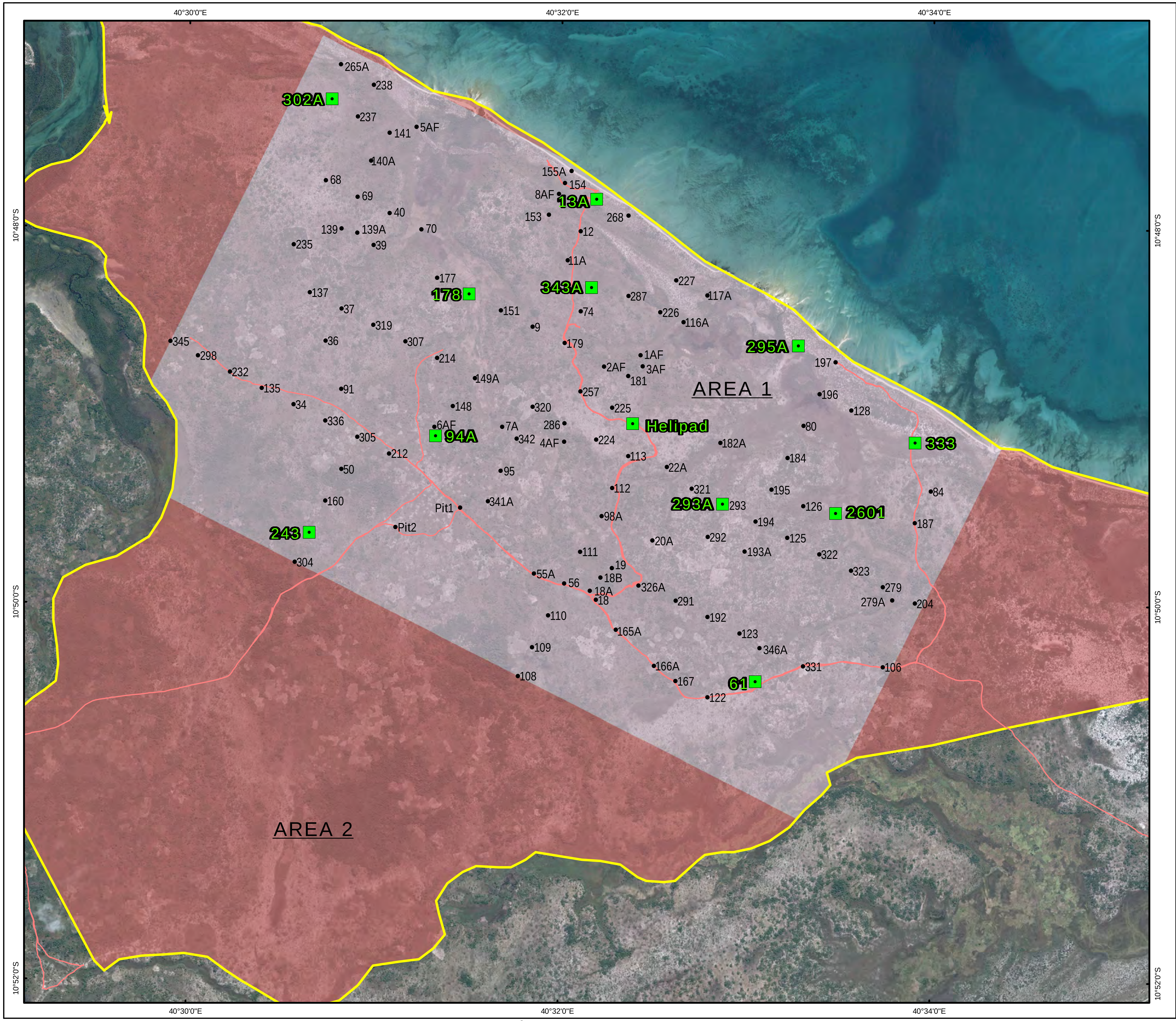
grazing. Small-scale farms or '*machambas*' (fragmented cultivated lands) are evident across the Afungi Project Site between open savannah woodland/bushland. Rice is cultivated in wetlands situated in lowlands along waterways. It is apparent that the local livelihood is dependent on the soil resource.

The soils in the Afungi Project Site comprise two soil units of significance:

- a large area comprising all land outside of the wetland zones (estuaries and marshes). This area comprises deep grey/white sands, referred to as sand units or S-Units; and

- areas representing the wetland zones, which include the estuaries, marshes and drainage course zones. These are referred to as wetland units or W-Units.

The distribution of these two soil units are illustrated in *Figure 8.4*.



Legend

- Soil Sampling Points
- Soil Observations Points
- Local Roads
- Area 1
- Area 2
- Afungi Project Site

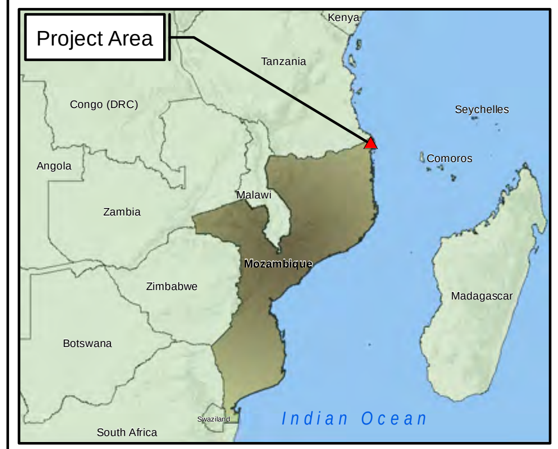


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Figure 8.3:
Soil Study and Survey Areas (including Observation and Sampling Points)

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Legend

- Villages / Settlements
- Local Roads
- Afungi Project Site
- W-Unit- Wetland Unit
- S-Unit- Sand unit

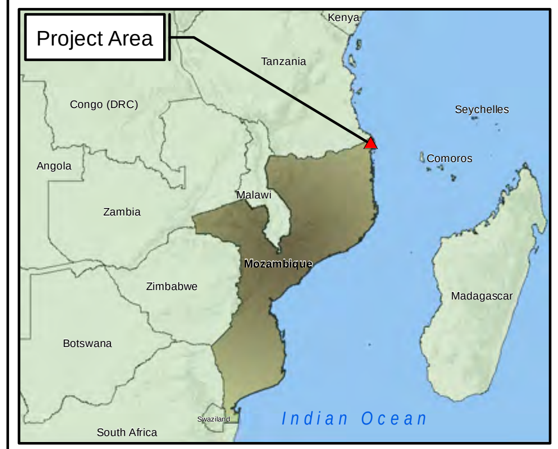

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Figure 8.4:
Distribution of Soil Units

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The Sand Unit (S-Unit)

The majority of the soils encountered outside of the wetland zones in the S-Unit comprise sand of the orthic phase, classified as a Namib soil type (Nb) (1). Infrequent occurrences of the Longlands form were observed, which is typically associated with wetland soils (2).

The physical characteristics of the S-Unit conform to the following:

- topsoil and subsoil (horizons) for the investigated depth of 150cm;
- in most cases, both horizons comprised pure medium to coarse sand and thus were without structure and had a loose consistency;
- the more organic rich topsoil ranged from 10 to 20cm in depth;
- grey-whitish coloured subsoil (quartz grains) made up the rest of the depth;
- clay content in both layers was estimated to be lower than 10 percent [ie pure sand in classification terms (MacVicar et al., 1991)];
- the ever-present process of leaching drains the sand very easily, resulting in inherent low fertility;
- the profile properties provide an inherent extremely high erosion hazard, especially on increased gradients (such as stockpiles); and
- rates for permeability in sands are classed as very rapid. Percolation rates of over 15cm/h serve as a reference (Pitty, 1979); therefore, water-holding capacities will be low.

Given the characteristics described above, the sand cannot be regarded as a high-potential crop production medium. However, due to the sandy nature of the soils, the following risks and sensitivities may arise.

- Constituents transported by surface water could potentially infiltrate rapidly into the sand and pose a risk to underlying groundwater.
- Sand will be highly susceptible to erosion where exposed (site clearance, stockpiles).
- A decrease in the fertility status can be expected during disturbance of the upper layers of the soil profile in which topsoil formation occurs.

(1) Classified according to MacVicar et al., 1991.
(2) Classified according to MacVicar et al., 1991.

Figure 8.5 Typical Profiles of the S-Unit

Left: Point # 135 – a typical sand profile within the Afungi Project Site. Right: Point # 155A – sand profile on the coastline.

Source: Digby Wells, 2012.

The Wetland Soil Unit (W-Unit)

Wetlands can be defined as ecosystems that are transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface, or where the land is periodically covered with shallow water, and where this land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil. [(1)]

A number of soils associated with wetlands were grouped to make the W-Unit. Wetness indicators are a main characteristic of all wetland soils, and are found in the soil in the form of grey colours, often in association with mottles or stains. The grey colouring and mottling are caused by a prolonged exposure to wet and dry phases and are induced by a fluctuating water table. The colour of the mottles can vary between yellow, orange, red and black, and combinations are commonly found. Four main soil types were identified in the delineated wetlands and comprise the greatest percentage of the W- Unit, in accordance with *Soil Classification – A Taxonomic System for South Africa* (Department of Agricultural Development, 1991):

- Ka – Katspruit (wetland soil, permanent wet subsoil);
- Ch – Champagne (organic wetland soil);
- Kd – Kroonstad (wetland soil, permanent wet subsoil); and
- Lo – Longlands (seasonal wet subsoil).

The physical characteristics of these four soil types are summarised in *Table 8.1* and their related properties are outlined below:

(1) Definition from South Africa National Water Act, 1998.

- very dark or greyish top layer varying between 15 and 60cm in depth;
- the dark variations relate to a significant content (5 to 10 percent) of organic carbon. The high organic matter content is also responsible for a heavier soil texture;
- the subsoil comprises grey loamy to clayey layers, showing variations in clay content from 5 to 40 percent. However, variation per soil type is less;
- in some cases, a sandy layer separates the topsoil and clay (Kd and Lo forms);
- infiltration rates will vary from extremely rapid (sands) to very slow (clays); and
- water-holding capacities vary from 60mm/metre in the sandy top (A) and subsoils (B, E, C) to between 90 and 120mm/metre in the heavier textured layers (G).

Figure 8.6 Profiles of the W-Unit

Top left: Point # 196 – Ch or Ka soil type in the W-Unit (note the very dark top layer). Top right: Point # 1AF – Lo profile. Bottom left: Point # 346A – Ch profile (dark topsoil underlaid by sand). Bottom right: Point # 295A – profile in a mangrove area.

Source: Digby Wells, 2012.

Table 8.1 Characteristics of W-Unit Soils

Soil Type Code	% of Wetland Unit	Summarised Description of Soil Type	Depth Interval per Layer (cm)	Estimated Clay Content Range per Layer	Texture Class per Layer	Permeability of Profile
Ka	30	A two-layer soil profile typical of wetland zones. Grey top layers overlie grey mottled clayey bottom layers. Water tables are commonly found.	**A**: 0-10/20 **G**: 10/20-30/100	**A**: 5-40 G: 15-40	**A**: Sand to clay **G**: Sandy loam to loam to clay	Rapid (sand) to very slow (clay)
Ch	30	The soil profile occurs in parts of wetlands with abundant vegetative cover. Very dark organic-rich top layers characterise the profile to depths beyond the usual 20/30cm and overlie sand to grey loamy bottom layers, occasionally dark blotched.	**O**: 0–20/60 **C**: 20/60–60/140	**O**: 10–35 **C**: 5–20	**O**: Silty loam to silty clay loam **C**: Sand to loam/silty loam	Moderate to rapid
Kd	20	A three-layer soil profile typical of wetlands. Beneath top sand, a leached sandy sub-layer overlies an orangey spotted and streaked bottom layer with significantly heavier texture.	**A**: 0–20/30 **E**: 20/30–30/75 **G**: 30/75–50/130	**A**: ≤5 **E**: ≤5 **G**: 15–35	**A**: Sand **E**: Sand **G**: Sandy loam to clay loam	Rapid (sand) to very slow (clay
Lo	15	A three-layer soil profile typical of wetlands and similar to the Kd for the first two layers, after which a somewhat heavier textured and mottled bottom layer follows.	**A**: 0–10/30 **E**: 10/30–30/120 **B**: 30/120–60/135	**A**: ≤5 **E**: ≤5 **B**: 5–20	**A**: Sand **E**: Sand **B**: Sand to sandy loam	Rapid

Source: Digby Wells, 2012.

The W-Units are regarded as highly sensitive due to their important functioning in the ecosystem, and for the following reasons:

- Wetlands play an important role in surface drainage and serve as a mechanism to recharge the groundwater system.

- Contamination of wetlands may lead to the transportation of potentially hazardous elements to the soil resource adjacent to and beneath them, posing potential risk to groundwater resources and nearby coastal waters.

8.3.2 Land Capability

A combination of terrain form, soil types, thickness and slope gradients in association with broad agricultural potential, define the land capability of an area (GDACE, 2008). Land capability can also be defined as an interpretive grouping of land units with similar potentials and continuing limitations or hazards. Land capability is a more general term than land suitability and is more conservation orientated. Land capability is also defined as the most intensive long-term sustainable use of land under rain-fed conditions. Land capability should aim to provide an objective basis for establishing post-use capability targets. Based on these definitions, two land capability classes were assigned for the Study Area (*Figure 8.7*):

- a combination of arable (1) (A)and grazing (G) capability ('A/G') for the S-Unit; and

- a wetland capability for the W-Unit.

Land Capability of the S-Unit

Where commercial cropping is practised, a grazing capability class would most probably be assigned to the Survey Area, due to factors such as low fertility and easily leachable status. The low fertility and ready leaching would require high management and cost inputs that would, in most cases, exclude it from a cropping production recommendation. In the Survey Area, the current land use is for food production exclusively. The land capacity of the S-Unit is considered to include a combination of grazing and arable capability.

Land Capability of the W-Unit

The wetland areas are defined in terms of the wetland delineation guidelines, which use hydrology, soil topography and vegetation criteria to define the limits of these areas. The zone is dominated by hydromorphic and organic soils and plant life that are associated with the wetland. Two of the four main soils found in the wetland zones are associated with permanent wetland zones (DWAF, 2003).

(1) Arable describes land that can be cultivated for growing crops.

The soils of the wetlands in the Survey Area are grey to black in the topsoil horizons. Transported clays, with pronounced mottling on gleyed backgrounds, characterise the subsoils. The soils occur within the zone of groundwater influence. The combination of soil types and hydromorphic vegetation was used to derive the wetland land capability classification for the W-Unit.

8.3.3 Soil – Chemical and Physical Properties

Table 8.3 contains the soil analytical results for the dominant soil types observed in the Study Area. The sampling locations are illustrated in *Figure 8.3*.

Organic carbon (C) in the topsoil ranges from 0.12 to 0.73 percent in the sandy topsoils. Generally soils with a C content of around 1 percent can be cultivated. Soil with a C content of less than 1 percent is considered to be low but expected for soil under tropical climatic conditions. The W-Unit soil, however, contains between 4.96 and 10.01 percent C. This is to be expected, because organic material cannot be oxidised easily under permanent waterlogged soil conditions and therefore accumulates in the topsoil.

The sodium (Na) content of the soil samples is generally high in relation to calcium (Ca), magnesium (Mg) and potassium (K). Na accumulates in soils because of the close proximity of the sea. The exchangeable sodium percentage (ESP column in *Table 8.2*) indicates the ratio of Na to the total Ca, Mg and K soil content. Generally, soil physical problems can be expected when the ESP exceeds five. Na is a large hydrated ion and causes clay dispersion if it is present in high concentrations on the soil clay exchange complex compared to other cations present [(1)]. Dispersion of clay particles will block soil pores, preventing rainwater infiltration. The clay content is, however, low and might not prevent the infiltration of rainwater.

Phosphorus (P) or fertility status, as outlined in *Table 8.2*, is low. P is an important macronutrient and the P content, with a low of 1 and a high of 5mg $kg^{-1,}$ is considered very low and indicative of very poor P soil status. Generally, soil P content needs to be 20-30 mg kg^{-1} to sustain agricultural crops.

The K fertility status of the soils is low. K is also an important macronutrient needed for optimal crop production. Generally, the soil K content needs to be 200mg kg^{-1} to sustain agricultural crops.

The topsoil pH ranges from 4.6 to 6.3. This pH range is indicative of acidic soil conditions, not only in the topsoil but also in the subsoil. A liming programme would be needed to optimise soil fertility if gardening is considered. An optimal soil pH is considered to be pH 6.5.

1) A positively charged ion.

Legend

- Villages / Settlements
- Local Roads
- Afungi Project Site
- W: Wetland
- A/G: Arable / Grazing

MAIN MAP SCALE:

0 1 2 3
Kilometers

N

TITLE:

Figure 8.7:
Land Capability

CLIENT:

Anadarko Moçambique Área 1, Lda

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 50 000

DRAWING:	REV:
Land Capability.mxd	A

ERM
Great Westerford Building
240 Main Road
Rondebosch, 7725
Cape Town, SOUTH AFRICA
Tel: +27 21 681 5400
Fax +27 21 686 073

Impacto Projectos e Estudos Ambientais

ERM

Projection: UTM Zone 37 S, Datum: WGS84 Source: Bing Maps ©2010 Microsoft Corporation. Digby Wells, 2012. Inset Map: Esri Data & Maps	SIZE: A3

T:\GIS Projects\0133576_Anadarko_Moz_LNG\Mapping\MXD\ESIA\Chapter8\Land Capability.mxd

The soils in this area have a low cation exchange capacity (CEC). A low CEC reflects low soil clay and organic matter content because CEC is a property of both clay and organic material. The CEC ranges from 0.89 to 7.22cmol (+)kg^{-1} for the non-waterlogged topsoils. Low CEC implies low nutrient content, while the opposite is true for high CEC. The topsoil CEC of the waterlogged soil is 7.22 to 23.22cmol (+)kg^{-1}, indicating the build-up of organic matter in the topsoil due to the waterlogged conditions.

The size limits for sand, silt and clay used in the determination of soil texture classes are sand: 2.000 to 0.050mm, silt: 0.050 to 0.002mm and clay: < 0.002mm. The clay content range is from 1.9 to 6.5 percent in the topsoil, while the subsoil has similar clay content. The clay content of the two waterlogged topsoil samples is higher: 10.8 percent and 18.9 percent. Higher clay content is expected, because the position of the waterlogged soil in the landscape allows clay to accumulate over time.

Table 8.2 Chemical and Physical Properties of the Dominant Soils Present

Sample Point	ESP %	Org C %	CEC Cmol (+) kg^{-1}	K mg kg^{-1}	Ca mg kg^{-1}	Mg mg kg^{-1}	Na mg kg^{-1}	P (Bray1)mg kg^{-1}	pH (H_2O)	Sand %	Silt %	Clay %
AMA1 178A	56.34	0.73	3.34	120	94	135	433	1	4.6	90.1	3.4	6.5
AMA1 178E									4.7	96.8	1.2	2.0
AMA1 178G									4.8	94.5	1.2	4.3
AMA1 243A	32.49	0.26	0.89	17	289	45	66	5	5.4	97.0	1.1	1.9
AMA1 243C									5.7	97.0	1.1	1.9
AMA1 2601A	14.43	10.06	23.20	498	804	923	770	1	5.4	60.4	28.8	10.8
AMA1 2601G									5.9	77.6	6.0	16.4
AMA1 2601C									5.4	92.6	1.2	6.2
AMA1 61A	10.19	0.16	1.08	17	47	35	25	1	4.8	97.0	1.1	1.9
AMA1 61C									5.3	97.0	1.1	1.9
AMA1 293A	2.77	1.66	10.83	121	415	302	69	2	5.0	77.4	3.7	18.9
AMA1 333A	89.76	0.12	0.94	34	16	53	195	1	4.5	97.0	1.1	1.9
AMA1 333G									5.1	94.8	1.1	4.0
AMA1 295A	53.88	4.98	7.22	501	673	1,429	895	2	5.5	94.7	1.2	4.1
AMA1 295E									5.9	97.0	1.1	1.9
AMA1 94A	30.80	0.30	0.96	44	200	51	68	1	5.8	96.9	1.1	1.9
AMA1 94E									5.9	96.9	1.1	1.9
AMA1 94B									5.4	96.8	1.2	2.0
AMA1 13A	5.64	0.72	0.69	29	410	44	9	4	6.3	97.0	1.1	1.9
AMA1 13C2									6.6	97.0	1.1	1.9
AMA1 13C3									7.2	97.0	1.1	1.9
AMA1 343A	1.94	1.32	3.28	40	15	20	15	3	5.6	96.8	1.2	2.0
AMA1 343C									5.3	96.9	1.1	2.0
AMA1 302A	30.82	0.11	0.02	22	3	21	1	1	5.0	97.0	1.1	1.9
AMA1 302C									5.4	97.0	1.1	1.9
AMA1Helipad A	6.19	0.11	0.21	27	57	28	3	1	5.0	97.0	1.1	1.9
AMA1Helipad C									5.3	97.0	1.1	1.9

Source: Digby Wells, 2012.

8.3.4 *Soil Erodibility*

One of the key sensitivities of the soil in the Survey Area is the risk of erosion taking place where natural vegetative cover has been removed. Erodibility is defined as the vulnerability or susceptibility of a soil to erosion. It is a function of both the physical characteristics and the treatment of the soil. Both forms of erosion (wind and water) selectively carry off fine particles from the soil surface, and both are eliminated by mulching the soil or by providing an adequate plant cover. Wind erosion is very selective, carrying the finest particles, particularly organic matter (clay and loam), for many kilometres. Loamy sand, rich in particles between 10 and 100 microns in size, is the most vulnerable soil (Bagnold, 1937). More clayey soil is much stickier and better structured, and hence more resistant to wind erosion. Coarse sand is also more resistant, since the particles are too heavy to be removed by wind erosion. The less structure-improving matter a soil has on the surface (organic matter, iron and free aluminium, lime), the more susceptible it will be to erosion. Soil moisture increases the cohesion of sand and loam, temporarily preventing their erosion by wind.

Inferred erodibility for the soils of the Survey Area is illustrated in *Table 8.3*. It is evident that nearly all of the soils (top to bottom) observed are highly erodible. Where the soil will be disturbed by activities including site clearance, removal, stockpiling, infill, levelling and grading, erosion will need to be managed carefully.

Table 8.3 Erodibility of the Soils

Horizon per Soil	**Soil Type**	**Texture**	**Structure**	**Organic Matter Content**	**Slope Gradient (%)**	**Erodibility**
A (top)	Nb, Kd, Lo	Sand	Loose medium/ coarse single-grained	Low	0–2	High
A (top)	Ka	Sand to clay loam	Loose medium/ coarse-grained to coarse block	Low to moderate	0–2	Moderate to high
E (sub)	Kd, Lo	Sand	Loose medium/ coarse-grained	Very low	0–2	High
G (bottom)	Ka, Kd	Sandy loam to clay	Massive to coarse block	Very low	0–2	High
B (bottom)	Lo	Sand to sandy loam	Loose to massive	Very low	0–2	High
C (sub)	Nb	Sand	Loose medium/ coarse-grained	Very low	0–2	High
O (top)	Ch	Silty loam to silty clay loam	Massive to weak block	High	0–2	Low
C (sub)	Ch	Sand to loam	Loose single grains to massive	High	0–2	Low

Source: Digby Wells, 2012.

8.3.5 *Agricultural Potential*

Agricultural potential of the soils in the Survey Area is determined by a combination of soil depth, soil properties and climatic conditions. The dominating soil occurring in the Survey Area is deep sand, well drained and low in soil fertility. The average rainfall in the area is very high, and this specific climate and soil combination results in low arable agricultural potential due to low fertility, a situation common in the tropics of Africa.

8.4 GROUNDWATER

8.4.1 *Context*

A groundwater study was conducted to establish the baseline conditions of the Afungi Project Site. Secondary data, including groundwater well data from adjacent areas, was used to assist in characterising the baseline, while primary data was collected within the Survey Area between February and December 2012 (see methodlogy in *Annex C*).

8.4.2 *Regional Hydrogeology*

MacDonald and Davies (2000) report that aquifers in the younger littoral deposits of calcarenites and reef limestone are the most productive, and that the fractured or weakly cemented sandstones, such as those in the northern coastal Mozambique region, can provide higher aquifer yields and are suited to large-scale development. For example tertiary sandstone aquifers, such as in the Mikindani Formation, are capable of specific capacities ranging from 0.13 to 1.1m^3/hr/m.

Aquifers in the younger littoral carbonates potentially offer more production with specific capacities of 0.53 to 3.3m^3/hr/m. However, these shallower aquifers are typically more mineralizsed and (with Total Dissolved Solid (TDS) concentrations greater than 1,000mg/l) and are considered to be vulnerable to saline water intrusion which is reported to have occurred in some areas as a result of over-abstraction (Ferro and & Bouman, 1987; Steyl &and Dennis, 2009). The groundwater quality of deeper aquifers is reportedly good, with TDS concentrations below 300mg/l.

The Quaternary alluvium aquifer has, in places, been exploited for supplies in the coastal areas (Smedley, 2002), especially along the main rivers where the alluvial deposits are better developed. Further, sand and gravel aquifers along floodplains, particularly where annual flooding provides recharge, can contain significant amounts of groundwater (MacDonald and & Davies, 2000) and higher specific capacities can occur.

8.4.3 *Local Hydrogeology*

Groundwater Occurrences

The main aquifer in the study area is a primary intergranular delivering yields of between 0.5 and 10L/s. Aquifer testing of groundwater exploration boreholes indicated relatively high aquifer transmissivities (T) ranging from $2 \cdot 10^0$ to $2 \cdot 10^2 m^2/d$. Relatively shallow groundwater conditions occur beneath the Afungi Project Site with differences in water levels being apparent, which is attributed to the presence of locally developed lenses of silt and clay. Based on the available geological information, indications are that there is no ubiquitous confining layer separating a shallow aquifer from a deeper aquifer.

Groundwater Elevations and Flow Direction

Groundwater levels range from 0.5 to 69.4 metres below ground level (mbgl). Shallower water levels were measured close to Palma Bay in the east and in low lying areas. Available data indicates shallower groundwater levels at the end of the rainy season (April) than in the dry season with fluctuations in the order of up to a few metres.

The groundwater flow direction across Afungi Project Site is generally to the east and south-east in the general direction of the coast. However, this varies locally due to groundwater discharge into drainage features such as rivers and wetlands.

Groundwater Recharge

Stable isotope data provide evidence that the groundwater in the area is fed by rainwater recharge, and that there are no differences in recharge source across the area. Considering the local geology, hydrology and hydrogeology, it is assumed that rapid direct recharge of rainfall occurs, as evidenced from site rainfall data and groundwater levels. Further, indications are that the topographic high to the west of the Afungi Project site is an area of recharge.

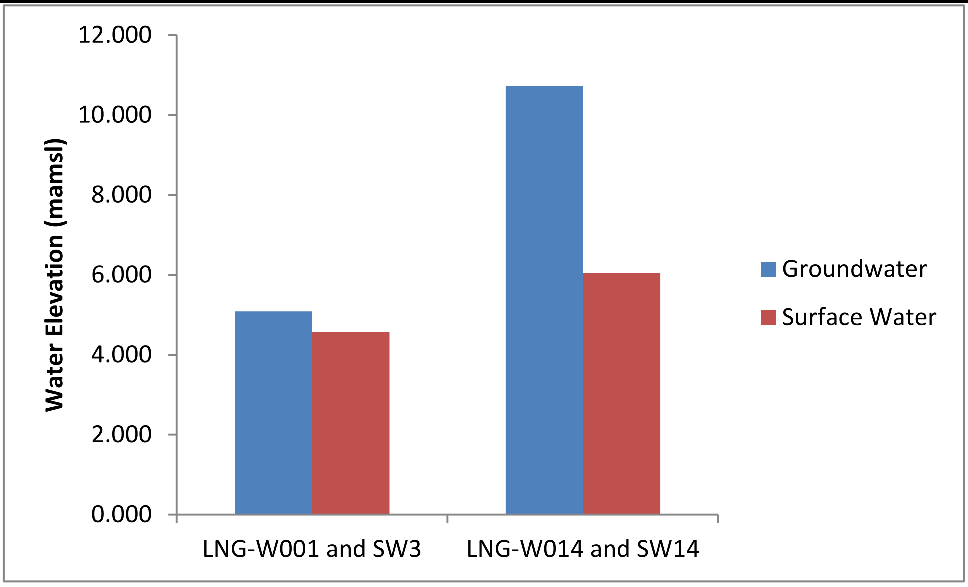
Ferro and Bouman (1987) described the aquifer recharge rates as being medium to high relative to other areas of Mozambique. Smedley (2002) assigned aquifer recharge rates of between 100 to 300mm/year for the region. This corresponds to a groundwater recharge rate of 9-26% of the mean annual precipitation at Palma of 1,165mm/year.

Surface Water – Groundwater Interaction

A comparison of water elevations in boreholes and surface water features indicates that the groundwater elevations are higher and that the surface water features are gaining systems, ie surface water features are receiving groundwater discharge (*Figure 8.8*). However, the spatial distribution of available data points with regards to surface water - groundwater interaction is limited, and hence the interaction between groundwater and the streams and wetlands remains poorly understood.

Based on field observations, it is currently assumed that groundwater discharges into streams and wetlands in areas close to the coast. It is also assumed that groundwater is in direct contact with the estuaries and the sea within Palma Bay.

Figure 8.8 *Comparison of Groundwater and Surface Water Elevations*



8.4.4 *Groundwater Field Assessment*

The groundwater field assessment consisted of (i) a hydrocensus (two initial field visits) to identify existing groundwater points and sensitive receptors, and perform baseline groundwater sampling during dry and wet season and (ii) an intrusive study including borehole drilling, aquifer testing and groundwater sampling. The findings are outlined below.

Hydrocensus

Two initial field visits were conducted, with the first being in February 2012 (dry season) and the second during May 2012 (wet season). A total of 20 existing water abstraction points were visited, including:

- Four community supply boreholes equipped with handpumps;
- Seven shallow hand-dug wells close to streams for community use;
- Seven monitoring boreholes installed by AMA1 (piezometers installed in geotechnical boreholes);
- One borehole at the Palma site camp; and
- One *dambo* (wetland area).

A description of the hydrocensus points is provided in *Table 8.4* and the locations of the hydrocensus points indicated in *Figure 8.9.*

Table 8.4 Location and Description of Hydrocensus Points

Well No.	Description	Latitude	Longitude	Altitude (amsl)	Topographical Setting	Comment
HC1	Handpump	10.82264	40.52168	30m	Flat surface	Working handpump in middle of village
HC2	Handpump	10.82222	40.52192	31m	Flat surface	Non-working handpump in middle of village
HC3	Handpump	10.82161	40.52272	29m	Flat surface	Working handpump in middle of village
HC4	Well	10.81800	40.52734	14m	Along stream	Hand-dug well next to stream
HC5	Well	10.82238	40.53188	13m	Along stream	Hand-dug well next to stream
HC6	Well	10.82039	40.56497	11m	Along stream	Hand-dug well next to stream
HC7	Well	10.81828	40.56903	8m	Along stream	Hand-dug well next to stream/beach
HC8	Well	10.81344	40.54964	9m	Next to mangrove	Hand-dug well next to stream/mangrove
HC9	Well	10.81087	40.50038	19m	Along stream	Hand-dug well next to stream
HC10	Handpump	10.84521	40.47839	51m	On hill	Working handpump in middle of village
HC11	Well	10.84782	40.47372	31m	Along stream	Hand-dug well next to stream
AF06	Borehole	10.81806	40.54095	15m	Flat surface	Piezometer installed in geotechnical borehole
AF14	Borehole	10.80762	40.53704	14m	Flat surface	Piezometer installed in geotechnical borehole
AF17	Borehole	10.80532	40.54504	10m	Close to ocean	Piezometer installed in geotechnical borehole
AF18	Borehole	10.80769	40.54285	12m	Flat surface	Piezometer installed in geotechnical borehole
AF19	Borehole	10.81248	40.54038	15m	Flat surface	No sample due to obstruction in borehole
AF20	Borehole	10.83976	40.50328	36m	Flat surface	Piezometer installed in geotechnical borehole
AF21	Borehole	10.80037	40.51055	26m	Flat surface	No sample due to obstruction in borehole
Camp	Borehole	10.76145	40.47345	24m	On hill	Borehole supplying the Palma Camp
Dambo	Wetland	10.84061	40.46881	38m	On hill	*Dambo*

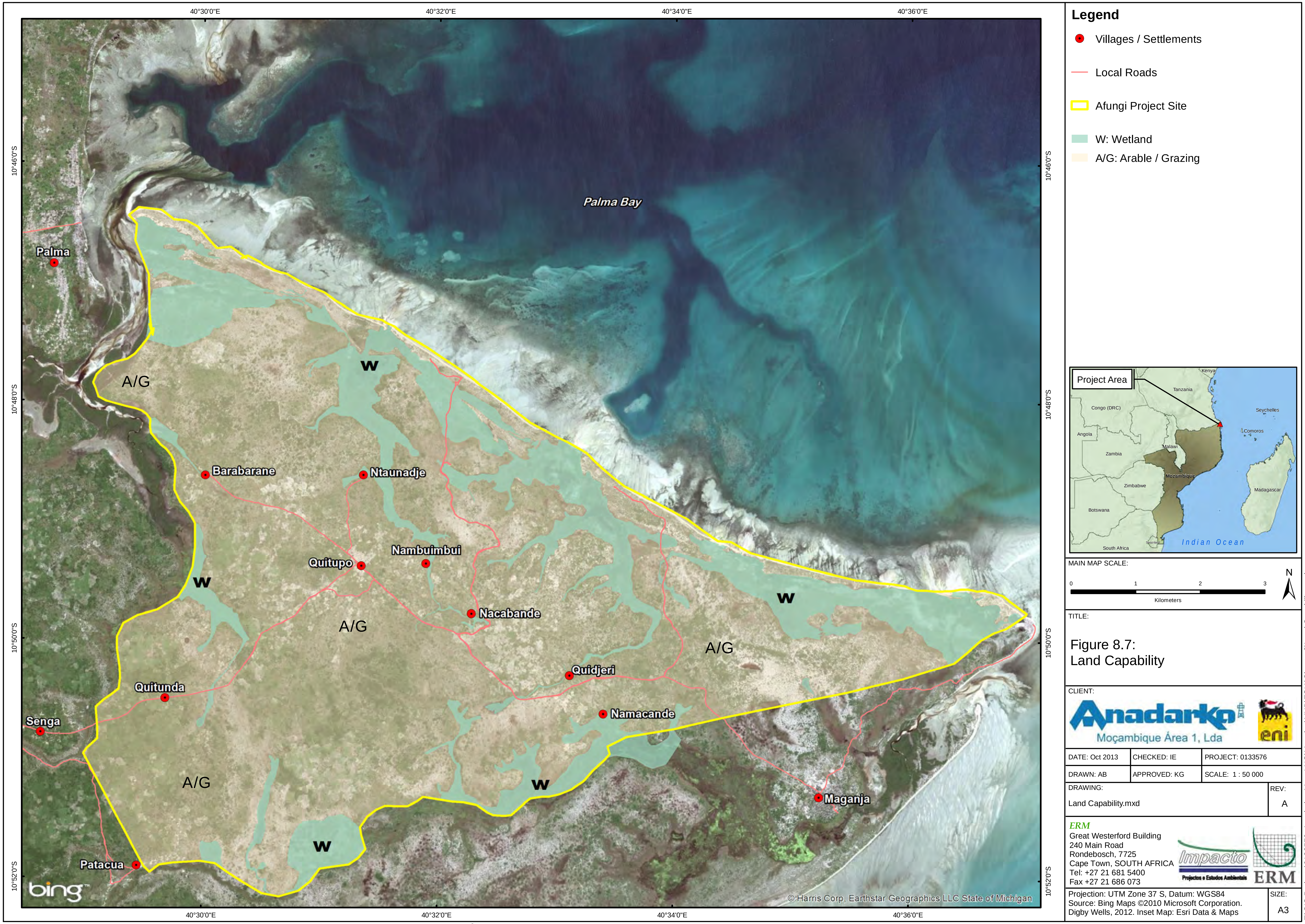


Figure 8.7:
Land Capability

Local communities use groundwater mainly for domestic purposes including drinking and, to a lesser extent, for livestock watering, irrigation and construction. The main source of water for communities and farmers in the area is from hand-dug wells, boreholes equipped with handpumps and surface water from several perennial streams that are present in the area. The following figures show common domestic-use well types.

Figure 8.10 Typical Community Borehole Equipped with Handpump (Senga Village)

Source: ERM, 2012.

Figure 8.11 Typical Hand-dug Well Used for Community Water Supply

Source: ERM, 2012.

Intrusive Investigation

Between August and September 2012, 14 boreholes were drilled under ERMs supervision to depths of between 35 and 90m. Five of these were drilled specifically for environmental monitoring purposes, six to assess Project water supply (groundwater exploration boreholes), and three to serve as water supply boreholes for local communities. Blow yields of between 0.3 and 10L/s were obtained. Details of these boreholes are provided in *Table 8.5* and the location is indicated in *Figure 8.9*.

Aquifer testing was carried out on each of these boreholes to determine hydrogeological parameters including transmissivity and hydraulic conductivity, and to assess the capacity of the aquifer for water supply.

Groundwater samples were taken from these 14 boreholes and an additional four boreholes supplying the Projects camps in December 2012 during the dry season. This data was collected to supplement the baseline data and additional parameters were analysed to perform groundwater fingerprinting. Newly installed community boreholes LNG-W008 and LNG-W009 could not be sampled. LNG-W008 could not be sampled as the installed hand pump was broken and LNG-W009 did not contain sufficient water for sampling.

Table 8.5 Details of Boreholes Drilled between August and September 2012

BHID	**Purpose**	**X (m)**	**Y (m)**	**Elevation (mamsl)**	**Depth of BH (m)**	**Blow Yield (L/s)**
LNG-W001	Project Water Supply	667930	8804020	16.59	90	4
LNG-W002	Project Water Supply	668207	8803800	16.69	39	4
LNG-W003	Project Water Supply	663784	8799918	32.16	60	3
LNG-W004	Project Water Supply	664354	8800548	25.95	60	3
LNG-W005	Project Water Supply	665479	8800537	21.15	60	3
LNG-W006	Project Water Supply	665235	8800562	20.68	60	10
LNG-W007	Community Water Supply	648678*	8791683*	89*	84	1
LNG-W008	Community Water Supply	661173*	8810343*	29*	60	2
LNG-W009	Community Water Supply	632160*	8812730*	78*	85	0.3
LNG-W010	Environmental Monitoring	668864	8805421	4.94	50	3
LNG-W011	Environmental Monitoring	673967	8800273	4.63	45	3
LNG-W012	Environmental Monitoring	663491	8804139	10.39	37	3
LNG-W013	Environmental Monitoring	660837	8800409	20.99	35	6
LNG-W014	Environmental Monitoring	666381	8799042	13.08	40	6

Notes: Datum WGS84, Projection UTM 37L
*Co-ordinates and elevation recorded using a hand-held GPS
Mamsl Metres above mean sea level

8.4.5 Baseline Groundwater Quality

Groundwater samples were taken during three different sampling campaigns being (i) hydrocensus dry season (February 2012), (ii) hydrocensus wet season (May 2012) and (iii) intrusive investigation dry season (December 2012) as described in *Section 8.4.4*. Data gathered from the following boreholes has been used to describe the quality of the groundwater according to the following groupings:

- Community boreholes equipped with handpumps (HC1, HC3, HC10 and LNG-W007);
- Shallow hand-dug community wells (HC4 to HC9 and HC11);
- Project water supply exploration boreholes (LNG-W001 to LNG-W006);
- Camp water supply boreholes (Palma Camp 2 and 3, BGP Main and Bactec Camp 1);
- Environmental monitoring boreholes (LNG-W010 to LNG-W014); and
- Piezometers installed in geotechnical boreholes (AF06, AF14, AF17 to AF20).

Analytical results of groundwater samples were screened against the Mozambican Water Quality Standards for Human Consumption (Ministerial Diploma no. 180/2004, of 15 September) and the World Health Organisation Drinking Water Quality Guidelines (WHO, 2011). The specific water quality standards are presented in *Table 8.6* below.

Table* 8.6 *Drinking Water Standards

onstituent	Unit	WHO (2011)	Mozambican Guideline (Ministerial Decree no. 180/2004)
Major Ions			
Calcium as Ca	mg/l		50
Magnesium as Mg	mg/l		50
Potassium as K	mg/l		
Sodium as Na	mg/l	200	200
Fluoride as F	mg/l	1.5	1.5
Sulphate as SO_4^2	mg/l	500	250
Chloride as Cl	mg/l	250	250
Nitrate as NO_3	mg/l	50	50
Nitrite as NO_2	mg/l	3	3
Ortho Phosphate as PO_4	mg/l		
Ammonium as NH_4	mg/l		1.5
Total Nitrogen as N	mg/l		
Total Alkalinity as $CaCO_3$	mg/l		
Total Hardness as $CaCO_3$	mg/l		500
Trace Elements (Metals)			
Aluminium as Al	µg/l	200	200
Antimony as Sb	µg/l	20	
Arsenic as As	µg/l	10	10
Barium as Ba	µg/l	700	700
Beryllium as Be	µg/l	12	
Bismuth as Bi	µg/l		
Boron as B	µg/l	2400	300
Cadmium as Cd	µg/l	3	3
Total Chromium as Cr	µg/l	50	50
Cobalt as Co	µg/l		
Copper as Cu	µg/l	2000	1000
Iron as Fe	µg/l	2000	300
Lead as Pb	µg/l	10	10
Lithium as Li	µg/l		
Manganese as Mn	µg/l	400	100
Mercury as Hg	µg/l	6	1
Molybdenum as Mo	µg/l	70	70
Nickel as Ni	µg/l	70	20
Selenium as Se	µg/l	40	10

Zinc as Zn	µg/l	3000	3000
Hydrocarbons			
Benzene	mg/l	0.01	
Toluene	mg/l	0.7	
Ethylbenzene	mg/l	0.3	
Xylenes	mg/l	0.5	
Naphthalene	mg/l		0.0001*

Notes: * Guideline value for polycyclic aromatic hydrocarbons

Community Boreholes Equipped with Handpumps

Community borehole HC3 complies with drinking water standards. HC1 and HC10 both exceeded standards for electrical conductivity (EC) and HC10 exceeded standards for Pb in one sampling round (dry season). The newly installed community water supply borehole at Moia, LNG-W007, exceeded the applicable standards for Pb and the measured pH was below the range recommended by the applied guidelines.

Shallow Hand-Dug Community Wells

Shallow hand-dug wells generally comply with applied standards with a few exceptions, these being HC5 (EC) and HC6 (Mn). Both exceedances were found in the dry season, however, HC5 was not sampled in the wet season.

Project Water Supply Exploration Boreholes

Each of the Project water supply exploration boreholes exceeds drinking water guidelines for a few constituents as follow: LNG-W001 (Na, Cl, Fe, Pb), LNG-W002 (Pb), LNG-W003 (pH), LNG-W004 (pH, Pb), LNG-W005 (Fe) and LNG-W006 (Fe).

Camp Water Supply Boreholes

In the camp water supply boreholes, the following screening levels are exceeded: BGP Main (pH), Palma Camp 2 (EC, Na, Cl, Pb), Palma Camp 3 (Ca, Na, Cl) and Bactec Camp 1 (Pb).

Environmental Monitoring Boreholes

LNG-W014 fully complies with the applied standards. Following exceedances were noted in the other environmental monitoring boreholes LNG-W010 (EC, Ca, Mg, Na, SO_4, Cl, B, Fe, Mn) and LNG-W011 (pH, Cl, Fe), LNG-W012 (Fe) and LNG-W013 (pH).

Piezometers Installed in Geotechnical Boreholes

AF18, AF19 and AF20 fully comply with applied standards. AF06 exceeded the WHO standard for Mn slightly in the wet season and AF14 exceeded Ca, Fe and Mn in the dry season.

Constituents of Concern – Drinking Water Quality

Sodium, chloride, calcium, sulphate, magnesium, iron and manganese are likely to affect the taste of the groundwater, while lead and boron present potential health risks. Boron was found above the levels outlined in *Table 8.6* at LNG-W010, which is located in close proximity to the coast at Palma Bay. As the groundwater from LNG-W010 will not be abstracted for potable purposes, lead is the sole constituent of concern. Lead was found in a number of boreholes at concentrations between 10.3 and 18.8µg/L, exceeding applicable drinking water standards (10.0µg/L). Affected boreholes include two community boreholes LNG-W007 and HC10, two groundwater production boreholes (Palma Camp 2 and Bactec Camp) and three groundwater exploration boreholes (LNG-W001, LNG-W002 and LNG-W004). It is recommended that the lead concentrations that have been detected are confirmed in future groundwater sampling rounds and if found to persist, the effected groundwater should be treated to remove lead before used for human consumption.

8.4.6 *Groundwater Fingerprinting*

Ion Ratios

The cations observed are generally Na-dominated, while anions vary from alkalinity (carbonate (CO_3^{2-}) + bicarbonate (HCO_3^-)) to chloride dominated. Generally those samples which are alkalinity-dominated have lower salinity than the chloride dominated samples. The chloride-dominance appears to increase with borehole depth and is greater in boreholes closer to the ocean (ie LNG-W010). Following four geochemical signatures are apparent:

- Group 1: Na-alkalinity signature – LNG-W002, W005, W006 and W014 have salinities ranging from 10 – 22mS/m;
- Group 2: Na- Cl-alkalinity-SO_4 signature – LNG-W004, W012, W013, Bactec Camp 1 and BGP Main have higher salinities (23-67mS/m);
- Group 3: Na -Cl-alkalinity signature – LNG-W003 and W007. Salinities range from 70 – 81mS/m; and
- Group 4: Na-Cl-SO_4 signature – LNG-W001, W010, W011, Palma Camp 2 and Palma Camp 3 have higher salinities than the other samples (114-731mS/m). Most of these samples have a Na:Cl ratio similar to that of seawater, suggesting that the aquifer from which groundwater is being abstracted may be affected by saline intrusion.

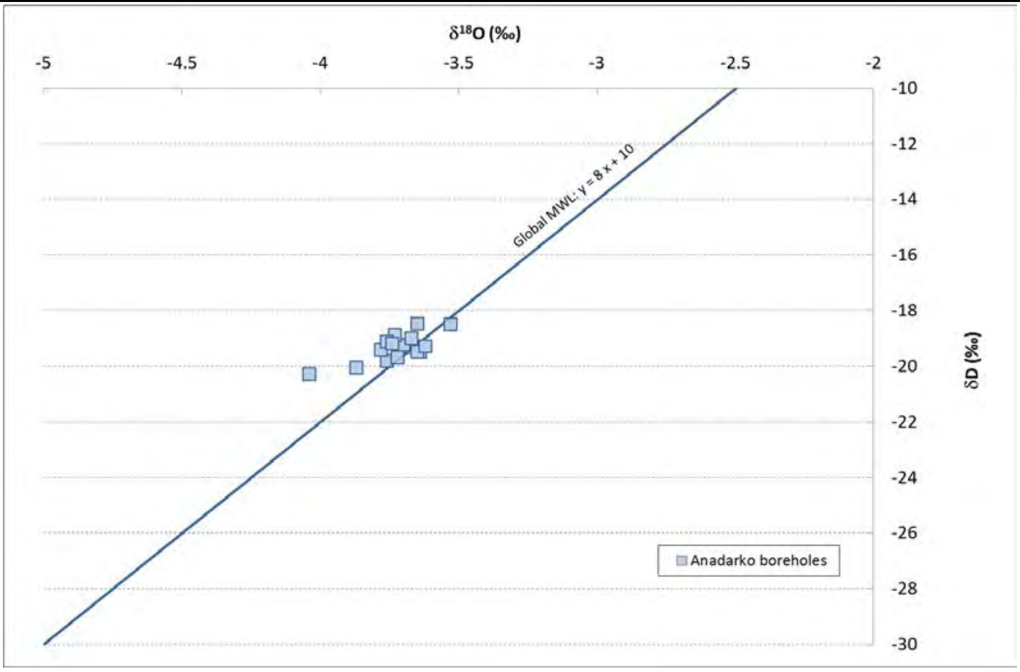
There is no identifiable spatial pattern to the signatures, however Group 4 samples are generally deep wells located close to the sea. Group 3 and Group 2 water may represent a mixture between fresher recharge (Group 1) and deeper more saline water with a marine influence.

Stable Isotope Data

The stable isotope data are plotted on a meteoric water line (MWL) in *Figure 8.12.* Despite the physical distance between the samples, the results are similar, within 1 ‰ of each other for δD and within 0.25‰ for $\delta^{18}O$. The samples plot near to the global meteoric water line, indicating recharge by rainwater and no evaporation.

This data provides evidence that the groundwater in the area is fed by rainwater recharge, and that there are no differences in recharge source across the area. The groundwater isotope ratios are more depleted than seawater, therefore no seawater intrusion is evident, and the observed marine influence may be due to salts present in the aquifer sediments related to the formation in a marine environment.

Figure 8.12 Stable Isotope Data from Boreholes Relative to the Global MWL



8.4.7 Seasonal Variation in Water Quality

The natural variation of the water quality in the Afungi Project Site was studied based on two hydrocensus sampling rounds, one during the wet season and one during the dry season.

Representative radial diagrams of the groundwater chemistry for hand-dug wells and deeper boreholes (ie >40m deep) in both the dry season (February 2012) and the wet season (May 2012) are presented in *Figure 8.13* and *Figure 8.14*. These radial diagrams graphically present the relative hydrochemical composition of the groundwater, allowing for a visual comparison between different seasons.

The chemistry of groundwater in shallow hand-dug wells, as shown by HC7, changes significantly between the wet season and the dry season. In the dry season, the water is dominated by sodium (Na) and chloride (Cl), whereas in the wet season the water is dominated by Na, calcium (Ca) and bicarbonate

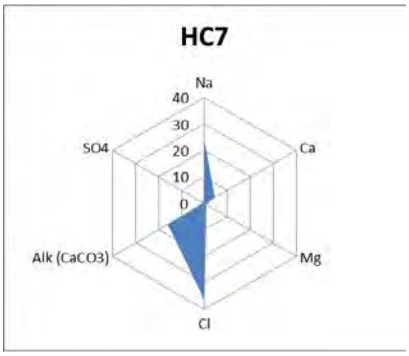
(HCO_3) (alkalinity). The seasonal change in shallow groundwater chemistry is attributed to direct and rapid rainfall recharge, and confirms that the shallow groundwater would be highly susceptible to any surface contamination.

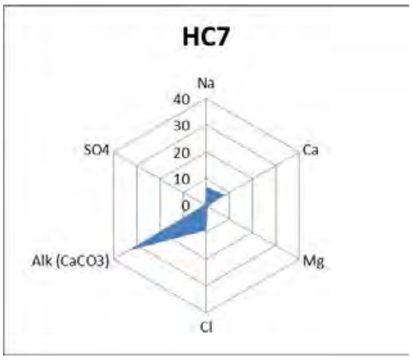
The chemistry in HC3 is dominated by alkalinity, Cl and Na, and suggests that the aquifer from which groundwater is being abstracted is recharged during the wet season. The results of HC3 are in contrast to the groundwater from HC10, which has a geochemical signature that does not suggest frequent recharge, with little seasonal variation in water quality. The depths of these two handpump-equipped boreholes are unknown, and the potential exists for them to be abstracting groundwater from aquifers at different depths.

Figure 8.13 Radial Diagrams for Hand-dug and Handpump Wells

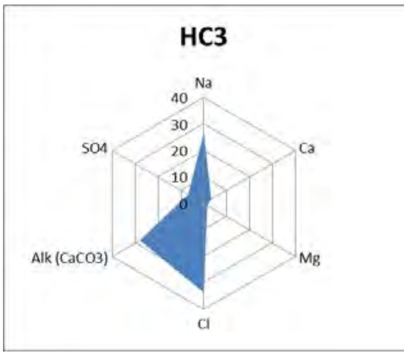
Dry Season **Wet Season**

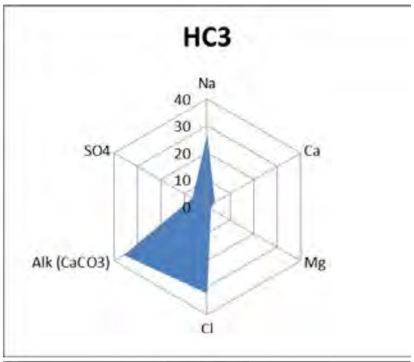
Shallow hand-dug wells

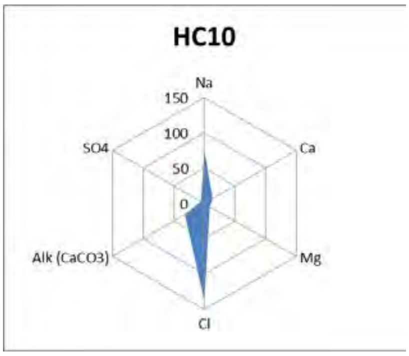




Handpump-equipped boreholes (unknown depth)







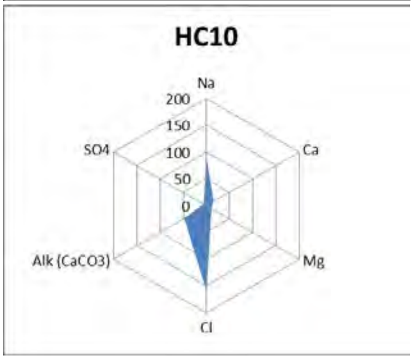
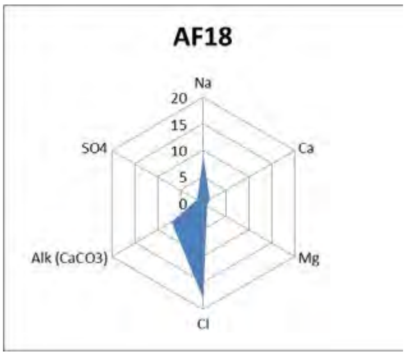
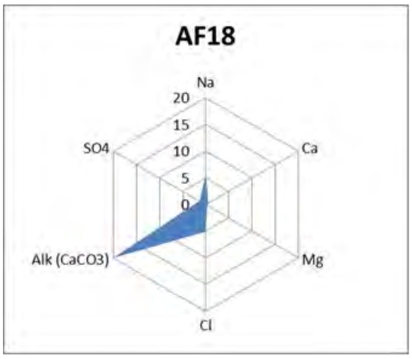


Figure 8.14 Radial Diagrams for Boreholes

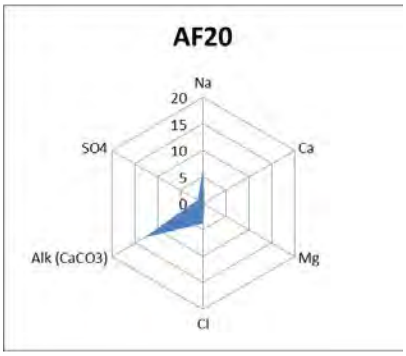
Dry Season	Wet Season

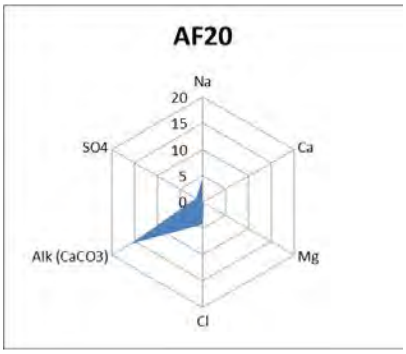
Borehole 40m



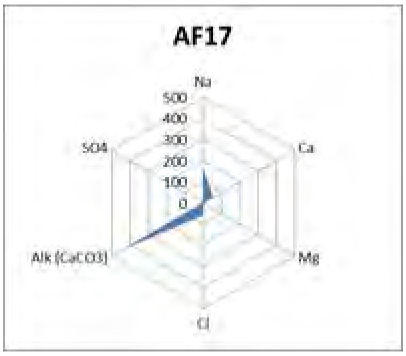


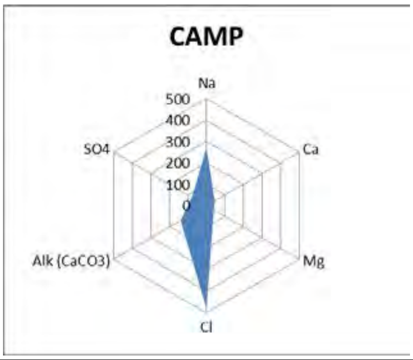
Borehole 40m

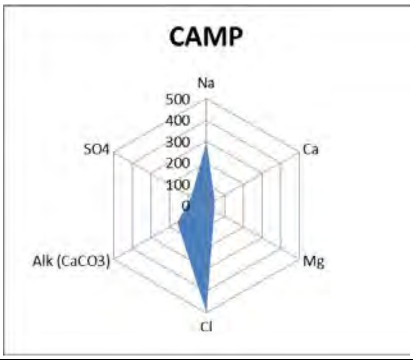




Borehole 100m







The geochemistry of the groundwater abstracted from the boreholes AF18 and AF20 confirms recharge of the aquifer at 40m below surface during the wet season, not unlike the pattern in the shallow hand-dug wells or the 100m deep borehole AF17.

8.5 HYDROLOGY

The objective of the hydrological baseline assessment is to assess the current surface water environment prior to development, to enable management steps to be put in place to maintain the integrity of surface water environments. To facilitate this, flowline and run-off models were developed (see *Annex C* for details on methodology).

8.5.1 Geographical Context

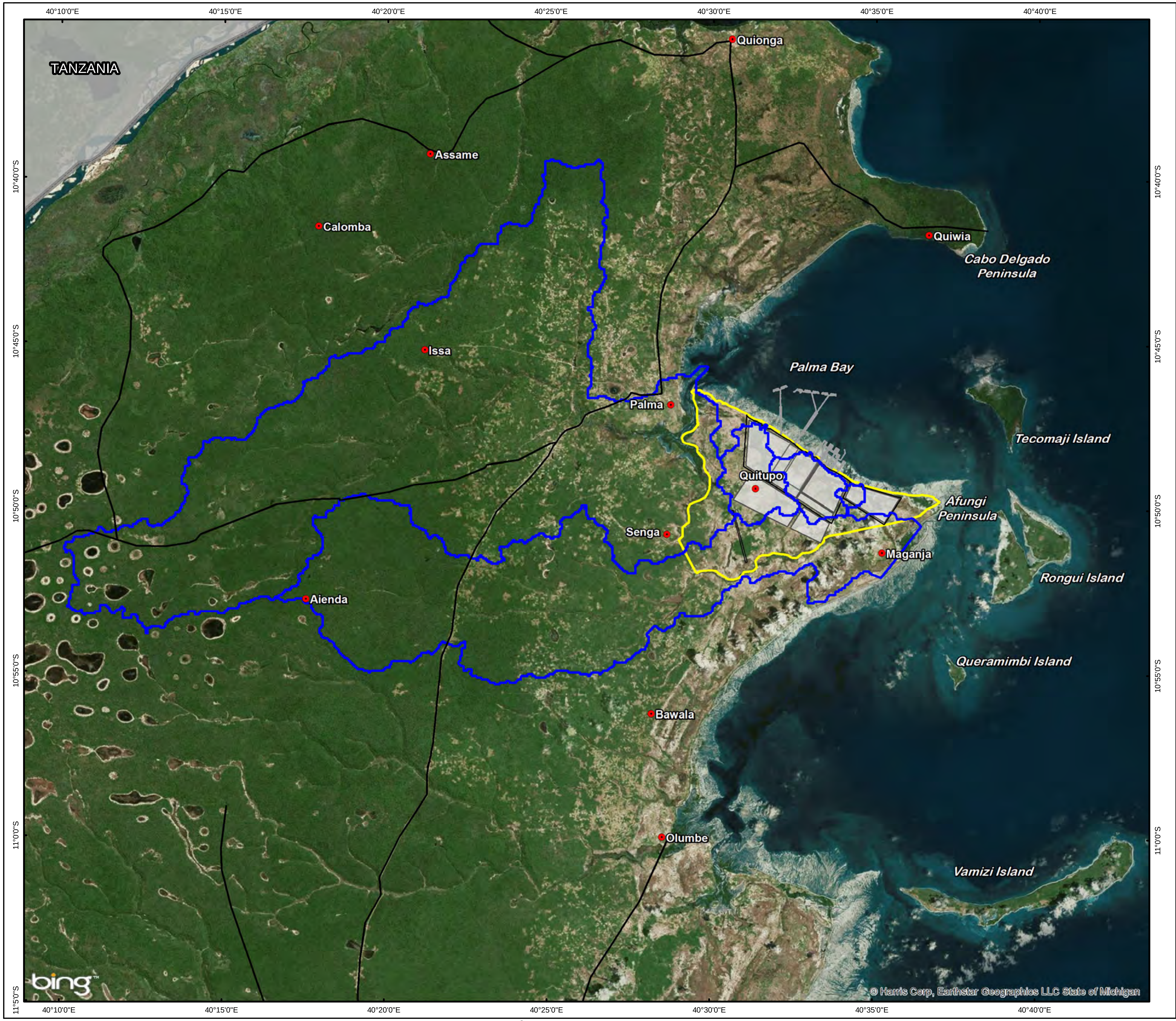
The hydrological baseline study was conducted within the Afungi Project Site and adjacent areas. Regional secondary data including climate, topographic, geologic and land cover/land-use data were assessed in characterising the baseline of the Study Area. Field observations were made within the Survey Area.

8.5.2 Regional Watershed Catchments

There are four main catchments in the vicinity of the Project Area, as illustrated in *Figure 8.15*:

- Catchment A (approximately 14km^2);
- Catchment B (approximately 10km^2);
- Catchment C (approximately 182km^2); and
- Catchment D (approximately 394km^2).

The catchment gradients are low, thus off-site flow rates can be expected to be low. It can be seen that the headwaters in the large catchments comprise pans or *dambos*, which do not have clearly defined stream channels due to the relatively flat topography on the coastal plain.



Legend

- Villages / Settlements
- Regional Roads
- Afungi Project Site
- Jetty
- Onshore Project Footprint
- Catchments

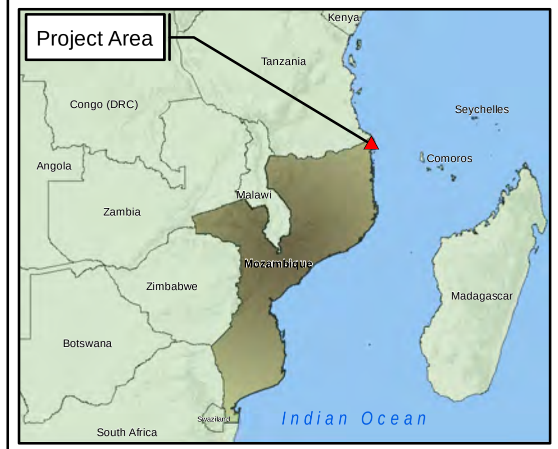


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Figure 8.15: Delineated Catchments in the Study Area

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: GM	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 180 000

DRAWING: Delineated_Catchments_in_the_Study_Area.mxd

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Tel: +27 21 681 5400
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Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
ERM, 2012. Inset Map: Esri Data & Maps

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8.5.3 *Watershed Modelling Methodology Overview*

The methodology used in the analysis of the watershed entailed a review of available data sets and reports from the public domain, a site visit and computer modelling. Once the watercourse and catchment boundaries were estimated, the physical properties of the area (climatic conditions, topography, soil conditions, vegetation cover and land use) were compiled to estimate peak run-off rates and develop the hydrological baseline of the area. Other baseline studies discussed herein were leveraged in the development of this analysis. A detailed discussion of the methodology applied in the modelling of the watershed is provided in *Annex C*; an overview of these methods is provided below.

Delineation of Watercourses and Catchment Boundaries

The modelled drainage network and catchments were developed by applying Watershed Modeling System (WMS) software and NASA's Aster Global Digital Elevation Model (GDEM). The WMS provides typical hydrologic and hydraulic modelling, using models such as HEC-HMS and HEC-RAS. River/stream/drainage networks and catchment basins were mapped using Digital Elevation Model data.

Determination of Peak Rainfall Estimates

The determination of peak rainfall events for the respective return periods and peak flow rates for the drainage areas within the catchments was undertaken by the Rational Method and SCS Method.

Determination of Floodlines

The HEC-RAS model is designed to perform one-dimensional hydraulic calculations for natural and constructed channel networks, and was used to assess all major surface water systems within the Survey Area. The floodlines were calculated by performing a steady-state analysis.

8.5.4 *Floodline Analysis*

The aim of the floodline analysis was to assess the distance that water will flow along the bank from the stream channel during an extreme rainfall event. The floodline analysis was performed for the rivers/streams that flow through the Survey Area.

Catchment Delineation and Catchment Characteristics

Stream length and gradient are key factors in floodline analysis, and are important in estimating the time of concentration, which can be defined as the time it would take for water to flow from the furthest point of the catchment to reach the point of consideration.

Size of Catchment

The size of the catchment has an important influence on the rainfall–run-off relationship. The areas visited along the coast have been largely cleared of vegetation and converted to cropland. The soils for the smaller catchments within the Survey Area comprise deep grey/white sands and sandy soils. Thus, for this study, the relationship between rainfall intensity and infiltration rate of the soils is important.

Field observations indicate that the predominant vegetation comprises forests and grasslands, with closed-canopy forest/woodland present on slightly elevated areas, interspersed with open grassland/wetlands. These vegetation types, together with the small-gradient topography, play a major role in the flood hydrology. A key characteristic of the stream channels is that they are interspersed with open grasslands and wetlands, which attenuate much of the flow. Although a high-intensity storm may produce considerable overland run-off flow, when this reaches the stream channels flows will be slowed considerably. For the larger catchments, water storage capacity plays a major role in the flood hydrology.

Catchment Shape

The catchments for this study can generally be described as long and narrow, and can be expected to reduce peak flows due to:

- topographical factors allowing for a smaller slope over the catchment;
- storm intensity being reduced, as a storm will not fall on the entire catchment at the same time; and
- longer travel time (Tc) through the catchment allows for more flow attenuation.

Catchment Slope

The slope of the catchment is important in determining flood peaks. Steep slopes cause water to flow faster and to shorten the critical duration of a flood-causing storm, thus leading to the use of higher rainfall intensities. On steep slopes, the vegetation is generally less dense, soils are shallower and there are fewer depressions, which cause water to run off more rapidly. The result is that infiltration is reduced and flood peaks are consequently even higher. A summary of the catchment characteristics is presented in *Table 8.7*.

Table 8.7 Summary of the Catchment Characteristics

Catchment	Catchment Area (km^2)	Longest Watercourse (km)	Slope (m/m)	Time of Concentration* (hrs)
Catchment A	14	6	0.003	2.4
Catchment B	10	6	0.002	3
Catchment C	182	35	0.003	9.2
Catchment D	394	40	0.004	9.6

* Time of concentration is defined as the required time for a storm of uniform area and temporal distribution to contribute to the run-off from the catchment.

Flood Peaks and Volumes

The estimated peak discharges for the respective catchments is presented in *Table 8.8*. The Rational Method and the SCS Method were used to calculate the peak discharges.

Table 8.8 Estimated Peak Discharges for Catchments

Catchment	Tc (hr)	Peak Discharge (m^3/s)			
		Rational Method		SCS Method	
		5 year	10 year	50 year	100 year
Catchment A	2.4	44	60	43	55
Catchment B	2.9	27	36	30	38
Catchment C	9.2	171	231	180	235
Catchment D	9.6	294	399	282	368

The estimated flood volumes, calculated from the SCS Method, are presented in *Table 8.9*.

Table 8.9 Estimated Peak Volumes for Catchments

Catchment	Discharge Volume (m^3)	
	50 year	100 year
Catchment A	642,040	812,110
Catchment B	493,880	624,700
Catchment C	7,570,000	9,760,000
Catchment D	15,000,000	19,320,000

Existing Conditions Flood Extent

The approximate extent of inundation of the Afungi Project Site in the 100-year event was determined using a HEC-RAS hydraulic model, with the peak determined using the Rational Method and SCS Method. The HEC-RAS model for the Study Area included five rivers, with the peak flows input for the five reaches. The tailwater level of 1.8m was considered in the model, corresponding to Mean High Water Spring (MHWS).

The floodline analyses performed for the 1 in 100 year event is illustrated in *Figure 8.16* below. It is apparent that a large extent of the coastal area is located within a flood area and the extent of inundation in the 100-year event covers a significant proportion of the proposed Project Footprint Area.

Legend

- Villages / Settlements
- Local Roads
- Regional Roads
- Jetty
- Onshore Layout
- Afungi Project Site
- 1 in 100 Year Floodline

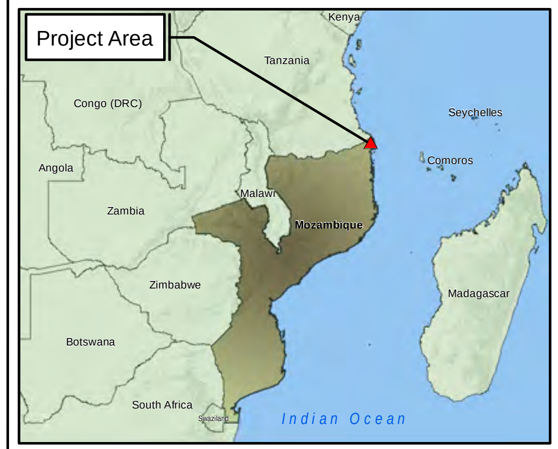

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Figure 8.16: Delineated Floodlines for the 1 in 100 year Rainfall Event

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: GM	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 70 000

DRAWING: Delineated_Floodlines.mxd

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ERM, 2012. Inset Map: Esri Data & Maps

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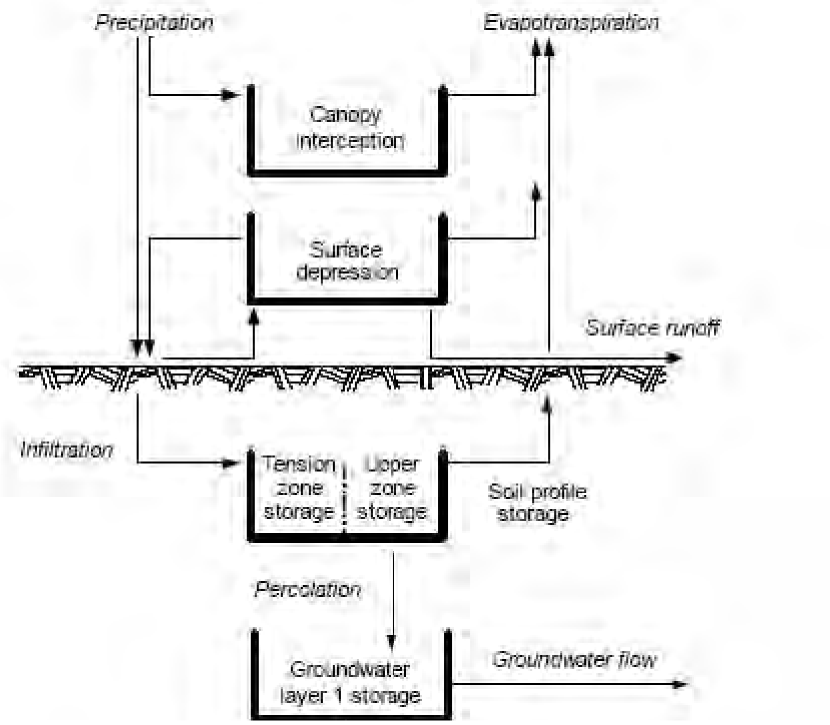
Stream Flow

HEC-HMS was used to perform long-term rainfall run-off simulations for the respective catchments. This is a physically based distribution model, which can be used to simulate hydrological processes such as vertical soil moisture flow, evapotranspiration (ET), infiltration, overland flow, channel flow and groundwater flow within the catchments. HMS includes the Soil Moisture Accounting (SMA) which requires rainfall depths and evapotranspiration rates, as input to define the rainfall, run-off, storage and losses relationships.

Four water storage zones were simulated, as shown in *Figure 8.17* below. For the simulation of water movement through the various storage zones, the maximum capacity (maximum depth) of each storage zone, initial storage condition in terms of percentage of the filled portion of each zone, and the transfer rates, such as the maximum infiltration rate, are required.

Figure 8.17 Schematic Diagram of HMS/SMA Water Storage Zones



Source: HEC, 2000.

The parameter estimates established in the model were determined from information sourced from the Rovuma River Basin (1) and rainfall data was extracted from the NOAA website (2). The mean annual evaporation data used in the study was estimated at 1,400mm/yr. The Clark unit hydrograph technique was used to determine run-off. In this method, the process of translation and attenuation of excess rainfall dominate the movement of flow through the catchment.

(1) http://ruvumariver.org/

(2)http://www.noaa.gov/ Hourly data from the period 18 February 2000 to 29 June 2012 was used in developing this model.

8.5.5 *Model Results*

The catchment characteristics (size, shape, slope, soil composition and vegetation cover) as well as variables such as infiltration rate, soil depth, percolation rates and groundwater depth all have a significant influence on the modelled flow rates. At the beginning of a rainfall event, much of the rain is intercepted by the vegetation and subsequently by the high infiltration and percolation rates of the soils. However, heavy rainfall events will produce quick overland flow (run-off) if the storage capacity of the soil is overwhelmed by the magnitude of rainfall.

Base flow (as opposed to subsurface flow) is the main contributor to stream flow in the catchments. The model shows an annual average stream flow of approximately 20 percent of the rainfall, and indicates that the river flow rates will reach zero over extended periods with no or low rainfall.

There are currently no stream flow records within the Survey Area or from watercourses in close proximity. Therefore, the modelled flows could not be verified through cross-reference with existing or historical data. Stream flow measurement would need to be performed to definitively confirm these simulations.

8.5.6 *Water Quality*

Surface water sampling was conducted between 14 and 18 May 2012. The results are summarised in *Table 8.10* below and the sampling locations illustrated in *Figure 8.18*. Water quality results were compared to Mozambique and WHO standards. The water quality is generally good, with concentrations of TDS well within drinking water standards. Some parameters, such as iron (Fe) and aluminium (Al), marginally exceed the WHO recommended limits for acceptability of water ie taste, odour and appearance, but no health-based guidelines are exceeded. The exception is sample S6, collected from adjacent to the sea, which shows a distinct marine influence with elevated salt concentrations.

Table 8.10 Surface Water Quality Constituents Compared against Mozambique and WHO Potable Water Standards

Constituent	Unit	Standards		Surface Water Sampling Location								
		Mozambique *	WHO (2011)	S1	S2	S3	S4	S5	S6	S7	S8	S9
pH – value at 25°C		6.5–8.5	6.5–8.5	6. 59	6. 80	6.91	6.43	6.65	7.28	6.67	6.45	6.59
Electrical conductivity at EC	mS/m	5–200	25	11.4	7.4	30.2	6.2	6.0	1027.6	75. 7	14.5	7.2
Total dissolved solids as TDS	mg/l	1000	ns	72.96	47.36	193.28	39.68	38.40	6576.64	484.48	92. 80	46.08
Total alkalinity as $CaCO_3$	mg/l	ns	ns	20	26	30	14	20	56	24	14	18
Suspended solids as SS	mg/l	ns	ns	<10	<10	<10	<10	<10	10	<10	<10	<10
Chlorides as Cl	mg/l	250	250	14.9	6.7	66.9	6.8	8.6	3333.6	15.5	9.9	13.2
Sulphate as SO_4	mg/l	400	500	2.48	0.76	8.42	<0.05	0.73	417.38	6.40	0.56	1.04
Nitrate NO_3 as N	mg/l	50	50	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	2.0	0.4	<0.2
Calcium as Ca	mg/l	50	ns	2.7	2.6	5.3	1.4	1.1	73.3	2.3	0.8	1.0
Magnesium as Mg	mg/l	50	ns	32	175	8	84	5	<2	<2	66	<2
Sodium as Na	mg/l	200	200	9. 7	4.5	41.7	4.4	7.8	1907.0	11.8	6.5	9.6
Potassium as K	mg/l	ns	ns	2.1	2.7	2.3	0.3	1.8	71.6	1.8	0.5	1.2
Aluminium as Al	mg/l	0.2	0.2	<0.020	0.08	0.09	0.27	0. 31	<0.020	0.08	0.13	0.11
Iron as Fe	mg/l	0.3	0.3	0.1	1.9	0.2	1.1	0.2	0.1	0.1	0.1	0.2
Manganese as Mn	mg/l	0.1	0.05	0.03	0.18	0.01	0.08	0. 01	<0.002	<0.002	0.07	<0.002
Total chromium as Cr	mg/l	0.0.5	0.05	0.0057	0.0026	0.0025	0.0044	0.0140	0.0078	0.0043	<0.0015	<0.0015
Copper as Cu	mg/l	1	2	<0.007	0.014	<0.007	0.007	<0.007	<0.007	0.0034	<0.007	<0.007
Nickel as Ni	mg/l	0.02	0.02	<0.002	0.002	<0.002	0.003	<0.002	<0.002	0.002	<0.002	<0.002
Zinc as Zn	mg/l	3	3	0.01	0.05	0.02	0.02	0.01	<0.003	0.01	0. 01	0.01
Cobalt as Co	mg/l	ns	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium as Cd	mg/l	0.003	0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.00 05	<0.0005	<0.0005
Lead as Pb	mg/l	ns	0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0. 005	<0.005
Benzene	ug/l	ns	ns	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	ug/l	ns	ns	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	ug/l	ns	ns	<2	<2	<2	<2	<2	<2	<2	<2	<2
p/m-Xylene	ug/l	ns	ns	<3	<3	<3	<3	<3	<3	<3	<3	<3
o-Xylene	ug/l	ns	ns	<2	<2	<2	<2	<2	<2	<2	<2	<2
Naphthalene	ug/l	ns	ns	<2	<2	<2	<2	<2	<2	<2	<2	<2
Surrogate Recovery Toluene D8	%	ns	ns	105	103	102	104	104	104	104	102	104
Surrogate Recovery 4--Bromofluorobenzene	%	ns	ns	108	108	109	109	109	109	110	108	109

Notes: * Mozambican Water Quality Standards for Human Consumption (Ministerial Diploma no. 180/2004, of 15 September

Legend

- Sampling Locations
- Villages / Settlements
- Regional Roads
- Local Roads
- Jetty
- Onshore Layout
- Afungi Project Site

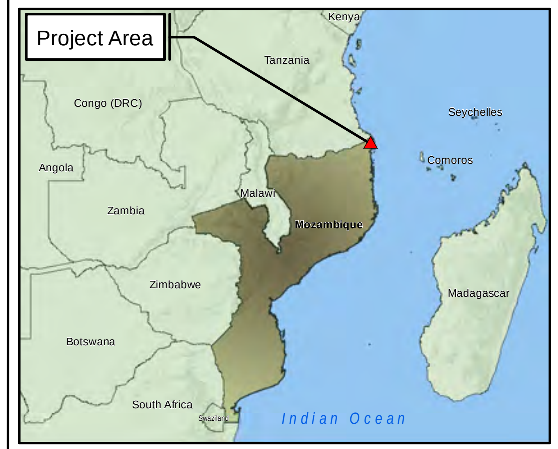


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Figure 8.18: Surface Water Quality Sampling Locations

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8.5.7 *Conclusion*

The Project is located in the drainage paths and low-lying areas within catchments A, B and D. During construction the sandy soils, which are highly susceptible to erosion, will be exposed. The Project Footprint Area falls inside the modelled flood zones of catchments A and B. Flooding in these areas could be managed by appropriate flood mitigation measures such as diversion channels to divert flows around and away from the site.

High-intensity rainfall events are experienced in the Study Area, but this will be tempered by the deep sandy soils which allow for high infiltration and permeability rates. These factors, combined with the slow velocity flows (due to the relatively flat topography) would reduce the flooding potential due to water infiltration. Therefore, high-intensity rainfall events would need to occur over a long period of time to allow for soil saturation before overland flow would likely occur.

Stream flow is highly variable and extremely large flow rates are experienced following high-magnitude rainfall events in the wet season. As base flow is the main contributor of stream flow in the catchments, indications are that significant quantities of water are temporarily stored in floodplains, resulting in shallow groundwater tables. It is recommended that continuous stream flow monitoring be undertaken to calibrate the model results against actual flow data, to further the understanding of the surface water environments.

8.6 *SURFACE WATER ECOLOGY*

8.6.1 *Overview*

The Afungi Peninsula is bordered by two major drainage basins: the Rovuma Drainage Basin, 35km to the north, and the Messalo Drainage Basin, approximately 90km to the south. Due to the low gradient of the peninsula, the fresh-water systems within the Afungi Project Site are largely interconnected wetland systems ending in estuaries connected to Palma Bay. There are no major rivers draining the immediate area. The rainfall in the area averages above 1,000mm/year; the highest flows are experienced in February to April, and the lowest flows in August. The local people use the estuaries and wetland systems for subsistence fishing, but not to a large extent.

8.6.2 *Baseline Surveys and Catchments within Study Area*

The Survey Area included 12 sampling sites, all wetlands, which are outlined in *Table 8.11*. Sampling was undertaken within the wetlands during low flow (14 to 17 October 2011 and 22 to 25 June 2012) and high flow (24 to 29

February 2012). Of the sampling sites, nine were fresh-water sites (lacustrine wetlands [(1)]) and three were estuaries.

Table 8.11 *Selected Sampling Sites (Wetland and Estuarine)*

Site Name	Description	Coordinates	
MOZ 1	Wetland	S 10°50′07.58″	E 40°33′21.57″
MOZ 2	Wetland	S 10°49′50.94″	E 40°31′50.89″
MOZ 3	Wetland	S 10°49′21.89″	E 40°31′55.34″
MOZ 4	Estuary	S 10°48′23.53″	E 40°33′09.69″
MOZ 5	Wetland	S 10°49′00.74″	E 40°31′36.83″
MOZ 6	Estuary	S 10°47′23.84″	E 40°31′35.83″
MOZ 7	Wetland	S 10°50′00.73″	E 40°30′20.72″
MOZ 8	Wetland	S 10°52′01.51″	E 40°29′27.94″
MOZ 9	Wetland	S 10°50′54.77″	E 40°33′16.08″
MOZ 10	Wetland	S 10°49′21.31	E″ 40°33′30.34″
MOZ 11	Wetland	S 10°48′20.53″	E 40°31′27.52″
MOZ 12	Estuary	S 10°49′15.53″	E 40°34′34.29″

Source: NSS, 2012.

Five major catchments have been identified within the Survey Area, as shown in *Figure 8.20*. *Table 8.12* describes the location of chosen sampling sites within each catchment. These wetlands are interconnected systems.

Table 8.12 *Catchments and Wetlands within Survey Area*

Catchment and Assessment Sites	Site Description
Catchment A	
MOZ 2	Upper catchment zone, close to the start of the permanent wetland
MOZ 3	Mid catchment zone
MOZ 5	Mid catchment zone
MOZ 6	Estuary
MOZ 11	Lower catchment zone with broad permanent wetland
Catchment B	
MOZ 1	Upper catchment, close to the start of the permanent wetland
MOZ 4	Estuary
MOZ 10	Lower catchment zone with broad permanent wetland
Catchment C	
MOZ 8	Upper catchment, close to the start of the permanent wetland
MOZ 9	Mid catchment zone
Catchment D	
MOZ 7	Upper catchment, close to the start of the permanent wetland
Catchment E	
MOZ 12	Estuary

Source: NSS, 2012.

(1) Lacustrine wetlands have permanent wet conditions and may include water bodies and shallow pans. The systems typically have plants growing in the water, although riparian zones or floodplain areas can become dryer during the dry season.

Within the 3,600ha Project Footprint Area, approximately 933ha of wetlands exist (see *Figure 8.20*). Of these wetlands, approximately 210ha are estuarine systems, 281ha are permanent fresh-water wetlands and 442ha are seasonal wetlands. A riparian buffer (indicated in red in *Figure 8.20*) that extends 150m [(1)] around all wetland systems expands this area to approximately 841ha. A discussion on these wetland systems is provided in the following sections.

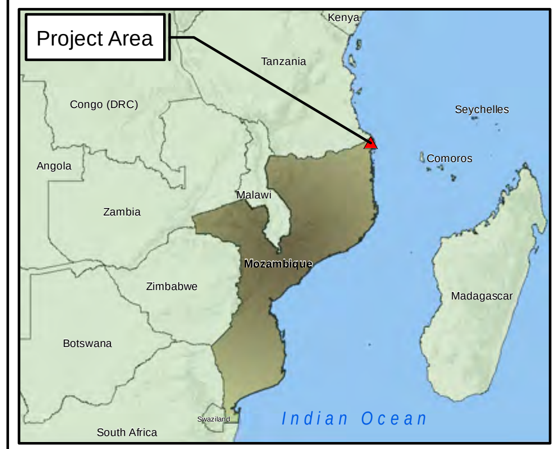
(1) The term riparian buffer is used to describe lands adjacent to streams where vegetation is strongly influenced by the presence of water.

Legend

- Villages / Settlements
- Aquatic and Wetland Sites
- Local Roads
- Onshore Project Footprint
- Nearshore Components
- Afungi Project Site

Wetlands

- Estuary
- Permanent wetland
- Seasonal wetland
- Un-delineated wetland
- Wetland Buffer (150 m)



MAIN MAP SCALE:

0 500 1 000 1 500 2 000

Metres

N

TITLE:

Figure 8.19: Surface Water Ecology Survey Area

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 50 000

DRAWING: Surface Water Ecology Survey Area.mxd

REV: A

ERM
Great Westerford Building
240 Main Road
Rondebosch, 7725
Cape Town, SOUTH AFRICA
Tel: +27 21 681 5400
Fax +27 21 686 073

Impacto Projectos e Estudos Ambientais

ERM

Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
Natural Scientific Services CC, 2012.
Inset Map: Esri Data & Maps

SIZE: A3

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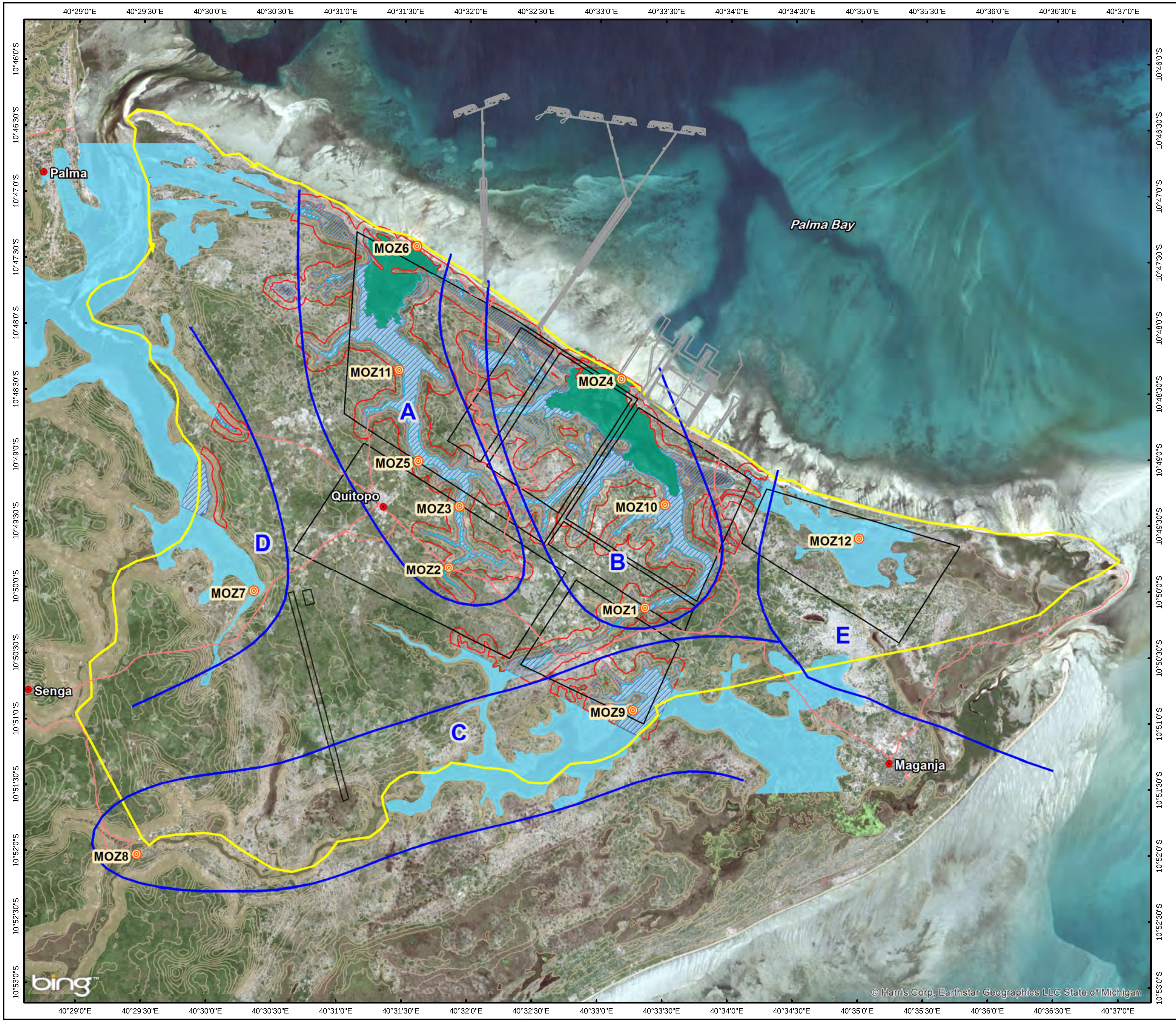


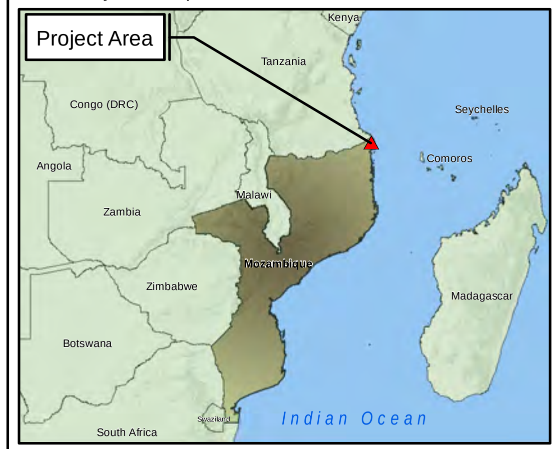
Legend

- Aquatic and Wetland Sites
- Villages / Settlements
- Local Roads
- Contours
- Nearshore Components
- Onshore Project Footprint
- Wetland Groups
- Afungi Project Site

Wetlands

- Estuary
- Permanent wetland
- Seasonal wetland
- Unspecified wetland
- Wetland Buffer (150 m)

Note:
Preliminary - to be updated with catchment E



MAIN MAP SCALE:

0 500 1 000 1 500 2 000
Metres

N

TITLE:

Figure 8.20:
Wetland Catchments

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 50 000

DRAWING: Wetland Catchments.mxd

REV: A

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Great Westerford Building
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Impacto Projectos e Estudos Ambientais

ERM

Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
Natural Scientific Services CC, 2012
Inset Map: Esri Data & Maps

SIZE: A3

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8.6.3 *Lacustrine Wetlands*

In their natural state, the lacustrine wetlands in the Survey Area are considered unchannelled valley bottom wetlands (1), according to the classification of Kotze et al. (2007). Basic characteristics of a wetland change as each wetland progresses through its catchment, from the source towards the coastline, with four recognisable zones being present within the Survey Area.

- In the **upper catchment zone** close to the source, wetlands tend to be narrow and the extent of seasonal wetland far exceeds the extent of permanent wetland. Terrain tends to be varied and the riparian zones are not strictly confined to slopes adjacent to the wetland. Sites were selected where sufficient permanent water was present for aquatic surveys.

- In the **middle zone**, between the start of a wetland and its end at the coastline, wetlands tend to be clearly defined by steep and high slopes and with a moderately broad permanent wetland. The riparian vegetation tends to be well developed and largely restricted to the steep slopes.

- Towards the **lower end of the catchment**, wetlands tend to be dominated by extensive permanent wetlands, with well-defined slopes that demarcate the wetland edges. The height of these slopes tends to be less than in the mid catchment areas, and the area of seasonal wetland tends to be small.

- **Estuarine areas** are discussed in *Section 8.6.4*.

Sediment and Biotopes

In terms of the aquatic environment, the beds of the wetlands in the Survey Area are composed of fine sands and muds, rather than rocks and cobbles. The bottom consists of soft sediment and the major biotopes (2) observed in the Survey Area include:

- open water, inhabited by suspended planktonic forms and fish;

- shallow-edged, inhabited by benthic (bottom-dwelling) forms; and

- marginal, with roots and plants inhibited by other assemblages of invertebrates and fish.

Water Quality

The following physical variables were examined for the fresh water wetlands:

(1) These are valley bottom areas with no clearly defined stream channel, usually gently sloped and characterised by alluvial sediment deposition, generally leading to a net accumulation of sediment. Water inputs occur mainly from the channel entering the wetland, as well as from adjacent slopes.
(2) A biotope is a region that has a characteristic set of environmental conditions and, consequently, a particular type of fauna and flora.

- dissolved oxygen (DO);
- temperature;
- electrical conductivity (EC);
- TDS;
- salinity; and
- pH.

The mean values of the physical variables measured at wetland (not estuarine) sampling locations are shown in *Table 8.13* and discussed further below. These are compared against the Target Water Quality Range (TWQR), a management objective developed by the South African Department of Water Affairs and Forestry (DWAF, 1996) for South African aquatic ecosystems and used to specify the desired or ideal concentration range and/or water quality requirements for a particular constituent. Although there are some water quality standards in place in Mozambique, none are specifically related to the standards required for optimal ecosystem functioning (Mozambique Environmental quality regulations, 2004). Consequently, the South African guidelines were used to give an indication of ecosystem deterioration in the Survey Area, with the understanding that these are not absolute for Mozambique.

Table 8.13 Physical Water Quality Parameters of the Wetland Sampling Sites in Low Flow (LF) 2011, 2012 and High Flow (HF) 2012

***In situ* variables**	**MOZ 1**		**MOZ 2**		**MOZ 3**		**MOZ 5**		**MOZ 7**	
TWQR*	**LF**	**HF**	**LF**	**HF**	**LF**	**HF**	**LF**	**HF**	**LF**	**HF**
DO (mg/l) **>8.00**	2.93	5.05	10.91	5.19	8.66	5.05	1.28	1.75	6.19	3.39
DO (%) **80–100**	36.64	65.0	149.9	71.72	107.92	64.07	16.3	23.63	84.2	45.77
Temp (C) **N/A**	26.9	28.2	35.2	32.1	26.6	27.2	27.5	30.9	31.3	30.5
EC (mS/m) **70**	12.40	11.55	11.68	9.48	14.96	12.38	28.87	15.37	21.8	18.19
TDS (mg/l) **450**	62	58	58	47	75	62	144	77	109	91
Salinity **N/A**	0.06	0.06	0.05	0.04	0.07	0.06	0.14	0.07	0.10	0.08
pH **6–9**	5.8	5.9	6.6	5.6	6.3	6.3	6.2	6.0	5.8	5.7
***In situ* variables**	**MOZ 8**		**MOZ 9**		**MOZ 10**		**MOZ 11**			
TWQR	**LF**	**HF**	**LF**	**HF**	**LF**	**HF**	**LF**	**HF**		
DO (mg/l) **>8.00**	5.26	7.68	3.31	4.35	4.99	3.76	2.53	1.68		
DO (%) **80–100**	64.07	99.51	41.80	58.29	62.88	50.77	32.02	21.88		
Temp (C) **N/A**	25.3	28.2	27.3	30.0	27.2	30.3	27.3	28.3		
EC (mS/m) **70**	14.17	67	22.78	217	19.30	254	19.40	103		
TDS (mg/l) **450**	71	13.29	114	43.49	96	50.92	97	20.52		
Salinity **N/A**	0.07	0.06	0.11	0.21	0.09	0.24	0.09	0.10		
pH **6–9**	6.3	6.1	5.8	6.0	5.9	6.0	5.6	6.2		

Key:
–: No data available; LF = low flow; HF = high flow.
*Red text delineates Target Water Quality Range (TWQR) (see methodology in *Annex C* for further information).
Constituents that did not meet the DWAF (1996) TWQR are highlighted in blue.

Source: NSS, 2012.

Dissolved Oxygen

Dissolved oxygen levels for water resources in naturally flowing systems should be between 8mg/l and 12mg/l (depending on temperature, TDS and height above sea level), and the percentage saturation should be between 80 and 120 percent (Dallas & Day, 2004). The oxygen values observed typically fell below the TWQR ranging from 1.28 to 6.19mg/l, with only two samples reaching levels within the suggested TWQR (at sites MOZ 2 and MOZ 3 Catchment A), as shown in *Table 8.13*. The wetlands in the Survey Area are naturally slow flowing and shallow, and therefore this guideline for oxygen levels is possibly unsuitable for such a system. Where levels fell within the TWQR (ie in Catchment A), it is likely that this was a result of higher levels of photosynthesis/decomposition of aquatic plants and increased temperatures.

The oxygen levels fluctuated drastically between seasons and no real trends could be identified at any of the sites. This is expected in watercourses with such low levels and slow-flowing waters. Therefore, the risk of oxygen depletion impacts in these ecosystems is not considered high.

Temperature

The water temperatures within the Survey Area wetlands ranged from approximately 25 to 35°C, as shown in *Table 8.13*. The sites with the highest temperatures generally aligned with the sites with low oxygen levels. No seasonal changes were evident from the observed temperatures, probably due to the natural tropical nature of the ecoregion, where the mean air temperature does not fluctuate substantially.

Electrical Conductivity (EC)

EC is a measure of the ability of water to conduct an electrical current. The TWQR for EC is 0 to 70mS/m (DWAF, 1996a). The EC values obtained at the wetland sampling sites fell within these ranges, typically 9 to 28 (see *Table 8.13*). However, EC at sites MOZ 9, MOZ 10 and MOZ 11 were considerably higher, likely to be a result of marine water flowing into the fresh-water systems at these points. The higher EC values observed during low flow indicate a seasonal variance.

Total Dissolved Solids

TDS measures the total amount of soluble material in a water sample, and includes organic, inorganic, ionised and un-ionised material. The greatest mass of this material in natural waters comprises inorganic ions. The most common of the cations are Na^+, K^+, Ca^{2+} and Mg^{2+} and the anions [(1)] are HCO_3^-, CO_3^{2-}, Cl^- and SO_4^{2-}. Less common inorganic ions include nutrients such as NO_3^- and PO_4^{2-}, various trace metals and inorganic material. The TDS values at the fresh-water sampling sites were low, which is considered good for such wetlands. Seasonal variance occurs as higher TDS concentrations were observed during the low flow period, especially at MOZ 5 (Catchment A), which had high concentrations of Na, Cl, K, Mg and SO_4 present.

Salinity

The salinity of the fresh-water sampling sites is tabulated in *Table 8.13*. The salinity values at the sites ranged from 0.04 to 0.24, and as expected were lower than those observed in marine water (32 to 36), indicating that the fresh-water sampling sites did contain mostly fresh water. No TWQR is available for salinity in inland waters.

pH

The pH values of the fresh-water sampling points are provided in *Table 8.13*. The TWQR for all aquatic ecosystems should be between the pH values of 6 and 9, which is typical of fresh-water habitats. However, pH should not vary from the range of the background pH for a specific site and time of day by >0.5 of a pH unit or by >5 percent, whichever estimate is the more conservative (DWAF, 1996). The pH recorded for most of the sites fell within the TWQR range, with the exception of sites MOZ 1, MOZ 2 and MOZ 7 at low flow 2011, and MOZ 9, MOZ 10 and MOZ 11 at high flow 2012. At these sites, the values observed are not of concern as they are not considered acidic.

Chemical Water Quality Parameters

The atmosphere, geological weathering, agriculture run-off, industrial effluents and acid mine drainage are the main sources of trace metals in water bodies (Dallas & Day, 2004). Almost all metals are toxic to aquatic organisms, and to humans at certain concentrations. Heavy metals, namely Cd, Cr, Cu, Pb, Fe, Hg, Mn and Zn (Roberts, 2001; Marchard, 2009) are the most toxic form of aquatic pollution (Laws, 2000).

As for physical constituents, chemical constituents were also compared against the TWQR and a few constituents were above the recommended target levels, including Al, Cu, Fe, Zn, Na, Cl, ammonium, sulphates, chemical oxygen demand (COD) and suspended solids (SS) at a number of the sampling sites [South African Water Quality Guidelines (SAWQG) for Aquatic Ecosystems (DWAF, 1996a) – see methodology in *Annex C*]. These concentrations were all considered to be relatively natural, apart from the nutrient and organic enrichment from the activities of the surrounding rural communities. In addition to this, all the sites had high levels of suspended solids. This was particularly evident in Catchment B at MOZ 1 and MOZ 10 in the high flow, where the levels were excessive – possibly related to increased sedimentation, likely to be from erosion and run-off from cultivated lands. Levels of suspended solids were much reduced at MOZ 10 during the low

(1) A negatively charged ion.

flow, which could indicate temporal changes at this site. However, this occurrence could not be confirmed at MOZ 1, where the constituent was only measured during the high flow.

The site that was shown to have the highest contamination was MOZ 5 (Catchment A), but this was only the case during the low flow and it is suspected that there was a small source of marine water in the low flow as higher levels of Na, Cl, sulphates and other ions that are normally in abundance in saline water were observed. In the high flow, MOZ 10 (Catchment B) and MOZ 9 (Catchment C) water quality had a similar WQ trend, suggesting that these sites also have an influx of salts, possibly from Palma Bay.

Diatoms

Diatom communities are widely used indicators of biological integrity and physico-chemical conditions in aquatic ecosystems because of their high dispersal rates, rapid growth rate and direct response to environmental changes (Taylor, 2011; 2012). This study considered species composition and abundance, but also examined a range of diatom indices, which are good indicators of present ecological status in wetlands. The indices used in the assessment included the Specific Pollution Sensitivity Index (SPI) and the Biological Diatom Index (BDI), the percentage of pollution-tolerant valves (%PTV) and the number of deformed cells (see *Annex C* for details of the methodology used).

The diatoms flora encountered is a typical acidic water flora with a considerable percentage of tropical African endemic species. Assessment of the diatom populations in the samples indicated that there were very high abundances of certain species present. A summary of all diatom taxa that were present above 50 individuals per sample is shown in *Table 8.14***.** The *Brachysira* genera tended to dominate in both seasons. This species is predominantly found in benthic slow-flowing habitats and is often found in high abundances in low conductivity and low pH wetland-type habitats, which dominated in the Survey Area.

Table 8.14 Diatom Genera and Species with Abundances of More Than 50

Site	Low Flow (2011/ 2012) Species Abundance	High Flow (2012) Species Abundance
MOZ 1	*Nitzschia* spp. (93)	
MOZ 2	*Brachysira vitrea* (182)	*Brachysira neoexilis* (85) *Frustulia* spp. (92)
MOZ 3	*Brachysira vitrea* (205)	*Brachysira* spp. (161) *Brachysira neoexilis* (65) *Eunotia* spp. (98) *Navicula heimansiodes* (122)
MOZ 5	Insufficient cells for count	None
MOZ 7	*Eolimna minima* (89) *Nitzschia pavuloides* (55)	*Eolimna minima* (69) *Achnanthidium exiguum* (64) *Eunotia* spp. (67) *Rhopalodia* spp. (61)
MOZ 8	*Eunotia* spp. (74)	*Brachysira neoexilis* (60)

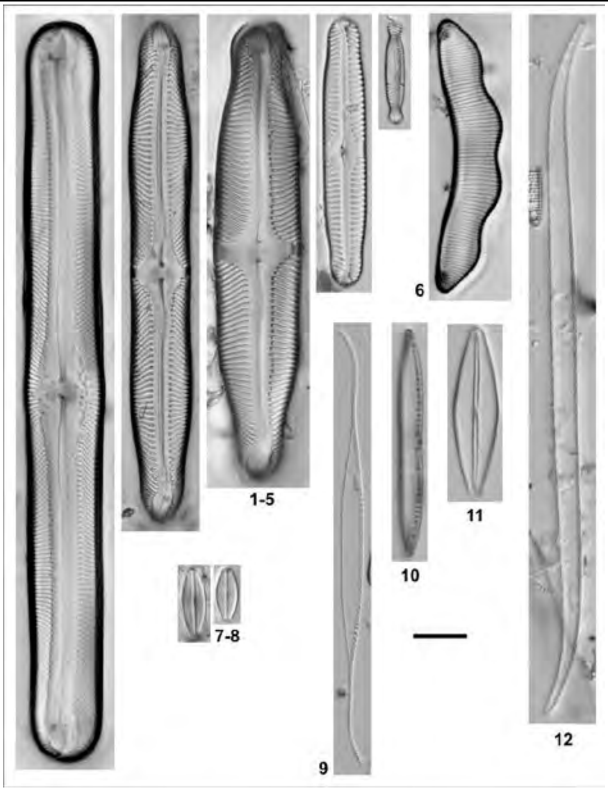
MOZ 9	*Brachysira neoexilis* (142) *Eunotia* spp. (71)	*Brachysira* spp. (161) *Eunotia* spp. (60)
MOZ 10	*Brachysira neoexillis* (234) *Brachysira procera* (87)	*Brachysira* spp. (148) *Brachysira neoexilis* (85)
MOZ 11	None	*Brachysira* spp. (165)

Source: NSS, 2012.

Some examples of diatoms observed in the fresh-water wetlands are shown in *Table 8.20*.

Few deformed cells were observed and communities were typically indicative of good water quality, with the exceptions of MOZ 1, MOZ 5 and MOZ 7 in the upper and mid zones of the catchments. Diatoms at these sites showed a higher percentage of pollutant-tolerant valves. The diatom community at MOZ 5 showed the impact by pollutants during the high flow sampling. This coincided with the water quality results that showed higher levels of metals (Cu and Zn) and organic pollutants (NH_4 and COD). The reason for this was possibly due to the proximity of this site (600m) to Quitupo, the largest settlement on Afungi Peninsula. The human activities included farming (rice paddies), the washing of clothes and bathing in water from this system. This may have resulted in the increased levels of organic pollution observed at this site. During low flow, MOZ 5 had insufficient cells available for a meaningful count. This may be the result of high TDS levels and sedimentation at the site, because the sample contained mostly detrital material and sediment.

Figure 8.21 Fresh-water Diatom Species



1–5: *Pinnularia* spp.; 6: *Eunotia zygodon*; 7–8: *Microcostatus* sp.; 9: *Nitzschia reversa*; 10: *Hantzschia* sp.; 11: *Frustulia* sp.; 12: *Stenopterobia anceps*. Scale bar = 10 µm.

Source: NSS, 2012.

Similarly, the diatoms at MOZ 1 and MOZ 7 specifically showed a higher percentage of pollutant-tolerant valves. This predominantly consisted of a high diversity of various *Nitzschia* species, which typically indicates high levels of organic material and waste. Such organic levels were indeed present at all sites, and particularly evident at MOZ 1 in the high flow, where there were eight species of *Nitzschia* and an extremely high concentration of organic contamination. The cause for this influx of organic material could, however, not be determined with certainty at this site, as no major anthropogenic activities were identified.

Macro-invertebrates

The general diversity of macro-invertebrates was low. The only families with abundances over 100 were Gomphidae (MOZ 1), Hydracarina (MOZ 2) and Caenidae (MOZ 7), and only during the low flow assessment. This was due to seasonal differences at the different sampling sites, because the macro-invertebrates showed a decrease in abundances during high flow. A low EPT indicated that the community structures consisted of a low number of sensitive taxa, probably due to low habitat availability for these taxa (see methodology in *Annex C*). For example, the stone habitat was absent and therefore no stoneflies (Plecoptera) were present. Overall, all sites were affected by low oxygen, high temperatures, no slow-flow conditions, and lack of biotope habitats (ie no stones). The water quality at the sites was considered good to high quality. However, Ca, Cu, Cl, Mg, Na, Zn, NH_4 and total hardness of the water at the sites (*Table 8.13*) could have affected and reduced the number of sensitive families present.

In general, the low abundance of present families indicated that even though most of the species that occur here were tolerant to the habitat and water quality conditions, only low numbers were naturally able to survive.

Ichthyofauna

No historical data is available for ichthyofauna in the Survey Area. The Rovuma River is one of the main rivers in the country in terms of flow, and runs along the border between Mozambique and Tanzania. It rises close to Niassa Lake and flows towards the Indian Ocean. This river is the closest large river to the Survey Area, but it does not flow into any of the aquatic systems sampled. The majority of species in the region (1) are considered of Least Concern (LC) or Data Deficient (DD) according to the IUCN, with the exceptions of *Barbus choloensis*, which is considered vulnerable (VU), and *Oreochromis mossambicus*, which has been categorised as Near Threatened (NT). Of these two species, the former was not sampled. However, the absence within the sample set recorded for this Project does not necessarily indicate the absence of this species in the system. The latter species, *O. mossambicus*, was sampled at a few sites within the Survey Area. This species is threatened due to interbreeding with the invasive species *Oreochromis niloticus.* However, in this area the extent or presence of such interbreeding could not be identified in this study. In addition to *O. mossambicus*, eight fish species were sampled at the fresh-water sites and these are listed in *Table 8.15*.

Table 8.15 Fish Observed at Fresh-water Sampling Sites during Low Flow 2011 and 2012 and High Flow 2012

Common Name	Species	IUCN Status
Redspot barb	*Barbus kerstinii*	LC
Sharptooth catfish	*Clarias gariepinus*	LC
Annual killifish	*Nothobranchius hengstleri*	DD
Mozambique tilapia	*Oreochromis mossambicus*	T
Black tilapia	*Oreochromis placidus*	LC
Southern moothbrooder	*Pseudocrenilabrus philander*	LC
Dusky sleeper	*Eleotris fusca*	DD
Indo-Pacific tarpon	*Megalops cyprimoides*	DD
Commerson's glassy perchlet	*Ambassis ambissis*	DD

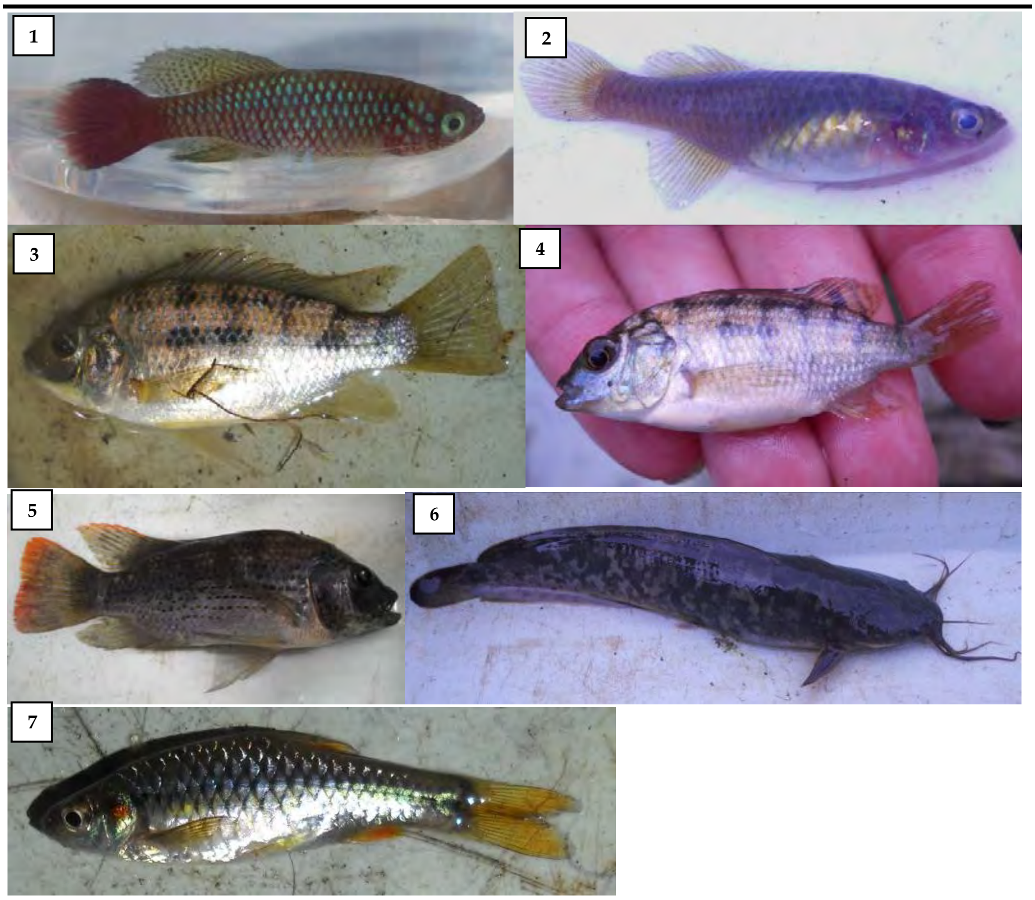
Key:
LC: Least Concern, T: Threatened, DD: Data Deficient, according to IUCN Red Data List, 2012.

Source: NSS, 2012.

(1) Based on the following sources: Livingstone (1859), who sampled fish in the lower reaches of the Rovuma River and deposited it to the British Museum of Natural History. Collections by South African Institute for Aquatic Biodiversity (SAIAB) have improved the knowledge of the fauna in the Rovuma River in the Niassa Reserve (Bills, 2004) and the wetlands of the Maputo Special Reserve (Bills, 2001).

For the Data Deficient species, it should be noted that species identified as being Data Deficient could have conservational importance and/or sensitivity to contaminants and should be considered during management decisions in the area. For instance, the presence of the species *N. hengstleri* might possibly be of importance, but this could not be established due to deficient data. This species was sampled at two catchments in the area, Catchments B and C. This was an interesting find, as currently this species is only known from its locality ie Nassoro Village, situated approximately 20km from Afungi Peninsula. Catchment B (at MOZ 1 and MOZ 10) and Catchment C (MOZ 8 and MOZ 9) are thus new localities for *N. hengstleri.*

Figure 8.22 Indigenous Fish Sampled during the High Flow and Low Flow Periods



1: Killifish (male) (*Nothobranchius hengstleri*); 2: Killifish (female) (*Nothobranchius hengstleri*); 3: Black tilapia (*Oreochromis placidus*); 4: Black tilapia (juvenile) (*Oreochromis placidus*); 5: Mozambique tilapia (*Oreochromis mossambicus*); 6: Sharptooth catfish (*Clarius gariepinus*); 7: Redspot barb (*Barbus kerstenii*).

Source: NSS, 2012.

Overall, the species sampled during this study preferred wetland habitats. As such, the species present all generally had no major sensitivities to water quality, flows or habitat alterations (Skelton, 2001). At many of the sites, the fish abundances usually increased during the summer season, due to greater fish activity as a result of spawning. The presence of some fish species highlighted the connectivity between the fresh-water wetlands and the estuaries. Two estuarine fish species, *M. cyprinoides* and *E. fusca*, were sampled at MOZ 5, a fresh-water site in Catchment A. This indicated that there was connectivity between the wetland and the estuarine site of Catchment A (MOZ 6). The presence of *M. cyprinoides, E. fusca* and another estuarine fish species, *A. ambassis*, at MOZ 11 (Catchment A) also indicated the connectivity with the estuary of Catchment B (MOZ 4).

Anthropogenic Influences

The majority of land alterations within the Survey Area were predominantly related to cultivation. Overall, the sites that were most severely altered by this were at MOZ 7 (Catchment D) and MOZ 8 (Catchment C), both are which were situated in close proximity to villages and could have been influenced by activities such as the the cultivation of alien plants, high algal content (due to nutrients from crop farming and the washing of clothes), organic enrichment (possibly from faecal matter), water abstraction and a change in hydrology due to artificially created channels. *Figure 8.23* shows some examples of existing anthropogenic alterations in the lacustrine wetlands.

Figure 8.23 Evidence of Anthropogenic Alteration at Wetland Sites

Top left: Artificial channel with raised banks for planting legumes at MOZ 7. Top right: Maize cultivation within wetland at MOZ 7. Bottom left: Cashew nut (*Anacardium occidentale*) and coconut (*Cocos nucifera*) trees planted in the upper zone at MOZ 3. Bottom right: Pond that developed as a result of a road crossing at MOZ 2.

Source: NSS, 2012.

Wetland Sensitivity

The wetland sites ranged from Sensitive to Highly Sensitive (as defined in *Annex C*). These are discussed further in *Section 8.6.6* by catchment.

8.6.4 Estuarine Wetlands

Overview

Along the coastline, approximately 20 estuaries occur within 100km of the Afungi Project Site, with varying catchment sizes feeding them. These estuaries include the large Rovuma estuary and the Palma estuary, which have the largest catchments in the area. The smallest estuaries are mainly areas created by tidal action on the beaches and the subsequent growth of mangroves. The numerous seagrass beds situated offshore also seem to play an important part in these estuaries, as decaying seagrass was evident in Catchments A and B (see *Figure 8.20*). This external input of nutrients and detritus is important in the cycling of nutrients within the ecosystems. The offshore marine environment plays a major part in the lives of the local people as fish are their major source of protein.

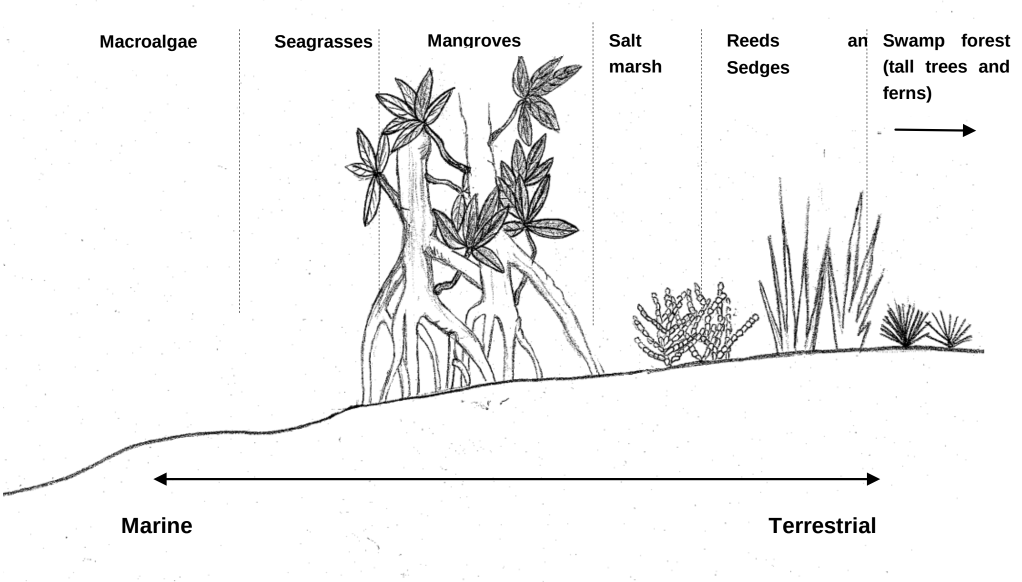
Estuarine systems have large variations in their abiotic and biotic characteristics. These variations are present within estuaries, as well as between different biogeographical regions. They can differ based on natural mean annual run-off, size, wave action at the mouth, biogeochemical characteristics of the adjacent marine environment and the catchment, and biotic composition. Thus, each estuary is unique and different from any other estuary (DWA, 2010).

Estuaries are normally classified based on their size, saline intrusion and the duration of the connection with the ocean. The estuaries of Catchments A, B and E are small when compared to the Palma estuary. The duration of the connection of these estuaries with the sea in Palma Bay is unknown; however, the tidal flow significantly influences the area of the estuary, as the water level fluctuates by approximately 1m between high tide and low tide. The amount of fresh water flowing into the system seems to be low, especially in Catchment B.

Estuarine Vegetation

The zonation of vegetation in intertidal habitats (ie estuaries) is a universal phenomenon (Turpie et al., 2010). Estuarine habitats are characterised by common representative species that are adapted to specific physico-chemical conditions. Plants in the estuarine environment undergo osmotic stress due to evaporation and high sediment and surface water salinities from sea-water inflow, which influences distribution as seen in *Figure 8.24*. For instance, hypersaline tolerant seagrasses, such as *Ruppia* spp., and red and green microalgae, such as *Porphyra* spp. and *Ulva* spp., are likely to occur in areas where salinity is high (≥35ppt). Shallow pools provide a habitat for bacterial crusts and benthic algal mats. In addition to this, microalgae in the form of diatoms, chlorophytes, dinoflagellates and filamentous blue-green algae are found in estuarine waters. The interface between the marine and terrestrial habitats is typified by salt marsh vegetation that includes herbaceous halophytes, grasses and low-growing shrubs.

Figure 8.24 ***Vegetation Distribution along a Typical Estuarine Gradient Showing Different Habitat Types***



Source: NSS, 2012.

The basic habitat types associated with the estuarine environment are listed in *Table 8.16,* in accordance with Turpie et al. (2010). Not all of these habitats may be represented in every estuary, as this is subject to a range of environmental factors.

Table 8.16 ***Flora Habitats associated with a Typical Estuarine Environments***

Habitat Type	Defining Features of a Habitat
Open surface water area	Habitat for phytoplankton
Intertidal sand and mudflats	Habitat for intertidal benthic microalgae
Submerged macrophyte beds	Eg *Zostera capensis* (eelgrass), *Ruppia cirrhosa, Potamogeton pectinatus*
Macroalgae	Distribution changes along a gradient from the sea landwards, eg *Ulva* spp., *Enteromorpha* spp., *Caulerpa filiformis*
Intertidal salt marsh	Halophytic species, often succulent, eg *Spartina maritima, Sarcocornia perennis, Triglochin* spp.
Supratidal salt marsh	Halophytic species tolerant of salt spray, which includes species such as *Sarcocornia pillansii, Sporobolus virginicus*
Reeds and sedges	*Phragmites australis, Schoenoplectus littoralis*
Mangroves	*Avicennia marina, Rhizophora mucronata, Bruguiera gymnorrhiza*
Swamp forest	Occurring on the landward side of the estuary, and includes species such as *Barringtonia racemosa, Hibiscus tiliaceus*

Classification adapted from Turpie et al.(2010) by NSS (2012).

Although the ecological significance of each of these estuarine habitats as a whole must not be overlooked, the mangroves within these habitats are of particular global importance. Mangroves are a unique forest type and are limited to the intertidal area of estuaries, lagoons and sheltered coastal zones. They act as nurseries for larval fish and certain fish are functionally dependent on them for survival. This unique forest type is a high priority for conservation, as natural expansion of populations is rarely ever documented (Spalding et al., 2010). Mangrove populations worldwide are declining at a rate of 0.66 percent per year (according to the most recent estimates), which is three to five times higher than the decline of other forest types (Spalding et al., 2010). While mangroves in Africa are generally not as diverse as in other regions in the world, the latest records (Spalding et al., 2010) show that Mozambique and Tanzania have the highest diversity in the African continent (excluding introduced species).

Both of the estuaries assessed for this study were identified as shallow-water saline systems with sandy substrates. Dense mats of decomposing organic matter were recorded at the south-eastern estuary site, MOZ 4 in particular. The description of the vegetation found at each estuary site is listed in the summary provided for each estuary sampled (see *Figure 8.36* and *Figure 8.38*). Overall, plant species diversity was low (which is not uncommon for saline systems) but mangrove diversity was considerably higher. The low diversity of submerged macrophytes may be attributable to low water levels, as submerged macrophytes require >1.5masl to develop (Van Niekerk et al., 2008).

Sediment

The grain size distribution within the estuaries (MOZ 4, MOZ 6 and MOZ 12) is dominated by medium and coarse sand, with very fine sand representing about 15 percent of the total sediment fractions. This is evident between the various sites sampled within the estuaries. The samples from the three estuarine sites indicate poorly sorted sediment (with the exception of MOZ 6b, which was classified as very poorly sorted), indicating that no severe impacts are present that have altered the physical properties of the sediment. The moisture content was found to be fairly low, at an average value of around 20 percent; this low percentage will have no significant impact on the ecosystems, but does influence the habitat character and the overall ecosystem composition. The organic content of the samples was classified as Low according to the USEPA (2001) for samples MOZ4a, MOZ4b and MOZ6a. It was evident during the sampling survey that organic content in the estuaries originates from upstream sources, local sources including mangroves and from the seagrass beds situated in the near shore.

A follow-up survey of the estuarine sites during June 2012 resulted in similar moisture content at the sites, while the additional sampling site MOZ 12 also indicated similar moisture content values. The organic content during the June survey was again Low to Very Low according to the USEPA (2001) scale, reinforcing that organic material is not staying within the system but being transported to the sea.

Water Quality

The following physical variables were examined for the estuarine systems:

- DO;
- temperature;
- EC;
- TDS;
- salinity; and
- pH.

The mean values of the physical variables measured are shown in *Table 8.17* and are discussed further in the sections below. The constituents were compared to the SAWQG for Coastal Aquatic Ecosystems (DWAF, 1996c) to see if the values fell within the TWQR. When these values were not available, the results were compared to the USEPA (2009), United Nations Water Quality guidelines (UNWQG) and Australian and New Zealand guidelines (ANZECC, 2000a) to give an indication of ecosystem deterioration in the Survey Area, with the understanding that these are not absolute for Mozambique.

Table 8.17 Physical Water Quality Parameters of the Estuarine Sampling Sites in Low Flow 2011 and 2012 and High Flow 2012

In situ Variables	Range	MOZ 4			MOZ 6			MOZ 12
		LF 2011	HF 2012	LF 2012	LF 2011	HF 2012	LF 2012	LF 2012
DO (mg/l)	A>5 B6-14	*4.62*	*4.55*	5.85	*3.86*	*2.73*	5.94	5.80
DO (%)	C>80–90	*73.40*	*73.44*	*77.17*	*60.47*	*44.39*	*78.80*	*73.09*
Temp (°C)	A Must not exceed ambient temp by 1%	28.3	29.5	26.5	29.4	30.7	27.9	26.1
EC (mS/m)	–	5,793	5,566	1,834	5,008	5,215	1,293	790
TDS (mg/l)	–	28,966	27,829	9,171	25,040	26,074	6,468	3,951
Salinity	32–36	*38.53*	*36.78*	10.85	32.67	34.15	7.42	4.40
pH	A7.3–8.2 B6.5–8.5	7.7	7.5	7.1	7.4	6.9	6.6	6.6

Key:
–: No data available.
A Water Quality Guidelines for South African coastal marine waters (DWAF, 1996c).
B USEPA (2009) WQ guidelines.
C Western Australian WQ guidelines.
Constituents that did not meet the TWQR for saltwater are *italicised*.

Legend: LF: low flow; HF: high flow.

Source: NSS, 2012.

Dissolved Oxygen

Dissolved oxygen levels usually range from 6 to 14mg/l in saline water because it has limited solubility. However, DO values observed in the estuaries are considered to be low in comparison, ranging from 2.73 to 4.62mg/l, with higher levels observed at Catchment B. This is typical of mangrove waters. DO concentrations naturally vary over a 24-hour period as a result of tidal exchange. Under warmer conditions, water is more likely to become anoxic or hypoxic because of a decreased ability of water to hold DO and increased bacterial respiration. The water temperature at MOZ 4 (Catchment B) was 1°C lower than MOZ 6 (Catchment A) and this may explain the higher DO value recorded at Catchment B. In addition, there was a visible increase in DO values at the two sites during low flow 2012, which was probably influenced by the drop in temperature at these sites. A similar DO value was recorded at MOZ 12 during this time.

Temperature

Temperatures ranging between 28.3 °C (Catchment B) and 30.7°C (Catchment A) were observed at low flow in 2011 and 2012. Water temperatures observed during the high flow 2012 survey were higher compared to those observed during the low flow 2011 survey, as the measurements were taken in February, a hot summer month in comparison to October (spring). The temperatures dropped to 26.5 °C (MOZ 4) and 27.9 °C (MOZ 6) during June 2012 (winter), with MOZ 12 showing a similar temperature of 26.1 °C as the other estuarine sites during this time. Water temperature influences the density (densest at 4°C), conductivity and pH of these water columns.

Electrical Conductivity

The EC values of the estuarine sites are considered to be high, as a result of the high concentrations of cations (Ca^{2+}, Mg^{2+}, Na^{+}) and anions (Cl^{-} and SO_4^{2-}) at these sites. These concentrations are natural for saline systems. An evident decreased EC was noted during the low flow 2012 sampling, which was probably due to an influx of fresh water into these systems as a result of the heavy rains in the area before and during sampling.

Total Dissolved Solids

The TDS values observed at the estuarine sites are considered extremely high, probably due to the fact that the TDS were measured at the mouth of the mangroves at low tide, and reflect the high concentrations of cations (ie Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (ie Cl^{-} and SO_4^{2-}) at these sites. However, these extremely high TDS values observed were also found in a similar study in the mangrove ecosystems in the south-east coast of India (Ramanathan et al., 1999).

The TDS values reduced considerably during the low flow 2012 sampling, which was probably caused by fresh-water floods entering these systems due to increased rainfall in the area. MOZ 12 had a similar TDS value as recorded from the other two estuaries during this time.

The estuarine systems were hypersaline and only dependent on tidal flow, with no fresh water flowing into these systems. The estuarine water can become denser than oceanic waters under these conditions, sinking and forming a high-saline bottom layer.

Salinity

Subtropical surface waters of the east coast of Africa are usually characterised by relatively high salinities (>35) caused by greater evaporation rates. The salinity at Catchment B was higher than at Catchment A, indicating that more saline water entered this system from Palma Bay. The limited fresh water draining from upstream wetlands did not reduce the salinity levels, as the levels were similar during both the low flow and high flow surveys. However, during low flow 2012, the salinity dropped as low as 11 (MOZ 4) and 7 (MOZ 6), which confirms the assumption that there was an influx of fresh water into these systems. A salinity value of 4, the lowest observed, was observed at MOZ 12.

pH

According to the international guidelines of the EPA, the pH for saline systems should range between 6.5 and 8.5. The pH values within the estuaries sampled range between 6.9 (MOZ 6 – Catchment A) and 7.7 (MOZ 4 – Catchment A), indicating alkaline brackish waters, probably due to dissolved calcium from shells and offshore coral influencing the estuaries.

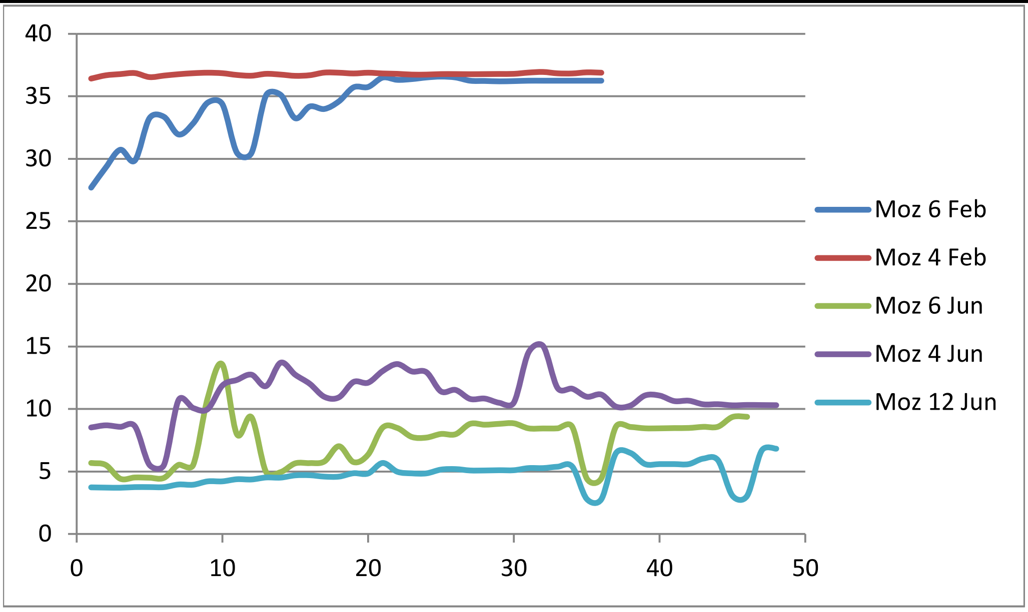
Water Quality Profiles

An important aspect of estuarine ecology is the gradient or profile of salinity within the estuary. Estuaries can be fresh-water dominated with a low level of sea water intrusion, or more marine dominated if the fresh-water inflow is limited. A salinity profile for each estuary is provided in *Figure 8.25* below.

No significant salinity profile was seen at site MOZ 4 (Catchment B) during the February 2012 survey, indicating that the fresh-water inflow to MOZ 4 was limited and the estuary was dominated by sea water. The salinity profile for the June 2012 survey indicated that no profile was evident from the head to the mouth of the estuary; however, the salinity was significantly lower than during February 2012. This trend was also observed at MOZ 6 (Catchment A) during the June 2012 survey, compared to the February 2012 survey. The slight salinity profile seen during February 2012 at MOZ 6 was still present during June 2012, even though it was less pronounced. These lower salinities will change during the high tide, as the tidal variation intrudes up to the head of both these estuaries. The salinity profile of MOZ 12 did indicate a salinity increase from the head to the mouth of the estuary. However, the salinity at MOZ 12 was lower than at MOZ 4 and MOZ 6, which possibly indicates a more significant fresh-water source.

Salinity is one of the key characteristics that determine the composition of the fauna and flora within an estuary, especially for the benthic invertebrate fauna. According to Gibson et al. (2000), the abundance of taxa present was affected by salinity with a relatively low richness found in brackish water as compared to fresh water and sea water.

Figure 8.25 *Salinity Profile of MOZ 6 (Catchment A), MOZ 4 (Catchment B) and MOZ 12 (Catchment E)*



Key:
X-axis: 10m intervals from the estuary mouth to upper reaches of the estuary.
Y-axis: salinity (in PSU).

Source: NSS, 2012.

The pH within sites MOZ 6 and MOZ 4 follows a similar trend to that of salinity. At site MOZ 6 in February 2012, the pH was approximately 5 at the upper reaches of the estuary, increasing to 7.2 at the mouth of the estuary. This is due to the increased salts of the sea water increasing the pH. The pH profiles during June 2012 for both MOZ 4 and MOZ 6 indicated a lower pH, corresponding to the decreased in salts due to the increased fresh-water inflow. The pH of MOZ 12 was similar to the pH profile measured at MOZ 6.

The percentage oxygen saturation for MOZ 6 and MOZ 4, measured together with the pH and salinity, indicates a relatively low saturation percentage in the upper reaches compared to the mouth of the estuary. This could be due to the notably higher water volume within the upper reaches compared to the mouth. In addition, the cover of the mangroves was significantly higher within the upper reaches compared to the mouth, which could lead to a slightly lower photosynthetic rate.

Chemical Water Quality Parameters

The concentrations of nutrients, metals and salts at each of the sampling sites are listed in *Table 8.18*. The constituents analysed at each site were compared to the SAWQG for Coastal Aquatic Ecosystems (DWAF, 1996c) to see if the values fell within the TWQR. When these values were not available, the results were compared to other international guidelines. It was found that the concentrations of Ba, Cu, Ni, Pb, Zn and NO_3 exceeded the TWQR. Seasonal trends were observed, with the concentrations of Ni, Cu and NO_3 being higher during low flow 2011 and Pb higher during high flow 2012.

The water in the estuaries mostly consisted of sea water. It was not possible to determine the sources that lead to the high concentrations in the estuaries.

Table 8.18 Constituents Measured at Estuarine Sampling Sites during Low Flow 2011 and 2012 and High Flow 2012

		MOZ 4			MOZ 6			MOZ 12
Constituents	**TWQR**	**Low Flow 2011**	**High Flow 2012**	**Low Flow 2012**	**Low Flow 2011**	**High Flow 2012**	**Low Flow 2012**	**Low Flow 2012**
Metals								
Al (mg/l)	-	<0.006	<0.006	<0.006	<0.006	<0.006	0.016	0.027
Ag (mg/l)	0.005[a]	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
B (mg/l)	-	6.309	5.185	0.909	3.631	4.538	0.546	0.750
Ba (mg/l)	**0.001[b]**	<0.001	*0.032*	*0.017*	*0.031*	*0.030*	*0.013*	*0.219*
Be (mg/l)	-	<0.001	-	-	<0.001	-	-	-
Bi (mg/l)	-	<0.01	-	-	<0.01	-	-	-
Ca (mg/l)	-	495.189	449.892	71.582	277.677	400.853	43.566	52.559
Cd (mg/l)	0.004[a]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Co (mg/l)	-	<0.002	0.016	<0.002	<0.002	0.004	0.006	0.004
Cr (mg/l)	0.008[a]	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cu (mg/l)	**0.005[a]**	*1.284*	*0.268*	*0.034*	*1.225*	*0.256*	*0.030*	*0.032*
Fe (mg/l)	0.1[b]	<0.006	<0.006	<0.006	<0.006	<0.006	0.024	<0.006
Ga (mg/l)	-	0.066	-	-	0.055	-	-	-
Hg (mg/l)	0.0003[a]	-	<0.001	<0.001	-	<0.001	<0.001	-
Li (mg/l)	-	0.224	0.192	0.032	0.118	0.164	0.020	0.024
Mn (mg/l)	-	0.028	<0.001	<0.001	0.075	<0.001	<0.001	<0.001
Mo (mg/l)	-	-	0.143	0.045	-	0.141	0.041	0.036
Ni (mg/l)	**0.025[a]**	*0.245*	<0.003	<0.003	*0.285*	<0.003	<0.003	0.042
Pb (mg/l)	**0.012[a]**	*0.14*	*0.246*	0.010	*0.20*	*0.366*	*0.025*	*0.037*
Si (mg/l)	-	6.816	6.122	0.930	9.176	6.408	4.214	2.105
Sr (mg/l)	-	9.329	8.064	1.304	4.993	7.081	0.793	0.872
Rb (mg/l)	-	1.607	-	-	1.011	-	-	-
Te (mg/l)	-	<0.023	-	-	<0.023	-	-	-
Tl (mg/l)	-	<0.087	-	-	<0.087	-	-	-
V (mg/l)	-	1.437	-	-	1.066	-	-	-
Zn (mg/l)	**0.025[a]**	*0.111*	*0.132*	*0.067*	*0.105*	*0.087*	*0.032*	*0.108*
Ions								
Cl (mg/l)	-	19,857.7	18,498.3	2,992.5	11,505.6	16,393.0	2,992.5	2,891.7
F (mg/l)	5[a]	0.987	0.915	0.353	0.678	0.815	0.258	0.280
K (mg/l)	-	470.613	413.779	69.127	261.087	362.184	41.226	47.646
Mg (mg/l)	-	1,538.947	1,319.052	226.873	860.329	1,161.638	159.530	171.680
Na (mg/l)	-	10,632.45	10,512.76	1,865.21	6,970.54	9,488.98	1,662.03	1,530.80
Nutrients								
NO_3 (mg/l)	**0.01[b]**	*0.180*	<0.057	0.098	*0.215*	<0.057	0.168	0.069

		MOZ 4			MOZ 6			MOZ 12
Constituents	**TWQR**	**Low Flow 2011**	**High Flow 2012**	**Low Flow 2012**	**Low Flow 2011**	**High Flow 2012**	**Low Flow 2012**	**Low Flow 2012**
NH_4 (mg/l)	0.6[a]	0.515	0.560	<0.057	0.348	0.516	<0.057	<0.057
NO_2 (mg/l)	-	-	<0.005	<0.005	-	<0.005	<0.005	<0.005
PO_4 (mg/l)	<6.7[a]	<0.025	<0.025	<0.025	<0.025	0.055	<0.025	0.041
SO_4 (mg/l)	-	2,490.34	3,208.88	593.21	1,584.60	3,159.75	348.66	356.20
Total alkalinity (mg/l)	-	33.7	32.8	15.8	47.4	26.4	22.9	23.0
Total hardness (mg/l)	-	7,574	6,555	1113	4,236	5,785	766	838
Soap, grease and oil (SOG) mg/l	-	-	0.10	2.80	-	0.25	0.60	1.4
Organic enrichment								
COD (mg/l)	-	-	953.10	53.65	-	868.50	1,061.60	599.10
Chlorohpyll A	-	-	-	<0.01	-	-	<0.01	<0.01
Turbidity								
SS (mg/l)	-	-	323	70	-	276	54	38
Turbidity (NTU)	-	-	2.1	3.6	-	1.6	4.5	3.9

Key:
– = Not available.
a = South African Guidelines for Coastal Waters (DWAF, 1996c).
b = International Guidelines – USEPA (2009).
Constituents in coastal water exceeding the South African (DWAF, 1996c) and USEPA (2009) TWQR are *italicised*.

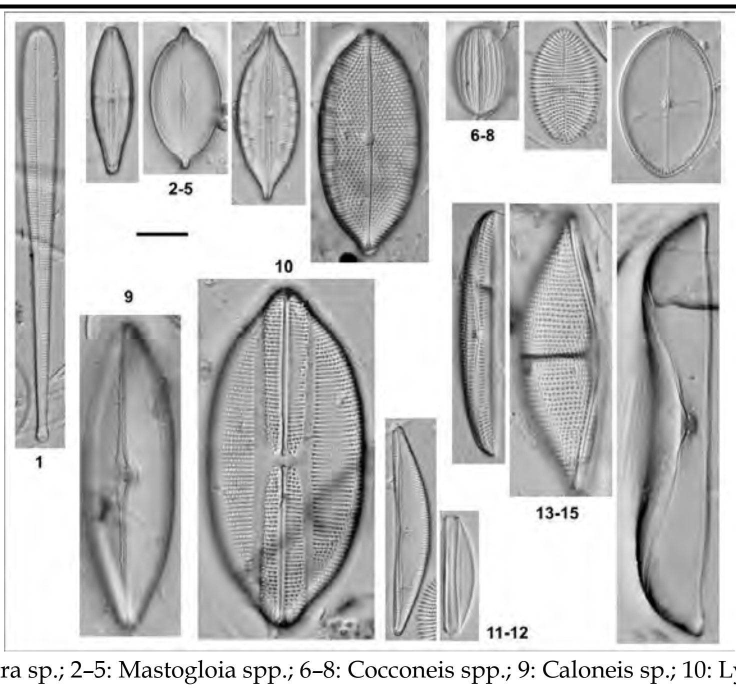
Source NSS, 2012.

Microalgae and Benthic Microalgae

Six different groups of microalgae were observed in the estuaries during the February 2012 survey: diatoms, chlorophyta, cynanophyta, crysophyta and dinoflagelletes. The most abundant taxa present are diatoms, followed by chlorophyta (green algae), in both the February and June surveys. A similar trend was seen for the benthic phytoplankton where the diatom group was the dominant taxa. Benthic microalgae and microalgae depend on fresh-water inflow to provide nutrients into the system and, as the fresh-water inflow is fairly low, their abundance are limited (Snow et al., 2000). No visible algal patches were seen to indicate significant amounts of nutrients within the system. Nutrients within the water samples were also found to be low and, as such, limiting the growth and abundance of microalgae and benthic microalgae.

The diatoms were dominated by a high abundance of *Gomphosphaenia* sp., *Amphora* sp., *Navicula* sp. and *Rhopalodia* sp. Twenty species were observed, all of which are considered to be naturally abundant in saline conditions. In terms of impacts, none could be identified with certainty, although no deformed cells were evident and the abundances tended to be natural, which suggested limited stress on diatom communities. Spatial analysis, however, did reveal that diatoms at MOZ 4 were composed of more tolerant species.

Figure 8.26 Brackish Water Diatom Species



1: Licmorphora sp.; 2–5: Mastogloia spp.; 6–8: Cocconeis spp.; 9: Caloneis sp.; 10: Lyrella sp.; 11–12: Seminavis spp.; 13–15: Amphora spp. Scale bar = 10 µm.

Invertebrates

Research has shown that up to 200 species are able to occur in the benthic substrate in subtropical estuaries (NSS, 2012). Four species of microinvertebrates were observed in the estuaries of Catchment A and B (see *Table 8.19*).

Table 8.19 Micro-invertebrate Species Observed at Estuarine Sites

Order	Family	Species
Decapoda	Palaemonidae	*Macrobranchium equidens*
Phyllodocida	Nereididae	*Dendronereis arborifera*
Phyllodocida	Nereididae	Unidentified sp.
Tanaidacea	Apseudidae	*Apseudes digitalis*

Source: NSS, 2012.

The zooplankton sampling resulted in nine taxa being collected, of which eight were sampled at site MOZ 6 and six taxa sampled at site MOZ 4 during February 2012. The June 2012 sampling survey resulted in eight taxa overall, with seven taxa sampled at MOZ 6, six taxa at MOZ 4 and only five taxa sampled at the additional site MOZ 12. The benthic invertebrates results showed 17 different taxa were sampled at site MOZ 4 and 14 taxa at site MOZ 6 during February 2012. The total taxa diversity between the two estuaries counted as 24 taxa. The June 2012 survey yielded 18 different taxa at site MOZ 4, MOZ 6 and MOZ 12. However, the abundances of especially the Amphipoda taxa were significantly higher in June than during February 2012. The sampling at MOZ 12 yielded seven taxa, MOZ 4 yielded eight, and 16 taxa were sampled at MOZ 6. Overall, the abundance of taxa was also the highest at MOZ 6. MOZ 6 also yielded one family that predominantly occur in fresh water ie Chironomidae.

A fairly diverse benthic invertebrate community supported by the poorly sorted sediment and the present organic content is present in the estuaries of the Survey Area. The important taxa group sampled in this assessment was the Decapoda. They are a very important part of the mangrove system, playing a key role in the cycling of nutrients in these systems, and were found to be the most abundant taxa at both estuary sites. These taxa were also evident throughout all the mudflats present in the upper reaches of the estuary systems. These areas possibly only receive water during flooding, and potentially at spring tide. The results also indicated no significant seasonal differences in diversity at MOZ 4 and MOZ 6, while the diversity at MOZ 12 was similar to the other sites. However, at MOZ 6 the abundances of zooplankton were significantly higher during the June 2012 survey. The abundance of zooplankton at site MOZ 12 was similar to MOZ 6, while at MOZ 4 a slightly decreased abundance as compared to MOZ 6 was seen. This is an indication of a functioning ecosystem, as the higher water levels in May and June 2012 have resulted in more nutrients being available for phytoplankton and, as such, the zooplankton community.

Ichthyofauna

The fish species sampled during the high flow and low flow surveys at the three estuary sites are presented in *Table 8.20*. A higher level of connectivity is present within MOZ 6, as is evident by the sampling of *M. cyprinoides* at fresh-water MOZ 5, indicating the connectivity of the system. The dusky sleeper, *E. fusca,* was also sampled at MOZ 5, providing further evidence of connectivity as well as the importance of the estuary. The fish species sampled within the estuaries are not considered to be under any serious conservational threat according to the IUCN, with the exception of *O. mossambicus,* which is listed as Near Threatened as this species inbreeds with *O. niloticus,* a species quite common in parts of Africa. Some of the species observed, however, have not been evaluated by the IUCN and therefore no information about their status is available. *Chanos chanos* (milkfish) may be considered as potential conservation concern, as it is a commercially exploitable species. However, most of this species sampled in the estuaries were juveniles, which rely on mangrove systems as a nursery ground. They are particularly susceptible to impacts in the water and habitat through direct toxicity or via indirect mechanisms (eg increased susceptibility to predation).

Table 8.20 Fish Species Sampled at Estuary Sites

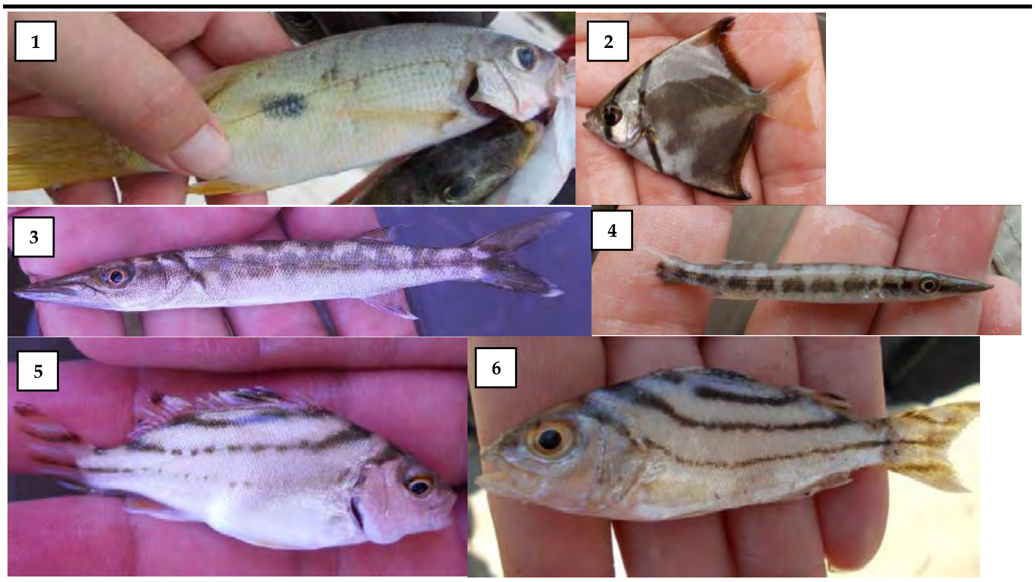
Common Name	Species Observed	Conservation Status*	Estuarine Use Functional Group
Mozambique tilapia	*Oreochromis mossambicus*	Near Threatened	FM
Halfbeak	*Hemiramphus far*	Not assessed	MMO
Round/Natal moony	*Monodactylus argenteus*	Not assessed	MM
White-spotted puffer	*Arothon hispidus*	Not assessed	MS
Mangrove red snapper	*Lutjanus argentimaculatus*	Not assessed	MMO
Great barracuda	*Sphyraena barracuda*	Not assessed	MMO
Milkfish	*Chanos chanos*	Not assessed	MMO
Dusky sleeper	*Eleotris fusca*	Least Concern	ER
African mudskipper	*Periophthalmus argentilineatus*	Not assessed	ER
Bentstick pipefish	*Trachyrhamphus bicoarctatus*	Not assessed	EM
Thornfish	*Terapon jarbua*	Least Concern	MM
Commerson's glassy perchlet	*Ambassis ambassis*	Least Concern	EM
Squaretail mullet	*Liza vagiensis*	Not assessed	MM
Mullet	*Liza dumerilii*	Not assessed	MM
Striped silver biddy	*Gerres methueni*	Not assessed	MMO
Cardinalfish	*Apogon* sp.	Not assessed	MS

Key:
FM = Fresh-water migrants; MM/MMO = Marine migrants; MS = Marine straggles; ER/EM = Estuarine species. * The conservation status is based on the IUCN Red List of Threatened Species (2012).

Source: NSS, 2012.

As evident in *Table 8.20*, the dominant guild within the estuaries is the marine migrant, which indicates a dominance of species that spawn in the ocean but then enter estuaries in large numbers and specifically as juveniles. These species are often euryhaline (capable of tolerating a wide range of salt concentrations). Some marine migrants depend on estuaries to survive, and most of the species classified in this guild observed are opportunistic and are able to use the near shore marine environment as an alternative habitat if estuarine conditions are not present (Elliot et al., 2007). Some examples of these species are shown in *Figure 8.27*.

Figure 8.27 Marine Fish Species Observed in the Estuaries Sampled



1: Mangrove red snapper *(Lutjanus argentimaculatus)*; 2: Round/Natal moony (*Monodactylus argenteus*); 3: Great barracuda (*Sphyraena barracuda*); 4: Juvenile great barracuda; 5–6: Thornfish (*Terapon jarbua*).

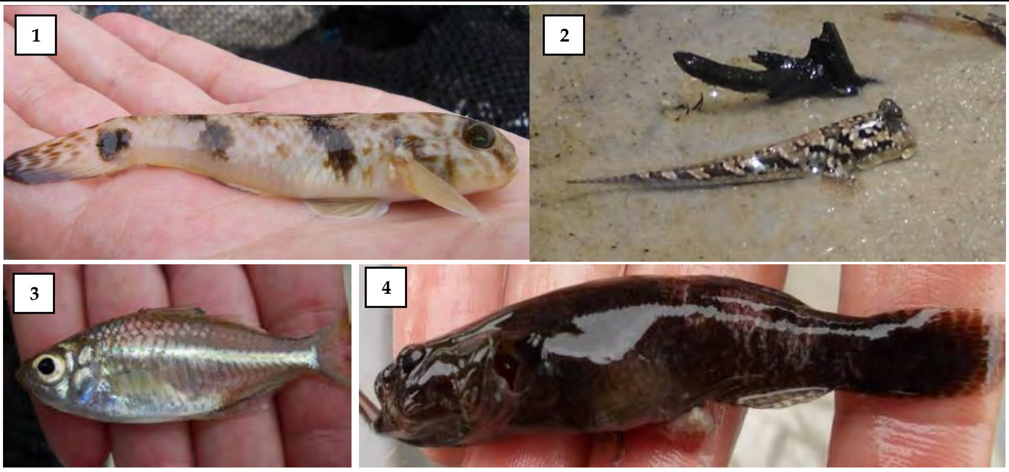
Source: NSS, 2012.

Estuarine residents were also present, and these species are capable of completing their full life cycle within the estuarine environment and are shown in *Figure 8.28*. Estuarine migrants can be species that have a larval stage of their life cycle that occurs outside of the estuary, or the species can be represented by a discreet marine population. Marine stragglers enter estuaries only in low numbers, occur only in the lower reaches of an estuary due to their limited tolerance to fresh water, and are mostly associated with the near shore marine environment (Elliot et al., 2007). Fresh-water migrant species frequent estuaries in moderate numbers and can occur beyond the oligohaline reaches of an estuary.

As shown in *Figure 8.28*, African mudskippers (*Periophthalmus argentilineatus*) were observed in the estuaries. These are restricted to the mangrove systems of East Africa. This fish species is amphibious and uniquely adapted to intertidal habitats – they can move in water as well as using their pectoral fins to walk on land. Other estuarine species observed are shown in *Figure 8.28.*

The fish communities present in Catchments A and B are diverse. The habitat conditions and fish observed indicate that numerous functions are provided for the fish community by these estuaries.

Figure 8.28 Estuarine Fish Species Observed in the Estuaries



1–2: African mudskipper (*Periophthalmus argentilineatus*); 3: Commerson's glassy perchlet (*Ambassis ambassis*); 4: Dusky sleeper (*Eleotris fusca*).

Source: NSS, 2012.

Avifauna

Birds make an important contribution to the recreational and aesthetic value of estuaries, as well as contributing to the maintenance of estuarine processes through predation and nutrient inputs (DWA, 2010). A number of species were observed within the estuarine habitats, including waders in the intertidal area; these are further detailed in *Section 8.9* of this chapter.

Estuarine Resources

The specific resources that are provided by estuaries are generally related to the provisioning fish (as bait and food) and shellfish resources that are important for recreational, subsistence and informal commercial purposes. Estuaries are also able to provide raw materials like reeds and sedges for crafts and fencing, while mangroves forests can provide material for building, firewood, timber and poles. The ecosystem services offered by estuaries differ between estuaries due to their catchment characteristics. The most important services of estuaries are their nursery functions and the export of sediment and nutrients needed for the marine environment (DWA, 2010). Estuaries serve as a nursery to many fish species that can then recruit into marine fisheries areas offshore (Lamberth & Turpie, 2003). These systems can also provide a refuge area for coastal species, as estuaries have sheltered habitats that are not generally present in the more exposed coastline. The habitats and biodiversity in estuaries can also provide cultural services in the form of recreation, education and research opportunities.

Estuarine Sensitivity

Based on present data, the quality of habitat, existing alterations (man-made) to the system and current land use in the Survey Area, these estuaries are considered to be in a good condition. The estuaries are considered to be Highly Sensitive (as defined in *Annex C*). These are discussed further in *Section 8.6.6* by catchment.

Four species of frogs were recorded at both MOZ 4 and MOZ 12, including the following species of conservation concern: Parker's reed frog (*Hyperolius parkeri*) and African bullfrog (*Pyxicephalus edulis*) at MOZ 4 and snoring leaf-folding frog (*Afrixalus crotalus)* and Lindner's toad (*Mertensophryne lindneri*) at MOZ 12. Only two species of frog were observed at MOZ 6, within highly brackish areas of the estuaries. Lindner's toad is considered to be the species of highest conservation importance of all the amphibians detected during the surveys of the estuaries. It belongs to the group of habitat-specific toads known as woodland toads. Channing (2001) indicates that this species has been recorded only three times and is restricted to a small region near the Mozambique/Malawi border, but reports that the species has been known to occur within southern Tanzania as well. Although woodland toads, like other toads, are frogs of low wetland association, it is a highly conservation-important species (although only listed as Least Concern) based on its range restriction and decreasing global population trend (IUCN, 2012).

A variety of other faunal species use the mangroves, and evidence of some of those observed are illustrated in *Figure 8.29*.

Figure 8.29 Faunal Species Observed in the Mangroves

Left: Fiddler crab (*Uca annulipes*). Right: Spoor of African clawless otter (*Aonyx capensis*).

Source: NSS, 2012.

The mangrove habitats provide an important buffering capacity between the marine and inland environment. Various marine fish depend on the estuaries as a nursery habitat for immature stages and a large number of bird species are also found to use these estuarine sites, as indicated in *Section 8.9*. The fish communities present in these estuary systems are diverse.

Anthropogenic Influences

Estuaries provide a habitat for important sources of food and building materials for local communities. Human activities such as the harvesting of natural resources (wood, reeds, sedges, snails, fish and salt) are currently affecting the estuarine wetlands (MOZ 4 and MOZ 6). However, all of these impacts are minimal and are currently not having any noticeable effect on the system. Alien vegetation is also present, as evidenced by the cultivation of fruit trees such as coconuts and cashews. *Figure 8.30* shows some examples of existing anthropogenic impacts in the estuaries.

Figure 8.30 Evidence of Anthropogenic Alteration at the Estuarine Sites

Top left: Snail harvesting at MOZ 6. Top right: Extensive coconut plantation – MOZ 6. Bottom left: Evidence of wood harvesting at MOZ 4. Bottom right: Alien tree *Casuarina equisetifolia* – often associated with swamp forest vegetation of estuaries.

Source: NSS, 2012.

8.6.5 Catchment Characteristics

This section describes the characteristics of each of the five catchment areas (A, B, C, D and E) as listed in *Table 8.12*, to provide an overview of the sensitivities of each of the systems.

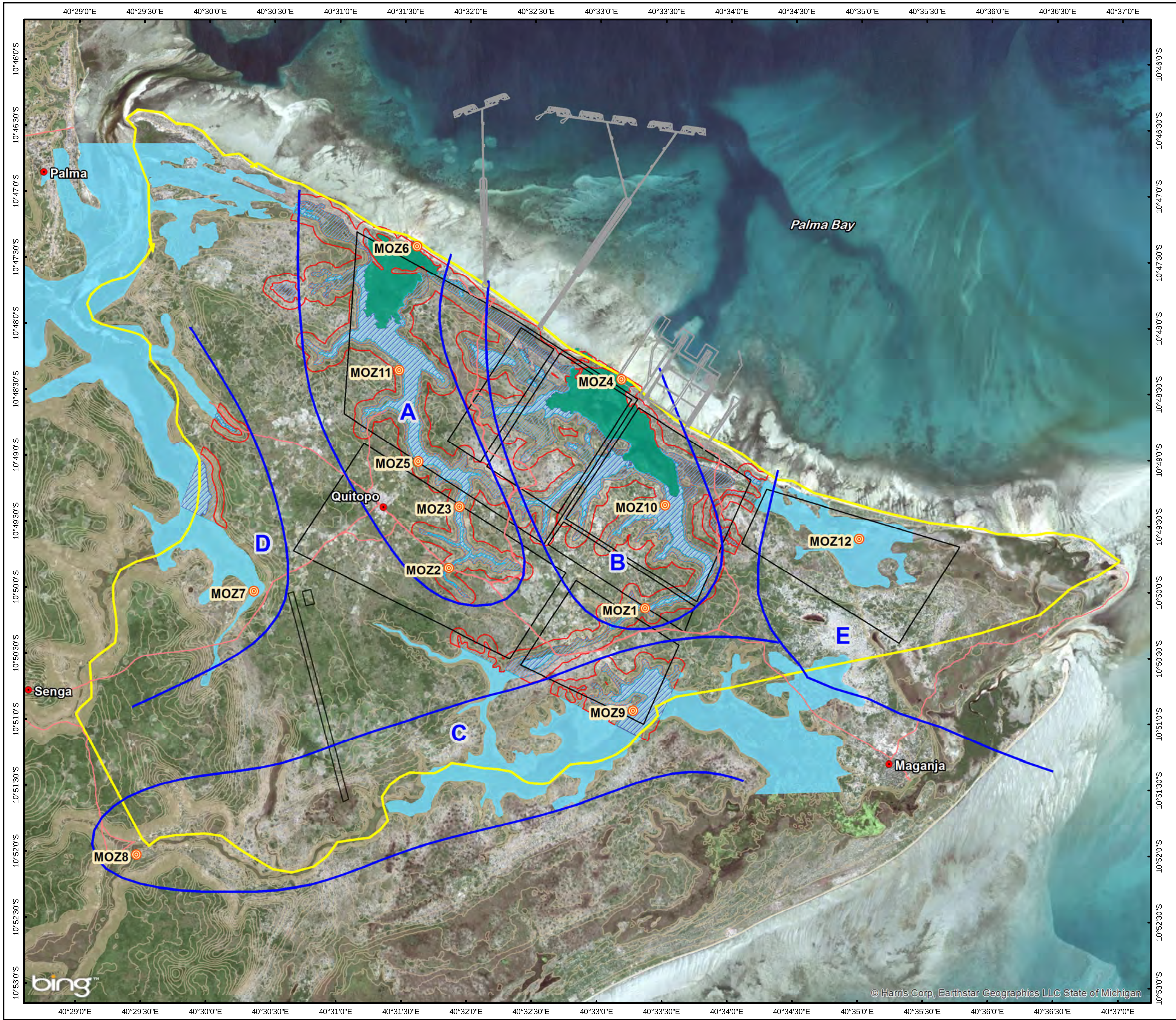
The present ecological status of the wetlands and estuaries has been determined by assessing water quality, diatoms, habitat, macro-invertebrates and fish community integrity based upon the following biotic scoring systems and indices: Index of Habitat Integrity (IHI), Macro-invertebrate Response Index (MIRAI), South African Scoring System, version 5 (SASS5) and Riparian Vegetation Response Assessment Index (VEGRAI). For further detail, see the surface water ecology methodology in *Annex C*. Ecological categories were used to define aquatic and riparian habitat integrity to determine the ecological condition of a river or fresh-water system in terms of the deviation of biophysical components from the natural reference condition (Kleynhans & Louw, 2008), based on scores. The Present Ecological Status categories range over a continuum of levels of disturbance of the natural state of the ecosystem, from no disturbance or natural (Category A) to critically modified (Category F) and are represented by characteristic colours, defined by Kleynhans and Louw (2008) in *Table 8.21***.** Aquatic and riparian habitat integrity has been calculated according to the methodology in *Annex C*.

In some cases, a particular entity may potentially have membership of two classes when there is uncertainty to which category a particular waterbody belongs, and this is reflected below where relevant.

Table 8.21 Present Ecological Status Codes and Descriptions

Category	**IHI (%), MIRAI (%), SASS5, VEGRAI**	**Short Description**	**Long Description**
A	90–100	Natural	Unmodified state with no impacts, conditions natural. (Scores between 87.4 and 92 = A/B)
B	80–89	Largely natural	Largely natural with few modifications. A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged. (Scores between 77.4 and 82 = B/C)
C	60–79	Moderately modified	Moderately modified – loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. (Scores between 57.4 and 62 = C/D)
D	40–59	Largely modified	Largely modified – a large loss of natural habitat, biota and basic ecosystem functions has occurred. (Scores between 37.4 and 42 = D/E)
E	20–39	Seriously modified	Seriously modified – the loss of natural habitat, biota and basic ecosystem functions are extensive. (Scores between 17.4 and 22 = E/F)
F	<20	Critically modified	Critically/extremely modified – modifications have reached a critical level and the system has been modified completely, with an almost complete loss of natural habitat and biota. In the worst instances, the basic ecosystem functions have been destroyed and the changes are irreversible.

Source: Modified from Kleynhans & Louw (2008); Kleynhans (1996, 1999) and Kleynhans et al. (2007).



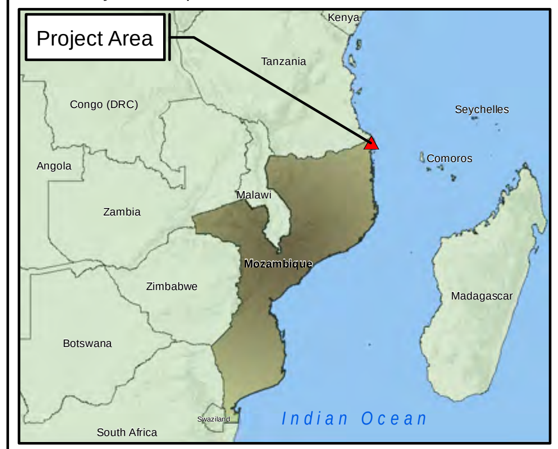
Legend

- Aquatic and Wetland Sites
- Villages / Settlements
- Local Roads
- Contours
- Nearshore Components
- Onshore Project Footprint
- Wetland Groups
- Afungi Project Site

Wetlands

- Estuary
- Permanent wetland
- Seasonal wetland
- Unspecified wetland
- Wetland Buffer (150 m)

Note:
Preliminary - to be updated with catchment E



MAIN MAP SCALE:

0 500 1 000 1 500 2 000

Metres

N

TITLE:

Figure 8.31: Wetland Catchments

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 50 000

DRAWING: Wetland Catchments.mxd

REV: A

ERM
Great Westerford Building
240 Main Road
Rondebosch, 7725
Cape Town, SOUTH AFRICA
Tel: +27 21 681 5400
Fax +27 21 686 073

Impacto Projectos e Estudos Ambientais

ERM

Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
Natural Scientific Services CC, 2012
Inset Map: Esri Data & Maps

SIZE: A3

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Catchment A

Five sampling sites were selected in Catchment A and these are outlined in *Table 8.22*. Catchment A is an unchannelled valley bottom system, ending in a shallow-water estuary with a sandy substrate. The system is a slow-flowing deep wetland, and has artificial channels dug within the wetland to increase the flow for agricultural purposes.

Table 8.22 Sampling Sites within Catchment A

Catchment and Assessment Sites	Site Description
Catchment A	
MOZ 2	Upper catchment zone, close to the start of the permanent wetland
MOZ 3	Mid catchment zone
MOZ 5	Mid catchment zone
MOZ 6	Estuary
MOZ 11	Lower catchment zone with broad permanent wetland

Source: NSS, 2012.

The aquatic habitat integrity of the lacustrine areas of the catchment was Largely Natural with some anthropogenic influences, eg the artificial channels and high algal presence (although no visible algal patches were seen within the estuary site, as described in *Section 8.6.4*).

The overall riparian habitat integrity ranges from Moderately to Largely Modified, with the main anthropogenic influences identified on the upper and lower riparian zones of the catchment from the removal of natural vegetation for the planting of crops, fruit trees, exotic trees, etc. The integrity of the marginal zone was high and ranged from Natural to Largely Natural. The riparian habitat integrity of the estuarine sampling point (MOZ 6) within the catchment was Natural, with virtually no anthropogenic influences present and dominated by dense groves of mangrove trees.

The main ecosystem services supplied by the lacustrine wetlands include natural resource provision and the cultivation of foods. Similarly, the estuary at the mouth of the catchment provides natural resources used by the local people.

In terms of water quality, low oxygen levels, influenced by high temperatures and slightly high salts content, were observed at each of the lacustrine wetland sites within Catchment A (see *Section 8.6.3*). NH_4, COD, SS and Zn had concentrations exceeding TWQRs, within the lacustrine sites, with site MOZ 11 in the lower catchment zone also exceeding levels of Al and Fe. SS, Zn and Al are considered to be naturally occurring constituents within these systems. The higher levels of NH_4, COD and Fe could be attributed to sewage within the lacustrine wetland systems. The water quality results in the estuarine site indicate that the oxygen levels were low and the salinity high (see *Section 8.6.4*). A decrease in the salinity profile was observed at site MOZ

6, indicating that there was fresh-water inflow into the estuary. Within the estuary, the water quality showed exceeding concentration levels of Ba, Cu, Ni, Pb, Zn and NO_3, and because most of the water was sea water, the exact source of contamination could not be determined. Nutrient variables within the estuarine water samples were also found to be low and, as such, limit the growth and abundance of microalgae and benthic microalgae.

The MIRAI scores were Largely Natural to Moderately Modified and indicated that the macro-invertebrates within the lacustrine wetland are influenced by flow modification, habitat and water quality. Low numbers of sensitive families and a generally low family diversity indicated that only tolerant families could survive in these wetlands with limited flow and absence of the stone biotope. In addition to this, there were also high percentages of airbreathers, which were also indicative of slow-flowing habitats with a lack of sufficient oxygen levels, high temperatures and high water levels. Only one species of macro-invertebrate, identified to family level only, was sampled at the estuary site MOZ 6 (see *Section 8.6.4)*. The most abundant benthic invertebrate taxa group sampled in the estuary site was the Decapoda, which play a very important role in the cycling of nutrients in the mangrove system. The zooplankton and benthic invertebrate sampling resulted in eight and 14 taxa sampled at site MOZ 6 respectively. The distribution and abundance of these species living in the benthic environment is dependent on the physical sediment composition. The fairly diverse benthic invertebrate community is supported by the poorly sorted sediment and the organic content present.

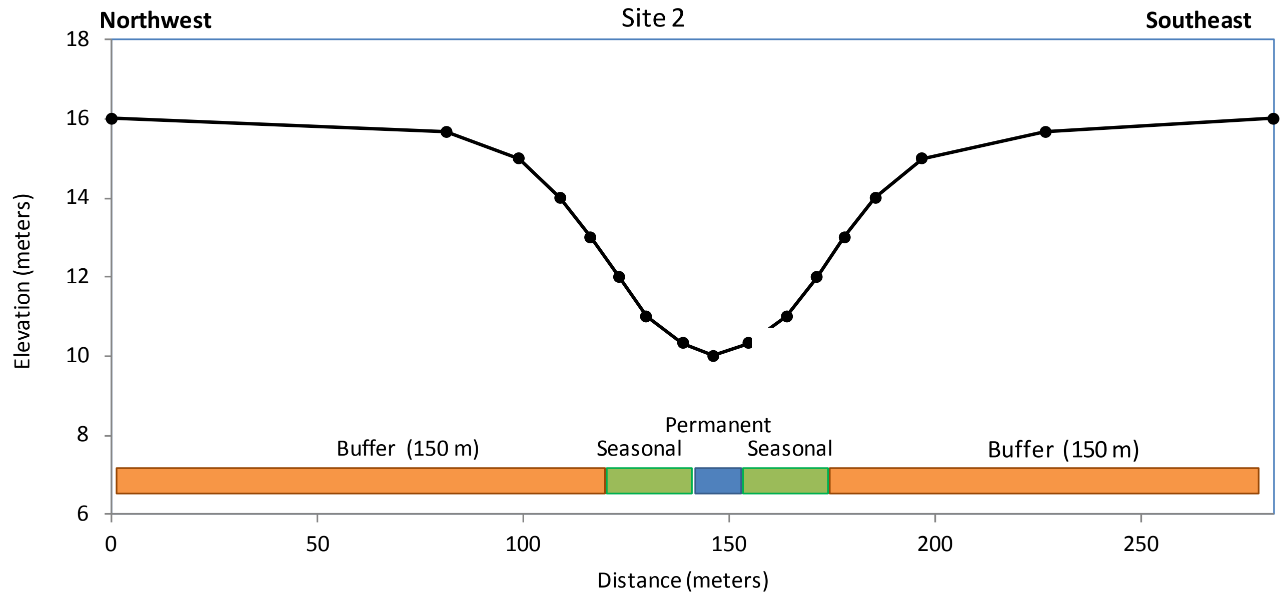
Fish species of note observed in the lacustrine wetlands of Catchment A including the data-deficient *Eleotris fusca* (MOZ 5), *Megalops cyprinoides* (MOZ 5) and *Ambasis ambassis* (MOZ 11). These data-deficient species are important to consider as they may have a conservational importance (see *Section 8.6.3*). The dominant fish guild in the estuary was the marine migrant guild, which indicates species that spawn in the ocean and then enter estuaries in large numbers, specifically as juveniles. The large number of juveniles indicated that the estuary is mostly used as a nursery ground. In terms of number of species, the estuary in Catchment A had a higher number of fish species and a higher abundance of species than the estuary in Catchment B (MOZ 4). This indicates that this estuary is more productive, potentially due to increased phosphates present in the system, the slightly larger size of the estuary and the catchment and connectivity of the estuary.

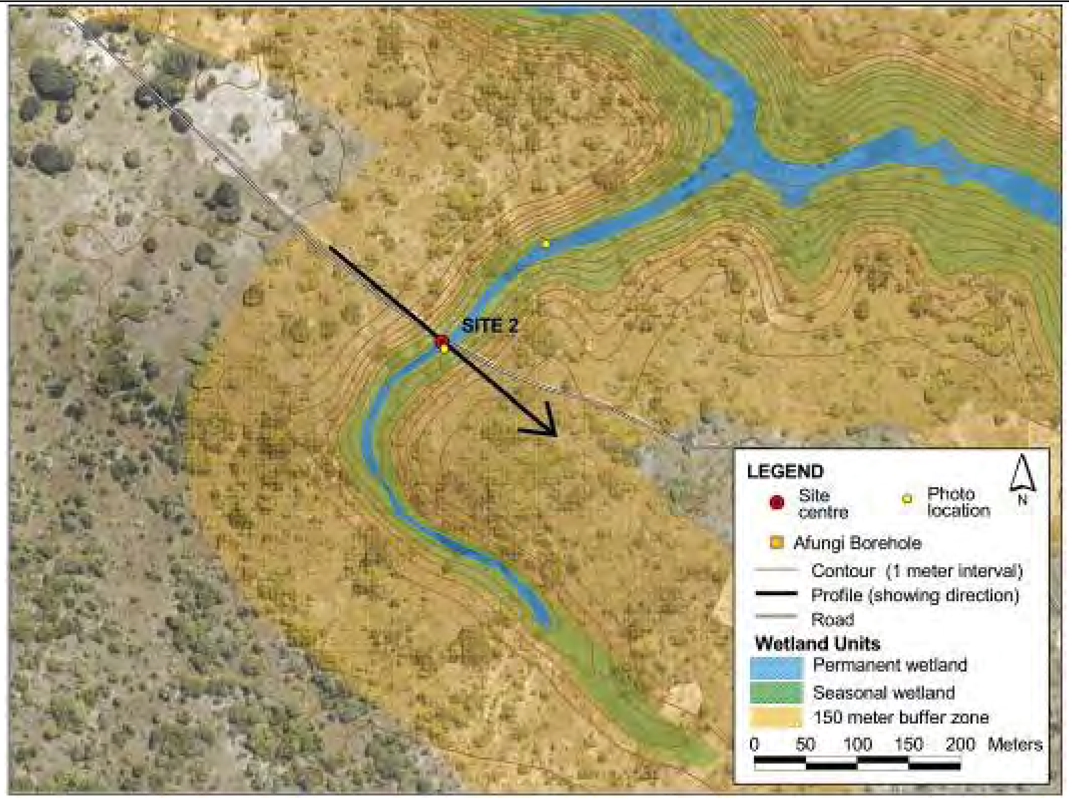
Figure 8.32 to *Figure 8.36* provide general information and detailed results for the high flow (October 2011) and low flow sampling assessments (February 2012) for each sampling site in Catchment A.

Figure 8.32 Sampling Site MOZ 2

Wetland Type	Unchannelled valley bottom wetland, but pooling has occurred due to a road crossing (Catchment A)
Location	In the proposed Project Footprint Area (24 masl). Latitude 10.830675S; Longitude 40.530832E (Geographic projection, WGS84); UTM Zone 39: 8802322S; 667347E

Wetland Layout



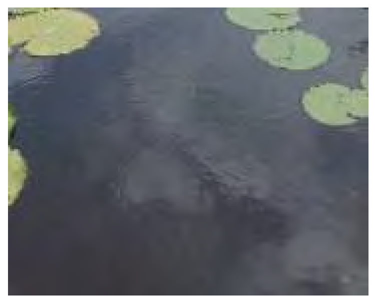


Source: Aerial image supplied by AMA1

General Site Description

This wetland is located towards the top of its catchment, and in the same wetland system as sites 3, 5 and 6. In its natural state, the wetland at this site would consist of a narrow unchannelled valley bottom, but has been altered into a dammed wetland at the site and channelled thereafter.

Photos

Low Flow 2011			High Flow 2012		
UPSTREAM	*DOWNSTREAM*	*CLOSE-UP*	*UPSTREAM*	*DOWNSTREAM*	*CLOSE-UP*
					

Riparian Zone Description

Marginal Zone (MZ)	The marginal zone was approximately 10m wide. There is a large pool of water up to 0.75m deep as a result of a flow obstruction created by building a road across the wetland. In its natural state, the zone was dominated by a diversity of ferns and sedges. A few naturally occurring woody species were present, up to a height of about 5m.
Lower Zone (LZ)	This zone covered an area with a topographical rise of approximately 7m above the marginal zone.
Upper Zone (UZ)	The upper zone was not readily distinguishable from the surrounding terrestrial vegetation, and much of the natural vegetation had been displaced by cultivation and planting of fruit and nut-bearing trees.

Vegetation

SPECIES	MZ	LZ	UZ	SPECIES	MZ	LZ	UZ
Ageratina adenophora *	x			*Hyphaene coriacea*		x	x
Acacia sp.		x		*Mangifera indica* *		x	x
Anacardium occidentale *			x	*Musa acuminata (hybrid)* *	x		
***Berlinia orientalis* (VU)**		x		*Nymphaea nouchali*	x		

Hyphaene coriacea – lala palm

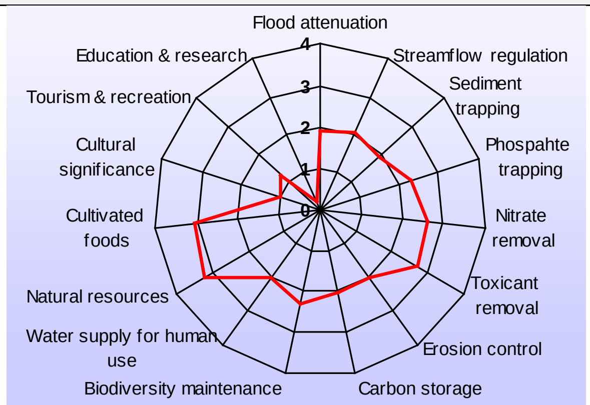
Xylotheca kraussiana

Crinum sp. – pyjama lily

Brachystegia spiciformis		x	x	*Ochna inermis*			x
Combretum apiculatum			x	*Ozoroa obovata*		x	
Combretum eleagnoides		x		*Parinari curatellifolia*		x	
Commelina sp.			x	*Strychnos pungens*			x
Crinum sp.			x	*Syzigium sp.*	x		
Cuscuta sp.	x			*Themeda triandra*		x	
Cyperus prolifer	x			*Uapaca* sp.	x		
Dichrostachys cinerea		x		*Vitex* sp.	x		
Ferns	x			*Xylotheca kraussiana*			x

Key: * denotes alien plant species; VU – Vulnerable as per IUCN Red List classification

Wetland Ecoservices



The ecoservices provided by MOZ 2 feature high levels of cultivated foods and natural resource provision to local communities. Toxicant removal and flood attenuation are moderately important services supplied by this part of the wetland.

Current Impacts

- Road crossing wetland, no culvert installed and causing obstructed flow
- Water extraction for drilling activities
- Litter
- Fish traps
- Water wells downstream
- Alien plants present

Aquatic Description

	Low Flow 2011	High Flow 2012
Water Surface Dimensions	Width: 10 m; Depth: 0.2–0.6m	Width: 10 m; Depth: 0.2–0.8m
Water Turbidity (Dallas 2005)	Clear	Opaque
Dominant Velocity-depth Classes	Slow deep	Slow deep
Water Quality Parameters	T(°C)=35.2; pH=6.6; EC(mS/m)=11.68; DO(mg/l)=10.19; DO(%)=146.9; TDS(mg/l)=58	T(°C)=32.1; pH=5.6; EC(mS/m)=9.48; DO(mg/l) = 5.19; DO(%)=71.72; TDS(mg/l)=47
Algae Presence	Abundant	Abundant
Dominant Biotope Diversity	Pool	Pool
Other Biota	Tadpoles and water birds	Frogs and terrapins
Highly Sensitive Taxa (Score 11–15)	None	None

Riparian Present Ecological State

ZONE	**Overall**	**Marginal**	**Lower**	**Upper**
VEGRAI %	65.3	87.5	57.5	51.0
Ecological Categories (EC)	**C – moderately modified**	**A/B – natural– largely natural**	**C/D – moderately – largely modified**	**D – largely modified**

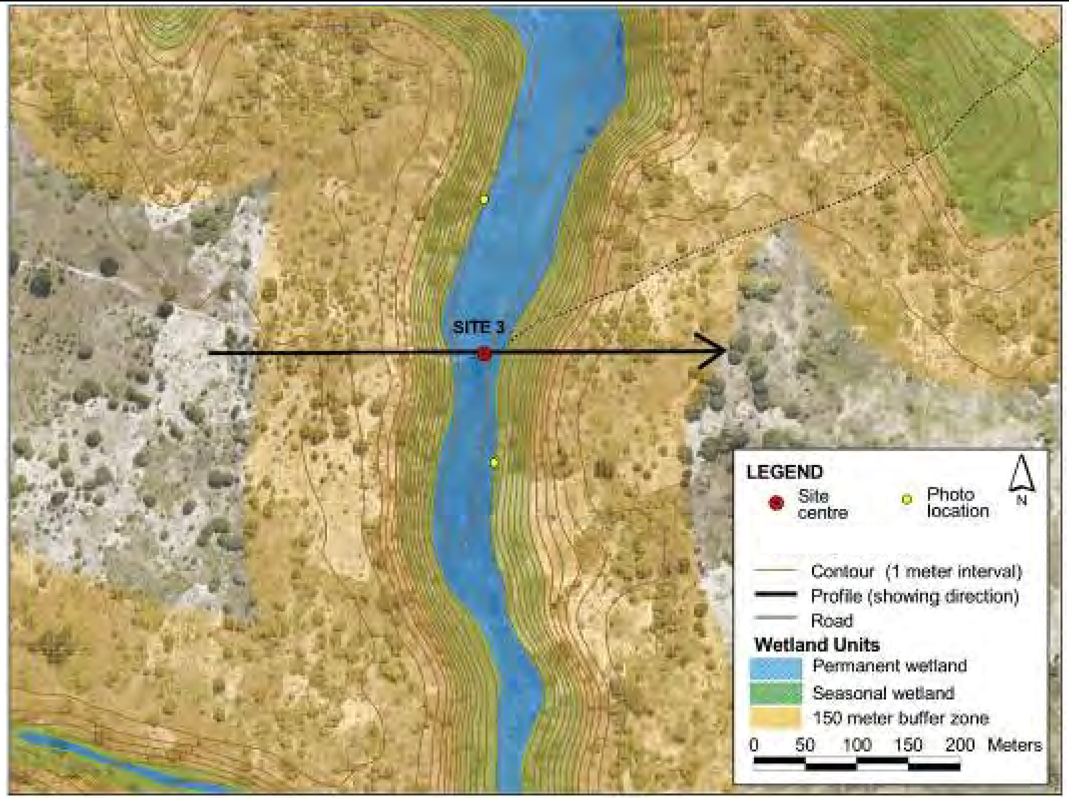
Aquatic Present Ecological State

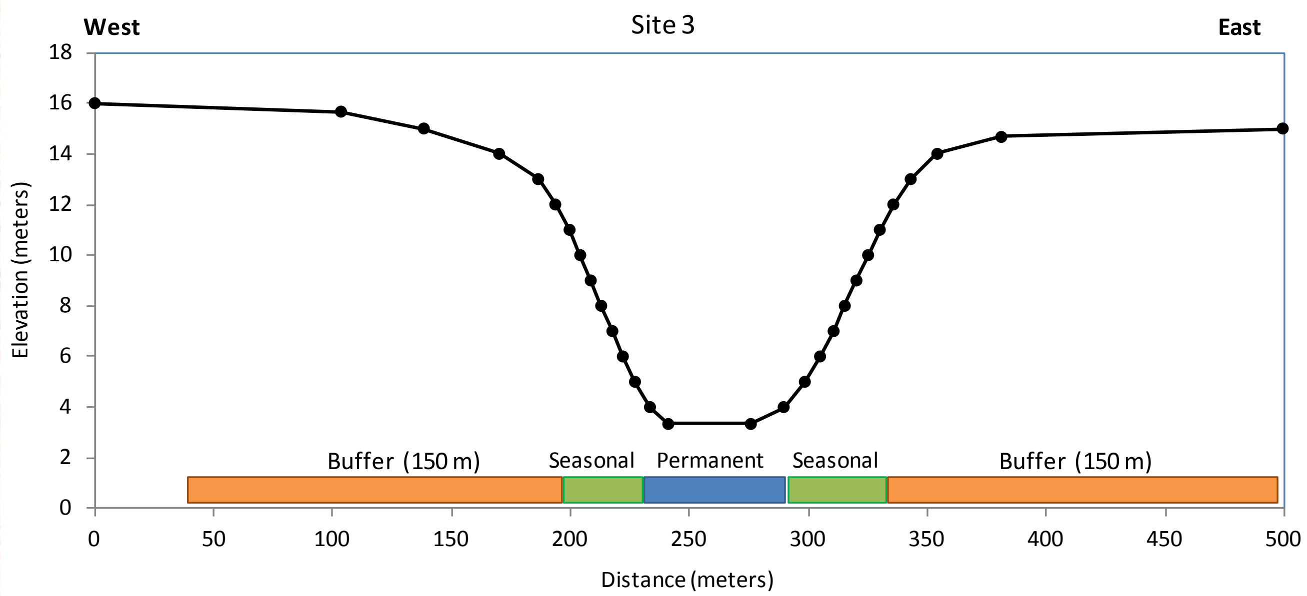
DATE	**SAMPLERS**	**WQ**	**Diatoms**			**IHI**	**SASS 5 & ASPT**	**MIRAI**	**Fish**
			SPI	**BDI**	**%PTV**				
14/10/2011	C. Renshaw A. Austin	√	**17.4**	**20.0**	**2.5**	**86 (B)**	**77 and 3.9**	**82 (B)**	√
24/02/2012	C. Renshaw W. Malherbe	√	**18.9**	**20.0**	**1.3**	**80 (B)**	**68 and 4.5**	**66 (C)**	√

Figure 8.33 Sampling Site MOZ 3

Wetland Type	Unchannelled valley bottom wetland (Catchment A)
Location	On the proposed main access road, upstream of Project Footprint Area (22 masl). Latitude 10.822934S; Longitude 40.532135E (Geographic projection, WGS84); UTM Zone 39: 8803178S; 667494E

Wetland Layout





Source: Aerial image supplied by Client

General Site Description

This site was located on the same wetland as sites 2 and 5, ultimately leading to the estuary that is described as Site 6. This site was accessed via a foot and bicycle path used by the local community, and some impacts caused by local communities were thus observed there. Various interesting plant species were identified at the site, despite the impacts occurring there. The only available water was in pools scattered through the system, with a very limited water flow. Lots of algae. Sulphuric smell within sediment.

Photos

Low Flow 2011			High Flow 2012		
UPSTREAM	*DOWNSTREAM*	*CLOSE-UP*	*UPSTREAM*	*DOWNSTREAM*	*CLOSE-UP*
					

Riparian Zone Description

Marginal Zone (MZ)	The marginal zone was moderately large with a width of approximately 40m. This zone consisted of an unchannelled system dominated by ferns and sedges. The centre of the marginal zone was significantly wetter and deeper than the outer edges. *Pandanus* and *Drosera* species (illustrated below) were unusual plants observed in this zone.
Lower Zone (LZ)	Large parts of the lower zone had been cleared of natural vegetation and planted with tree crops such as coconuts, cashew nuts and mangoes; however, patches of mature riparian vegetation dominated by large *Brachystegia spiciformis* trees still remained.
Upper Zone (UZ)	The upper zone closely resembled the surrounding terrestrial vegetation and had been heavily impacted by the planting of alien trees.

Vegetation

SPECIES	MZ	LZ	UZ	SPECIES	MZ	LZ	UZ
Ageratina adenophora *	x			*Hyphaene coriacea*		x	x
Anacardium occidentale *		x	x	*Mangifera indica* *		x	x
Andropogon gayanus		x	x	*Cyperus prolifer*	x		
Brachystegia spiciformis		x	x	*Nymphaea nouchali*	x		

Chamaecrista sp.				*Ochna inermis*			x
Cocos nucifera *				*Pandanus livingstonianus*	x		
Crinum sp.		x		*Parinari curatellifolia*			x
Cuscuta sp.	x			*Pseudolachnostylis maprouneifolia*		x	
Drosera indica	x			*Cyperus* sp.	x		
Gardenia ternifolia		x	x	*Sclerocarrya birrea*		x	
Hibiscus sp. *(pink)*		x		*Strychnos* sp.			
Hibiscus sp. *(yellow)*		x		*Strychnos pungens*			x
Hypericum sp.	x			*Utricularia* sp. *(white)*			
Hyperthelia dissoluta			x				

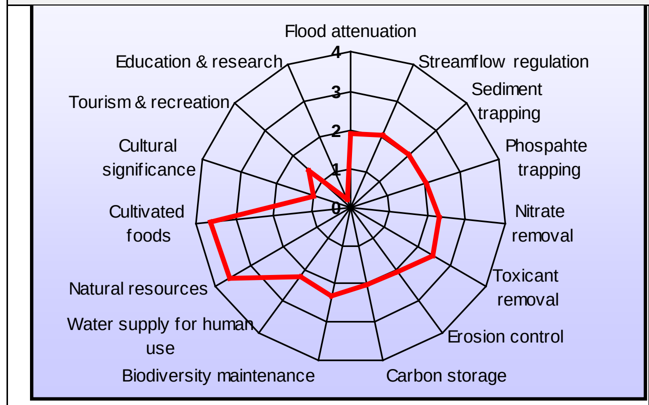
Pandanus livingstonianus – screw pine

Drosera indica – sundew (insectivorous plant)

Ochna inermis – stunted plane

Key: * denotes alien plant species; VU – Vulnerable as per IUCN Red List classification

Wetland Ecoservices



Important ecoservices supplied by MOZ 3 include provision of cultivated foods and natural resources to local communities. Capacity for removal of various toxicants is moderate.

Current Impacts

- Artificial channel created
- Former rice cultivation downstream
- A footpath through marginal zone continuing eastwards across wetland, causing pooling

Aquatic Description

	Low Flow 2011	High Flow 2012
Water Surface Dimensions	Width: 1–5 m; Depth: 0.2–0.6m	Width: 1–5 m; Depth: 0.2–0.8m
Water Turbidity (Dallas 2005)	Clear	Clear
Dominant Velocity-depth Classes	Slow deep	Slow shallow
Water Quality Parameters	T(°C)=26.6; pH=6.3; EC(mS/m)=14.96; DO(mg/l)=8.66; DO(%)=107.92; TDS(mg/l)=75	T(°C)=27.2; pH=6.3; EC(mS/m)=12.38; DO(mg/l)=5.05; DO(%) = 64.07; TDS(mg/l)=62
Algae Presence	Abundant	Abundant
Dominant Biotope Diversity	Pool	Pool
Other Biota	Tadpoles and frogs	Tadpoles and frogs
Highly Sensitive Taxa (Score 11–15)	None	None

Riparian Present Ecological State

ZONE	Overall	Marginal	Lower	Upper
VEGRAI %	58.0	85.3	47.5	41.3
Ecological Categories (EC)	C/D – moderately – largely modified	B – largely natural	D – largely modified	D/E – largely modified – seriously modified

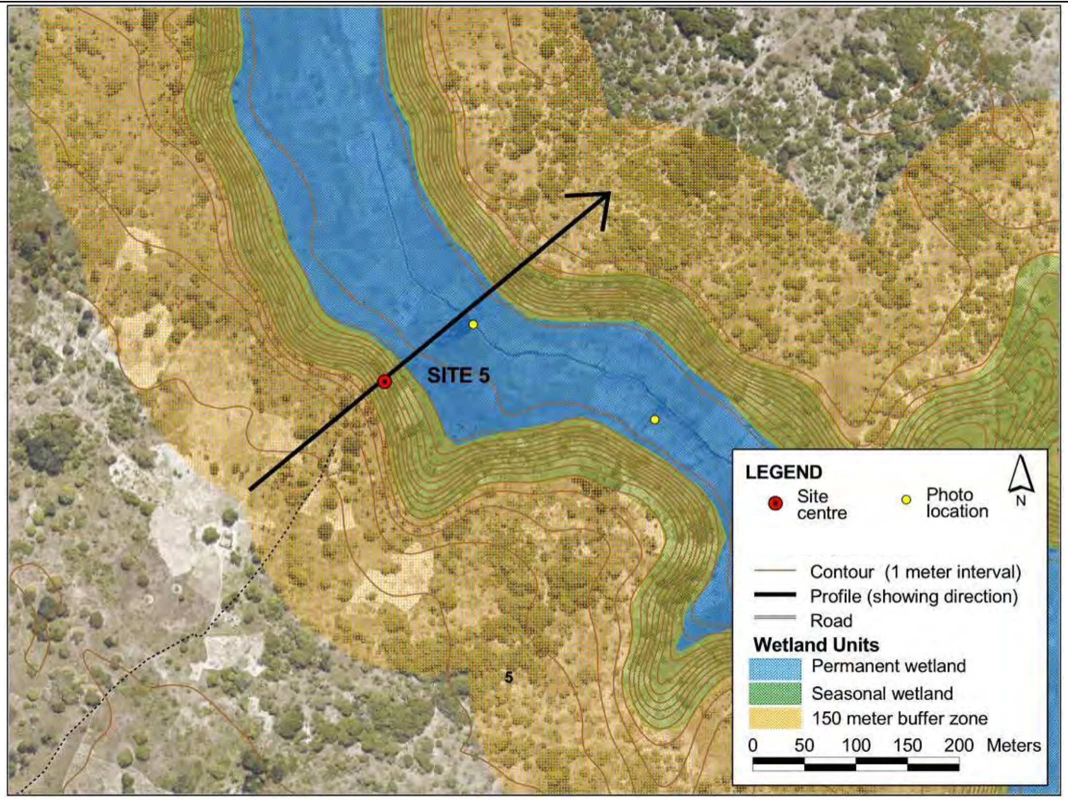
Aquatic Present Ecological State

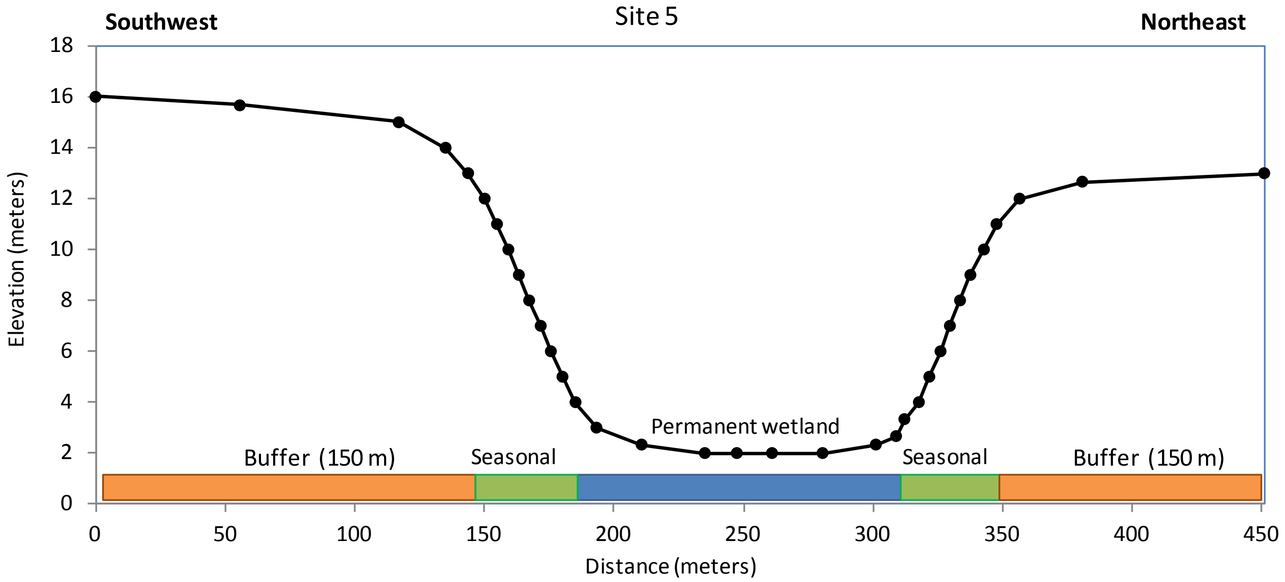
DATE	SAMPLERS	WQ	Diatoms			IHI	SASS 5 & ASPT	MIRAI	Fish
			SPI	BDI	%PTV				
15/10/2011	C. Renshaw A. Austin	√	18.6	20.0	0.8	88 (B)	72 and 4.2	70 (C)	√
25/02/2012	C. Renshaw W. Malherbe	√	21.0	20.0	0.5	87 (B)	68 and 4.5	65 (C)	√

Figure 8.34 Sampling Site MOZ 5

Wetland Type	Unchannelled valley bottom wetland that has been partially channelled artificially (Catchment A)
Location	Upstream from proposed Project Footprint Area. Latitude 10.817248S; Longitude 40.526839E (Geographic projection, WGS84); UTM Zone 39: 8803810S; 666918E

Wetland Layout





Source: Aerial image supplied by Client

General Site Description

This site consisted of a broad permanent wetland located close to the large Quitupo Village. A significant channel had been excavated in the centre of the wetland, but limited flow was apparent. Large pools of standing water dominated by water lilies were a prominent feature of the site.

Photos

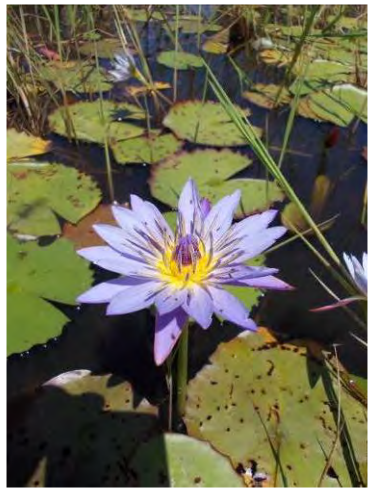
Low Flow 2011			High Flow 2012		
UPSTREAM	*DOWNSTREAM*	*CLOSE-UP*	*UPSTREAM*	*DOWNSTREAM*	*CLOSE-UP*
					

Riparian Zone Description

Marginal Zone (MZ)	The marginal zone was over 100m wide and consisted mostly of a thick floating mat of ferns, sedges and *Juncus* reeds. Walking over the floating mat was treacherous, with the risk of breaking through into the unknown depths below. A number of specimens of a large *Eulophia* orchid were observed in this zone.
Lower Zone (LZ)	The lower zone was largely transformed by the planting of tree and herbaceous crops such as coconuts and cassava.
Upper Zone (UZ)	The upper zone was largely transformed through cultivation and, to a lesser extent, by human habitation.

Vegetation

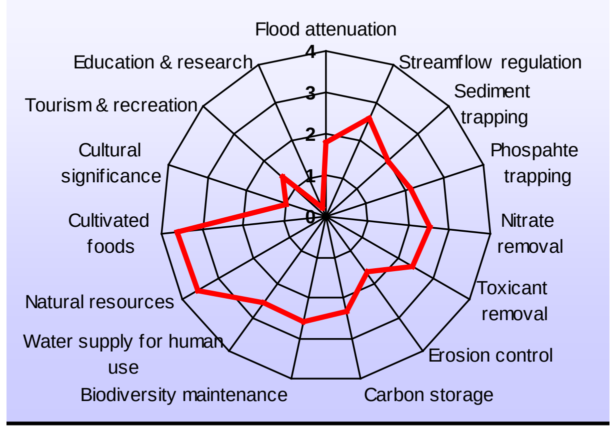
SPECIES	MZ	LZ	UZ	SPECIES	MZ	LZ	UZ
Ageratina adenophora *	x						
Anacardium occidentale *		x	x	*Mangifera indica* *		x	x
Andropogon gayanus			x	*Manihot esculenta* *		x	
Berlinia orientalis (VU)			x	*Cyperus prolifer*	x		
Brachystegia spiciformis		x	x	*Musa acuminata* (hybrid) *	x	x	

		
Eulophia rosea	*Nymphaea nouchali*	Ferns

Cassia sp.		x		*Nymphaea nouchali*	x		
Cocos nucifera *		x		*Ochna inermis*			x
Combretum eleagnoides			x	*Panicum coloratum*			x
Eulophia rosea	x			*Parinari curatellifolia*		x	x
Ferns	x			*Phoenix reclinata*	x	x	
Gymnosporia sp.			x	*Pseudolachnostylis maprouneifolia*			x
Heteropogon contortus		x		*Psidium guajava* *	x		
Hibiscus sp. (yellow)		x		*Sclerocarrya birrea*			x
Hyphaene coriacea		x		*Searsia* sp.			x
Juncus sp.	x			*Strychnos pungens*		x	x
Leersia hexandra	x			*Themeda triandra*		x	

Key: * denotes alien plant species; VU – Vulnerable as per IUCN Red List classification

Wetland Ecoservices



The ecoservices supplied by the wetland at MOZ 5 feature strongly in the provision of natural resources and cultivated foods. The water supply for human use and maintenance of biodiversity are also important, as is the capacity for removal of various toxicants.

Current Impacts

- Paths and channels bisecting wetland
- Alien plants present
- Algal growth
- Artificial channelisation present
- Evidence of rice cultivation

Aquatic Description

	Low Flow 2011	High Flow 2012
Water Surface Dimensions	Width: 10–20m; Depth: 0.1–1m	Width: 10–20m; Depth: 0.1–1m
Water Turbidity (Dallas 2005)	Discoloured	Discoloured
Dominant Velocity-depth Classes	Slow shallow	Slow shallow
Water Quality Parameters	T(°C)=27.5; pH=6.2; EC(mS/m)=28.86; DO(mg/l)=1.28; DO(%)=16.30; TDS(mg/l)=144	T(°C)=30.9; pH=6.0; EC(mS/m)=15.37; DO(mg/l)=1.75 ; DO(%)=23.63; TDS (mg/l)=77
Algae Presence	Common	Common
Dominant Biotope Diversity	Pool	Pool
Other Biota	Water birds and mongoose	Water birds, frogs and snails
Highly Sensitive Taxa (Score 11–15)	None	None

Riparian Present Ecological State

ZONE	Overall	Marginal	Lower	Upper
VEGRAI %	59.3	84.3	45.0	48.8
Ecological Categories (EC)	C/D – moderately – largely modified	B – largely natural	D – largely modified	D – largely modified

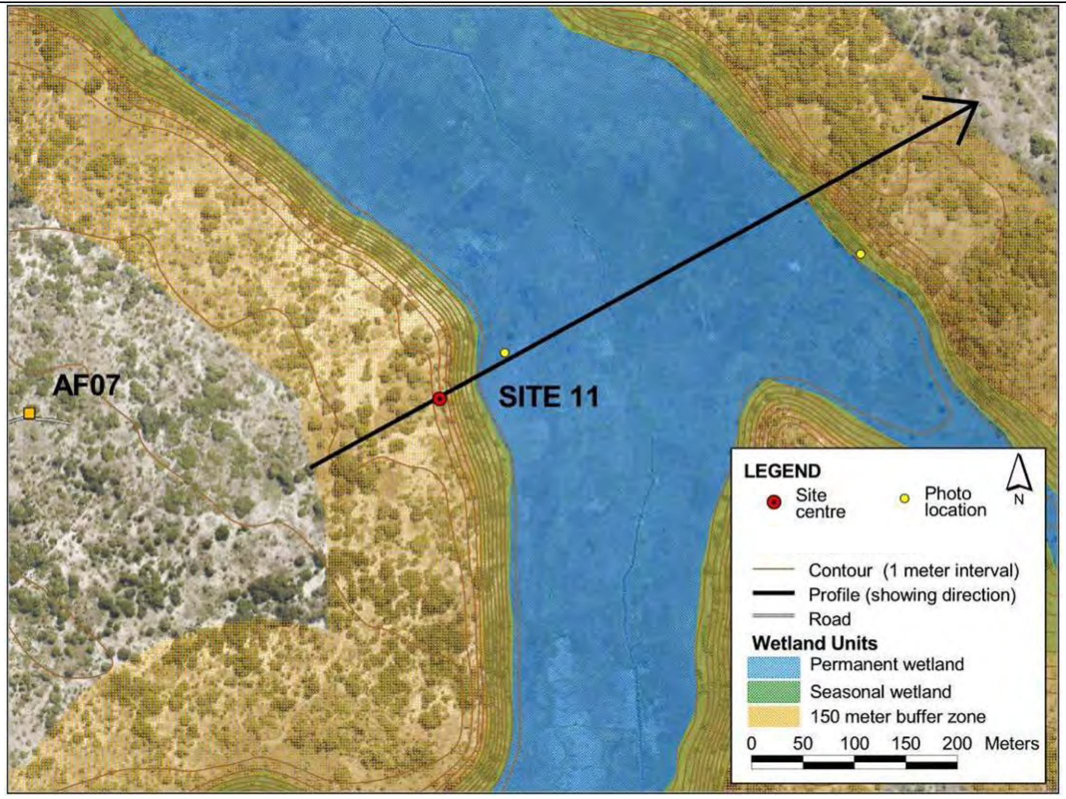
Aquatic Present Ecological State

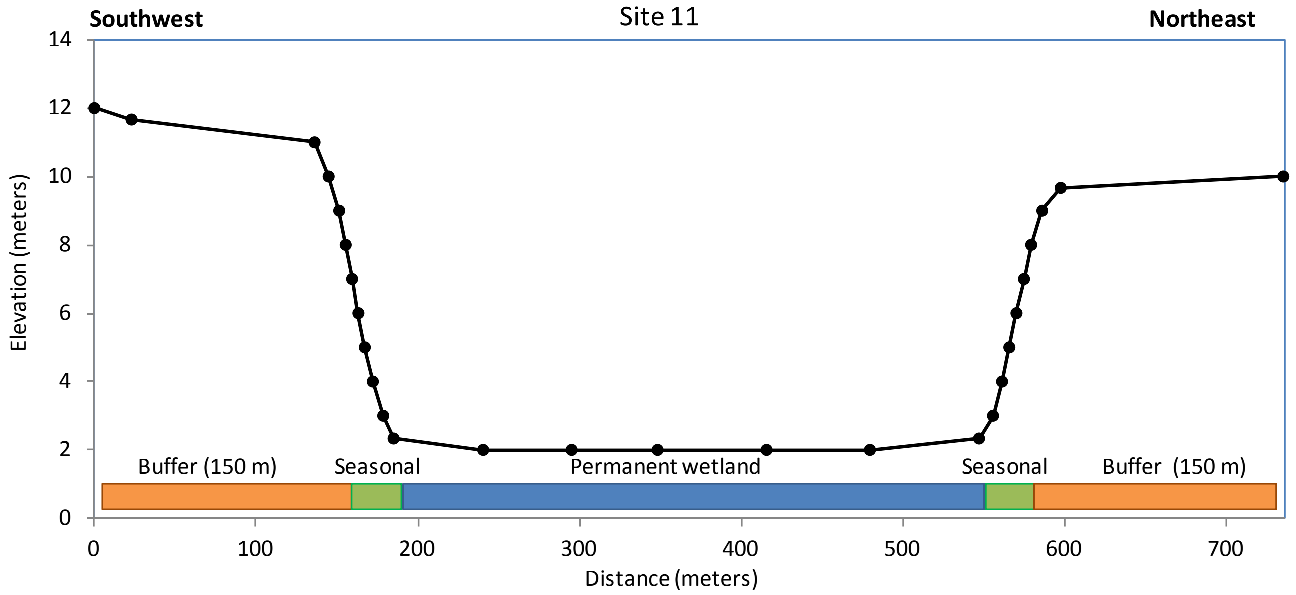
DATE	SAMPLERS	WQ	Diatoms			IHI	SASS 5 & ASPT	MIRAI	Fish
			SPI	BDI	%PTV				
16/10/2011	C. Renshaw A. Austin	√	Insufficient cells for count			94 (A)	101 and 4.2	87 (B)	√
25/02/2012	C. Renshaw W. Malherbe	√	15.5	17.7	21.3	88 (B)	79 and 4.9	66 (C)	√

Figure 8.35 Sampling Site MOZ 11

Wetland Type	Unchannelled valley bottom wetland in the lower catchment zone and in close proximity to the estuary (Catchment A)
Location	Downstream from the proposed Project Footprint Area (13 masl). Latitude 10.80576S; Longitude 40.52435E (Geographic projection, WGS84); UTM Zone 39: 8805081S; 666653E

Wetland Layout





Source: Aerial image supplied by Client

General Site Description

This site is located towards the end of the fresh-water component of this wetland system and within sight of the coast, portrayed by a row of tall coconut palms on the north-western horizon. The woody riparian vegetation is well developed and with few anthropogenic disturbances.

Photos

High Flow 2012

UPSTREAM	DOWNSTREAM	CLOSE-UP
		

Low Flow 2012

UPSTREAM	UPSTREAM	UPSTREAM
		

Riparian Zone Description

Marginal Zone (MZ)	The marginal zone consists of a broad stretch approximately 400m wide, with large volumes of water and dominated by sedges and other aquatic plants. The outer edges of the marginal zone support many grasses, and the small insectivorous *Drosera indica* was found there growing among a terrestrial *Utricularia* species.
Lower Zone (LZ)	The lower zone occurs on a steep slope of approximately 10m in height, and supports a varied amount of riparian vegetation. Some patches are sparse while other patches are tall and dense.
Upper Zone (UZ)	The upper zone merges gradually in the surrounding terrestrial vegetation, marked by numerous *Strychnos* shrubs and *Hyphaene* palms. Abandoned huts and many cashew-nut trees provide evidence of recent settlement in the area.

Vegetation

SPECIES	MZ	LZ	UZ	SPECIES	MZ	LZ	UZ
Afzelia quanzensis			x	Ferns	x		
Andropogon gayanus		x		*Gardenia ternifolia*			x
Aristida congesta			x	*Hyparrhenia tamba*			x
Berlinia orientalis (VU)		x	x	*Hyphaene coriacea*		x	x

Brachystegia spiciformis		x		*Leersia hexandra*	x		
Chamaecrista sp.	x			*Melinis repens*			x
Cocos nucifera *			x	*Musa acuminata* (hybrid) *	x		
Cuscuta sp.	x			*Nymphaea nouchali*	x		
Cyperus dives	x			*Phoenix reclinata*	x	x	
Cyperus prolifer	x			*Strychnos spinosa*	x		
Digitaria eriantha			x	*Utricularia* sp. (*white*)	x		
Drosera indica	x			*Xylotheca kraussiana*			x
***Eulophia speciosa* (Decl)**		x		*Xyris capensis*	x		

Marginal zone where *Drosera indica* was found

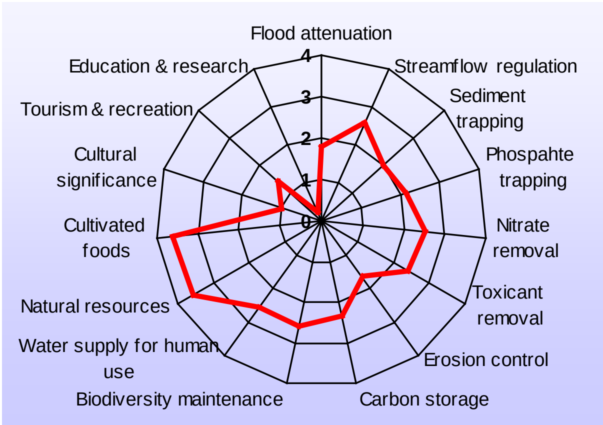
Brachystegia trees and *Hyphaene* palms in the riparian vegetation

Eulophia speciosa – terrestrial orchid

Key: * denotes alien plant species; VU – Vulnerable as per IUCN Red List classification

Wetland Ecoservices

v



The ecoservices provided by the wetland at MOZ 11 rank high in natural resource provision, biodiversity maintenance and toxicant removal.

Current Impacts

- Passage through the wetland in the form of pedestrian and bicycle traffic
- Limited cultivation of fruit trees
- Limited vehicle passage has occurred

Aquatic Description

	High Flow 2012	Low Flow 2012
Water Surface Dimensions	Width: 0.5–3m; Depth: 0.1–0.5m	Width: 0.5–3m; Depth: 0.1–1m
Water Turbidity (Dallas 2005)	Discoloured	Discoloured
Dominant Velocity-depth Classes	Slow shallow	Slow shallow
Water Quality Parameters	T(°C)=28.3; pH=6.2; EC(mS/m)=20.52; DO(mg/l)=1.68; DO(%)=21.88; TDS(mg/l)=103	T(°C)=27.3; pH=5.6; EC(mS/m)=19.40; DO(mg/l)=2.53; DO(%)=32.02; TDS(mg/l)=97
Algae Presence	Common	Abundant
Dominant Biotope Diversity	Pool	Pool
Other Biota	Firefly larvae, tadpoles and frogs	Frogs, shrimps and prawns
Highly Sensitive Taxa (Score 11–15)	None	None

Riparian Present Ecological State

ZONE	Overall	Marginal	Lower	Upper
VEGRAI %	64.2	89.3	55.5	47.8
Ecological Categories (EC)	C – moderately modified	A/B – natural – largely natural	D – largely modified	D – largely modified

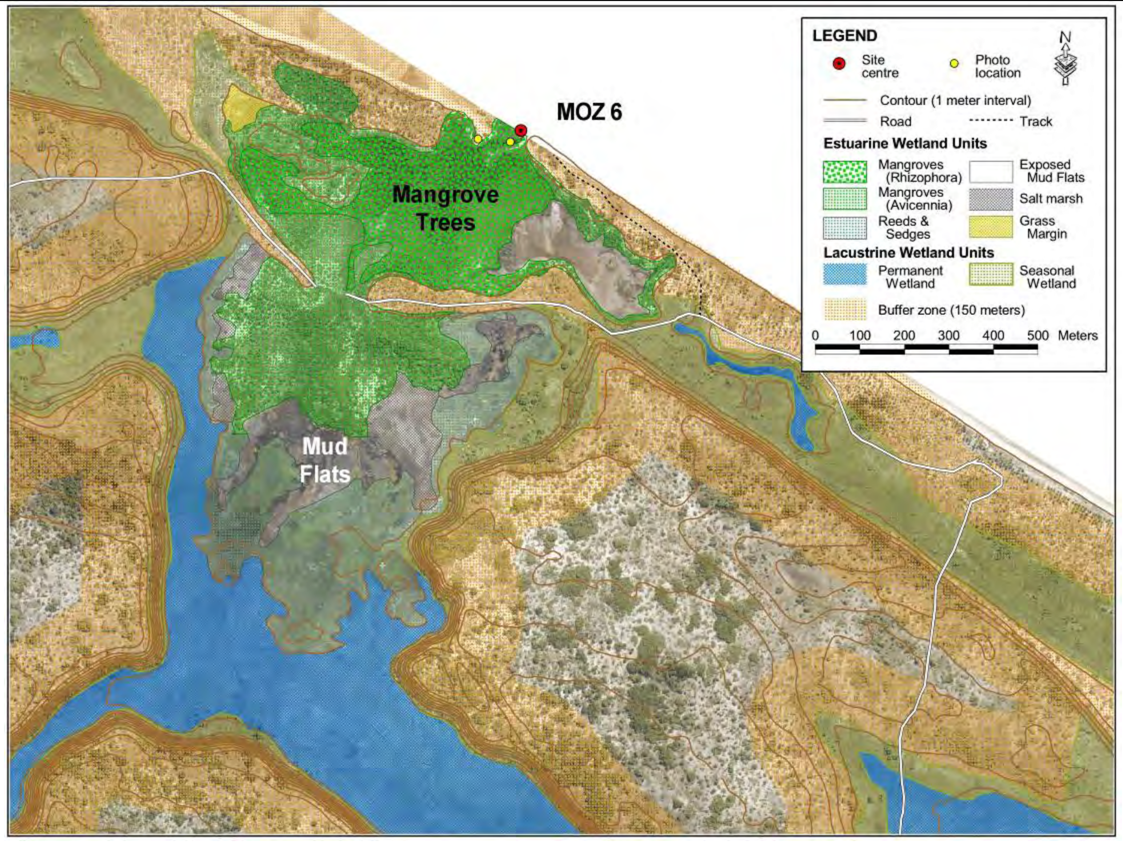
Aquatic Present Ecological State

DATE	SAMPLERS	WQ	Diatoms			IHI	SASS 5 & ASPT	MIRAI	Fish
			SPI	BDI	%PTV				
29/02/2012	C. Renshaw A. Austin W. Malherbe	√	18.7	20.0	0.3	88 (B)	57 and 4.4	61 (C)	√
22/06/2012	A. Austin W. Malherbe	√	15.8	20.0	2.0	89 (B)	136 and 5.4	78 (C)	√

Figure 8.36 Sampling Site MOZ 6

Wetland Type	Saline estuarine wetland (Catchment A)
Location	This site is in the proposed Project Footprint Area, downstream from the fresh-water site MOZ 11 (2 masl). Latitude 10.79008S; Longitude 40.526542E (Geographic projection, WGS84); UTM Zone 39: 8806815S; 666900E

Wetland Layout

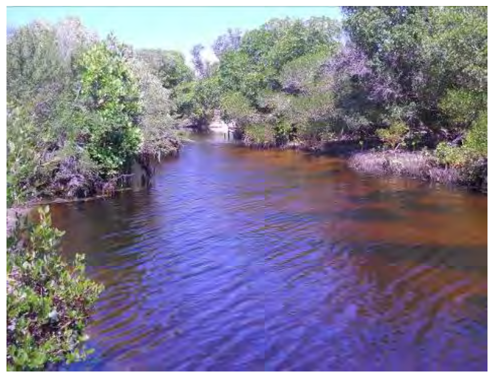


Source: Aerial image supplied by Client

General Site Description

This site consists of a lesser estuary in comparison to MOZ 4, covering approximately 65ha extending below the high tide level. It is connected to the ocean during high flow, where most of the water in the estuary originates. This estuary could, similarly, not be separated into different riparian zones and only one zone is therefore considered. Despite the smaller area, this estuary supported denser groves of mangrove trees than were seen at MOZ 4. Species composition was, however, similar. Limited tree cutting was observed. The fauna was impacted by local communities to a greater extent than the vegetation, with extensive harvesting of snails and fishing seen.

Photos

Low Flow 2011		**High Flow 2012**	
UPSTREAM	*ESTUARY MOUTH*	*UPSTREAM*	*ESTUARY MOUTH*
			

Estuarine Vegetation Description

Four of the main estuarine habitats were identified at MOZ 6: submerged macrophytes, mangroves, supratidal salt marsh and reeds and sedges. Seagrasses of the submerged macrophyte habitat were concentrated in the lower regions of the estuary, at the mouth, and extended outwards towards the subtidal zone. Mangroves dominated the largest proportion of the estuary, covering a total area of 38.38ha. This was comprised of 23.48ha of open *Avicennia marina* forest and 14.90ha of dense *Rhizophora mucronata* and *Ceriops tagal* forest. The average tree height was 6 to 8m and the canopy cover was approximately 80 percent. Adult, juvenile and seedling mangrove trees were recorded, and this is indicative of healthy population structure and recruitment. Significant adult die-off was observed in the open *Avicennia marina* habitat. The majority of the mangrove forest was comprised of *Rhizophora mucronata* interspersed with *Ceriops tagal*. Flowers and propagules were present on *Avicennia marina* and propagules on *Ceriops tagal* and *Rhizophora mucronata.* The supratidal salt marsh habitat was minimal in extent, with a small population of *Sarcocornia decumbens* (glasswort), which was replaced by sedges and grasses. Diversity in this habitat was low, owing to the stressful nature of the physical environment. Grasses and a sporadic distribution of mangrove fern (*Acrostichum aureum)* occurred at the transition between wetland and the forest/woodland.

Estuarine Vegetation

		
Xylocarpus granatum – cannonball mangrove	*Sonneratia alba* – mangrove apple	*Ceriops tagal* – Indian mangrove

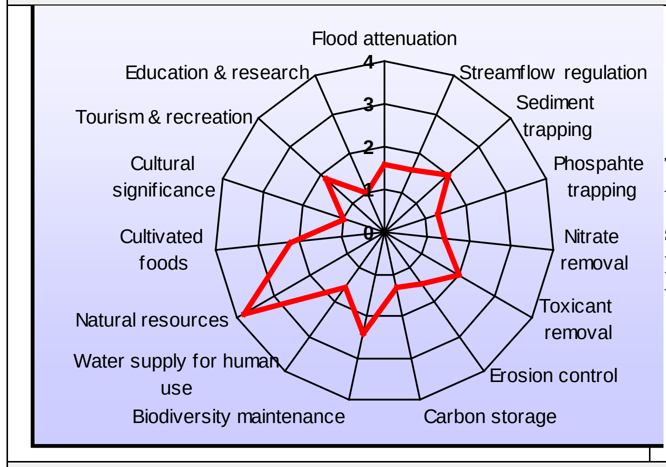
SPECIES

Avicennia marina	*Ceriops tagal*	*Elaphoglossum* sp.
Bruguiera gymnorrhiza	*Cocos nucifera* *	*Sonneratia alba*
Casuarina equisetifolia *	*Cynodon dactylon*	*Xylocarpus granatum*

Key: * denotes alien plant species

	
Main channel exiting the estuary	*Rhizophora mucronata* – mangrove trees

Wetland Ecoservices



The ecoservices supplied by MOZ 6 are similar to those supplied by MOZ 4, due to the similar conditions that prevail at both sites. The sites are important sources of natural resources to local communities, and important for the maintenance of biodiversity.

Current Impacts

- Alien plants introduced – coconut plantations and *Casuarina equ*isetifolia along beach. *C. equisetifolia* is often associated with swamp forests adjacent to estuaries
- Harvesting of mangroves for wood (outer edges of forests only)
- Snail harvesting by local community
- Foot and vehicle paths through the mangrove forests

Aquatic Description

	Low Flow June 2012	High Flow 2012
Water Surface Dimensions		Width: 1–10m; Depth: 0.1–1.2m
Water Turbidity (Dallas 2005)		Discoloured
Dominant Velocity-depth Classes		Slow deep
Water Quality Parameters	T(°C)=29.4; pH=7.4; EC(mS/m)=5008; DO(mg/l) = 3.86; DO(%)=60.47; TDS(mg/l)=25040; Salinity=32.67	T(°C)=30.7; pH=6.9; EC(mS/m)=5215; DO(mg/l) = 2.73; DO(%)=40.39; TDS(mg/l)=26074 Salinity=34.15
Dominant Biotope Diversity		Pool
Other Biota		Estuarine prawns

Riparian Present Ecological State

Estuarine Health Index	97.5	Present Ecological Status	**A – natural**

Aquatic Present Ecological State

DATE	SAMPLERS	WQ	Diatoms			Invertebrates	Fish
			SPI	BDI	%PTV		
17/10/2011	C. Renshaw A. Austin	√	9.3	10.8	13.5	√	√
22/02/2012	W. Malherbe C. Renshaw A. Austin	√	10.3	3.2	7.2	√	√

Catchment B

Three sampling sites were considered in Catchment B, and these are outlined in *Table 8.23*. Catchment B is similar to catchment A; an unchannelled valley bottom system, ending in a shallow-water estuary system with a sandy substrate. Similarly, the system is a slow-flowing deep wetland, and has artificial channels dug within the wetland to increase the flow.

Table 8.23 Sampling Sites within Catchment B

Catchment and Assessment Sites	Site Description
Catchment B	
MOZ 1	Upper catchment, close to the start of the permanent wetland
MOZ 4	Estuary
MOZ 10	Lower catchment zone with broad permanent wetland

Source: NSS, 2012.

The aquatic habitat integrity of the lacustrine sampling sites within Catchment B is considered Natural, showing very limited effects of anthropogenic influence in comparison to the other catchments sampled. The overall riparian habitat integrity ranged from Largely Natural to Moderately Modified, with only limited removal of natural resources and cultivation of fruit trees. The riparian habitat integrity of the estuary was Natural, with virtually no anthropogenic impacts present and dense groves of mangrove trees. The main ecosystem services supplied by the lacustrine and estuarine wetlands in Catchment B included natural resource provision and the maintenance of biodiversity.

In terms of water quality, low oxygen levels, influenced by high temperatures and slightly high salts content (EC and TDS), were observed at all of the lacustrine wetland sites within Catchment B. NH_4, COD and SS had exceeding concentrations within the lacustrine sites. MOZ 10 (in the lower area of the catchment) also had exceeding levels of Al, Cu and Zn. SS, Zn and Al are considered to be naturally occurring constituents within these systems. The slightly elevated levels of Cu at site MOZ 10 may be due to infiltration of saline water. The higher levels of NH_4 and COD could be attributed to sewage within the lacustrine wetland systems. The water quality results in the estuarine site indicated that the oxygen levels were low and salinity high. No significant salinity profile was seen at the estuary site MOZ 4, which indicates that the fresh-water inflow to MOZ 4 was limited and that the estuary is dominated by sea water. The water quality showed exceeding concentration levels of Ba, Cu, Ni, Pb, Zn and NO_3 in the estuary and, because most of the water was sea water, the exact source of contamination could not be determined.

The low EPT (*Ephemeroptera*, *Plecoptera* and *Trichoptera*) richness indicated that the macro-invertebrate community structures of the lacustrine wetland consisted of a low number of sensitive taxa, probably due to low habitat availability for these taxa. The MIRAI scores for the wetlands were Largely Natural to Moderately Modified and indicated that the macro-invertebrates within Catchment B were influenced by flow modification, habitat and water quality. Three species of macro-invertebrate were sampled at the estuary. The important benthic invertebrate taxa group sampled in the estuary site was the Decapoda. They are a very important part of the mangrove system and were found to be the most abundant taxa at the estuary. The distribution and abundance of the zooplankton and benthic invertebrates living in the benthic environment are dependent on the physical sediment composition. The fairly diverse benthic invertebrate community is supported by the poorly sorted sediment and the organic content present.

Fish species of note observed in the lacustrine wetlands within Catchment B included the data-deficient killifish (found in MOZ 1 and 10). Previously, this species was discovered in only one other location worldwide, described in 2007 (see *Section 8.6.3*). Due to the lack of data, this species has not been assigned a conservation status by the IUCN. The dominant fish guild in the estuary was the marine migrant guild, which indicated species that spawn in the ocean and then enter estuaries in large numbers, specifically as juveniles. The large number of juveniles indicated that these estuaries are mostly used as nursery grounds.

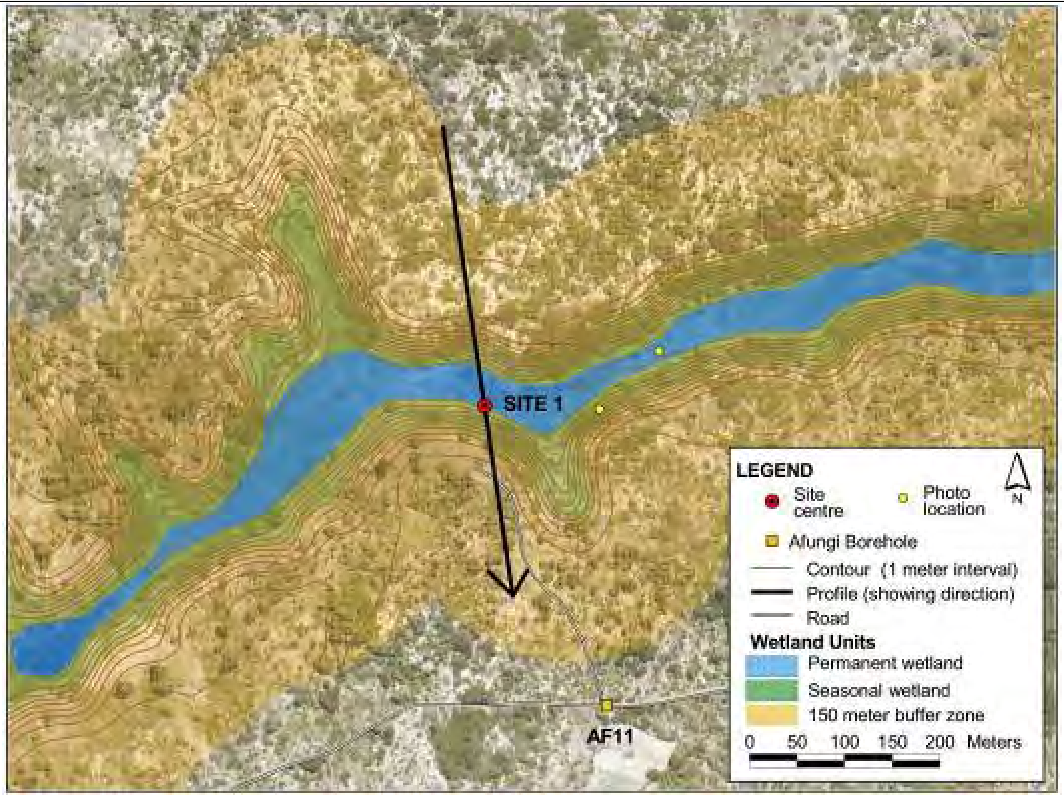
Catchment B is particularly sensitive, both in the upper and mid reaches of the catchment, due to the presence of threatened Red Data plant species – the *Platycoryne mediocris* orchid and *Berlinia orientalis* along the catchment.

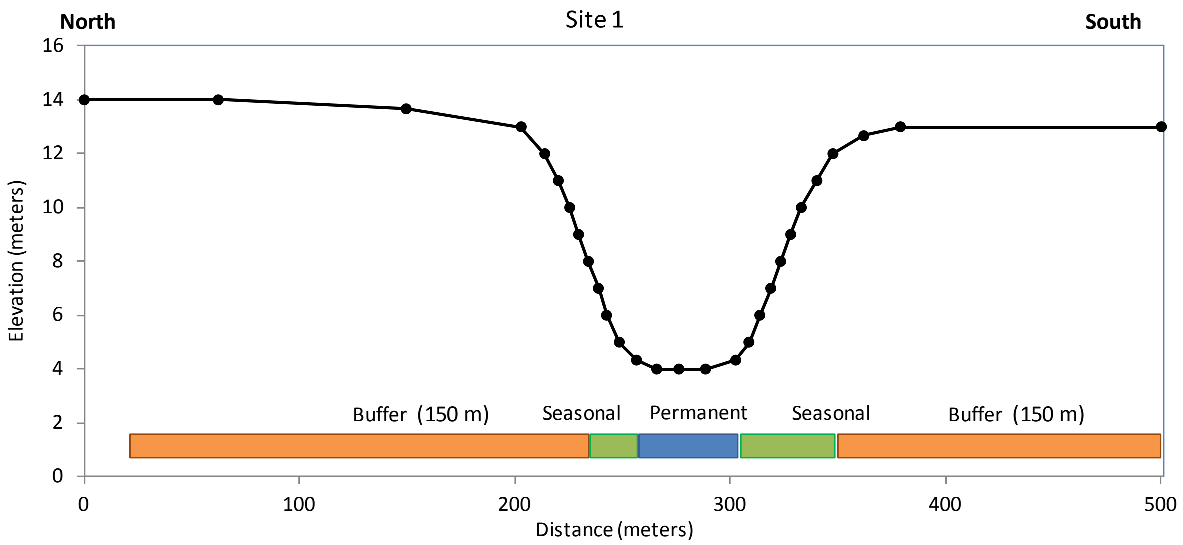
Figure 8.37 to *Figure 8.39* provide general information and detailed results for the high flow (October 2011) and low flow sampling assessments (February 2012) for each sampling site in Catchment B.

Figure 8.37 Sampling Site MOZ 1

Wetland Type	Unchannelled valley bottom wetland (Catchment B)
Location	In the proposed Project Footprint Area (21 masl). Latitude 10.83564S; Longitude 40.555946E (Geographic projection, WGS84); UTM Zone 39: 8801759 S; 670090 E

Wetland Layout





Source: Aerial image supplied by Client

General Site Description

A moderately broad unchannelled valley bottom with a perennial slow flow of slightly brackish water. The site was observed in a largely natural state with healthy vegetation cover in all riparian zones. The *Nothobranchius hengstleri* (killifish) caught suggests that the system may experience both dry and wet periods, but it is unlikely that these systems dry out completely. Limited impacts were observed, and this site was considered suitable as a reference for various other sites.

Photos

Low Flow 2011			High Flow 2012		
UPSTREAM	*DOWNSTREAM*	*CLOSE-UP*	*UPSTREAM*	*DOWNSTREAM*	*CLOSE-UP*
					

Riparian Zone Description

Marginal Zone (MZ)	The marginal zone was approximately 40m wide at the site and permanently wet across its width. The vegetation was dominated by various sedge species and a few grasses, notably *Leersia hexandra*. This species appears to grow where former mounds had been created to place fish traps or for rice cultivation, and its presence could be the result of former disturbances.
Lower Zone (LZ)	The lower zone incorporated an approximately 8m topographical rise above the marginal zone. Riparian vegetation was sparse and discontinuous along the length of the zone, but reached a tree height of approximately 10m to 12m.
Upper Zone (UZ)	Very little riparian vegetation was present in the upper zone, and the zone could not be easily distinguished from adjacent terrestrial vegetation.

Vegetation

SPECIES	MZ	LZ	UZ	SPECIES	MZ	LZ	UZ
Musa acuminata (hybrid) *	x			*Hyphaene coriacea*		x	x
Berlinia orientalis (VU)		**x**	**x**	*Mangifera indica* *			x
Commelina sp.		x		*Cyperus prolifer*	x		
Nymphaea nouchali	x			*Parinari curatellifolia*			x

Brachystegia spiciformis

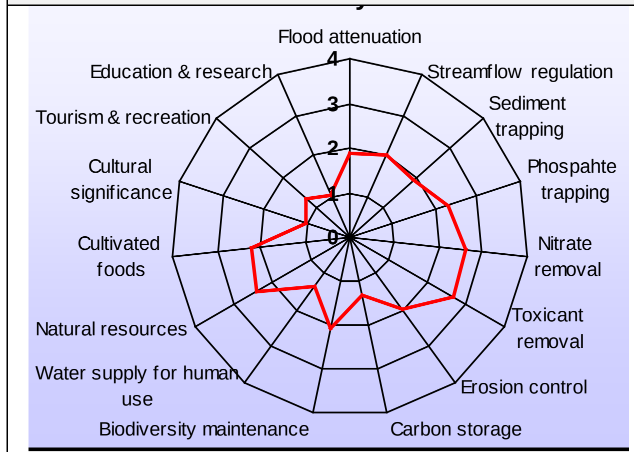
Berlinia orientalis **(VU)**

Utricularia sp.

Brachystegia spiciformis	x	x	*Phoenix reclinata*		x	
Anacardium occidentale *	x	x	*Cyperus* sp.	x		
Commelina sp.	x	x	*Rauvolfia caffra*		x	
Dichrostachys cinerea	x		Sensitive Ground Plant			x
Diplorhynchus condylocarpon		x	*Strychnos (tight)*			x
Gardenia ternifolia		x	*Strychnos pungens*			x
Hibiscus sp. *(yellow)*	x		*Utricularia* sp. *(yellow)*	x		
Hyparrhenia sp.		x	*Vitex* sp.	x		

Key: * denotes alien plant species; VU – Vulnerable as per IUCN Red List classification

Wetland Ecoservices



The ecoservices provided by MOZ 1 are generally low. The site provides few natural resources or cultivated foods to local communities, but provides for moderate levels of biodiversity maintenance, erosion control and removal of various toxicants.

Current Impacts

- Artificial channel created
- Evidence of past rice cultivation
- Algal growth
- Fishing traps in deeper sections of channel
- Few aliens plants present
- Water abstraction

Aquatic Description

	Low Flow 2011	High Flow 2012
Water Surface Dimensions	Width: 0.3–5m; Depth: 0.1–0.6 m	Width: 0.3–5m; Depth: 0.1–0.6 m
Water Turbidity (Dallas 2005)	Clear	Opaque
Dominant Velocity-depth Classes	Slow shallow	Slow shallow
Water Quality Parameters	T(°C)=26.9; pH=5.8; EC(mS/m)=12.40; DO(mg/l)=2.93; DO (%)=36.6; TDS(mg/l)=62	T(°C)=28.2; pH=5.9; EC(mS/m)=11.55; DO(mg/l)=5.05; DO(%)=65.0; TDS(mg/l)=58
Algae Presence	Abundant	Abundant
Dominant Biotope Diversity	Pools and run	Pools
Other Biota	Tadpoles, frogs, snails and birds	Tadpoles, frogs and snails
Highly Sensitive Taxa (Score 11–15)	Helodidae (Marsh beetles)	None

Riparian Present Ecological State

ZONE	Overall	Marginal	Lower	Upper
VEGRAI %	84.7	90.0	84.5	79.5
Ecological Categories (EC)	B – largely natural	A/B – natural – B – largely natural	B – largely natural	B/C B – largely natural – moderately modified

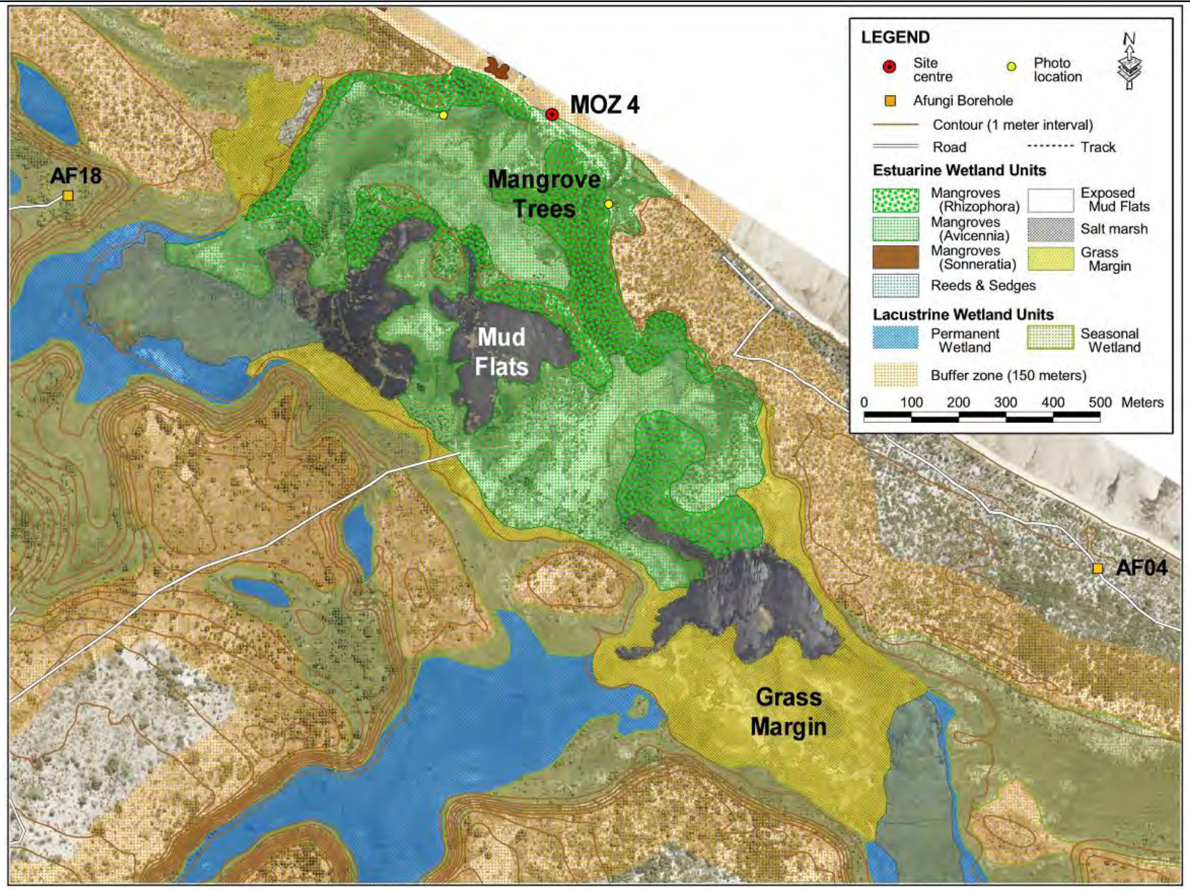
Aquatic Present Ecological State

DATE	SAMPLERS	WQ	Diatoms			IHI	SASS 5 & ASPT	MIRAI	Fish
			SPI	BDI	%PTV				
14/10/2011	C. Renshaw A. Austin	√	12.7	17.6	12.0	93 (A)	78 & 4.6	81 (B)	√
24/02/2012	C. Renshaw W. Malherbe	√	15.5	15.8	14.8	91 (A)	97 & 4.4	80 (B)	√

Figure 8.38 Sampling Site MOZ 4

Wetland Type	Saline estuarine wetland (Catchment B)
Location	In the proposed Project Footprint Area (masl 4m). Latitude 10.806762S; Longitude 40.552766E (Geographic projection, WGS84); UTM Zone 39: 8804955S; 669759E

Wetland Layout



Source: Aerial image supplied by Client

General Site Description

This site consists of a large estuary covering approximately 100ha and extending well below the high-tide level. Most of the water in this estuary originates from the ocean, to which it is connected during high flow. The wide flat estuary could not be separated into different riparian zones, and only one zone was therefore considered. Some parts of the estuary supported virtually impenetrable groves of mangroves, whereas other areas consisted of open mudflats or permanent pools of brackish water. Low faunal and floral species diversity was apparent, although a unique diversity of mangrove species was observed. Extensive die-off of trees was observed in the upper reaches of the estuary, but no evidence of tree cutting was observed in these areas and it is thus assumed to be a natural phenomenon.

Photos

Low Flow 2011		High Flow 2012	
UPSTREAM	*ESTUARY MOUTH*	*UPSTREAM*	*ESTUARY MOUTH*
			

Estuarine Vegetation Description

Two estuarine habitats were identified at MOZ 4: mangroves and reeds and sedges. In addition to this, a grass margin and a mudflat habitat was observed. Mangrove habitat dominated the site across length of the estuary and covered 59.66ha. This was mostly composed of open *Avicennia marina* habitat, covering 41.11ha, and dense *Rhizophora mucronata* and *Ceriops tagal* forest with some *Bruguiera gymnorrhiza,* covering 18.55ha. *Sonneratia alba* was found on small islands in the intertidal zone, covering only 0.90ha. Interspersed in the mangrove forest was some herbaceous cover of sea purslane (*Sesuvium portulacastrum*), a sprawling coastal succulent, and some grasses. The average mangrove tree height was 4 to 6 m and there was variable cover, ranging from 20 percent in areas of high adult mortality to 75 percent in dense patches of impenetrable forest of *Avicennia marina*. Tree mortality appeared to be related to natural causes. Significant recruitment of new individuals, with 60 percent of the population as seedlings was also recorded. Flowers were present on *Avicennia marina*, *Lumnitzera racemosa* and *Sonneratia alba*. Propagules were present on *Bruguiera gymnorrhiza*. An absence of halophytic succulents was noted on the mud flats in the supratidal zone and this may be due to limited tidal inflow. The sedges were replaced by grasses, and there was an abundance of the golden leather fern (*Acrostichum aureum*).

Estuarine Vegetation

Avicennia marina – white mangrove

Acrostichum aureum – golden leather fern

Bruguiera gymnorrhiza – large-leaved mangrove

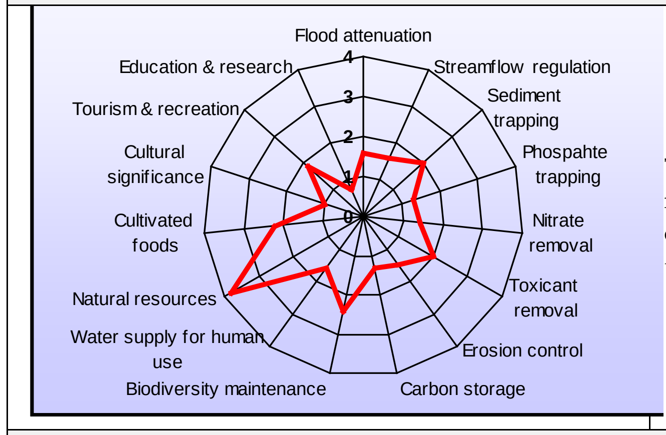
SPECIES		
Avicennia marina	*Ceriops tagal*	*Rhizophora mucronata*
Acrostichum aureum	*Cocos nucifera* *	*Sonneratia alba*
Bruguiera gymnorrhiza	*Crassula* sp.	
* *Casuarina equisetifolia*	*Cynodon dactylon*	

Key: * denotes alien plant species

Mangroves (*Rhizophora mucronata*) lining a channel

Mangrove trees (*Avicennia marina*) on the mudflats

Wetland Ecoservices



The saline estuary at MOZ 4 is important for the provision of natural resources such as snails, wood and fish to local communities. The estuary also provides an important site for the maintenance of unique biodiversity.

Current Impacts

- Track traversing upper reaches of mangroves lined with sandbags
- *Casuarina equisetifolia* found on the banks of the lower estuary. *C. equisetifolia* is often associated with swamp forests adjacent to estuaries
- Foot and vehicle paths through the mangrove forests
- Aliens plantations on outer edges
- Harvesting wood from mangroves
- Former salt harvesting in upper reaches
- Aquaculture

Aquatic Description

	Low Flow 2011	High Flow 2012
Water Surface Dimensions		Width: 1–10m; Depth: 0.1–1.2m
Water Turbidity (Dallas 2005)		Discoloured
Dominant Velocity-depth Classes		Slow deep
Water Quality Parameters	T(°C)=28.3; pH=7.7; EC(mS/m)=5793; DO(mg/l)=4.62; DO(%)=73.40; TDS (mg/l)=28966; Salinity=38.53	T(°C)=29.5; pH=7.5; EC(mS/m)=5566; DO(mg/l)=4.55; DO(%)=73.44; TDS (mg/l)=27829; Salinity=36.78
Dominant Biotope Diversity		Pool
Other Biota		Estuarine prawns

Riparian Present Ecological State

Estuarine Health Index	97.5	Present Ecological Status	A– natural

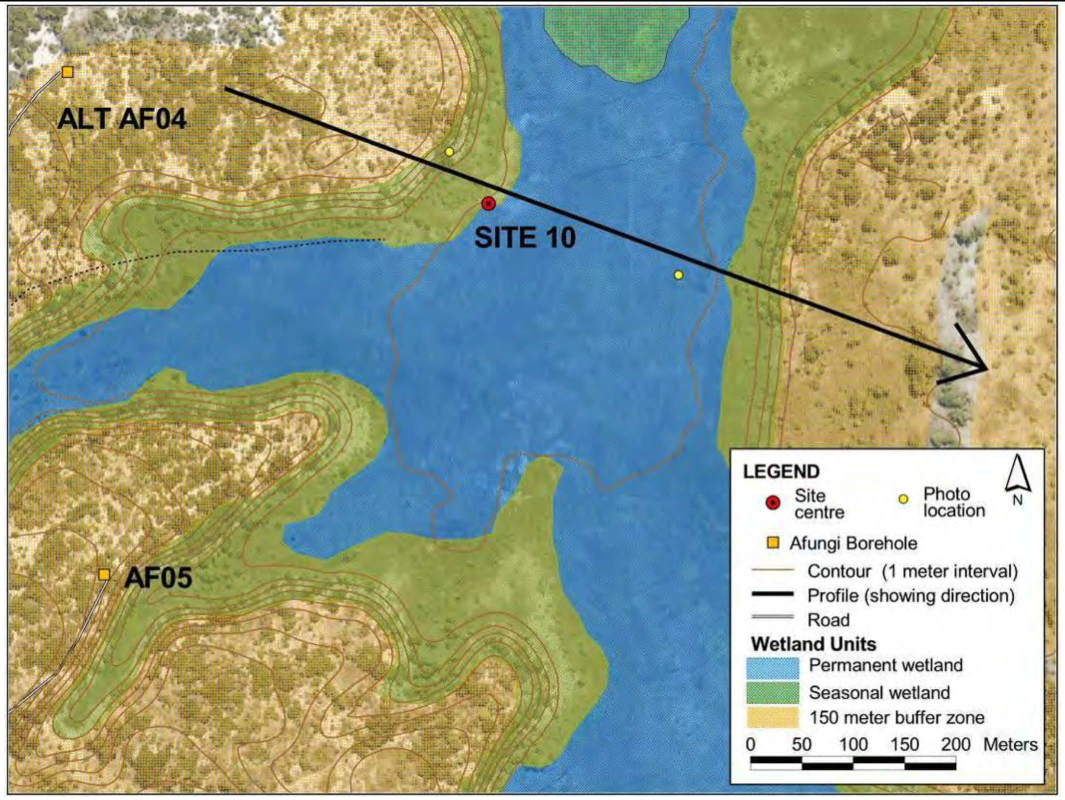
Aquatic Present Ecological State

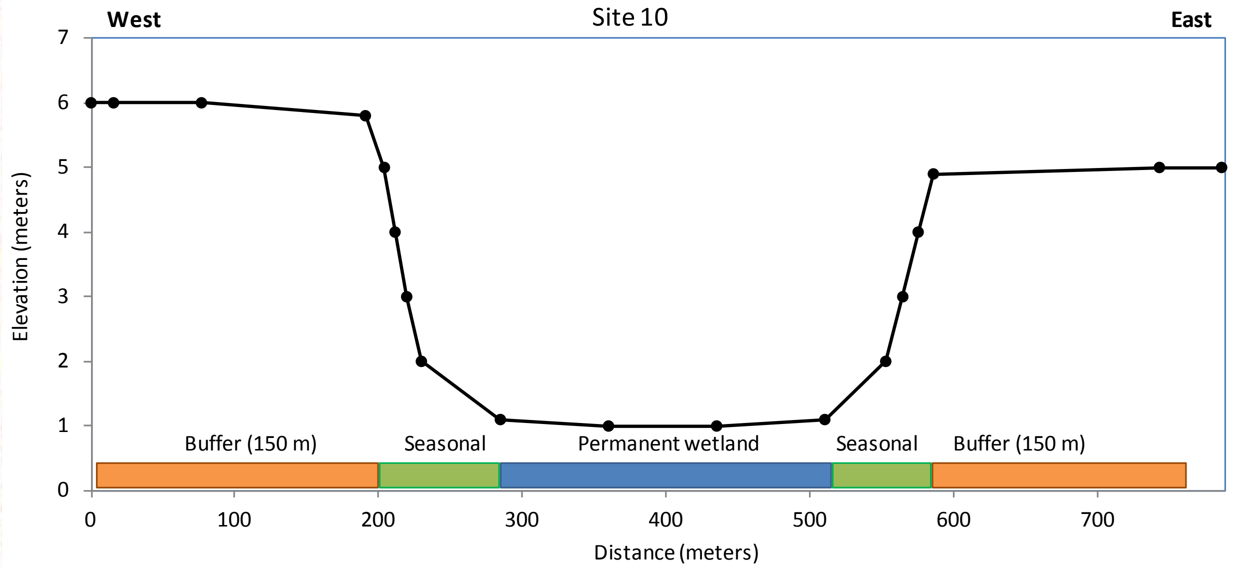
DATE	SAMPLERS	WQ	Diatoms			Invertebrates	Fish
			SPI	BDI	%PTV		
15/10/2011	C. Renshaw A. Austin	√	√	9.6	3.5	√	√
23/02/2012	W. Malherbe C. Renshaw A. Austin	√	√	9.2	3.4	√	√

Figure 8.39 Sampling Site MOZ 10

Wetland Type	Unchannelled valley bottom wetland in the lower catchment zone and in close proximity to the estuary (Catchment B)
Location	In the proposed Project Footprint Area (5 masl). Latitude 10.82262S; Longitude 40.55843E (Geographic projection, WGS84); UTM Zone 39: 8803198S; 670369E

Wetland Layout





Source: Aerial image supplied by Client

General Site Description

This site is located towards the end of the fresh-water component of this wetland system, within sight of the estuary and tall coconut palms that line the coast. The wetland in this part is typical of the lower end of the catchments, with an extensive permanent wetland bordered by small slopes of seasonal wetlands. Minimal settlement has occurred in the vicinity, resulting in this area remaining in a relatively pristine state.

Photos

High Flow 2012			Low Flow 2012	
UPSTREAM	*DOWNSTREAM*	*CLOSE-UP*	*UPSTREAM*	*DOWNSTREAM*
				

Riparian Zone Description

Marginal Zone (MZ)	The marginal zone consists of an extensive plain of sedges and aquatic grasses growing in water up to half a meter deep. The zone is approximately 250m wide and bordered by short but steep slopes up to 5m high.
Lower Zone (LZ)	Dense riparian vegetation grows on the slopes of the lower zone, which provides a distinct contrast to the extensive marginal zone.
Upper Zone (UZ)	The upper zone merges gradually into the surrounding terrestrial vegetation with limited anthropogenic impacts, although some removal of taller trees does appear to have occurred here.

Riparian Vegetation

SPECIES	MZ	LZ	UZ	SPECIES	MZ	LZ	UZ
Anacardium occidentale *		x	x	*Melinis repens*		x	
Andropogon gayanus		x		*Nymphaea nouchali*	x		
Aristida congesta		x		*Ochna inermis*		x	x
***Berlinia orientalis* (VU)**		**x**	**x**	*Ozoroa obovata*			x

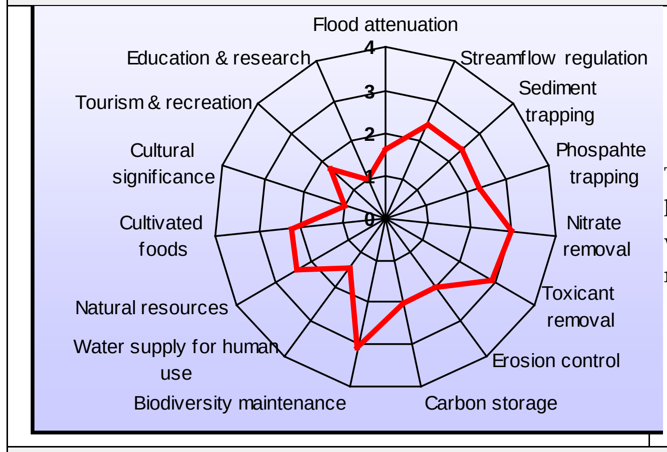
Utricularia vulgaris – aquatic bladderwort

Ozoroa obovata – resin tree

Brachystegia spiciformis		x	x	*Pandanus livingstonianus*		x	
Chloris gayana	x			*Perotis patens*		x	
Combretum eleagnoides	x			*Phoenix reclinata*	x		
Crinum sp.		x		***Platycoryne mediocris* (EN)**		**x**	
Cyperus prolifer	x			*Pseudolachnostylis maprouneifolia*			x
Digitaria eriantha		x	x	*Ctenium concinnum*		x	
Eleocharis sedge	x			*Striga* sp.		x	
Flueggea virosa			x	*Strychnos spinosa*			x
Hyparrhenia sp.		x		*Swartzia madagascariensis*			x
Hyparrhenia tamba			x	*Utricularia vulgaris*	x		
Hyphaene coriacea		x	x	*Vitex* sp.	x		
Juncus sp.	x			*Xylotheca kraussiana*		x	

Key: * denotes alien plant species; VU – Vulnerable as per IUCN Red List classification

Wetland Ecoservices



The lack of local communities living in the vicinity of MOZ 10 has a profound influence on the ecoservices supplied by the wetland. Biodiversity maintenance and various toxicant removals are the most important ecoservices provided there.

Current Impacts

- Limited removal of riparian vegetation
- Limited cultivation of fruit trees

Aquatic Description

	High Flow 2012	Low Flow 2012
Water Surface Dimensions	Width: 0.5–10m; Depth: 0.1–0.5m	Width: 0.5–10m; Depth: 0.1–0.5m
Water Turbidity (Dallas 2005)	Clear	Clear
Dominant Velocity-depth Classes	Slow shallow	Slow shallow
Water Quality Parameters	T(°C)=30.3; pH=6.0; EC(mS/m)=50.92; DO(mg/l)=3.76; DO(%)=50.77; TDS(mg/l)=254	T(°C)=27.2; pH=5.9; EC(mS/m)=19.30; DO(mg/l)=4.99; DO(%)=62.88; TDS(mg/l)=96
Algae Presence	Abundant	Abundant
Dominant Biotope Diversity	Pool	Pool
Other Biota	Water birds, frogs and killifish	Frogs and killifish
Highly Sensitive Taxa (Score 11–15)	None	None

Riparian Present Ecological State

ZONE	Overall	Marginal	Lower	Upper
VEGRAI %	77.6	88.3	77.8	66.7
Ecological Categories (EC)	**B/C – largely natural – moderately modified**	**A/B – natural to B – largely natural**	**B/C – largely natural – moderately modified**	C

Aquatic Present Ecological State

DATE	SAMPLERS	WQ	Diatoms			IHI	SASS 5 & ASPT	MIRAI	Fish
			SPI	BDI	%PTV				
28/02/2012	C. Renshaw A. Austin W. Malherbe	√	**17.9**	**20.0**	**2.5**	**92 (A)**	**74 and 4.4**	**72 (C)**	√
22/06/2012	A. Austin W. Malherbe	√	**18.5**	**20.0**	**2.3**	**93 (A)**	**81 and 4.5**	**75 (C)**	√

Catchment C

Three sampling sites were considered in Catchment C and these are outlined in *Table 8.24*. Catchment C is an unchannelled valley bottom system. The system is a slow-flowing deep wetland.

Table 8.24 Sampling Sites within Catchment C

Catchment and Assessment Sites	Site Description
Catchment C	
MOZ 8	Upper catchment, close to the start of the permanent wetland
MOZ 9	Mid catchment zone

Source: NSS, 2012.

The aquatic habitat integrity of the lacustrine wetlands within Catchment C are Natural, showing limited anthropogenic impacts. The overall riparian habitat integrity ranged from Moderately to Largely Modified, with the main impacts identified at site MOZ 8 in the upper section of the catchment. Cultivation within all of the riparian zones (marginal, lower and upper) takes place. There is extensive cultivation of cassava in the upper zone of site MOZ 9 with the marginal and lower zones relatively natural, comprising dense vegetation. The main ecosystem services supplied by the lacustrine wetlands in Catchment C include natural resource provision and the cultivation of foods.

In terms of water quality, low oxygen levels, influenced by high temperatures and slightly high salts content (EC and TDS), were observed at each of the lacustrine wetland sites, together with exceeding concentrations of NH_4, COD and SS.

The MIRAI scores were Moderately Modified and indicated that the macro-invertebrates within the lacustrine wetland are influenced by flow modification, habitat and water quality. Low numbers of sensitive families and a generally low family diversity indicated that only tolerant families could survive in these wetlands with limited flow and absence of the stone biotope. In addition to this, there were also high percentages of airbreathers, which are also indicative of slow-flowing habitats with a lack of sufficient oxygen levels, high temperatures and water levels.

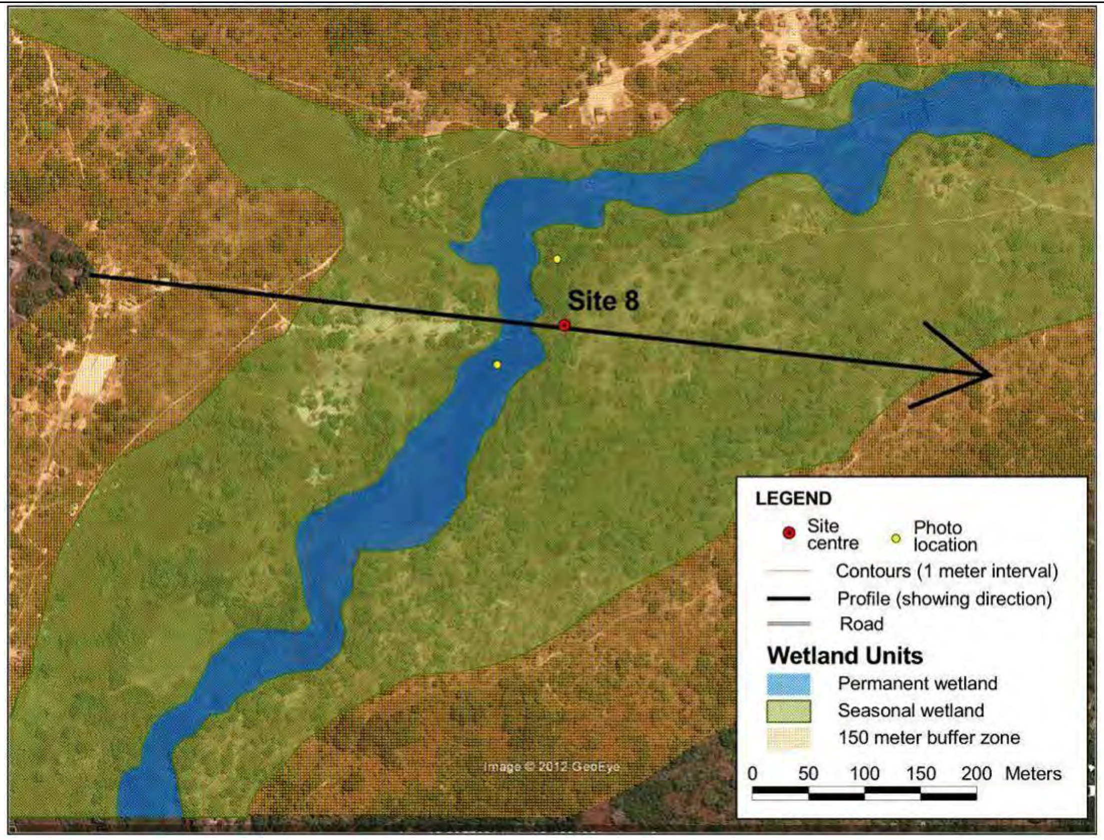
Fish species of note observed in the lacustrine wetlands within Catchment C included the data-deficient killifish (see *Section 8.6.4*).

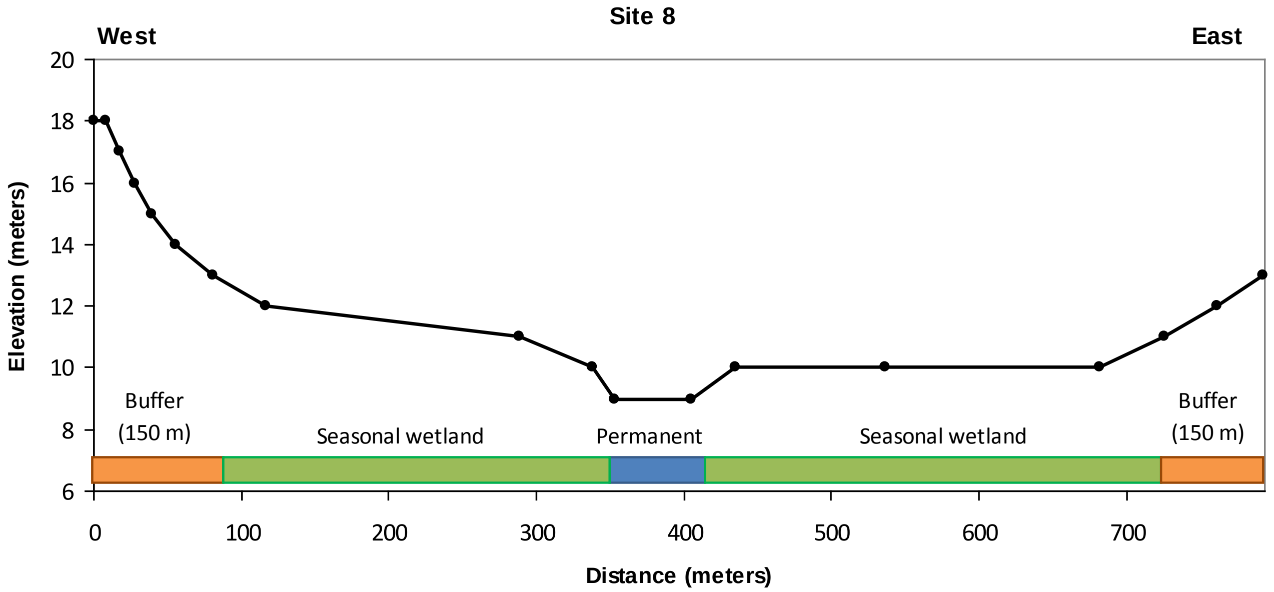
Figure 8.40 to *Figure 8.41* provide general information and detailed results for the high flow (October 2011) and low flow sampling assessments (February 2012) at each sampling site in Catchment C.

Figure 8.40 Sampling Site MOZ 8

Wetland Type	Unchannelled valley bottom wetland (Catchment C)
Location	Upstream from the proposed airstrip (12 masl). Latitude 10.86707S; Longitude 40.49108E (Geographic projection, WGS84); UTM Zone 39: 8798319S; 662981E

Wetland Layout





Source: Aerial image supplied by Client

General Site Description

The site forms part of a large wetland system draining eastwards in the direction of Maganja settlement, and is located at the start of the permanent wetland where a reliable source of water becomes available. The wetland at this point shows the typical characteristics of an upper catchment. A small village occurs in the vicinity of the site and numerous impacts associated with the settlement.

Photos

High Flow 2012			Low Flow 2012	
UPSTREAM	DOWNSTREAM	CLOSE-UP	UPSTREAM	DOWNSTREAM
				

Riparian Zone Description

Marginal Zone (MZ)	The marginal zone at this site is narrow and not clearly distinguishable from the adjacent lower zone, partly due to the site being in the upper reaches of the catchment, and partly due to extensive cultivation of crops and fruit trees in the lower zone.
Lower Zone (LZ)	The lower zone differs between the north and south banks of this wetland. The north bank is settled and supports considerable amount of agriculture, while the south bank remains in a relatively pristine state with tall dense riparian vegetation in close proximity of a village. There must be reasons unknown to the assessment team for the protection of this area of riparian vegetation.
Upper Zone (UZ)	The upper zone exists on a gradual slope extending upwards from the lower zone, and no clear topographical definition between the two zones exists. The zones cannot thus be easily distinguished from one another on the ground.

Vegetation

Nymphoides indica – waterlily

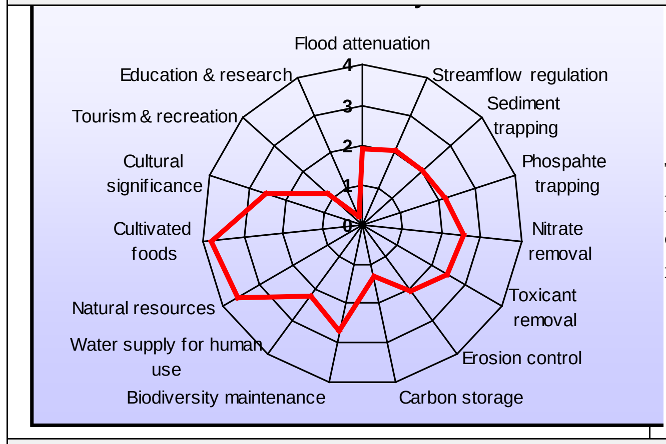
Acampe sp. – epiphytic orchid

Platycoryne mediocris – terrestrial orchid

SPECIES	MZ	LZ	UZ	SPECIES	MZ	LZ	UZ
Acampe sp.		x		*Nymphoides indica*			x
Anacardium occidentale *		x		*Ochna inermis*	x		
Ananas comosus		x		*Panicum coloratum*		x	
Chamaecrista sp.	x			*Panicum maximum*	x	x	
Cocos nucifera *		x	x	*Parinari curatellifolia*	x		
Crinum sp.	x			*Phoenix reclinata*		x	x
Cyperus dives	x			***Platycoryne mediocris* (EN)**		**x**	
Cyperus prolifer	x			*Psidium guajava* *		x	
Dactyloctenium aegyptium	x	x		*Ctenium concinnum*		x	
Ferns	x			*Strychnos* sp.	x		
Gardenia ternifolia			x	*Strychnos spinosa*	x		
Gladiolus sp.		x		*Syzigium* sp.			x
Imperata cylindrica		x		*Vangueria infausta*	x		
Mangifera indica *		x	x	*Xeromphis* sp.	x		
Nymphaea nouchali	x						

Key: * denotes alien plant species; VU – Vulnerable as per IUCN Red List classification

Wetland Ecoservices



The wetland at MOZ 8 provides important ecoservices to the local communities in the form of cultivated foods and provision of natural resources. Maintenance of biodiversity is of moderate importance there.

Current Impacts

- Cultivation within each of the riparian zones: rice, cassava and orchards including coconuts, mangoes, guavas
- High algae content due to nutrients from crops and washing
- Passage through the wetland
- Removal of natural vegetation
- Water abstraction
- Fishing

Aquatic Description

	High Flow 2012	Low Flow 2012
Water Surface Dimensions	Width: 5–10m; Depth: 0.1–0.7m	Width: 5–10m; Depth: 0.1–0.8m
Water Turbidity (Dallas 2005)	Clear	Clear
Dominant Velocity-depth Classes	Slow shallow	Slow shallow
Water Quality Parameters	T(°C)=28.2; pH=6.1; EC(mS/m)=13.29; DO(mg/l)=7.68; DO(%)=99.51; TDS(mg/l)=67	T(°C)=25.3; pH=6.3; EC(mS/m)=14.17; DO(mg/l)=5.26; DO(%)=64.07; TDS(mg/l)=71
Algae Presence	Common	Abundant
Dominant Biotope Diversity	Pool	Pool
Other Biota	Water birds and frogs	Water birds and frogs
Highly Sensitive Taxa (Score 11–15)	None	Crambidae (Score=12)

Riparian Present Ecological State

ZONE	Overall	Marginal	Lower	Upper
VEGRAI %	54.5	78.3	46.8	38.5
Ecological Categories (EC)	D – largely modified	B/C – largely natural – moderately modified	D – largely modified	D/E – largely modified – seriously modified

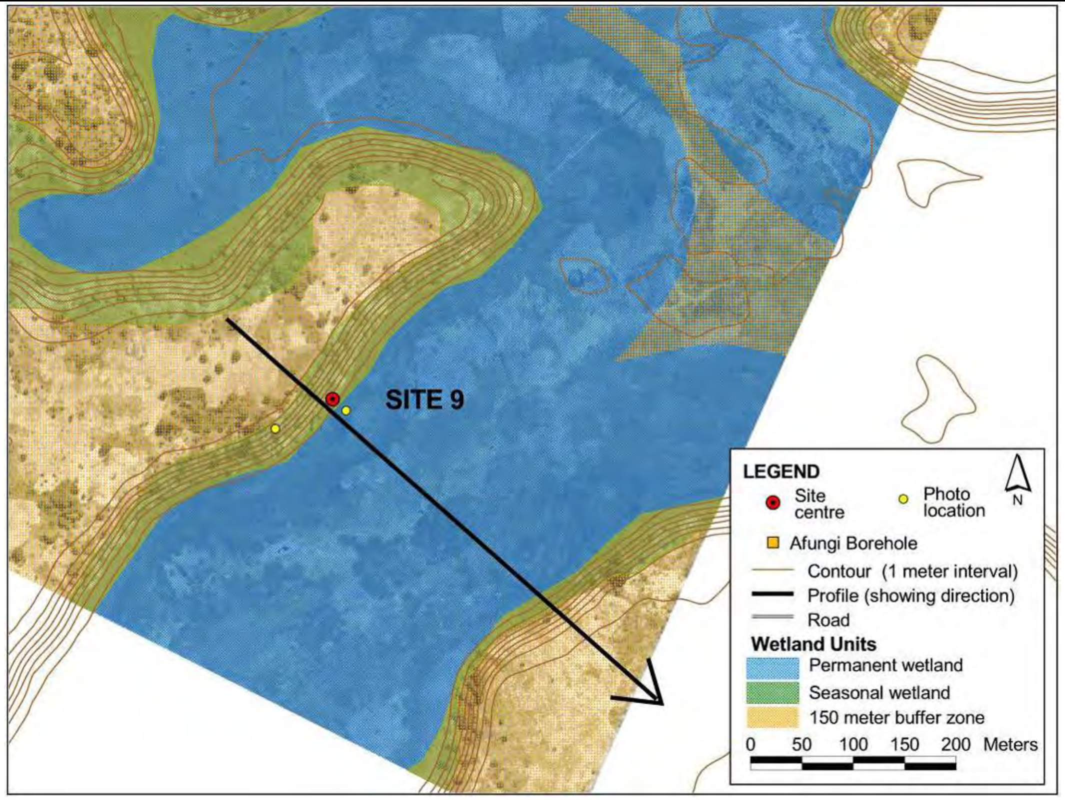
Aquatic Present Ecological State

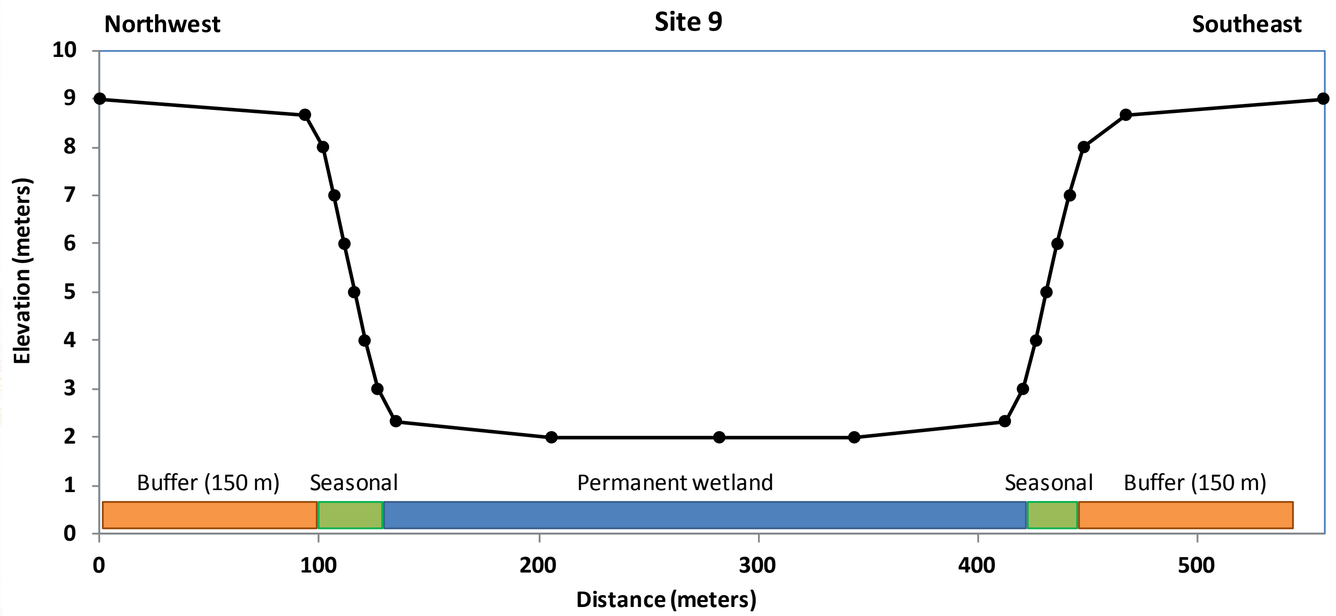
DATE	SAMPLERS	WQ	Diatoms			IHI	SASS 5 & ASPT	MIRAI	Fish
			SPI	BDI	%PTV				
27/02/2012	C. Renshaw A. Austin W. Malherbe	√	**18.2**	**20.0**	**2.0**	**91 (A)**	**63 and 4.2**	**64 (C)**	√
26/06/2012	A. Austin W. Malherbe	√	**17.3**	**19.2**	**1.0**	**90 (A)**	**78 and 5.5**	**67 (C)**	√

Figure 8.41 Sampling Site MOZ 9

Wetland Type	Unchannelled valley bottom wetland (Catchment C)
Location	Upstream of the Project Footprint Area (9 masl). Latitude 10.8486S; Longitude 40.55446E (Geographic projection, WGS84); UTM Zone 39: 8800328S; 669921E

Wetland Layout





Source: Aerial image supplied by Client

General Site Description

This site is located on the same wetland system as Site 8, but shows many characteristics of a lower catchment zone, with an extensive permanent wetland zone bordered by a narrow seasonal zone supporting sparse woody riparian vegetation. Extensive cassava plantations and settlement occur in the outer edges of the upper zone. The communities living here have no vehicle access and live in a somewhat isolated state, depending on agricultural and locally acquired natural resources.

Photos

High Flow 2012			Low Flow 2012	
UPSTREAM	*DOWNSTREAM*	*CLOSE-UP*	*UPSTREAM*	*DOWNSTREAM*
				

Riparian Zone Description

Marginal Zone (MZ)	The marginal zone consists of a broad permanent wetland approximately 300m wide, with considerable water resources within.
Lower Zone (LZ)	The lower zone consists of sparse riparian vegetation growing on moderately tall steep slopes.
Upper Zone (UZ)	Extensive plantations of cassava and an associated settlement have been established within the outer edges of the upper seasonal wetland zone. Extensive removal of vegetation has occurred as a result of the settlement.

Vegetation

Chamaecrista sp.

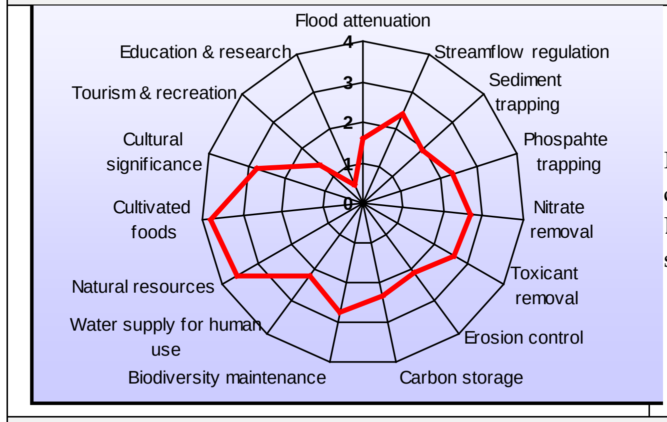
Gymnosporia sp.

Striga sp.

SPECIES	MZ	LZ	UZ	SPECIES	MZ	LZ	UZ
Anacardium occidentale *		x		*Leersia hexandra*	x		
Andropogon gayanus		x		*Manihot esculenta* *			x
***Berlinia orientalis* (VU)**		**x**		*Nymphaea nouchali*	x		
Brachystegia spiciformis		x		*Ochna inermis*		x	x
Chamaecrista sp.	x			*Ozoroa obovata*		x	
Cocos nucifera *			x	*Perotis patens*		x	x
Combretum eleagnoides		x		*Phoenix reclinata*	x	x	
Crinum sp.	x			*Striga* sp.		x	
Cynodon dactylon			x	*Strychnos* sp.		x	x
Cyperus prolifer	x			*Strychnos spinosa*			x
Dactyloctenium aegyptium		x		*Syzigium* sp.	x		
Gymnosporia sp.		x		*Themeda triandra*		x	
Hyphaene coriacea		x	x	*Vangueria infausta*		x	
Juncus sp.	x			*Vitex* sp.	x		

Key: * denotes alien plant species; VU – Vulnerable as per IUCN Red List classification

Wetland Ecoservices



Important ecoservices provided at MOZ 9 include provision of cultivated foods and natural resources to the local communities. Biodiversity maintenance, water supply and cultural significance rank as moderately important there.

Current Impacts

- Extensive cultivation of cassava in the upper zone
- Water abstraction
- Removal of riparian vegetation

Aquatic Description

	High Flow 2012	Low Flow 2012
Water Surface Dimensions	Width: 2–5m; Depth: 0.1–0.8m	Width: 2–5m; Depth: 0.1–0.8m
Water Turbidity (Dallas, 2005)	Clear	Clear
Dominant Velocity-depth Classes	Slow shallow and deep	Slow shallow and deep
Water Quality Parameters	T(°C)=30.0; pH=6.0; EC(mS/m)=43.49; DO(mg/l)=4.35; DO(%)=58.29; TDS(mg/l)=217	T(°C)=27.3; pH=5.8; EC(mS/m)=22.78; DO(mg/l)=3.31; DO(%)=41.80; TDS(mg/l)=114
Algae Presence	Common	Abundant
Dominant Biotope Diversity	Pool	Pool
Other Biota	Frogs and killifish	Frogs and killifish
Highly Sensitive Taxa (Score 11–15)	None	None

Riparian Present Ecological State

ZONE	Overall	Marginal	Lower	Upper
VEGRAI %	62.4	88.5	57.5	41.3
Ecological Categories (EC)	**C – moderately modified**	**A/B – natural – largely natural**	**D – largely modified**	**D/E – largely modified – seriously modified**

Aquatic Present Ecological State

DATE	SAMPLERS	WQ	Diatoms			IHI	SASS 5 & ASPT	MIRAI	Fish
			SPI	BDI	%PTV				
27/02/2012	C. Renshaw A. Austin W. Malherbe	√	**18.3**	**20.0**	**1.3**	**96 (A)**	**71 and 4.7**	**74 (C)**	√
23/06/2012	A. Austin W. Malherbe	√	**18.3**	**20.0**	**0.3**	**94 (A)**	**76 and 5.0**	**69 (C)**	√

Catchment D

Only one sampling site was considered in Catchment D: MOZ 7, located in the upper zone of the lacustrine wetland (see *Figure 8.20*). The wetland system is classified as an unchannelled valley bottom system that has been artificially channelled by local people for agriculture. The system is a slow-flowing shallow to deep wetland. This site is located in the upper reaches of a permanent tributary to a larger wetland system that drains into a large estuary at the edge of Palma town. The wetland takes on a seasonal appearance upstream of this site.

The aquatic habitat integrity of site is Natural to Largely Natural. The overall riparian habitat integrity is Largely Modified. The marginal zone consists of a broad wetland that has been channelled by the local communities. The wetland has been widely terraced to create dry ridges on which small herbaceous crops such as beans are cultivated. Much vegetation has been cleared from the lower zone for cultivation; however, some patches of natural vegetation remain. Most of the upper zone has been transformed for cultivation. Remnant large trees are common indicating the area must formerly have consisted on a tall thicket; however, little of that thicket now exists. The main ecosystem services supplied by the wetland in Catchment D include natural resource provision and the cultivation of foods.

In terms of water quality, low oxygen levels, influenced by high temperatures and slightly high salts content (EC and TDS), were observed at site MOZ 7, together with exceeding concentrations of NH_4, COD, SS and Zn (see *Section 8.6.4*). SS and Zn are considered to be a naturally occurring constituent within these systems, while the higher levels of NH_4 and COD could be attributed to sewage within the wetland system.

The diatoms at MOZ 7 specifically showed a higher percentage of pollutant-tolerant species, dominated by a high diversity of various *Nitzschia* species, which typically indicates high levels of organic material and waste. The macro-invertebrate community structures of the lacustrine wetlands consisted of a low number of sensitive taxa, probably due to low habitat availability for these taxa. The MIRAI scores were Moderately Modified, indicating that the macro-invertebrates within the lacustrine wetland were influenced by flow modification, habitat and water quality. Only tolerant families can survive in this wetland, and this is likely a result of the limited flow and absence of the stone biotope. In addition, a high percentage of airbreathers observed is indicative of slow-flowing habitats with a lack of sufficient oxygen levels, high temperatures and water levels.

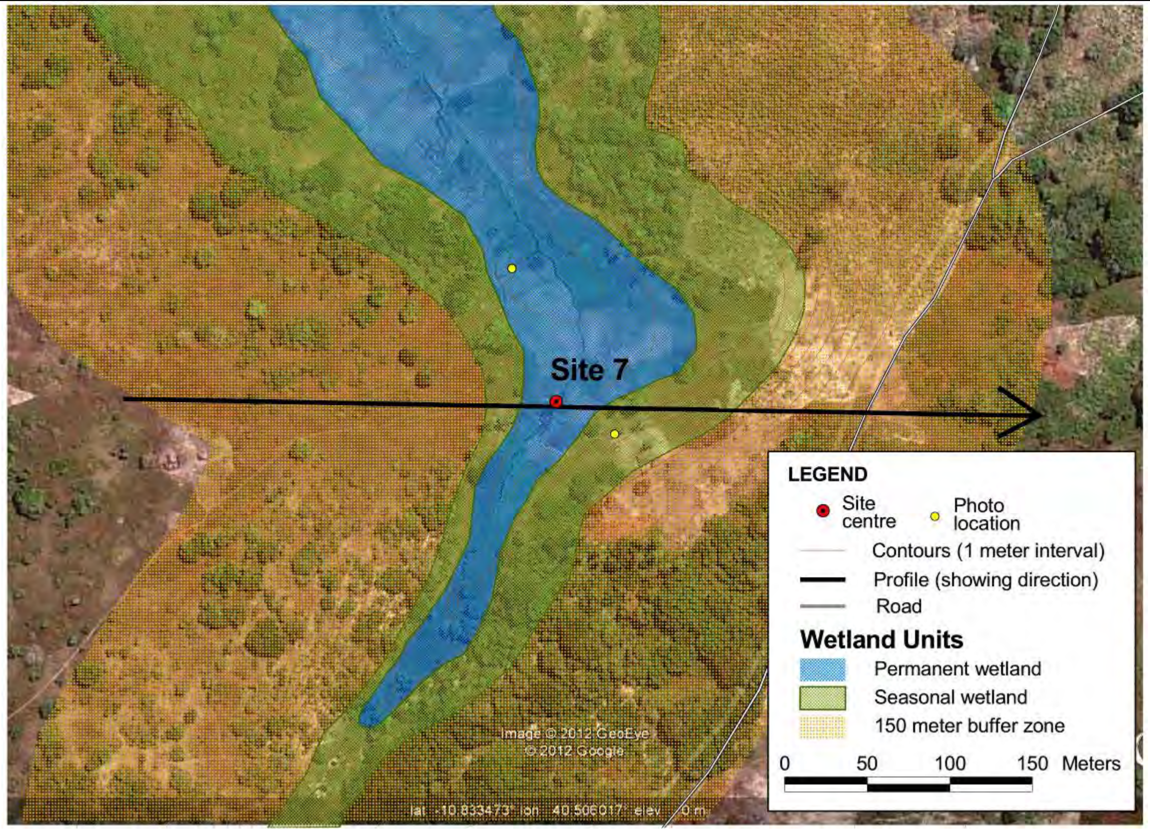
No fish species of high conservational importance were observed at site MOZ 7. However, it must be noted that *Barbus choloensis*, a vulnerable species, is expected to occur within the catchment.

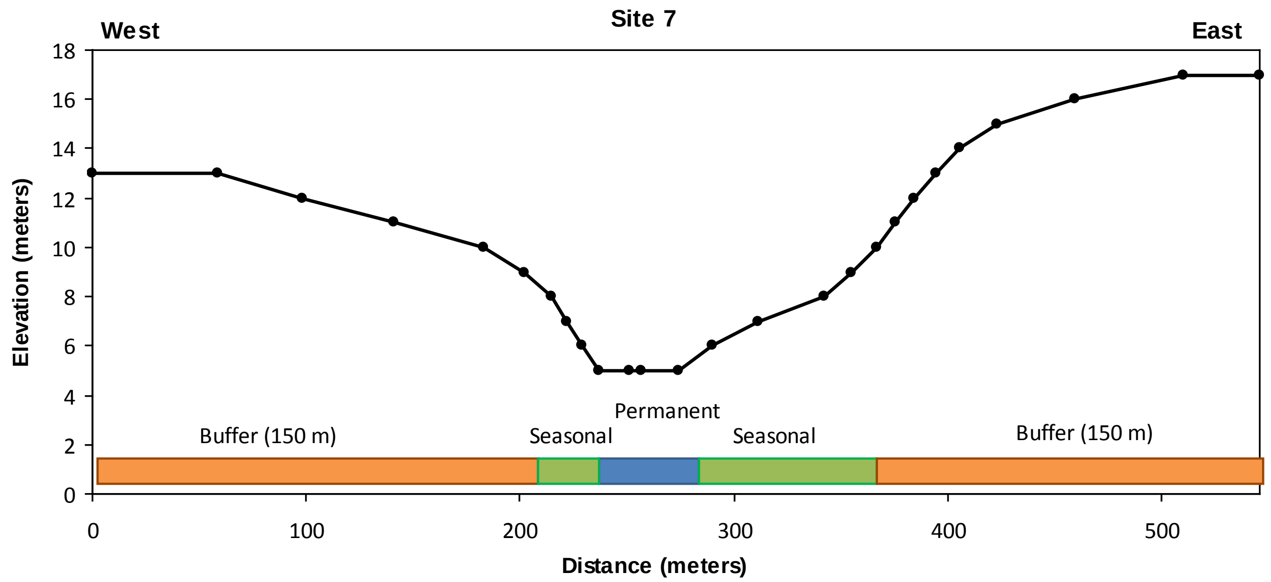
Figure 8.42 provides general information and detailed results for the high flow (October 2011) and low flow sampling assessments (February 2012) at each sampling site in Catchment D.

Figure 8.42 Sampling Site MOZ 7

Wetland Type	Unchannelled valley bottom wetland that has been artificially channelled (Catchment D)
Location	Upstream from proposed airstrip (15 masl). Latitude 10.83272S; Longitude 40.505436E (Geographic projection, WGS84), UTM Zone 39: 8802110S; 664569E

Wetland Layout





Source: Aerial image supplied by Client

General Site Description

This site is located in the upper reaches of a tributary to a larger wetland system that drains into a large estuary at the edge of Palma town. This site is located at the upper edge of the permanent wetland, which is slow flowing. The wetland takes on a seasonal appearance shortly upstream of this site.

Photos

Low Flow 2011			High Flow 2012		
UPSTREAM	*DOWNSTREAM*	*CLOSE-UP*	*UPSTREAM*	*DOWNSTREAM*	*CLOSE-UP*
					

Riparian Zone Description

Marginal Zone (MZ)	The marginal zone consists of a broad wetland that has been channelled by the local communities. The wetland has been widely terraced to create dry ridges on which small herbaceous crops such as beans are cultivated.
Lower Zone (LZ)	Much vegetation has been cleared from the lower zone for cultivation; however, some patches of natural vegetation remain. A large thicket that overlaps into the upper zone was seen a short distance upstream of the site.
Upper Zone (UZ)	Most of the upper zone has been transformed for cultivation. Skeletons of large trees remain and the area must formerly have consisted on a tall thicket; however, little of that thicket now remains.

Vegetation

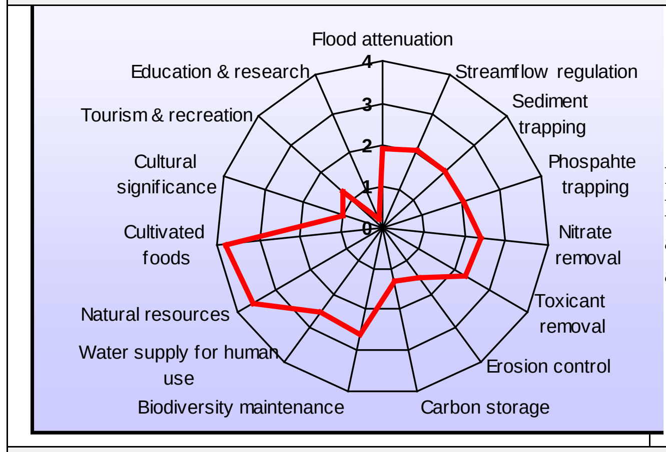
SPECIES	MZ	LZ	UZ	SPECIES	MZ	LZ	UZ
Acacia sp.		x		*Mangifera indica* *		x	
Adansonia digitata		x	x	*Manihot esculenta* *			x
Anacardium occidentale *		x		*Cyperus prolifer*	x		

		
Ficus sur – broom cluster fig	*Lycopodium* sp.	*Cyperus dives*

***Berlinia orientalis* (VU)**		x	x	*Musa acuminata* *	x		
Beans *	x			*Nymphaea nouchali*	x		
Brachystegia spiciformis		x		*Ochna inermis*			x
Cassia sp.		x		*Panicum maximum*		x	
Cocos nucifera *		x		*Parinari curatellifolia*			x
Cuscuta sp.	x			*Phoenix reclinata*		x	x
Cyperus esculentis	x			*Pseudolachnostylis maprouneifolia*			x
Ferns	x			*Strychnos pungens*		x	
Ficus sur		x		*Trema orientalis*			x
Flueggea virosa			x	*Trichilia emetica*		x	
Hyparrhenia tamba		x		*Typha capensis*	x		
Hyphaene coriacea			x	*Utricularia* sp. (yellow flower)	x		
Kigelia africana		x	x	*Vitex* sp.			x
Leersia hexandra	x			*Xylotheca kraussiana*		x	
Lycopodium	x						

Key: * denotes alien plant species; VU – Vulnerable as per IUCN Red List classification

Wetland Ecoservices



Ecoservices supplied by MOZ 7 are similar to those supplied by MOZ 5. These rank high on the provision of natural resources and cultivated foods to local communities. Water provision is an important service, as is the maintenance of biodiversity.

Current Impacts

- Alien trees cultivated and displacing natural vegetation
- Artificial channel created
- High algae content due to nutrients from crops and washing in the wetland
- Bank erosion
- Presence of solid waste
- Limited maize cultivation in marginal zone
- Evidence of tillage within marginal to lower zone for legume cultivation
- Water abstraction
- Washing of clothes
- Fish 'air sucking' from lack of sufficient oxygen levels

Aquatic Description

	Low Flow 2011	High Flow 2012
Water Surface Dimensions	Width: 0.5–3m; Depth: 0.1–0.4m	Width: 1–3m; Depth: 0.1–0.8m
Water Turbidity (Dallas, 2005)	Clear	Discoloured
Dominant Velocity-depth Classes	Slow deep	Slow shallow
Water Quality Parameters	T(°C)=31.3; pH=5.8; EC(mS/m)=21.80; DO(mg/l)=6.19; DO(%)=84.20; TDS(mg/l)=109	T(°C)=30.5; pH=5.7; EC(mS/m)=18.19; DO(mg/l)=3.39; DO(%)=45.77; TDS(mg/l)=91
Algae Presence	Abundant	Abundant
Dominant Biotope Diversity	Pool	Pool
Other Biota	None	Frogs and terrapin
Highly Sensitive Taxa (Score 11–15)	None	None

Riparian Present Ecological State

ZONE	Overall	Marginal	Lower	Upper
VEGRAI %	53.3	77.4	45.0	37.5
Ecological Categories (EC)	D – largely modified	B/C – Largely natural – moderately modified	D – largely modified	D/E – largely modified – seriously modified

Aquatic Present Ecological State

DATE	SAMPLERS	WQ	Diatoms			IHI	SASS 5 & ASPT	MIRAI	Fish
			SPI	BDI	%PTV				
17/10/2011	C. Renshaw A. Austin	√	9.3	10.8	13.5	90 (A)	75 and 3.9	76 (C)	√
28/02/2012	C. Renshaw W. Malherbe	√	13.7	12.8	10.7	81 (B)	58 and 3.8	60 (C)	√

Catchment E

Only one sampling site was considered in Catchment E: MOZ 12, located in an estuary (see *Figure 8.20*). This was sampled in the June 2012 low flow assessment. The estuary is a shallow-water saline system with a sandy substrate. The habitat in Catchment E ranges from shoreline to extensive mangrove systems and large salty mudflats, dominated by halophytic plants, to more fresh-water marshlands punctuated by islands of coastal dry forest, which provides an important habitat to a wide diversity of faunal species.

The salinity profile of MOZ 12 indicates a salinity increase from the head to the mouth of the estuary. However, the salinity at MOZ 12 was lower than at in the other estuaries sampled, which possibly indicates a more significant fresh-water source. The water quality results showed exceeding concentration levels of Ba, Cu, Pb, and Zn, and because most of the water was sea water, the exact source of contamination could not be determined. Nutrient variables within the estuarine water samples were also found to be low and, as such, limit the growth and abundance of microalgae and benthic microalgae.

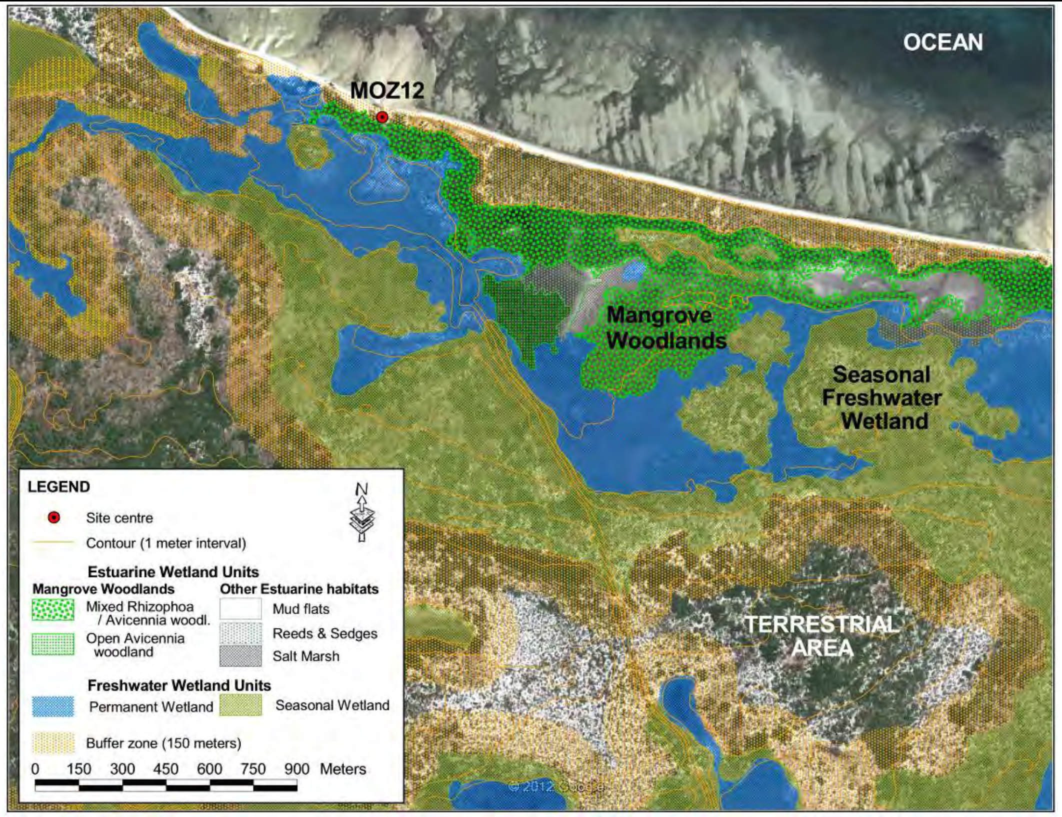
Eight fish species were identified during the June 2012 survey, with the dominant guilds being estuarine migrants and estuarine residents. A total of four frog species were identified in June 2012, which is a good result granted its estuarine nature. Two species of conservation concern, namely the snoring leaf-folding frog and Lindner's toad, were recorded. The latter is considered to be restricted in its geographic extent (see *Section 8.6.4*).

Catchment E is considered to be a Highly Sensitive environment, based on the low levels of anthropogenic influence within this large and diverse system. Salt harvesting is evident, but is on a small scale and restricted to a patch in the eastern interior. A small isolated fishing village is located within the extreme north-eastern corner of the system (outside of the Onshore Project Footprint Area) but its effects on the ecosystem appear to be small, with footpaths and bicycle tracks traversing the estuary.

Figure 8.43 Sampling Site MOZ 12

Wetland Type	Saline estuarine wetland (Catchment E)
Location	In the proposed Project Footprint Area (masl 4m). Latitude 10.820980S; Longitude 40.576191E (Geographic projection, WGS84) UTM Zone 39: 8802850S; 672772E.

Wetland Layout



Source: Aerial image supplied by Client

General Site Description

The salinity profile reveals that there is a source of fresh-water inflow into the site; however, the source is deceiving when onsite. The estuary is very shallow and narrow. A slight ridge of sand on the western side approximately 2m high retains the estuary to its current location, preventing a westward spread along the coast. There was a clear lack of herbaceous vegetation within the main part of the estuary, due to the high salt content and fluctuation in salinity. Extensive die-off of mangrove trees was observed, as in other estuarine sites, and is thought to be the result of salinity fluctuations, which may be a natural phenomenon. Limited evidence of tree cutting was observed, but was not the cause of the significant die-back of trees.

Photos

Low Flow 2012		High Flow 2012	
UPSTREAM	*ESTUARY MOUTH*		
			

Estuarine Vegetation Description

The vegetation in and around this estuary was not assessed in detail. The extent of the estuary and the species composition towards the outer peripheries requires further investigation. The estuary mouth was dominated by *Rhizophora mucronata* trees, while the mudflats deeper within the estuary were dominated by *Avicennia marina* shrubs.

Estuarine Vegetation

SPECIES		
Avicennia marina	*Cocos nucifera* *	*Cynodon dactylon*
* *Casuarina equisetifolia*	*Crassula* sp.	*Rhizophora mucronata*

Key: * denotes alien plant species

Wetland Ecoservices	Current Impacts
Important site for provision of natural resources for the local community.	• The Marampa village nearby resulted in a considerably higher human presence at this site than other estuarine sites assessed • Foot and bicycle traffic between Marampa and Maganja villages

Aquatic Description	
	Low Flow 2012
Water Surface Dimensions	Width: 1–5m; Depth: 0.1–0.6m
Water Turbidity (Dallas 2005)	Discoloured
Dominant Velocity-depth Classes	Slow shallow
Water Quality Parameters	T(°C)=29.4; pH=7.4; EC(mS/m)=5008; DO(mg/l) = 3.86; DO(%)=60.47; TDS(mg/l)=25040; Salinity=32.67
Dominant Biotope Diversity	Pool
Other Biota	Fiddler crabs

Aquatic Present Ecological State

DATE	SAMPLERS	WQ	Diatoms			Invertebrates	Fish
			SPI	BDI	%PTV		
23/06/2012	W. Malherbe A. Austin	√	√	**9.2**	0.5	√	√

8.6.6 Sensitivity of Catchments

The wetland sites ranged from sensitive to highly sensitive (as defined in *Annex C*). These are discussed further in *Section 8.6.5* by catchment. For the Onshore Project Footprint Area, the wetlands (1) in Catchments A, B and E are relevant. The wetlands in Catchment A were found to be more disturbed by human activities (settlements, cultivation and tree felling in the riparian zones) than at Catchment B and Catchment E. It appears that Catchment A has been subject to human activities and modification for a greater period of time than wetlands in Catchment B. This notwithstanding, the estuary of Catchment A has a higher abundance and diversity of estuarine fish species than Catchment B. Catchment A also has high habitat diversity (estuaries, broad lower catchment, narrow upper catchment, permanent wetland, seasonal wetlands and riparian zones).

Catchment B, like Catchment A, has high habitat diversity (estuaries, broad lower catchment, narrow upper catchment, permanent wetlands, seasonal wetlands and riparian zones). However, unlike Catchment A, Catchment B has a greater degree of connectivity with natural habitats than Catchments C and E. This connectivity promotes more robust floral and faunal populations and higher terrestrial faunal diversity (in particular the larger species). Threatened Red Data plant species, *Platycoryne mediocris* orchid and *Berlinia orientalis* tree (see Vegetation Baseline, *Section 8.7* for more detail) were more widespread and abundant in Catchment B than at either Catchment A or Catchment E. The possible new skink species was only observed in Catchment B, despite similar searches in Catchment A (2). The data-deficient killifish was identified in only two locations: Catchment B and two in Catchment C. They were not found in Catchment A, despite extensive sampling (habitats at Catchment E are not suitable for the killifish). Moreover, the wetlands in Catchment B had a higher abundance and diversity of frog species than in Catchment A (3). In terms of human disturbance, the wetlands and their buffer zones in Catchment B have been less modified than in Catchment A.

Catchment E has a low level of human disturbance (low levels of salt harvesting). There isn't an upstream fresh-water inflow, which has resulted in limited wetland habitat diversity being present. However, Catchment E wetland habitats are connected to those in Catchments B and C. As indicated earlier, this connectivity supports robust wetland floral and faunal populations and terrestrial faunal diversity.

(1) Includes fresh-water wetlands, estuaries and associated riparian zones and buffers.

(2) The skink species was only found in natural habitat, undisturbed by human activity. This may explain why it was not found in Catchment A.

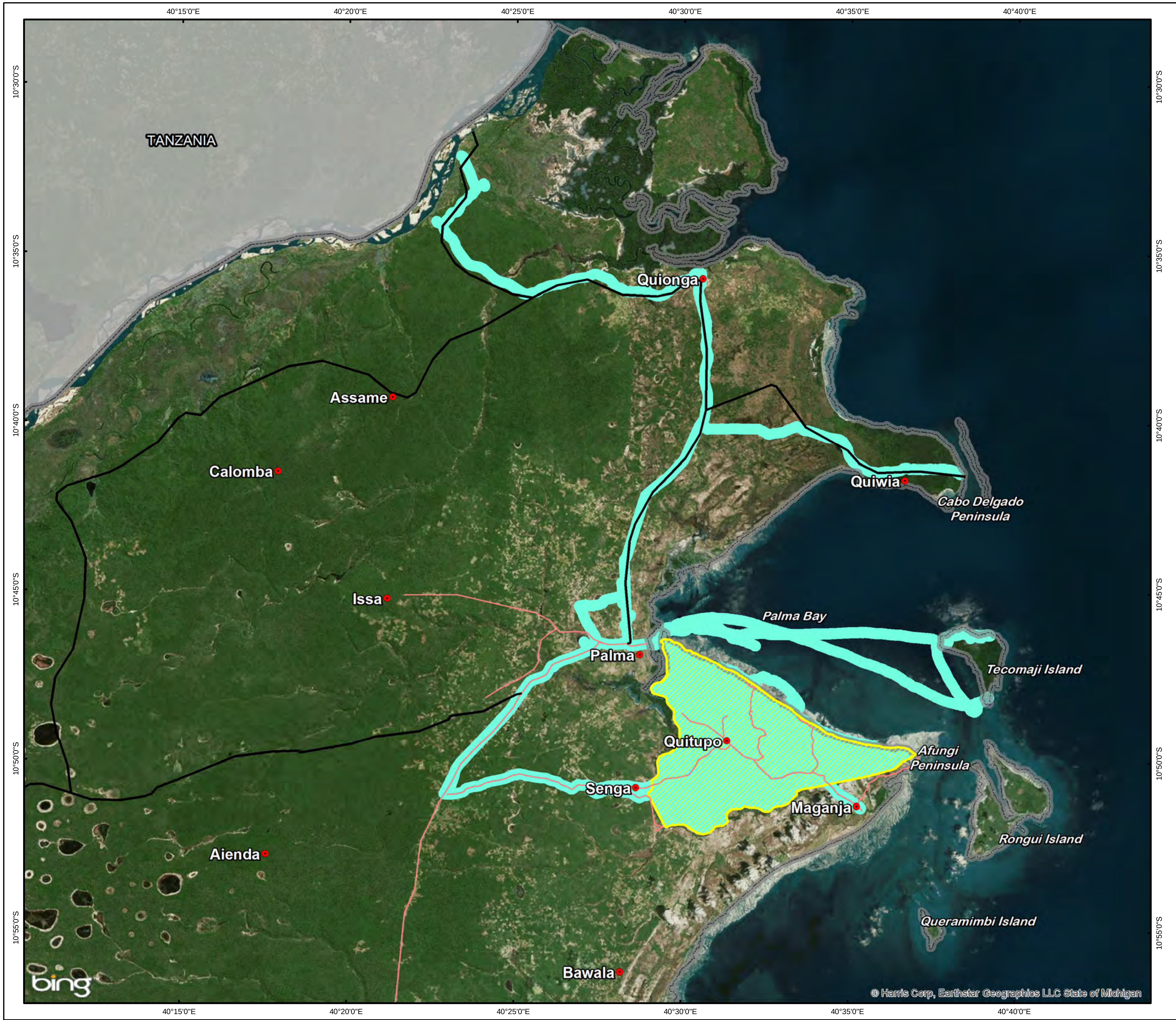
(3) It should be noted that while a high number and diversity of frog species were noted in Catchment E, night-time surveys were not allowed in this catchment for safety reasons. Thus, it is not possible to draw a direct comparison to Catchment B. However, given the low levels of human disturbance in Catchment E, it is likely that Catchment E has a similar abundance and diversity of frog species as Catchment B.

In light of the above, wetlands in Catchments B and E are considered to be highly sensitive, while wetlands in Catchment A are considered to be sensitive.

8.7 *VEGETATION*

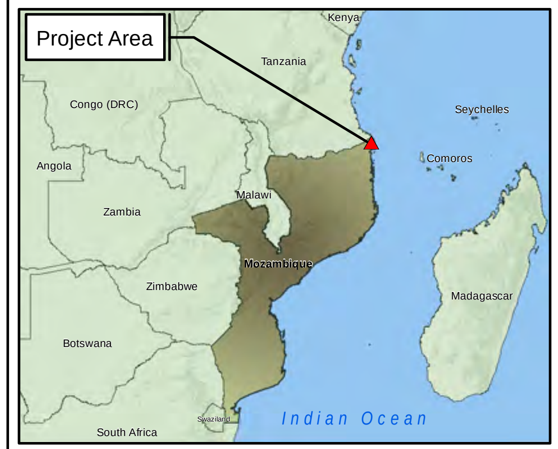
8.7.1 *Geographical Context*

The vegetation and flora study was conducted over an extensive area, including the Afungi Project Site and main travel arteries to and from Cabo Delgado and the Rovuma River. The Survey Area incorporates the Afungi Project Site and its immediate surroundings. Transects and site-specific surveys were conducted to record changes in vegetation composition and habitat diversity attributed to environmental gradients. The transects highlighted areas of unique composition, where site-specific vegetation surveys were conducted to identify more subtle nuances in plant community development. The Study Area was evaluated to better understand the extent of existing anthropological impacts; this was used for comparative analysis in understanding ecosystem functionality. More intensive surveys were conducted in the Survey Area to develop the vegetation and flora baseline of the Afungi Project Site. *Figure 8.44* shows the extent of the Survey Area and the surrounding Study Area.



Legend

- Villages / Settlements
- Local Roads
- Regional Roads
- Afungi Project Site
- Study Area
- Survey Area
- Mozambique Borders



MAIN MAP SCALE:

0 2 4 6 8 10

Kilometers

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TITLE:

Figure 8.44: Vegetation Study and Survey Areas

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 195 000

DRAWING: Vegetation Study and Survey Areas.mxd

REV: A

ERM
Great Westerford Building
240 Main Road
Rondebosch, 7725
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ERM

Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
Enviro-Insight, 2012.
Inset Map: Esri Data & Maps

SIZE: A3

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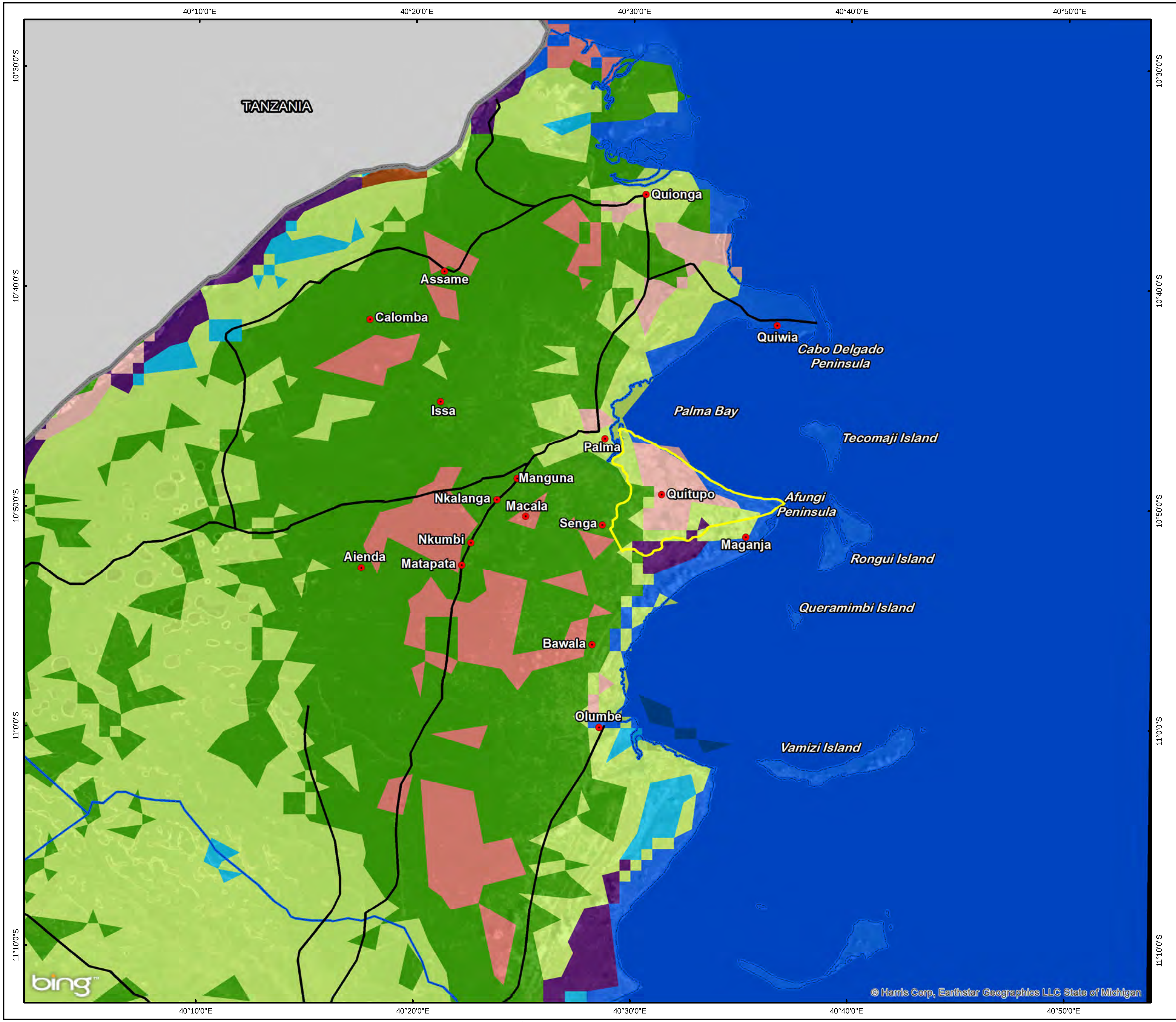
8.7.2 Mozambique Regional Vegetation Context

A limited amount of publically available data exists on the composition of the vegetation in Cabo Delgado Province. Vegetation classification done by Wild and Barbosa (1967) suggests that the Survey Area can be divided into two vegetation types: Coastal Thickets and Savannah Woodland. Coastal Thickets (and forest) are found on littoral dunes and occur as a narrow band along the eastern boundary of the Afungi Project Site, with *Mimusops caffra* as the characteristic plant species. The western half of the Survey Area, with Quitupo as the epicentre, is classified as Woodland and Savannah Woodland, characterised by the presence of *Berlinia* and *Brachystegia* species.

However, ground-truthing within the Afungi Project Site shows that Wild and Barbosa's classifications were generalised and are not considered to be representative of the vegetation present. The coastal thickets found on the littoral dunes are highly fragmented and segregated by mangrove swamps. Furthermore, *Mimusops caffra* is not considered a character species of this area. Although *Berlinia* and *Brachystegia* are considered characteristic of savannah woodland areas, the vegetation structure varies from open grassland, to grassland with thickets, to savannah and woodland. The most recent land-use and land-cover maps of the Survey Area indicate that the vegetation is degraded due to historic land-use and agricultural practices. Therefore, the species composition and structure of the area has been modified.

8.7.3 Vegetation Context of Cabo Delgado Province

An intensive vegetation survey conducted by Timberlake et al. (2010) culminated in the publication of *Coastal Dry Forests in Cabo Delgado Province, Northern Mozambique – Botany and Vegetation*. These East African coastal forests have a high level of endemism and, despite their relatively small area, are now considered an important and distinct ecoregion. It is estimated that only 10 percent of East Africa's coastal forest is intact, remaining under constant threat due to expanding rural and agricultural settlements and increased pressure on the natural resources available. Despite this vegetation type's highly fragmented nature, a chain of natural forest relics are found within the secondary savannah woodland. However, low-altitude Moist forest, Miombo woodlands, mangroves and vegetation associated with watercourses and rivers are excluded from the defined coastal cry forests. The Survey Area is thus located outside the vulnerable coastal dry forest.



Legend

- Villages / Settlements
- Regional Roads
- Boundary with Tanzania
- Afungi Project Site

Land Cover

- 1 Tree Cover, broadleaved, evergreen
- 2 Tree Cover, broadleaved, deciduous, closed
- 3 Tree Cover, broadleaved, deciduous, open
- 8 Tree Cover, regularly flooded, saline water
- 9 Mosaic: Tree Cover/Other natural vegetation
- 12 Shrub Cover, closed-open, deciduous
- 13 Herbaceous Cover, closed-open
- 14 Sparse herbaceous or sparse shrub cover
- 15 Regularly flooded shrub and/or herbaceous cover
- 16 Cultivated and managed areas
- 17 Mosaid: Cropland / Tree Cover / Other natural vegetation
- 19 Bare Areas
- 22 Artificial surfaces and associated areas
- 20 Water Bodies

MAIN MAP SCALE :

0 5 10 15

Kilometers

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TITLE:

Figure 8.45: National land cover data (30 arc seconds resolution) shown at regional scale (courtesy Global Land Cover 2000)

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 300 000

DRAWING: LandCover.mxd

REV: A

ERM
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ERM

Projection: UTM Zone 37 S, Datum: WGS84
Source: Global Land Cover, 2000 and Enviro-Insight, 2012.

SIZE: A3

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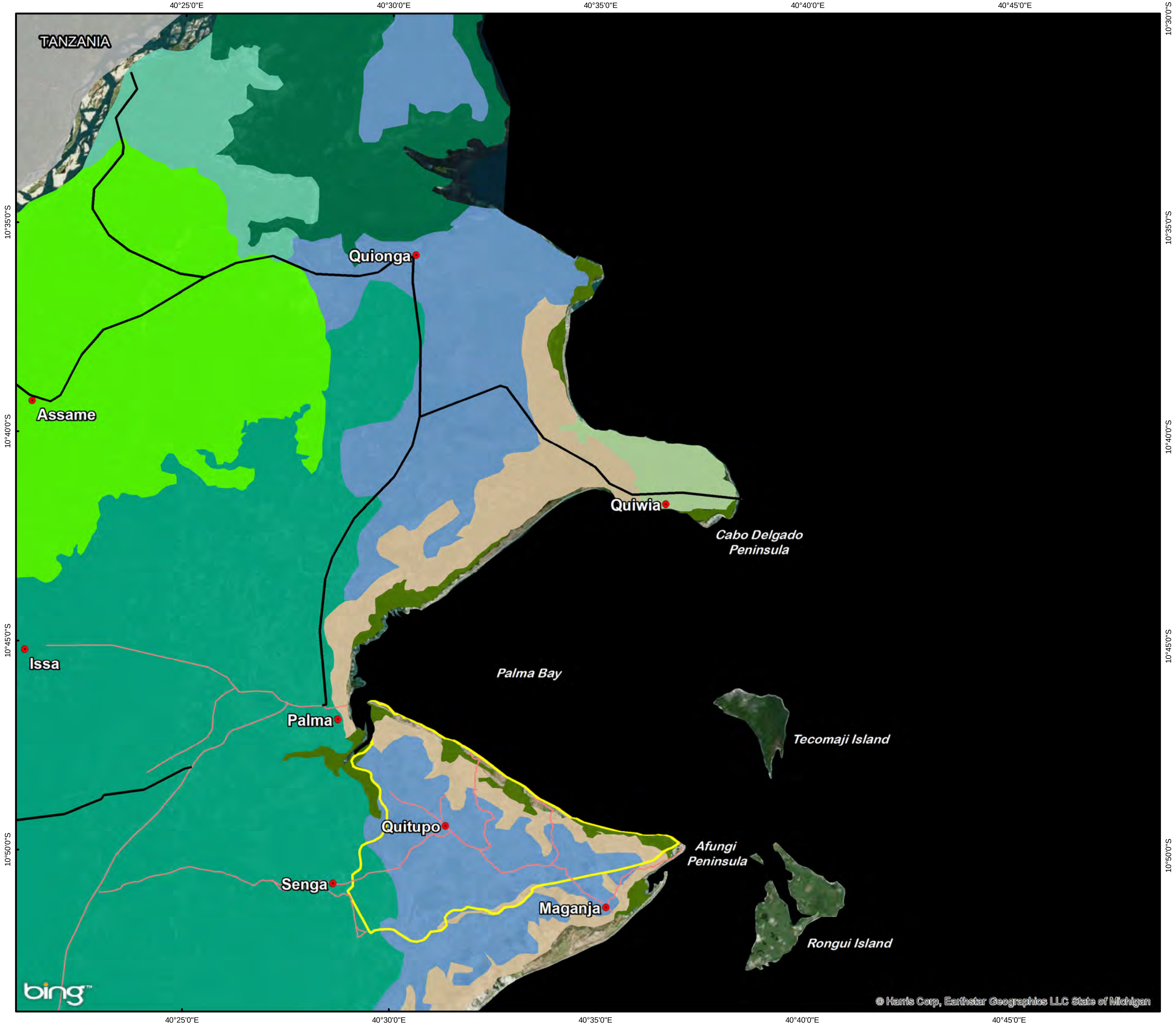
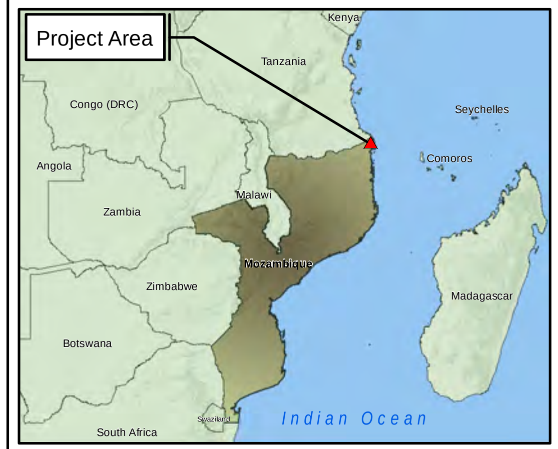


Legend

- Villages / Settlements
- Regional Roads
- Local Roads
- Afungi Project Site

Vegetation Units

- Coastal river delta with mangroves
- Coral rag forest
- Dense forest
- Inland dense woodland with miombo
- Mangrove
- Near coastal open savanna-wetland mosaic
- Riverine savanna-wetland mosaic
- Sandy coastal open woodland



MAIN MAP SCALE:

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Kilometers

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TITLE:

Figure 8.46:
Regional structural Vegetation Units derived from remote sensing imagery and ground truthing

CLIENT:

Anadarko Moçambique Área 1, Lda
eni

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 160 000

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Regional structural Vegetation Units.mxd	A

ERM
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Fax +27 21 686 073

Impacto
Projectos e Estudos Ambientais
ERM

Projection: UTM Zone 37 S Datum: WGS84 Source: Bing Maps ©2010 Microsoft Corporation. Enviro-Insight, 2012 Inset Map: Esri Data & Maps	SIZE: A3

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8.7.4 *Vegetation Context of the Survey Area*

The Survey Area comprises a diversity of habitats and vegetation types. This system is driven by a moisture regime dependent on subsurface water flow from higher elevations, through a network of wetlands, '*dambos*' (1) and mangroves eventually to reach the sea. The spatial arrangement of different vegetation communities is clearly dependent upon the availability of the subsurface water flow. Along this flow gradient, seven distinctly different Vegetation Units have been identified and are discussed below.

Rural villages and smaller household settlements are found scattered throughout the Survey Area. However, indications are that these settlements are not static and that many households move to a new area if agricultural soils become nutrient-depleted or when natural resources become difficult to obtain. Much of the vegetation in the Survey Area has been transformed or modified by local agricultural practices, as indicated by the structural analysis of the vegetation and comparison of plant species composition and diversity. Although species composition has been maintained in some of the identified Vegetation Units, the structure and density varies tremendously within each. This variation can be attributed to the clearing of vegetation for cultivation, and slash-and-burn agricultural practices frequently implemented. However, recovery of degraded environments is also evident, as many damaged trees such as the msasa (*Brachystegia spiciformis*) regenerate readily.

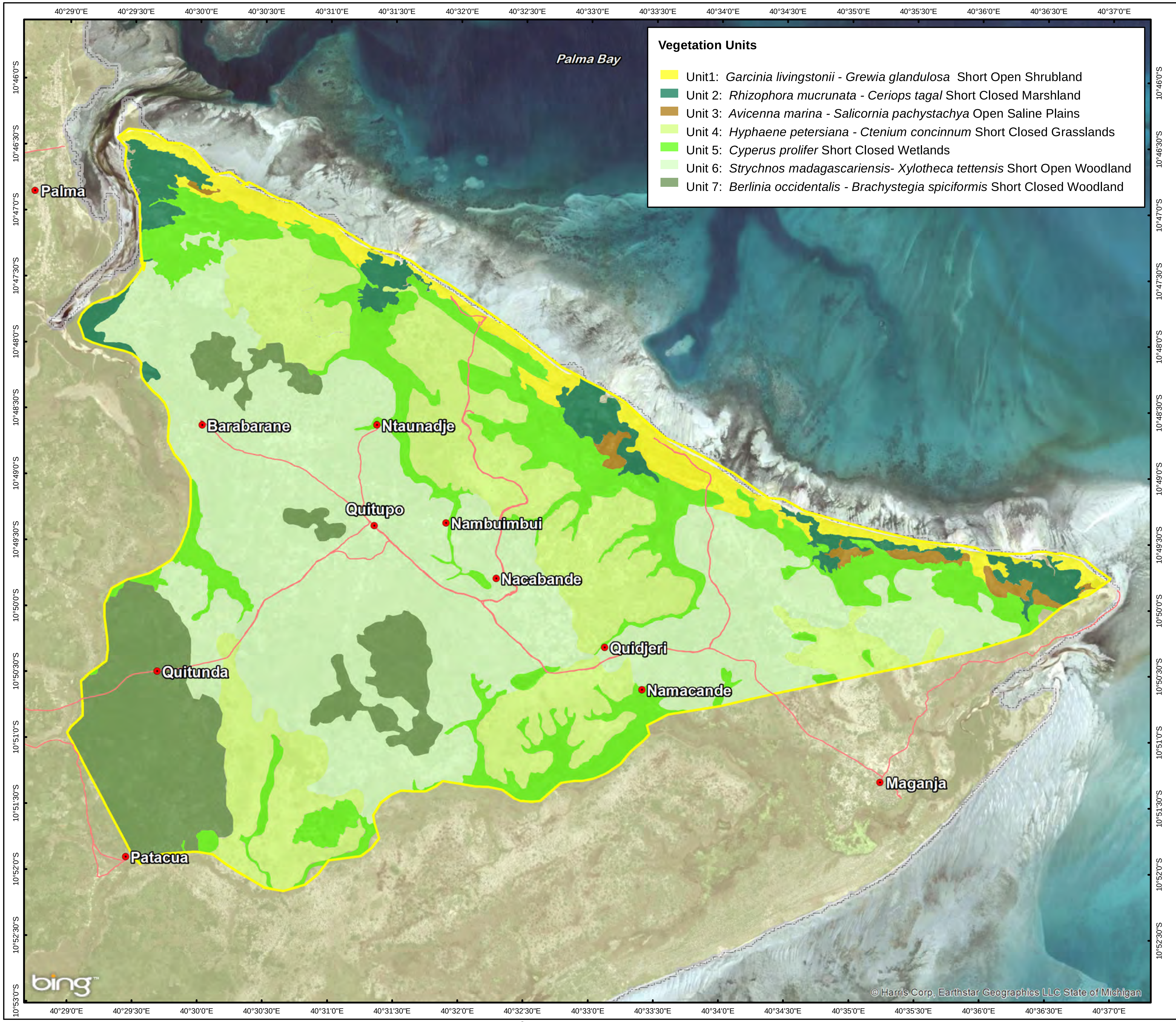
Analysing the data collected in the Survey Area identified the presence of approximately 250 different plant species, predominantly trees and shrubs. The probability of more species occurring in the Survey Area is high, considering the rapid phenological adaptations of plants to changing climatic conditions. Since much of the plant identification is based on fertile material such as flowers and seeds or fruits present during the survey periods, some plant species would have escaped positive identification(2). Not all species were used in the classification of Vegetation Units, as some of the species were inconsistently distributed. Despite the fact that the greater part of the area is considered to be duneveld, seven major Vegetation Units were identified. These are defined as:

- **Vegetation Unit 1**: The *Garcinia livingstonii – Grewia glandulosa* Short Open Shrubland;
- **Vegetation Unit 2**: The *Rhizophora mucrunata – Ceriops tagal* Short Closed Marshland;
- **Vegetation Unit 3**: The *Avicenna marina – Salicornia pachystachya* Open Saline Plains;
- **Vegetation Unit 4**: The *Hyphaene petersiana – Ctenium concinnum* Short Closed Grasslands;

(1) Dambos are depressions within wetland systems where water levels are not dependent on surface rainfall run-off, but rather on water welling up from below. Dambos are also found at higher elevations outside wetland systems and are presumably fed from arterial springs, and retain water for longer periods during the dry season.
(2) Note:tThe presence of threatened Red Data plant species, *Platycoryne mediocris* orchid and *Berlinia orientalis* were observed by the Surface Water Ecology specialist team but were not observed during the vegetation baseline fieldwork.

- **Vegetation Unit 5**: The *Cyperus prolifer* Short Closed Wetlands;
- **Vegetation Unit 6**: The *Strychnos madagascariensis– Xylotheca tettensis* Short Open Woodland; and
- **Vegetation Unit 7**: The *Berlinia occidentalis – Brachystegia spiciformis* Short Closed Woodland.

The location of the seven Vegetation Units is shown in *Figure 8.47*. Description of the Vegetation Units includes common names, followed by the scientific name in italics. However, considering the vast number of taxa, many plant species have no common names, necessitating the use of scientific names only in these instances.



Legend

- Villages / Settlements
- Local Roads
- Afungi Project Site
- Mozambique Borders

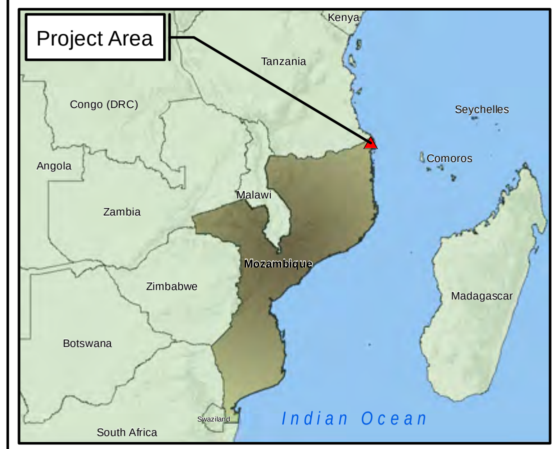


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Figure 8.47
Vegetation Units within the Afungi Project Site

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DRAWING: egetation Units within the Afungi Project Site.mxd

REV: A

ERM
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Impacto Projectos e Estudos Ambientais

ERM

Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
Enviro-Insight, 2012
Inset Map: Esri Data & Maps

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8.7.5 *Vegetation Units within the Afungi Project Site*

The seven Vegetation Units identified are discussed below.

Vegetation Unit 1: The Garcinia livingstonii – Grewia glandulosa Short Open Shrubland

This is a relatively narrow Vegetation Unit found along the Afungi Project Site coastline (*Figure 8.47*, above). It forms a fragmented mosaic with Vegetation Units 2 and 3 and is dominated by mangrove species and exposed saline estuaries. The geomorphology is relatively flat and the substrate is dominated by shifting dunes and sandy soils. This area is a more arid than the surrounding areas; this is likely due to exposure to oceanic influences such as dramatic tidal fluctuations, high humidity and the presence of salt spray (see *Figure 8.48* below).

Figure 8.48 Short Shrubland Structure of Vegetation Unit 1

Source: Enviro-Insight (December, 2011).

The dominant feature along the coastline is the presence of the white mangrove (*Avicenna marina*) and the mangrove apple (*Sonneratia alba*) growing in the oceanic tidal zone, but also found as scattered individuals on the narrow stretch of white sand stretching the length of the beachfront. The most visual features found in this littoral zone are the tall coconut palms (*Cocos nucifera*), horsetail tree (*Casuarina cunninghamiana*), an abundance of raisin bush (*Grewia glandulosa*), the dune morning glory (*Ipomoea pes-caprae*), bush tick-berry (*Chrysanthemoides monilifera*) and small bush violet (*Barleria repens*). The vegetation quickly gives rise to other trees and shrubs that form a short open shrubland with an abundance of white thorn (*Acacia seyal*), needle bush (*Azima tertacantha*), coast bone apple (*Catunaregam spinosum*), forest corkwood (*Commiphora woodii*), dune myrtle (*Eugenia capensis*), rubber euphorbia

(*Euphorbia tirucalli*), African mangosteen (*Garcinia livingstonei*), copalwood (*Guibourtia schliebenii*), common spike-thorn (*Gymnosporia buxifolia*), climbing turkey-berry (*Keetia gueinzii*), Zulu milkberry (*Manilkara concolor*), cork bush (*Mundulea sericea*), glossy currant (*Searcia lucida*), white milkwood (*Sideroxylon inerme*), green monkey orange (*Strychnos spinosa*), climbing tarenna (*Tarenna junodii*), lagoon tulip tree (*Thespesia populnea*) and chocolate berry (*Vitex payos*).

The herbaceous layer is poorly represented with large open sandy patches interspersed with forbs such as spiderling (*Boerhavia diffusa*), *Centimopsis gracilenta*, fishbone dwarf cassia (*Chamaecrista mimosoides*), sand crown-berry (*Crossopteryx febrifuga*), *Cyperus crassipes*, *Dicerocaryum zanguebaricum*, *Indigofera eriocarpa* and devil's thorn (*Tribulus terrestris*).

Vegetation Unit 2: The Rhizophora mucrunata – Ceriops tagal Short Closed Marshland

This is a highly fragmented Vegetation Unit found along the coastline, where water flowing from drainage lines throughout the Survey Area dissipates into the ocean. Due to erosive water action and oceanic tidal influences, these give rise to estuaries dominated by mangrove species. This fresh and saline water interaction forms a mosaic with Vegetation Unit 3, where fresh water from higher altitudes is prevalent during oceanic low tide, but inundated by sea water during high or spring tides. The geomorphology is relatively flat and the substrate dominated by high salinity, sandy soils. The zone is permanently wet, either due to fresh/brackish water outflow (during low tide) or inundated with sea water during high or spring tides (see *Figure 8.49*).

Figure 8.49 Mangrove Vegetation from Vegetation Unit 2

Source: Enviro-Insight (March 2012).

The vegetation is dominated by relatively short mangroves, less than 5m in height. Although black mangrove (*Bruguieria gymnorrhiza*) generally dominates on the seaward side, larger white mangroves were found in the littoral zone. The most dominant mangroves on the landward side are the red mangrove (*Rhizophora mucronata*) and the Indian mangrove (*Ceriops tagal*). The red mangrove is especially prevalent along the river embankment, forming a dense, almost impenetrable stand of old and young germinating mangrove trees. Scattered individuals of the mahogany mangrove (*Xylocarpus moluscensis*) also occur. Moving deeper inland, the white mangrove and Tonga mangrove (*Lumnitzera racemosa)* become more dominant.

No herbaceous plant species occur within this Vegetation Unit.

Vegetation Unit 3: The Avicenna marina – Salicornia pachystachya Open Saline Plains

This Vegetation Unit is associated with the areas located inland of Vegetation Unit 2 and forms an integral part of the *Rhizophora mucrunata – Ceriops tagal* Short Closed Marshland ecosystem. This system is dependent on an influx of fresh water from higher altitudes and sea water from the ocean during high or spring tides. Seasonal rainfall also effects ecosystem functionality, and this Vegetation Unit becomes inundated during the rainfall season. Due to its location in the landscape, minerals are constantly supplemented from higher elevations due to subsurface water flow. This Vegetation Unit also forms part of the wetland ecosystem. The soils are sandy with a high salinity and play an important role in salt harvesting by local communities (see *Figure 8.50*).

Figure 8.50 Saline Plains of Vegetation Unit 3

Source: Enviro-Insight (December 2011).

The area is characterised by large open sandy areas, usually with water accumulation in depressions to form shallow open water bodies. Vegetation is limited to white mangroves and scattered individuals of Indian and Tonga mangroves. Although grass species such as couch grass (*Cynodon dactylon*) and sedges occur along the periphery of these water bodies, the only forb (1) of prominence is glasswort (*Salicornia pachystachya*), which is adapted to the high salinity.

Vegetation Unit 4: The Hyphaene petersiana – Ctenium concinnum Short Closed Grasslands

This Vegetation Unit is found as a fragmented mosaic, inland of the primary dune vegetation identified in Vegetation Unit 1. Characteristic are the exposed sandy patches with a sparse herbaceous canopy cover and scattered individuals of plant species reminiscent of the diversity also found in Vegetation Unit 1. The terrain is relatively flat, dominated by sandy soils much like beach sand, and a relatively poor canopy cover. Disturbance is evident and attributed to historic land-use practices and agriculture. Water percolation is good, but water retention is very poor (see *Figure 8.51*).

Figure 8.51 Grassland Structure of Vegetation Unit 4

Source: Enviro-Insight (December 2011).

The dominant trees and shrubs of this unit are wild custard-apple (*Annona senegalensis*), northern lala palm (*Hyphaene petersiana*), Cape plane (*Ochna* aborea), sand plane (*Ochna kirkii*), mobola plum (*Parinari curatellifolia*), *Senna sangueana*, black monkey orange (*Strychnos madagascariensis*), green monkey orange and African dog-rose (*Xylotheca tettensi*). Other woody plant species of importance are the yellow peeling plane (*Brackenridgea zanguebarica*), coast bone-apple, horsewood (*Clausena anisata*), hairy corkwood (*Commiphora africana*), forest corkwood, zebrawood (*Dalbergia arbutifolia*), Natal milkplum

(1) Herbaceous flowering plants, not sedges, grasses and rushes.

(*Englerophytum natalense*), Natal guarri (*Euclea natalensis*), wild gardenia (*Gardenia ternifolia*), red-heart tree (*Hymenocardia ulmoides*), sand nightstar (*Leptactina delagoensis*), *Maprounea africana*, kooboo berry (*Mystroxylon aethiopicum*), snake bean (*Swartzia madagascariensis*), chocolate berry and sourplum (*Ximenia caffra*).

The dominant grass species is sickle grass (*Ctenium concinnum*) with hairy blue grass (*Andropogon chinensis*) being subdominant. Other grasses encountered in a forb-dominated herbaceous layer are Natal red top (*Melinis repens*), white buffalo grass (*Panicum coloratum*), cat's tail (*Perotis patens*) and giant spear grass (*Trachypogon spicatus*).

The dominant forbs present are *Indigofera eriocarpa*, *Indigofera schimperi*, miniature morning glory (*Merremia tridentata*), *Oldenlandia herbacea*, *Rhynchosia minima*, spiky mother-in-law's tongue (*Sansevieria canaliculata*), wing-seeded sesame (*Sesamum alatum*), witchweed (*Striga junodii*), narrow-leaved wild sweetpea (*Vigna vexillata*) and two species of mistletoe (*Tapinanthus kraussianus* and *Tapinanthus natalitius).*

Vegetation Unit 5: The Cyperus prolifer – Short Closed Wetlands

This Vegetation Unit includes both seasonal wetlands and permanently wet *dambos*, as the two are considered to be inherently linked in ecosystem functionality. Furthermore, the apparent seasonal drying of the wetlands is only superficial as subsurface water flow continues unabated to feed fresh water through Vegetation Units 2 and 3, before flowing into the sea. The soil is considered alluvial in origin, with illuviation of minerals from higher elevations. Due to the relatively high nutrient content and moisture regime within the wetland system, rice is cultivated by local communities living in the Survey Area. Approximately 10 percent of this Vegetation Unit has been modified by agriculture (see example in *Figure 8.52*).

Figure 8.52 Wetlands of Vegetation Unit 5

Source: Enviro-Insight (December 2011).

Tree and shrub species are relatively scarce, with only scattered individuals of octopus cabbage tree (*Cussonia aborea*), orange bird berry (*Hoslundia opposita*), northern lala palm, giant sensitive plant (*Mimosa pigra*), woodland umdoni (*Syzygium guineense*), narrow-leaved mahobohobo (*Uapaca nitida*) and black plum (*Vitex doniana*) along the periphery.

The grass layer is dominated by hairy blue grass, snowflake grass (*Andropogon eucomus*), swamp grass (*Diplacne fusca*), cottonwool grass (*Imperata cylindrica*) and Guinea grass (*Panicum maximum*).

The dominant forbs are *Asystasia gangetica*, common sedge (*Bulbostylis burchellii*), blue commelina (*Commelina erecta*), Moore's crinum (*Crinum moorei*), doll's powderpuff (*Cyanotis speciosa*), *Cyperus crassipes*, winged sedge (*Cyperus denudatus*), *Cyperus exaltatus*, white sedge (*Cyperus hemisphaericus*), white-flowered sedge (*Cyperus obtusiflorus*), dwarf papyrus (*Cyperus prolifer*), purple nutsedge (*Cyperus rotundus*), *Cyperus vestitus*, *Dissotus debilis*, dwarf dissotis (*Dissotus phaeotricha*), sundew (*Drosera* sp.), *Eulophia livingstoneana*, *Eulophia seleensis*, *Eulophia speciosa*, water ipomoea (*Ipomoea aquatica*), *Juncus rigidus*, *Mariscus solidus*, blue waterlily (*Nymphaea nouchali*), knotweed (*Persicaria madagascariensis*), *Platycoryne buchananiana*, *Pycreus polystachyos* and common xyris (*Xyris capensis*).

Vegetation Unit 6: The Strychnos madagascariensis – Xylotheca tettensis Short Open Woodland

This Vegetation Unit is dominant throughout the Afungi Project Site, and typically very disturbed due to agricultural practices. Approximately 70 percent has been modified by agriculture, with only remnants of the original vegetation structure and species composition existing as isolated thickets reminiscent of Vegetation Unit 7. Fallow lands have been found to retain or recover in species composition, but vegetation structure remains impaired. Cassava (*Manihot esculenta*) is the main produce, with maize, pumpkin, squash and ground nuts as supplementary or alternative crops. The soils are relatively poor in minerals, necessitating slash-and-burn practices. However, rotational planting with groundnuts is beneficial in extending the production potential of agricultural lands, thus reducing slash-and-burn agriculture practices in establishing new lands (see *Figure 8.53*).

Figure 8.53 Open Woodland Structure of Vegetation Unit 6

Source: Enviro-Insight (December 2011).

The dominant tree species are cashew nut (*Anacardium occidentale*), mango (*Mangifera indica*), Cape plane, plane tree (*Ochna mossambicensis*), Natal plane (*Ochna natalitia*), mobola plum, *Senna sangueana*, black monkey orange, green monkey orange and African dog-rose. Other trees encountered are baobab (*Adansonia digitata*), bitter false-thorn (*Albizia amara*), *Berlinia orientalis*, msasa, yellow peeling plane, coast bone-apple, four-leaved bushwillow (*Combretum adenogonium*), sand crown-berry, marula (*Sclerocarya birrea* subsp. *caffra*), zebra wood, wild pear (*Dombeya kirkii*), Kei-apple (*Dovyalis hispidula*), common saffron (*Elaeodendron croceum*), Natal guarri, African mangosteen, white cross-berry (*Grewia pachycalyx*), munondo (*Julbernardia globiflora*), sausage tree (*Kigelia africana*), forest milkberry (*Manilkara discolor*), *Maprounea africana*, broad-leaved resin tree (*Ozoroa obovata*), kudu-berry (*Pseudolachnostylis maprouneifolia*), African star-chestnut (*Sterculia africana*), woodland umdoni, pigeonwood (*Trema orientalis*), jackal coffee (*Tricalysia coriacea*), narrow-leaved mahobohobo, lesser mahobohobo (*Uapaca sansibarica*), wild medlar (*Vangueria infausta*), plum finger-leaf (*Vitex ferruginea*) and sourplum.

The dominant grass species are finger grass (*Digitaria eirantha*), Natal red top, yellow thatching grass (*Hyperthelia dissoluta*), white buffalo grass, Guinea grass, cat's tail, red grass (*Themeda triandra*), giant spear grass and couch grass.

Forbs are found in strong association with *Agelanthus zizyphifolius*, Madeira vine (*Anredera cordifolia*), broom asparagus (*Asparagus virgatus*), sorel (*Biophytum umbraculum*), common sedge,, fishbone dwarf cassia, Ecklon's blue commelina (*Commelina eckloniana*), blue commelina and commelina zambesiaca, Moore's crinum, wild grape (*Cyphostemma cirrhosum*) and *Cyphostemma natalitium*, *Drimiopsis burkei*, flame lily (*Gloriosa superba*), common dwarf wild hibiscus (*Hibiscus aethiopicus*), prickly tree hibiscus (*Hibiscus diversifolius*) and *Hibiscus surattensis*, small pink ipomoea (*Ipomoea magnusiana*), African cucumber (*Momordica trifoliolata*), *Psorospermum febrifugum*, forest burr (*Pupalia lappacea*), *Rhynchosia caribaea*, fire-ball lily (*Scadoxus multiflorus*), thorny rope (*Smilax anceps*) and mistletoe (*Tapinanthus natalitius*). The thorny rope and prickly tree hibiscus are most prevalent in cultivated areas.

Vegetation Unit 7: The Berlinia occidentalis – Brachystegia spiciformis Short Closed Woodland

This Vegetation Unit is predominantly found as isolated patches within Vegetation Unit 6, with the largest remaining vestige found below the Senga pass to the west of the Afungi Project Site. Although this area remained relatively unaffected by agricultural activities, newly opened areas cleared for cultivation are evident. All other Unit areas are highly fragmented and sparsely distributed. The soils are humic in nature, but nutrients are rapidly leached when the existing canopy cover is destroyed. Due to the closed nature of the canopy cover, the herbaceous layer is poorly developed with almost no grass species present (see *Figure 8.54*). This Vegetation Unit shows habitat features with high potential in feeding, breeding, nesting and resting requirements for all wildlife. The structure is well developed and evidence of resource use by the local population is less in this vegetation structure than in many of the others identified.

Figure 8.54 Closed Woodland Structure of Vegetation Unit 7

Source: Enviro-Insight (December 2011).

The dominant and characteristic tree species are *Berlinia orientalis*, msasa and munondo. Other trees found in profusion are pod mahogany (*Afzelia quanzensis*), coffee neat's foot (*Bauhinia petersiana*), sand ivory (*Berchemia* discolor), horsewood, flame creeper (*Combretum paniculatum*), large-fruited bushwillow (*Combretum zeyheri*), hairy corkwood, forest corkwood, zebrawood, zebra wood flat-bean (*Dalbergia melanoxylon*), Kei-apple, false gardenia (*Heinsia crinita*), red-heart tree, *Hypericanthus* sp., false marula (*Lannea schweinfurthii*), dwaba-berry (*Monanthotaxis caffra*), mobola plum, black bird-berry (*Psychotria capensis*), marula, glossy currant, *Senna sangueana*, black monkey orange and green monkey orange, climbing tarenna, narrow-leaved mahobohobo and lesser mahobohobo, white ironwood (*Vepris lanceolata*), chocolate berry and wing bean (*Xeroderris stuhlmannii*).

The grass layer is poorly developed within the thicket, with yellow thatching grass dominating the more exposed areas. Other grasses encountered are hairy blue grass, white buffalo grass and Guinea grass.

Dominant shrubs and creepers are brooms and brushes (*Acalypha villicaulis*), the orchid (*Acampe pachyglossa*), blue aneilema (*Aneilema dregeanum*), broom asparagus, sorel, Ecklon's blue commelina, Moore's crinum, dodder (*Cuscuta campestris*), wild grape, *Cyphostemma natalitium* and hairy grape bush (*Cyphostemma woodii*), *Dalechampia capensis*, wild yam (*Dioscorea sansibarensis*), *Dorstenia psilurus*, sea-bean (*Entada wahlbergii*), flame lily, *Plectranthus gracillimus*, bushman's grape (*Rhoicissus tridentata*), mother-in-law's tongue (*Sanseviera hyacinthoides*), fire-ball lily, thorny rope and *Triainolepis africana*.

8.7.6 *Analysis of Flora*

Threatened and Endangered Flora Analysis

No Red Data plant species (above Least Concern category according to IUCN, 2012) were recorded within the seven Vegetation Units. Although no Red Data flora species were encountered, suitable habitat is present. A number of locally protected plant species such as baobab, white mangroves, black mangrove, Indian mangrove, Tonga mangrove, red mangrove and star-apple mangrove occur in the Afungi Project Site (see *Annex G* for a complete list). These plant species strongly contribute to habitat diversity by extending feeding, breeding, nesting and resting attributes to wildlife.

The presence of various orchids in the Vegetation Unit 5 (*Eulophia livingstoneana*, *Eulophia seleensis*, *Eulophia speciosa* and *Platycoryne buchananiana*) in conjunction with observations by the Surface Water Ecology specialist team of the Red Data orchid species *Platycoryne mediocris,* indicates the potential for many more orchid species to be present. The occurrence of Red Data species cannot be resolved without further surveys during periods when the various inflorescence stages in potential orchids are most prevalent. Therefore, it is reasonable to assume that species of Red Data orchids may be present in the Survey Area.

Alien Flora Analysis

The alien plant species present in the Survey Area include cashew nut, coconut palm, mango and guava (*Psidium guajava*). These tree species occur throughout the Survey Area – at villages, old settlements/households and newly settled areas. These settlement areas with associated agricultural practices are dominated by pioneer and undesirable/invasive plant species such as devil's weed (*Datura stramonium*) and castor oil bush (*Ricinus communis*). Horsetail tree and sisal (*Agave sisalana*), both found in Vegetation Unit 1, are known invasive species, and active intervention may be required if control is desired.

Floristic Sensitivity Analysis

A sensitivity analysis was performed for all seven Vegetation Units identified in the Afungi Project Site. Evaluations of sensitive flora were developed, based on:

- attributes such as plant species diversity and fragmentation;
- presence or absence of undesirable or invasive flora species; and
- presence or absence of Red Data plant species.

The following factors, with the criteria used for classification, were considered important in determining the floristic sensitivity of each area:

- habitat availability, status and suitability for the presence of Red Data plant species;

- landscape or habitat sensitivity;
- current floristic status;
- floristic diversity; and
- ecological performance/fragmentation.

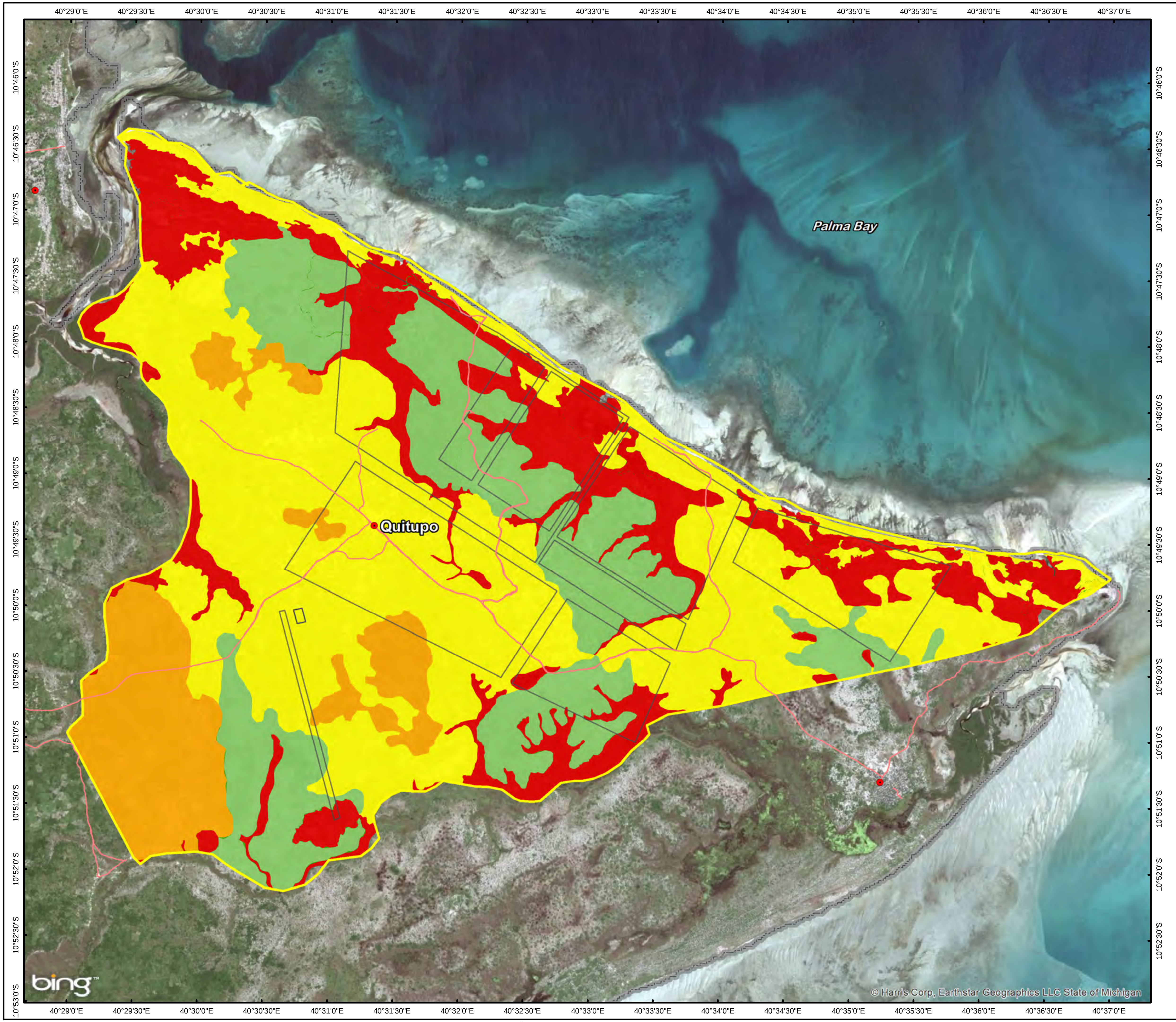
High sensitivity values indicate areas that are considered natural, relatively unaffected by human influences or generally managed in an ecologically sustainable manner. Low sensitivity values indicate areas of poor ecological status or importance in terms of floristic attributes, including areas that have been negatively affected by human impacts or poor management. A summary is provided in *Table 8.25* below, and further detail has been included in *Annex C* (Baseline Methodology).

Table 8.25 Floristic Sensitivity Analysis for Each Vegetation Unit

Vegetation Unit	Floristic Sensitivity Status	Rationale
1	Moderate	Habitat modification and the highly fragmented nature of this Vegetation Unit
2	Very High	Highly specialised ecosystem functionality and contribution in maintaining other ecosystems
3	Moderate	Presence of mangrove species and its importance in maintaining ecosystem functionality of Vegetation Unit 2
4	Low	Poor species diversity and limited habitat potential
5	Very High	High ecological functioning and influence in ecosystem functionality of various other Vegetation Units. Furthermore, the potential for the presence of Red Data species is high
6	Moderate	Habitat modification and the highly fragmented nature of this Vegetation Unit
7	High	Suitable Red Data habitat potentially available in this Vegetation Unit

Source: Enviro-Insight, 2012.

As *Figure 8.55* below illustrates, the floristic sensitivity of most of the interior of the Survey Area is mostly considered Moderate. However, areas of greater sensitivity are interspersed throughout and concentrated near the coastal areas.



Legend

- Villages / Settlements
- Local Roads
- Onshore Project Footprint
- Afungi Project Site
- Mozambique Borders

Vegetation Sensitivity

- Very Low Sensitivity
- Low Sensitivity
- Moderate Sensitivity
- High Sensitivity
- Very High Sensitivity

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Figure 8.55: Red Data Flora Sensitivity Analysis

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Anadarko Moçambique Área 1, Lda

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DRAWING: Red Data Flora Sensitivity Analysis.mxd

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ERM

Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
Enviro-Insight, 2012.
Inset Map: Esri Data & Maps

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8.8 HERPETOFAUNA

8.8.1 *Geographical Context*

The herpetofauna study was conducted within the general vicinity of the Afungi Project Site, including the main travel corridors to Cabo Delgado and the Rovuma River, as well as Tecomaji Island. The Survey Area consists of the Afungi Project Site and its immediate surroundings; this includes Tecomaji Island and the access roads between the Palma Camp and the Afungi Project Site. Sightings of herpetofauna outside of the Afungi Project Site were recorded to better understand the regional context; however, active sampling and trapping were performed in the Survey Area only. Field surveys were conducted to establish the baseline conditions as they relate to the herpetofauna on site. A map of the Study Area and Survey Area is presented in *Figure 8.56*.

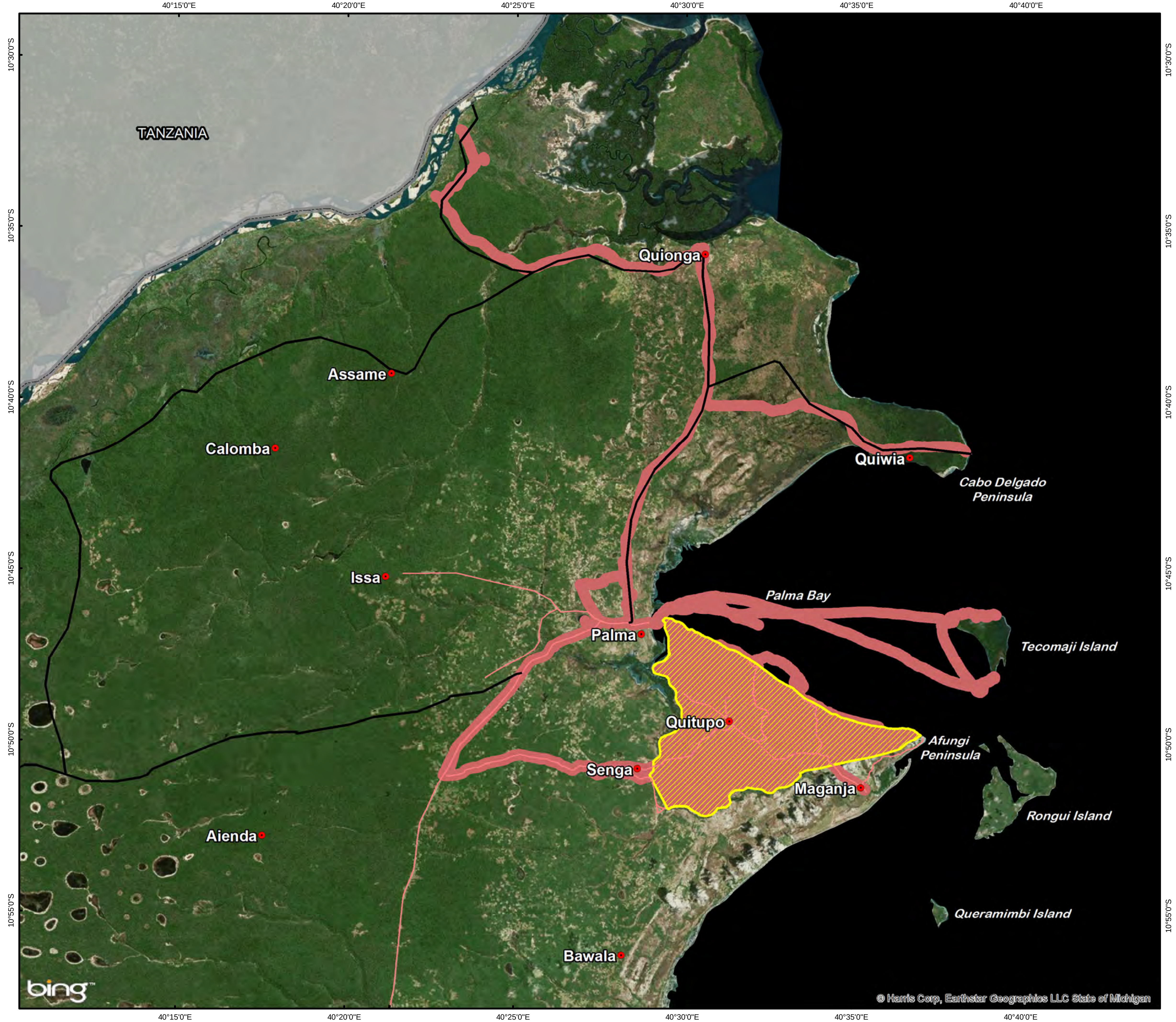
8.8.2 *Mozambique Regional Herpetofauna Context*

Mozambique's vast north/south extent provides a large number of different habitat types, resulting in a large diversity of herpetofauna within the country. While there are no formal publications that deal explicitly with this topic, reputable sources indicate that 215 reptile (Utez et al., 2011) and 69 amphibian species (Amphibiaweb, 2012) are expected to occur in Mozambique. This is likely an underestimation of the actual diversity, due to under-sampling in many of the remote areas of Mozambique; especially in the northern areas of Cabo Delgado Province. The *National Report on Implementation of the Convention on Biological Diversity in Mozambique* (MICOA, 2009) lists only 167 reptile species and indicates that the number of amphibian species is unknown. This document further indicates that threats to herpetofauna include collection for food, skin and medicinal purposes, the pet trade and habitat destruction.

8.8.3 *Cabo Delgado Province Herpetofauna Context*

Published secondary data related to the existing land cover and vegetation maps do not provide a sufficient level of detail and, in some instances, appear inaccurate when compared to field evaluations. Therefore a map of the structural vegetation and land cover was created from the available remote sensing imagery and an understanding of the vegetation from field observations. Input from the botanical specialists was also leveraged in the development of these maps.

From a herpetological perspective, the landscape classification is similar to the Vegetation Units discussed in the Vegetation and Flora Baseline (*Section 8.7*). However, this representation (*Figure 8.57*) provides the general landscape types necessary to inform the herpetological field studies, so the nomenclature differs slightly.



Legend

- Villages / Settlements
- Regional Roads
- Local Roads
- Afungi Project Site
- Study Area
- Survey Area

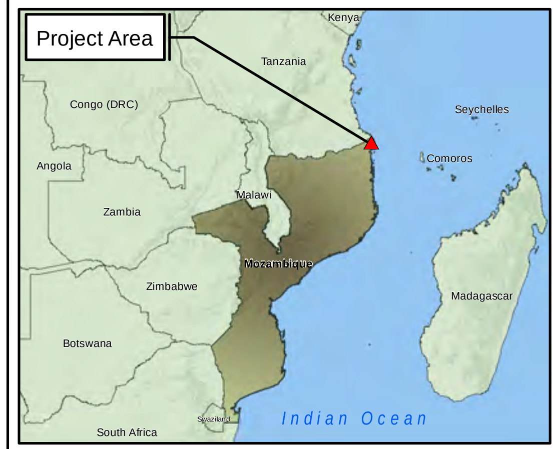


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Figure 8.56:
Herpetological Study and Survey Areas

CLIENT:

Anadarko
Moçambique Área 1, Lda

eni

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Legend

- Villages / Settlements
- Local Roads
- Afungi Project Site
- Mozambique Borders

Landscape Classification

- Coastal Sandy Scrub
- Contiguous Trees
- Fresh Wetland
- Mixed Woodland Savanna & Agriculture
- Saline Wetlands, Mangroves & Beaches

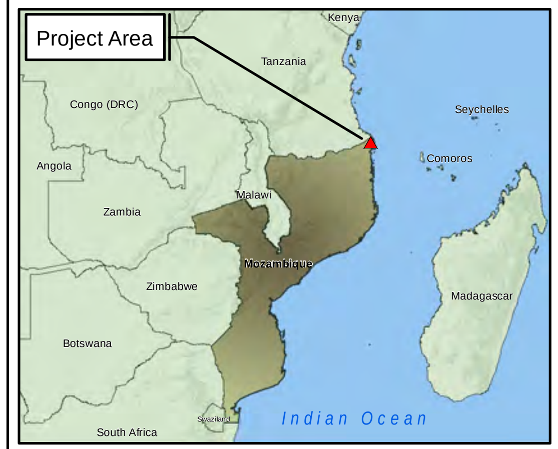

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Figure 8.57: Structural Landscape Classification of Afungi Project Site

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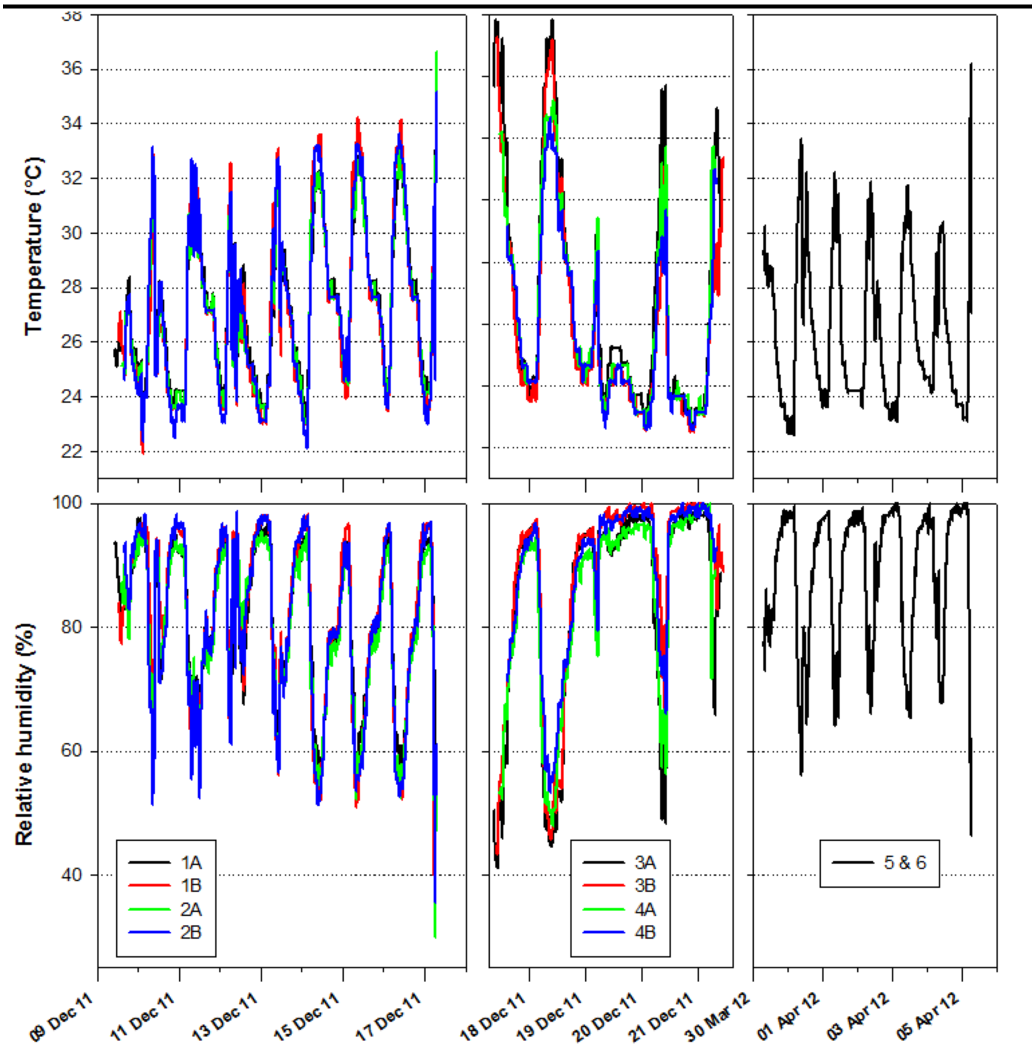
8.8.4 *Herpetological Fauna Results*

Several survey methods were applied to study the herpetological fauna within the Survey Area; these are described in *Annex C* (Baseline Methodology). This section presents an overview of the field observations and the data obtained.

Ideal climatic conditions were experienced throughout the herpetofauna field surveys conducted in December and March/April (*Figure 8.58*). The warm and very humid conditions resulted in very good trapping success, and 487 individuals (representing 35 species) were captured.

Figure 8.58 Temperature and Humidity during the Herpetological Survey



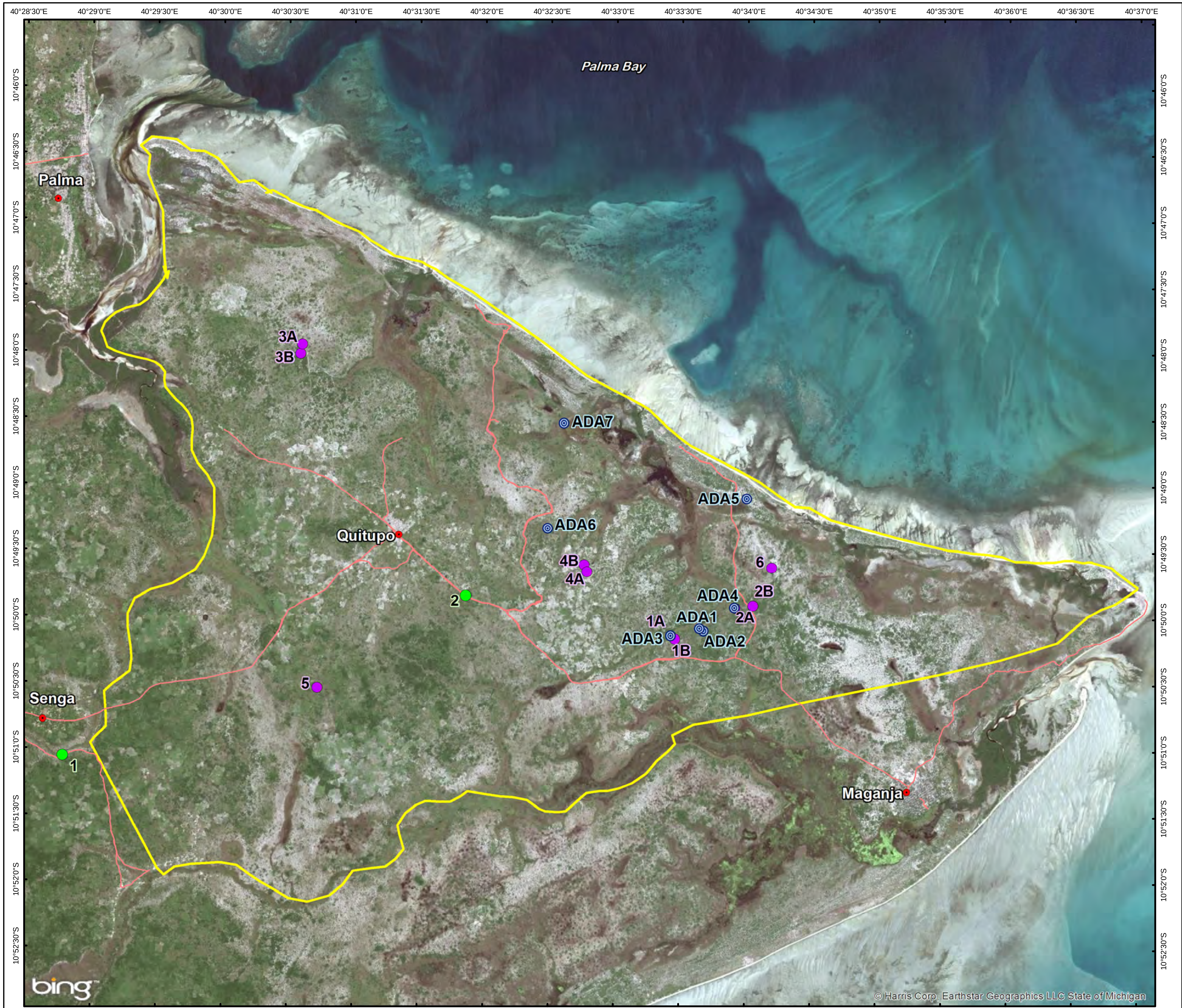
Source: Enviro-Insight, 2012.

Ten trapping arrays were deployed during the herpetofauna surveys, and their locations are provided in *Table 8.26*. An attempt was made to undertake a spatially representative trapping effort to cover the various habitat types within the Survey Area. An overview of these trap locations and active searching routes are provided in *Figure 8.59*.

Table 8.26 Drift Fence Funnel Trap Array Locations and Descriptions

Trap Site	Coordinates and Altitude	Habitat Description	Aerial Photo	Photo 1	Photo 2
1A	S: 10°50'8.21" E: 40°33'25.36" Alt: 17m	Dense closed woodland vegetation with tall trees bordering a large wetland Trap location within Vegetation Unit 5			
1B	S: 10°50'9.63" E: 40°33'27.34" Alt: 17m	Ecotone of dense closed woodland vegetation and open grassy woodland Trap location within Vegetation Unit 6			
2A	S: 10°49'55.47" E: 40°33'54.82" Alt: 23m	Dense forest with tall trees and closed canopy; heavy leaf litter on floor Trap location within Vegetation Unit 6			
2B	S: 10°49'54.47" E: 40°34'3.09" Alt: 23m	Open grassy woodland and mixed woodland mosaic Trap location within Vegetation Unit 6			
3A	S: 10°47'56.68" E: 40°30'36.16" Alt: 19m	Near coastal open grassy woodland with adjacent palm plantations Trap location within Vegetation Unit 4			
3B	S: 10°48'0.95" E: 40°30'35.35" Alt: 27m	Thick stand of low-growing trees with closed canopy and heavy leaf litter on floor Trap location within Vegetation Unit 7			
4A	S: 10°49'39.26" E: 40°32'46.92" Alt: 32m	Open grassy woodland with few trees/bushes near a small drainage line Trap location within Vegetation Unit 4			

4B	S: 10°49'36.20" E: 40°32'45.66" Alt: 33m	Dense forested patch within open grassy woodland Trap location within Vegetation Unit 4			
5	S: 10°50'32.31" E: 40°30'43.51" Alt: 25m	Mixed woodland mosaic with tall grass stands; cashew and mango trees present Trap location within Vegetation Unit 6			
6	S: 10°49'37.26" E: 40°34'11.67" Alt: 19m	Near coastal sandy grassy woodland with patchy forested stands Trap location within Vegetation Unit 6			



Legend

- Villages / Settlements
- Active Sample Sites
- Major Frogging Sites
- Reptile Trap Arrays
- Local Roads
- Afungi Project Site

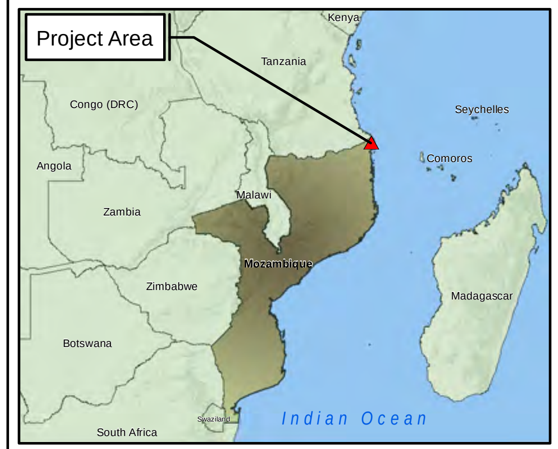


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Figure 8.59: Herpetofauna Trapping and Active Searching Sites

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Traps were usually placed on the ecotones of two or more distinct habitat types to maximise the species diversity of trapped individuals. For example, one of the drift fence arms of Array 1B extended into the sandy open grassland, while the remaining two arms extended into the forested patch and the mixed habitat. *Figure 8.60* below illustrates a typical drift fence location spanning various habitat types.

Figure 8.60 Typical Herpetofauna Trapping Array

Source: Enviro-Insight, 2012.

Observations from the trapping and active searching methodologies resulted in a total of 769 individual reptiles and amphibians being documented within the Survey Area (representing 72 species in total). *Table 8.27* illustrates these field observations. A selection of the reptiles and amphibians photographed during the surveys are shown in *Figure 8.61* and *Figure 8.62* respectively.

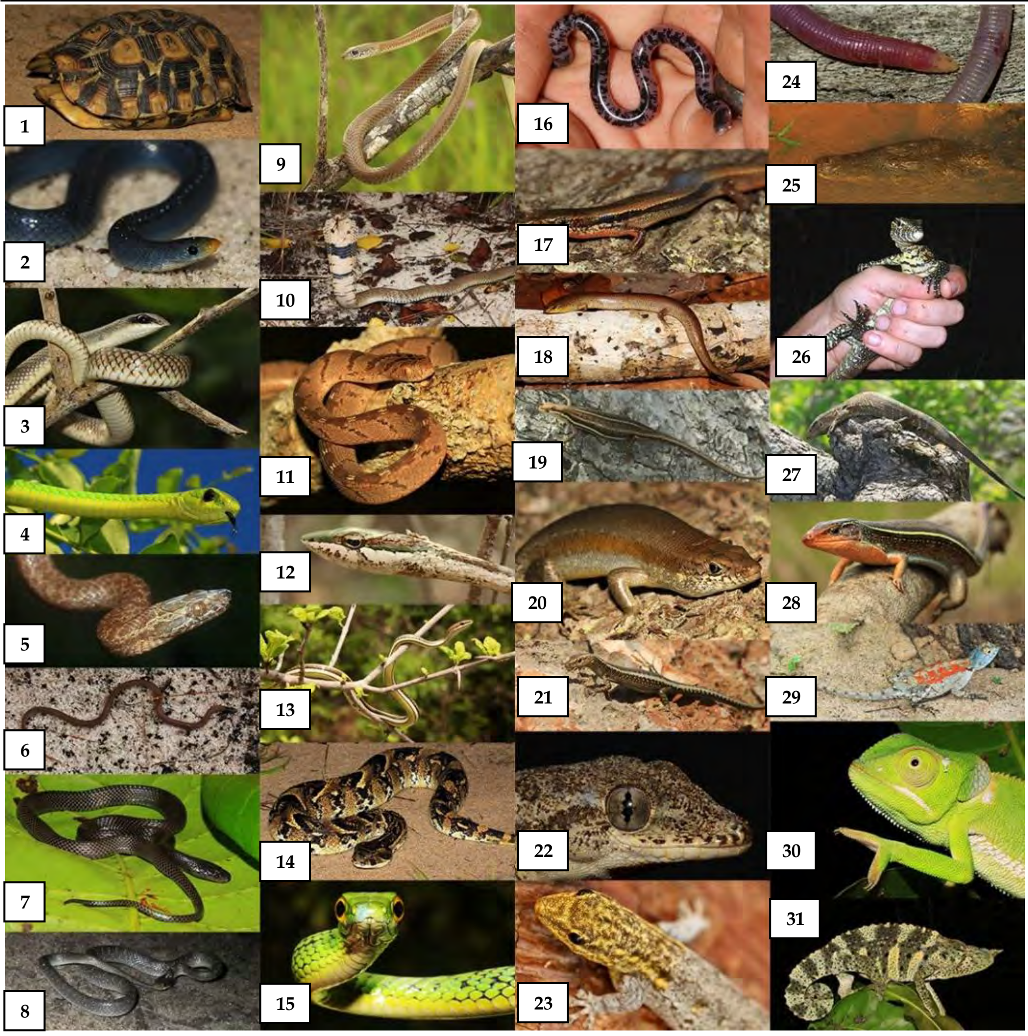
Table 8.27 Herpetofauna Field Survey Results

	Funnel Trap		**Active Search**		**Total Species Observed**	**Total Species Expected**	**% Observed**
	Individ-uals	**Species**	**Individ-uals**	**Species**			
Reptile	85	19	153	28	36	112	32
Amphibian*	402	16	128*	34	36	49	74
Totals	487	35	281*	62	72	161	

Key:
* This represents the minimum total, as chorusing frogs were not counted.

Source: Enviro-Insight, 2012.

Figure 8.61 Selection of Reptile Species Photographed during Field Surveys



1: Kinixys belliana; 2: Prosymna stuhlmanni; 3: Rhamphiophis rostratus; 4: Dispholidus typus; 5: Lamprophis fuliginosus; 6: Aparallactus capensis; 7: Mehelya nyassae; 8: Crotaphopeltis hotamboeia; 9: Psammophis mossambicus; 10: Naja mossambica; 11: Dasypeltis medici; 12: Thelotornis mossambicanus; 13: Psammophis orientalis; 14: Bitis arietans; 15: Philothamnus punctatus; 16: Rinotyphlops mucroso; 17: Panaspis wahlbergii; 18: Lygosoma afrum; 19: Mabuya varia; 20: Mabuya maculilabris; 21: Cryptoblepharus boutonii; 22: Hemidactylus platycephalus; 23: Lygodactylus luteopicturatus; 24: Unidentified amphisbaenian; 25: Crocodylus niloticus; 26: Varanus niloticus; 27: Varanus albigularis; 28: Gerrhosaurus nigrolineatus; 29: Agama mossambica; 30: Chamaeleo dilepis; 31: Chamaeleo melleri.

Source: Enviro-Insight, 2012.

Figure 8.62 Selection of Amphibian Species Photographed during Field Surveys

1: Bufo lindneri; 2: Bufo taitanus; 3: Bufo maculatus; 4: Chiromantis xerampelina; 5: Hildebrandtia ornata; 6: Pyxicephalus edulis; 7: Arthroleptis stenodactylus; 8: Leptopelis broadleyi; 9: Phrynomantis bifasciatus; 10: Kassina maculata; 11: Kassina senegalensis; 12: Hylarana galamensis; 13: Hyperolius tuberilinguis; 14: Hyperolius argus; 15: Hyperolius acuticeps; 16: Afrixalus fornasini; 17: Afrixalus delicatus; 18: Xenopus muelleri; 19: Hemisus marmoratus; 20: Ptychadena oxyrhynchus; 21: Ptychadena taenioscelis; 22: Ptychadena guibea; 23: Breviceps mossambicus; 24: Phrynobatrachus natalensis; 25: Phrynobatrachus mababiensis.

Source: Enviro-Insight, 2012.

8.8.5 Herpetofauna Species of Conservation Concern

The southern African python (*Python natalensis*) is currently not listed by the IUCN, and the South African Reptile Conservation Assessment (SARCA, 2012) lists the southern African python as 'Not Evaluated'. However, the southern African python was listed in the South African Red Data book (Branch, 1998) as vulnerable, and the Mozambique Forestry and Wildlife Law Regulation (Decree No. 12/2002) lists the '*Python or Boa Constrictor*' as protected. Since the boa constrictor does not occur in Africa, it is assumed that this is in reference to the southern African python. This species was not directly observed during field surveys; however, the local interviewees were unanimous in their agreement that pythons are often found within the Survey

Area. In South Africa, the National Environmental Management: Biodiversity Act No. 10 of 2004 (NEMBA) lists the southern African python as a protected species. It is therefore prudent to treat this snake as a vulnerable species, despite its lack of current IUCN status in Mozambique. Apart from the southern African python, no other herpetofauna species of conservation concern are expected to occur within the Afungi Project Site.

8.8.6 Possible Novel Species

During the December 2011 survey, four individuals of a fossorial legless skink were found that do not appear to be known to science. These small legless skinks belong to either the *Acontias* or *Typhlosaurus* genus, as there is some disagreement about the recent taxonomical revision based on the phylogenetic relationship of this Acontinae subfamily (Lamb et al., 2010).

Given the characteristics observed and the fact that these skinks have very limited dispersal capabilities, it is very likely that this is either a novel species or at least a subspecies. Further studies would be necessary to understand the population density and/or distribution of this skink.

Three of the individuals were found within 2m of each other on the banks of the fresh-water wetland near trap Array 1A, and the other individual was found in the dense wooded patch around Array 4B (see *Figure 8.59* above). As a precautionary measure, it is suggested that the preliminary protection of this skink can be achieved by the protection of the wetlands and the contiguous tree habitat types, which are classified as sensitive (see habitat and sensitivity map discussion below).

The unidentified amphisbaenian (*Figure 8.62*, #24) must still be fully identified before any strong statement can be made about its relative significance. The fact that it is not identifiable from the high-resolution photography obtained suggests that it may either be a novel species or a different form of an existing species. A specimen that was injured during the construction of a trap array was collected and preserved to aid with the identification, using museum reference material and possibly the help of a specialist.

It is not possible to know or predict the conservation status of the possible new fossorial skink species and the unidentified amphisbaenian. The precautionary approach is to assume that they are rare and require special consideration during Project development.

8.8.7 Herpetofauna Habitat Sensitivity

It is difficult to assign herpetofauna communities accurately to a structural habitat type unless extensive long-term surveying has taken place. However, the data collected during the surveys does allow for certain generalisations to be made. These are discussed based on the structural landscape classification provided in *Section 8.6.5* and shown previously in *Figure 8.57*.

Each of the habitat types was assigned a sensitivity rating, as evaluated from a herpetofauna perspective. The sensitivity rating of each of these habitat types was based on the importance of the ecosystem function; ie the evaluated herpetofauna species diversity, abundance and relative importance (conservation status). The landscape type and its resilience to disturbance were also evaluated, as well as the connectivity between other landscape types of similar sensitivity. High connectivity was seen to increase the sensitivity rating, because completely isolated/fragmented areas of a high sensitivity provide less useful ecological function than connected areas.

Six sensitivity categories were defined. These are presented in *Figure 8.63* below:

1. **Very High:** limited landscape type essential for the functioning of the herpetofauna community and at high risk from disturbance.

2. **High:** very important for the functioning of the herpetofauna community and at risk from disturbance.

3. **Medium:** this landscape type is useful for functioning of the herpetofauna community and can be at risk from extensive disturbance. Some disturbance has already taken place.

4. **Low–Medium:** not essential for the functioning of the herpetofauna community, but provides habitat for many common species. At low risk from disturbance that has already taken place over long periods of time.

5. **Low:** not essential for the functioning of the herpetofauna community, because few species occur here. Herpetofauna in this landscape therefore not at great risk from disturbance.

6. **Negligible:** because almost no herpetofauna exist here, disturbance of this landscape type is unlikely to have a direct influence on the herpetofauna community.

For example, the sensitivity category of Very High would be afforded to landscape types that meet the following criteria:

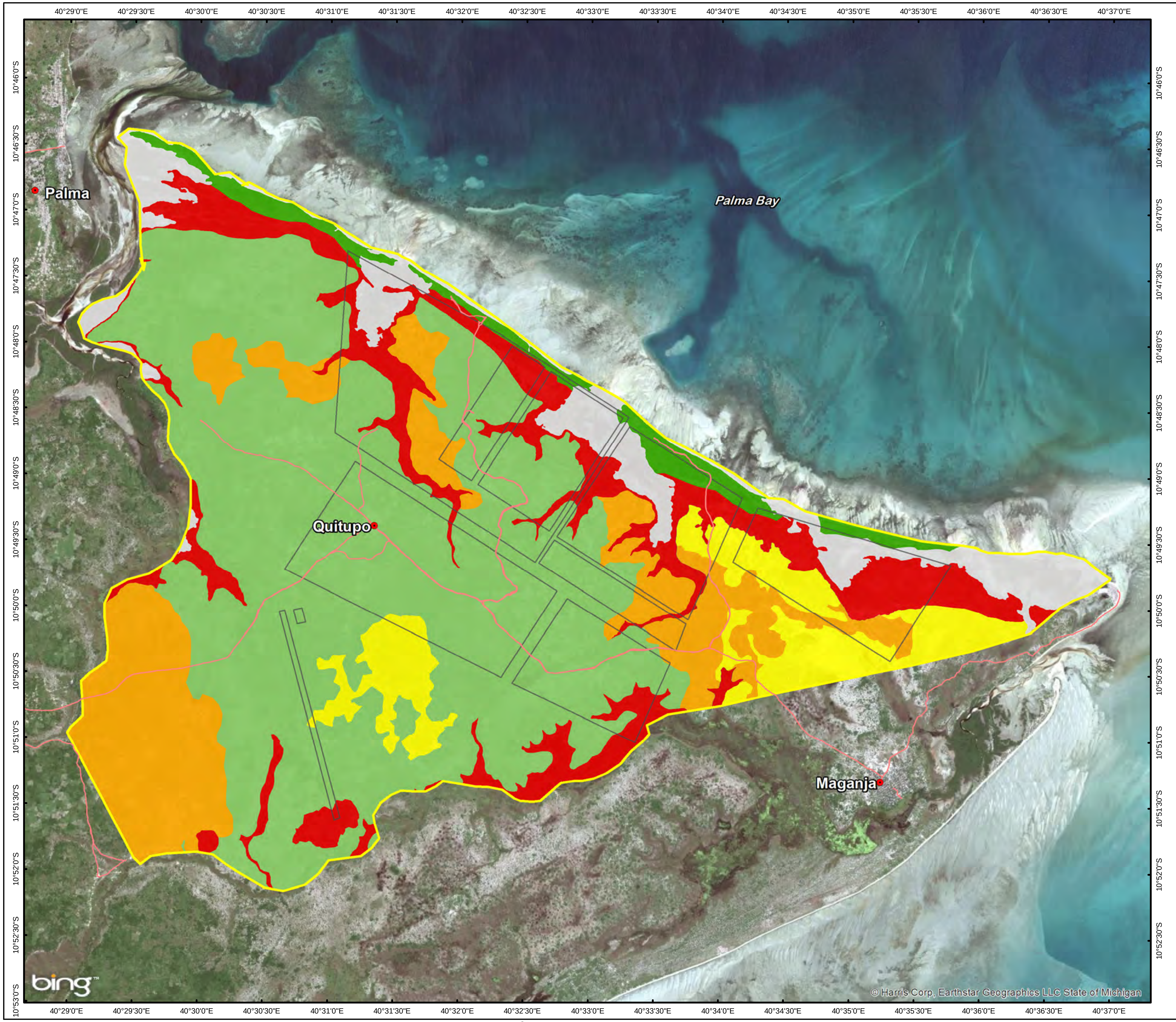
- provides an essential lower trophic-level tier (low in the food web) on which many other trophic levels (predators) are dependent;

- provides additional ecological services (such as breeding, shelter and foraging habitat);

- provides for a great diversity and density of herpetofauna;

- consists of a relatively small total area of occurrence and a low resilience to impacts (high susceptibility);

- exhibits good connectivity to other landscape types of high sensitivity; and
- consists of areas in which species of conservation concern are likely to occur.



Legend

- Villages / Settlements
- Local Roads
- Onshore Project Footprint
- Afungi Project Site

Herpetofauna Sensitivity

- Negligible
- Low
- Low-Medium
- Medium
- High
- Very High

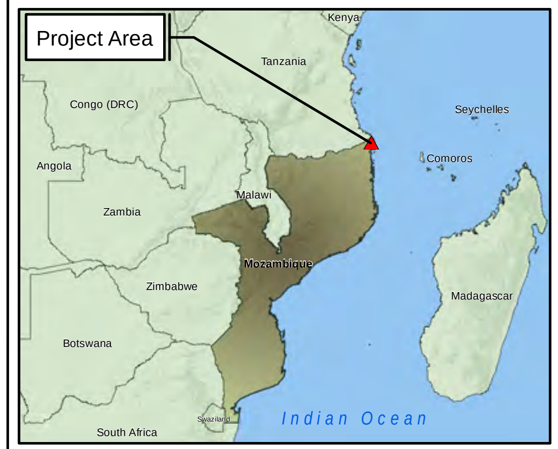


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Figure 8.63: Herpetofauna Sensitivity Map

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8.8.8 *Habitat Types within the Survey Area and their Sensitivity*

Short Closed Wetlands – Vegetation Unit 5

The key drivers of the herpetofauna community are the fresh-water wetland systems. These systems provide active breeding opportunities for amphibians for more than half the year. However, amphibians had already bred during the first visit in October 2011 and most of the same species were still breeding (calling and mating) in April 2012. It is likely that this breeding activity occurs for most of the year, and some species may even breed continually throughout the year. With such a long breeding season and such ideal conditions for breeding (shallow warm slow-moving water that is heavily vegetated), it is not surprising that many vertebrate predators rely on the extensive amphibian population as a source of food.

The densely vegetated nature of the fresh-water wetlands and woodland vegetation of the wetland banks of Vegetation Unit 5 provide an ideal corridor for the natural migration and dispersal of herpetofauna. The dense closed woodland along the wetland banks is almost all that remains intact after many years of bush-clearing for agricultural practices; agricultural fields cannot be made on the sloped banks of the wetland as they will erode. The importance of such corridors is highlighted, as it is only through migration and dispersion that populations can exchange gene alleles and avoid homozygosis (inbreeding). The recolonisation of areas that have suffered localised population collapses (from hunting, fire and flooding) can take place more easily through established dispersal corridors such as these productive wetlands. Fragmentation of the landscape through agriculture and/or development can therefore be mitigated by maintaining these dispersal/migration corridors.

Although rain occurs frequently at certain times of the year, there are very few ponds/puddles that remain for any length of time. This is mostly due to the sandy nature of the soil and the absence of clay. Consequently, nearly all available surface fresh water in the area is restricted to the wetlands. This dependable source of fresh water attracts a variety of animals, at least periodically, throughout the year. Reptile species reliant on surface water, such as the crocodile and southern African python, are typically restricted to fresh-water wetlands except during migration.

It bears note that very few small mammals were trapped/observed during these surveys. It is strongly suspected that the high density and diversity of mammalian meso-predators (see *Section 8.10,* Mammals baseline) is explained directly by the availability of amphibian prey (or availability of other amphibian-reliant prey such as birds, snakes and lizards). This is supported by the fact that very few snake species were observed that do not eat amphibians rather there were specialist feeders such as centipede-eaters and egg-eaters. If the amphibian community does indeed serve as one of the major contributors to the lower trophic levels of the food web as is suggested, then the maintenance of this community is essential for the continued existence of the vertebrate communities reliant on this trophic level. If maintenance of the amphibian community relies upon the maintenance of the fresh-water wetland habitat, then the maintenance of the majority of the vertebrate community will therefore also rely upon the maintenance of the fresh-water wetland habitat.

Finally, all of the terrestrial reptile or amphibian species (including the possible new fossorial skink and the unidentified amphisbaenian) found within the Survey Area can be expected to occur in Vegetation Unit 5. This observation, in conjunction with the three points discussed above, makes these fresh-water wetlands of integral importance to the continued functionality of the herpetofauna community and all other vertebrate communities that rely on the herpetofauna assemblages. The wetlands are therefore afforded the highest possible sensitivity category: Very High.

Short Closed Woodland – Vegetation Unit 7

This landscape type was most likely the dominant structural landscape type during historical times. Land alterations such as bush-clearing for agricultural purposes, fires and tree felling (for both timber and fuel) have reduced the area occupied by contiguous stands of trees to a few remnant patches. The selective avoidance of felling useful fruit or nut trees, notably cashew and mango trees, has resulted in dense stands of these exotic trees with few naturally occurring species in-between. Therefore, Short Closed Woodlands are not necessarily of great botanical importance, but do provide a significant structural habitat type for herpetofauna.

Trees contribute to herpetofauna refugia in the following ways:

- the spaces under exfoliating tree bark is occupied by numerous species (eg geckos, lizards, frogs and small snakes);

- hollow branches or tree holes provide refuge for larger-bodied reptiles (eg monitor lizards, agamas and snakes);

- arboreal species shelter in dense patches of leaves (eg chameleons);

- leaf litter under dense stands of trees provides shelter and a foraging habitat for numerous fossorial reptiles (eg snake-eyed skinks and worm-lizards) and amphibian species (eg rain frogs);

- detritus tree material attracts insects and other invertebrates, providing a valuable foraging habitat and shelter for a multitude of herpetofauna species; and

- herpetofauna are prone to overheating and rely on extensive well-shaded areas for effective thermoregulation while inactive and taking shelter.

Trees provide a food source for many herbivorous animals, large stands of trees are particularly valuable to such herbivores as food is easily accumulated. The presence of many different prey species attracts a variety of herpetofauna predators that use these dense stands of trees as foraging sites.

Finally, the fact that only a few large stands of this landscape type still remain intact, in conjunction with the refugia and foraging potential discussed above, results in a habitat sensitivity classification of either High or Medium. The ultimate classification is dependent on the connectivity of this habitat with other sensitive habitats; greater connectivity results in a higher sensitivity (*Figure 8.63*).

Short Closed Grasslands and Short Open Woodland – Vegetation Units 4 and 6

Short closed grasslands and short open woodland interspersed with agriculture are the dominant landscape types within the Survey Area. A large proportion of this area has been used for agriculture repeatedly over many years, resulting in a mosaic of regrowth (from past agricultural disturbances) interspersed with natural stands of trees and grass and current agricultural fields. While the clearing of vegetation initially impacts heavily on the herpetofauna community, the surrounding patches of natural and semi-natural vegetation allow for the continued presence of many herpetofauna species. Certain species fond of open areas such as the plated lizards (*Gerrhosaurus* spp.) are benefited by such agricultural practices; hunting for insects is performed in the agricultural fields and refuge is taken in the dense bush adjacent to the fields. Other species such as the dwarf geckos (*Lygodactylus* spp.) also benefit from the creation of agricultural fields because trees are felled at approximately 1.5m above the ground, which provides good refugia when the bark starts to exfoliate.

Nevertheless, all of the species found in Vegetation Units 4 and 6 are relatively common and are also found in the more sensitive landscape types. A sensitivity classification of Low–Medium was therefore given to this landscape type, except for the south-eastern portion near the village of Maganja. This area is surrounded by sensitive habitat types and therefore has its sensitivity rating elevated to Medium (*Figure 8.63*).

Short Open Scrubland – Vegetation Unit 1

Very few herpetofauna species were observed in this landscape type, mostly because of the close proximity to the ocean. Most terrestrial reptiles (with a few exceptions) are not tolerant of the salty conditions associated with open vegetation near ocean beaches. Amphibians are especially intolerant of saline conditions, and very few species are found here.

The entire coastal sandy scrub habitat is considered to be of Low sensitivity, regardless of its proximity to other sensitive habitat types, because this landscape type has low value to herpetofauna even for dispersal purposes (*Figure 8.63*).

Beaches, Short Closed Marshland and Open Saline Plains – Vegetation Units 2 and 3

As mentioned above, few herpetofauna species are tolerant of saline conditions. Only a single reptile species, the yellow-headed dwarf gecko (*Lygodactylus luteopicturatus*), was found in the mangrove stands. It is possible that a few other arboreal species may be found in this habitat. In Nigeria (West Africa), numerous reptile species are found in mangroves (Luiselli & Accani, 2002) but evidence of the importance of mangroves for East African species is lacking (Nagelkerken et al., 2008). As expected, no amphibians were found in the saline wetlands. The sandy ocean beaches represent a dry and salty environment that does not favour East African herpetofauna.

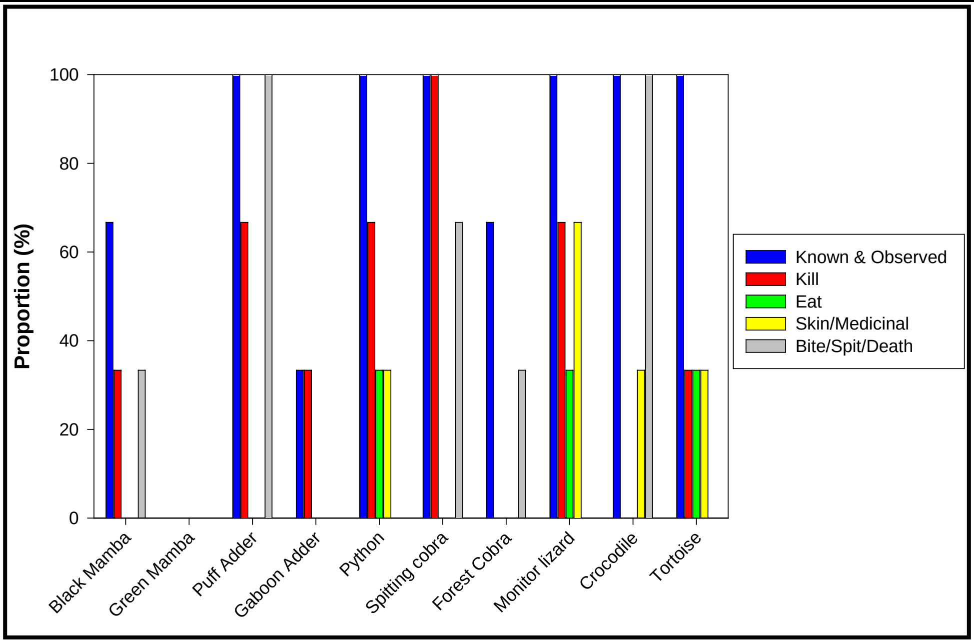
Despite the obvious unique botanical characteristics of the mangroves and the unique food web of the saline wetlands and mangroves, this landscape type cannot be afforded a herpetofauna sensitivity classification other than Negligible (*Figure 8.63*).

8.8.9 Herpetofauna Health and Safety Concerns

Several potentially dangerous herpetofauna were encountered during the surveys, and venomous snakes were also encountered within the confines of the Palma Camp. The potential health and safety risks associated are highlighted below.

Informal interviews with the communities of Quitupo, Maganja and Senga were undertaken with the village elders and their trusted companions; questions were asked with the aid of an interpreter. The results of the interviews are summarised in *Figure 8.64.*

Figure 8.64 Results of Interviews Conducted at the Villages of Quitupo, Maganja and Senga



Note:
The Bite/Spit/Death column represents the pooled results of individuals with knowledge of someone being bitten, spat in the eyes, or killed by a particular reptile.

Source: Enviro-Insight, 2012.

The primary outcomes from these interviews are:

- Villagers are at risk from potentially dangerous reptiles:
  - seven cases of crocodile bites have occurred since 2010 (no deaths but amputations required, all occurring in or near fresh-water wetlands);
  - five deaths from black mamba bites have occurred since 2005; and
  - two puff adder bite cases occurred (dates uncertain) with no fatalities.
- The Christian village of Senga differs markedly from the Muslim villages of Quitupo and Maganja in that they use some reptiles as a food source (Muslims from these two villages do not eat terrestrial reptiles).
- The use and killing of reptiles does not appear to occur at an intensity that is likely to affect the local reptile population. This is predominantly because the villagers are very fearful of most large snakes and crocodiles and lack the necessary means to kill them safely.
- The villagers consider all green arboreal snakes to be the same species, especially the boomslang (male), green mamba and the non-venomous speckled green snakes. For this reason, it is unclear if the identification of a green mamba during the field surveys was accurate.

From the interview data obtained and from encountering potentially dangerous reptiles during the surveys, it is clear that there is a potential health and safety risk associated with Project staff and contractors interacting with reptiles in the field. The *National Census of Wildlife* (Agreco, 2008) documents reports that crocodiles in Mozambique account for more human deaths than that from all mammals combined (elephants, lions, etc). In fact, for deaths where the responsible animal was reported (204), crocodiles accounted for 134 (66 percent) of these deaths. Similarly, for injuries that did not result in death (82), crocodiles were responsible for 36 (44 percent). Only three individual crocodiles were encountered during the surveys, but they nonetheless need to be considered to represent a potential safety risk.

8.9 AVIFAUNA

8.9.1 Geographical Context

An avian study was conducted within the general vicinity of the Afungi Project Site, including the main travel corridors to Cabo Delgado and the Rovuma River as well as Palma Bay and Tecomaji Island. Qualitative surveys (direct observations and habitat interpretation) were used to better understand the avian context of the broader region. The resulting data was used to emphasise the importance between bird assemblages in the local context (Survey Area) with the region (Study Area). The Study Area was evaluated to establish a comparative analysis between the Afungi Project Site and the surrounding region, while more intensive surveys were conducted in the Survey Area to establish the baseline conditions as they relate to the avifauna on site. Avian surveys and data collection (quantified bird point counts) were undertaken within the Afungi Project Site and the immediately adjacent intertidal habitat. *Figure 8.65* shows a map of the Survey and Study Areas.

8.9.2 Mozambique Regional Avifauna Context

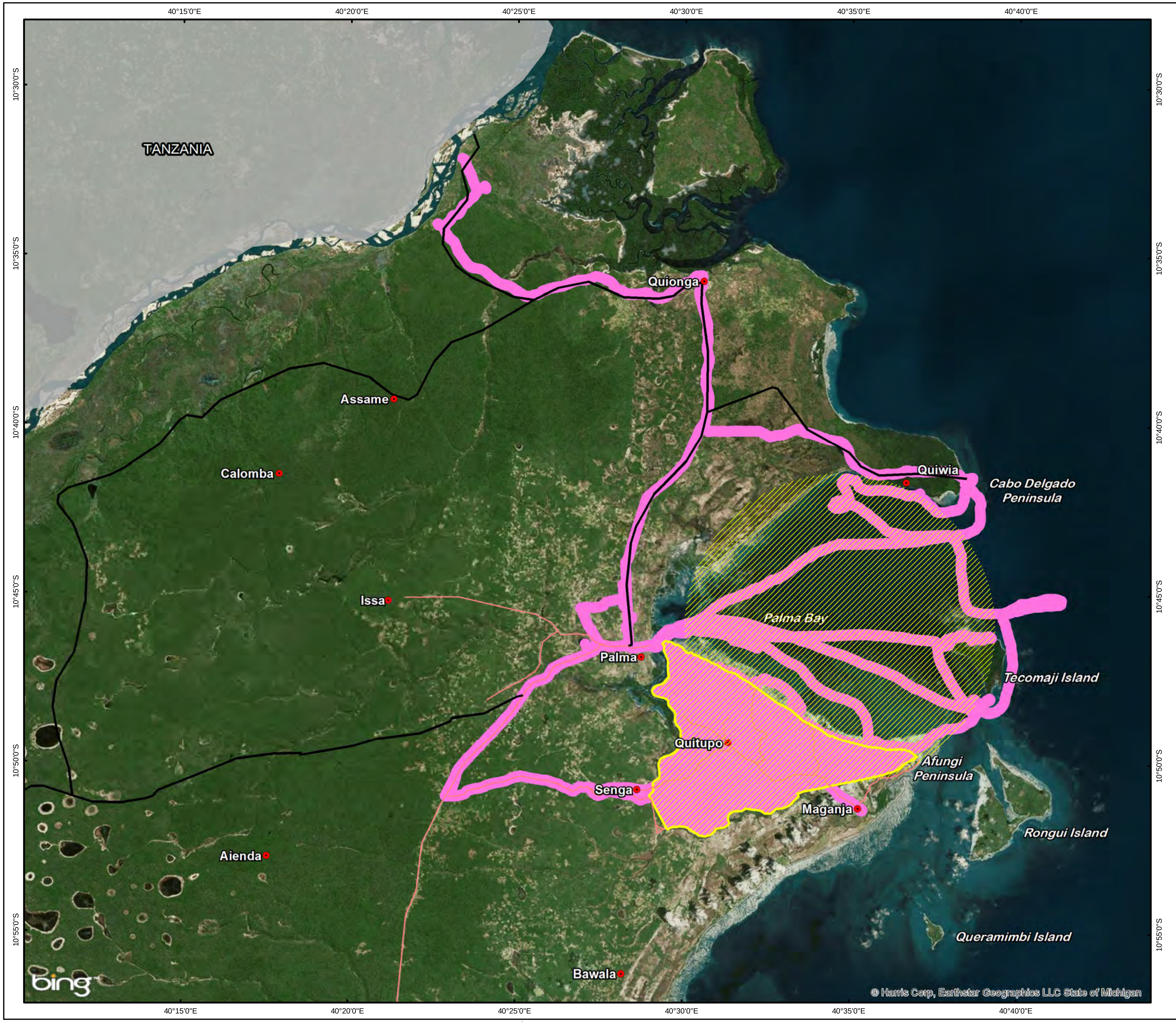
Mozambique is largely unexplored in terms of its avifaunal diversity although it is well received internationally as a fascinating and very rewarding birding destination (Cohen et al., 2006). The country holds more than 730 bird species, of which approximately 530 species are breeding within its boundaries (Parker, 2001; Lepage, 2012). It has long been recognised as an area of great avifaunal interest, supporting high bird diversities (Parker, 2001; MICOA, 2009).

However, being a vast country, it is surprising that Mozambique has only one true endemic bird species, namely the Namuli apalis (*Apalis lynesi*), which only occurs in northern Mozambique on Mount Namuli (Parker, 2001; Sinclair & Ryan, 2010).

From a conservation perspective, Mozambique sustains a number of range-restricted species, in particular forest birds. Many of these species are near-endemic to the country and are confined to four Endemic Bird Areas, which are shared with neighbouring countries such as Zimbabwe, Malawi and South Africa. Two of these areas are located in mountainous terrain (eg the Eastern Zimbabwe Mountains and the Tanzania–Malawi Mountains) while another two are restricted to an extension of the South African forests and the coastal plain south of Maputo. The Afungi Project Site does not overlap with any of these geographical areas.

Typical examples of taxa restricted to the coastal plain south of Maputo are the Rudd's apalis (*Apalis ruddi)*, Neergaard's sunbird (*Cinnyris neergaardi)*, pink-throated twinspot (*Hypargos margaritatus)* and lemon-breasted canary (*Serinus citrinipectus)* (all known as Maputaland endemics in South Africa). A typical example of taxa restricted to the Eastern Zimbabwean highlands is the Swynnerton's robin (*Swynnertonia swynnertonii*). And lastly, taxa restricted to the Tanzanian–Malawi Mountains include the Thyolo alethe (*Alethe choloensis)*, dapple-throat (*Modulatrix orotruthus)* and long-billed forest warbler (*Artisornis moreaui)*.

Furthermore, the country holds a number of biome-restricted species, of which 30 species have Afro-temperate (highland) affinities, 25 species are restricted to the East African coastal littoral and another 26 species are restricted to the Zambezian woodlands (Parker, 2001). Species with Zambezian affinities are restricted to one of Africa's most extensive biomes, which is well represented in Mozambique by mopane (*Colophospermum mopane*) and *Brachystegia* woodland.



Legend

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- Local Roads
- Regional Roads
- Afungi Project Site
- Survey Area
- Study Area

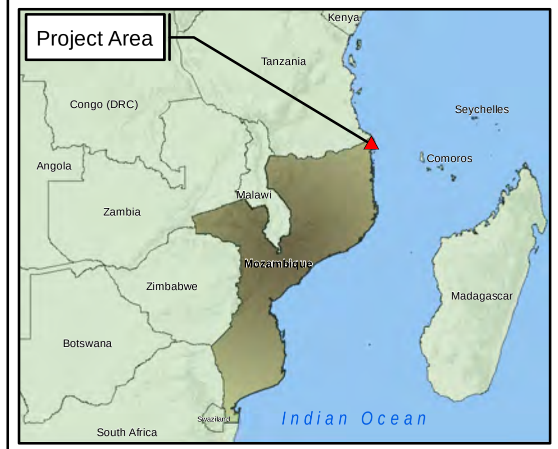

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Figure 8.65:
Avian Study and Survey Areas

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Anadarko Moçambique Área 1, Lda

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DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 195 000

DRAWING: Avian Study and Survey Areas.mxd

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Impacto Projectos e Estudos Ambientais

ERM

Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
Enviro-Insight, 2012
Inset Map: Esri Data & Maps

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Mozambique recently gained favour with avian tourists for its avifaunal diversity, especially after the disclosure of its climax lowland forests and *Brachystegia* woodlands north of the Save River. This richness in species has contributed to an increased influx of ornithologists and citizen scientists to the region, mainly with the intention of investigating the avian tourism potential of the area.

From an avifaunal perspective, certain parts of Mozambique have become well-known birding destinations for many sought-after species, of which some are threatened and restricted in range. These include the African pitta (*Pitta angolensis*), green-headed oriole (*Oriolus chlorocephalus*), white-chested alethe (*Pseudoalethe fuellebornii*), East Coast akalat (*Sheppardia gunningi*) and Mascarene martin (*Phedina borbonica*).

8.9.3 Cabo Delgado Province Avifauna Context

The avifauna of Cabo Delgado Province is poorly known but is believed to be an important wintering area for water birds and particularly waders, as evidenced by the large concentrations of crab plover (*Dromas ardeola*), greater sand plover (*Charadrius leschenaultii*) and other Palaearctic scolopacid waders.

The area is generally located on low-lying plains and consists of coastal woodland, of which large parts are modified by crop cultivation. There are also numerous rivers and streams that flow eastwards to the Indian Ocean and terminate in extensive mangrove forests. However, the province holds many biome-restricted species that are confined to the coastal plain.

There are no Important Bird Areas (IBAs) [(1)] in Cabo Delgado Province. The nearest IBAs are located in Tanzania on the opposite side of the Rovuma River, namely:

- Mnazi Bay (TZ028, located approximately 45km north of the Afungi Project Site); and
- Mtwara and Newala district coastal forests (TZ052 and TZ053, located approximately 40km north-west of the Afungi Project Site) (Baker & Baker, 2001).

The nearest Mozambican IBA (known as Netia) to the Afungi Project Site is located in Nampula Province, approximately 440km south of the Afungi Project Site.

8.9.4 Avian Habitat Types Identified in the Survey Area

The following text provides an overview of the avifaunal habitat types associated with Vegetation Units present within the Survey Area. Avian community types are discussed in *Section 8.9.6*

(1) As defined by Bird Watch International.

Short Closed Woodland – Vegetation Unit 7

This habitat is scattered in the Survey Area and consists as closed woodland and forest remnants surrounded by open woodland and cultivated land (mainly used for the production of cassava). It is more prominent on the northern section of the Survey Area, where it tends to be better defined and less disturbed. Typical canopy include *Berlinia orientalis,* mobola plum and msasa (*Figure 8.66*), although some areas were also dominated by alien species such as cashew nut trees and mango trees. However, intact examples of mature woodland persist outside the Survey Area boundary and can be viewed either en route to the Afungi Project Site or north of Palma towards the Rovuma River.

The presence of lianas (mainly thorny rope) and a well-developed layer of leaf litter are characteristic of the closed woodlands and provide a very specific habitat for bird species with elusive and unobtrusive behavioural traits.

Figure 8.66 Floristic Structure of Short Closed Woodland

Source: Enviro-Insight, December 2011.

Short Closed Grassland and Short Open Woodland – Vegetation Units 4 and 6

This woodland type is structurally similar to savannah grassland and is shaped by long-term anthropogenic disturbances that range from firewood collection to frequent burning regimes. It is widespread in the Survey Area and characterised by a short to medium woody cover with a well-defined graminoid layer. Typical woody species include the black monkey orange, African mangosteen, *Xylotheca tettensis* and northern lala palm. It is often regarded as a secondary variant of mature *Berlinia orientalis* woodland.

Figure 8.67 Floristic Structure of Short Closed Grassland and Short Open Woodland

Source: Enviro-Insight, December 2011 (top images) and March 2012 (bottom images).

Short Open Shrubland – Vegetation Unit 1

This habitat type is restricted to the coastal littoral zone and consists of a species-rich floristic composition of short dense thicket (mainly milkwood members of the Sapotaceae) and coconut palms (*Figure 8.68)*. As with most of the vegetation communities in the Survey Area, the composition and structure is also a function of human-induced activities.

An important ecological function of this habitat type, although artificial, is the roosting and nesting habitat provided by the senescent palm trees for a large variety of hole-nesting bird species (eg woodpeckers, parrots, rollers, starlings and barbets). It is also the only area within the Survey Area that provided a habitat for the collared palm-thrush (*Cichladusa arquata*) and the biome-restricted Dickinson's kestrel (*Falco dickinsoni*).

Figure 8.68 Anthropogenic-modified Coastal Thicket (with Coconut Palms)

Source: Enviro-Insight, December 2011 (top images) and April 2012 (bottom images).

Short Closed Wetlands – Vegetation Unit 5

The fresh-water wetlands are represented by landscape features of linear configuration and include a number of drainage lines and seasonally inundated grassy *dambos* (or vleis) that are part of five major wetland systems within the Study Area (*Figure 8.69*). These systems are confined to the bottom valleys of ancient dune typologies that are responsible for a rather complex and localised catchment area. The vegetation cover is characterised by obligate and facultative wetland species, depending on the surface water retention ability of the wetland. Dominant species include dwarf papyrus, *Leersia hexandra, Panicum repens, Typha capensis, Nymphaea nuchalis, Diascia* spp. and *Desmodium* spp. The edges of the wetlands are invariably occupied by swamp forest elements such as *Voacanga thouarsii* and *Syzygium cordatum*.

Small inundated pools contained within this habitat type are an important non-breeding foraging habitat for the endangered Madagascar pond heron (*Ardeola idae*), while also sustaining large numbers of rallids (rails and flufftails) and ploceid weavers and widowbirds (*Euplectes* spp.) during the austral summer.

Figure 8.69 Diversity of Fresh-water Wetlands and Dambos within the Survey Area

Source: Enviro-Insight, April 2012 (top left image) and October/December 2012 (remaining images).

Open Saline Plains – Vegetation Unit 3

This habitat type is ecotonal and constitutes the transition between the inland fresh-water wetlands and the mangrove forests (*Figure 8.70*). It is therefore periodically inundated by surface water with a high salinity due to tidal fluctuation. A typical woody layer is near-absent while the vegetation cover is predominantly composed of dwarf halophytes (eg glasswort) and short white mangroves.

This habitat is an important foraging area for Palaearctic wader taxa, storks and the Vulnerable wattled crane (*Grus carunculatus*).

Figure 8.70 Typical Estuarine Salt Marsh Conditions within the Survey Area

Source: Enviro-Insight, December 2011 (top and bottom left images) and March 2012 (bottom right).

Short Closed Marshland – Vegetation Unit 2

These forests are species-poor and comprise of monospecific stands of vegetation with highly specialised plant species that are adapted to survive the high salinity of the surface water and associated anoxic conditions (*Figure 8.71*). The mangrove forests are restricted to estuaries along the coastline of the Afungi Project Site, and occur between mean sea level and the high-water spring tide level. It is dominated by white mangrove and red mangrove species, although part of its composition is made up of *Bruguiera gymnorrhiza,* Indian mangrove, Tonga mangrove and star-apple mangrove.

The mangrove forests are equally poor in avifaunal species, although they are an essential foraging habitat for sunbird taxa and the mangrove kingfisher (*Halcyon senegaloides*). The latter is common in the mangroves during the austral winter.

Figure 8.71 Mangrove Forests Compositions Observed within the Study Area

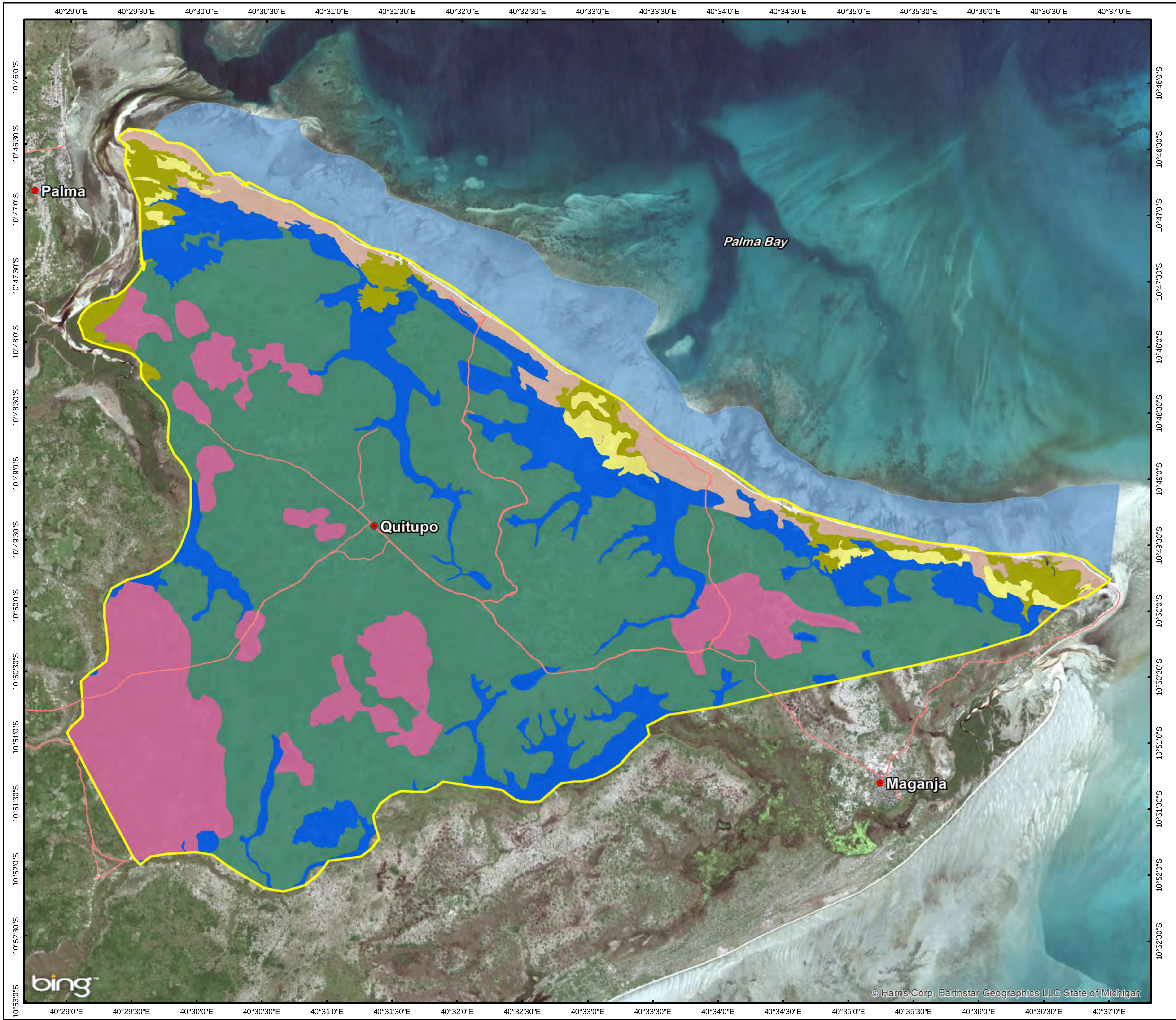
Source: Enviro-Insight, October 2011 (top left image) and April/March 2011 (top right and bottom images).

Habitat Types Associated with Intertidal Beaches and Mudflats

This habitat type is confined to the intertidal zone of sandy coastal sediments that are inundated during high tide but exposed during low tide (*Figure 8.72*). This habitat type is a critical important foraging area for large concentrations of shorebirds, especially Palaearctic waders, the crab plover and the dimorphic egret (*Egretta dimorpha*).

Figure 8.72 Extensive Intertidal Beaches Evident during Low Tide

Source: Enviro-Insight, April 2012 (top images) and October 2011 (bottom images).



Legend

- Villages / Settlements
- Local Roads
- Afungi Project Site

Avifauna Sensitivity

- Open mixed woodland
- Modified palm savanna and coastal thicket
- Closed Berlinia orientalis woodland and forest
- Freshwater wetlands and dambos
- Estuarine salt marsh
- Mangrove forest
- Avifauna Intertidal Zone

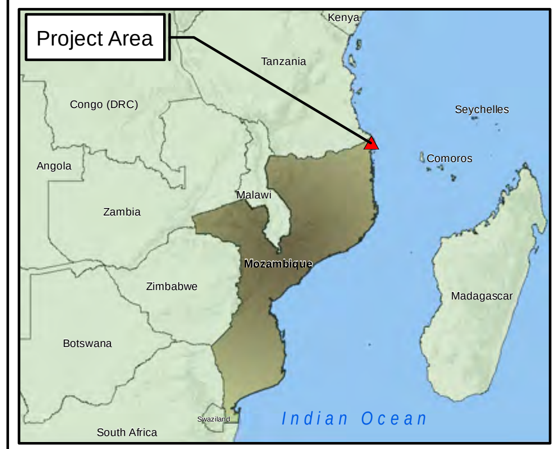


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Figure 8.73: Avifaunal Habitat Types within the Survey Area

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DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
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DRAWING: Avifaunal Habitat Types within the Survey Area.mxd

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Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
Enviro-Insight, 2012
Inset Map: Esri Data & Maps

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8.9.5 *Avifaunal Richness and Composition*

Field Observations

The field survey observations recorded 323 bird species within the Survey Area (*Figure 8.65*), which equates to 44 percent of the approximate 736 species listed for Mozambique (according to Lepage, 2012**).**

It was evident during the survey that the avifauna is poorly documented with many species previously unknown or anecdotal to the area, especially when their current distribution patterns are compared to Sinclair and Ryan (2010). Examples of these species include the palm-nut vulture (*Gypohierax angolensis*), red-chested flufftail (*Sarothrura rufa*), wattled crane, lesser jacana (*Microparra capensis)*, silvery-cheeked hornbill (*Bycanistes brevis)*, two species of *Acrocephalus* warblers, pale flycatcher (*Bradornis pallidus*), blue-mantled crested flycatcher (*Trochocercus cyanomelas*), variable sunbird (*Cinnyris venustus*), southern brown-throated weaver (*Ploceus xanthopterus*), southern red bishop (*Euplectes orix*), brimstone canary (*Crithagra sulphurata*) and Reichard's seed-eater (*Crithagra reichardi*). This illustrates the lack of ornithological knowledge and need for more intensive avifaunal surveys and exploration in northern Mozambique.

Of more importance is the discovery of two taxa that have not been previously recorded in Mozambique. These taxa include the *reichnowi* race of the short-tailed batis (*Batis* sp. nr. *B. mixta*) and the eastern black-headed batis (*Batis minor*) (Fjeldså et al., 2006). In addition, the surveys also confirmed the presence of the vulnerable wattled crane, which was until recently only known from historical records along the Rovuma River (personal communication, Mr Richard Beilfuss of the International Crane Foundation). The confirmation of this species in the Survey Area and the Rovuma River delta highlights the possibility of a breeding population that could represent formerly displaced birds from Tanzania.

Table 8.28 provides a summary of the total number of species, threatened (and Near Threatened) species, endemics and biome-restricted species observed in the Survey Area when compared to the entire avifauna of Mozambique.

Table 8.28 Avian Species of Concern within the Survey Area

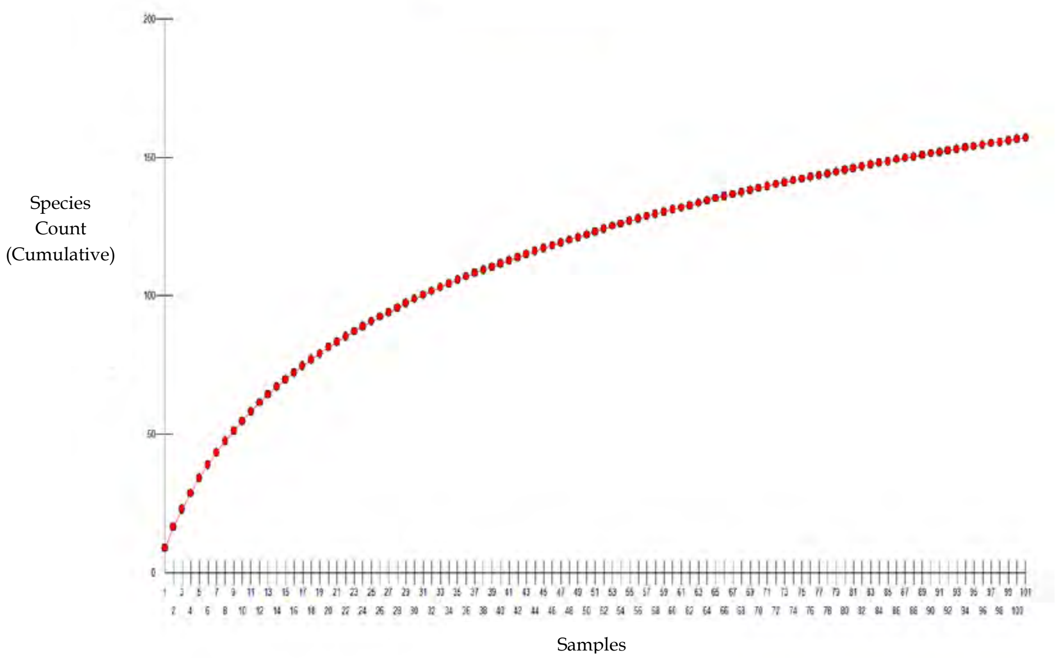
	Number of Species Observed	**Number of Species Recorded in Mozambique**	**Percent**
Total number of species	323	736	43.8
Number of globally threatened/Near Threatened species (IUCN, 2011)	11	48	22.9
Number of locally threatened species (Parker, 2005)	3	22	13.6
Number of restricted-range species pertaining to Endemic Bird Areas (Parker, 2001)	0	15	0
Number of East African near-endemic species shared with adjacent Tanzania	9	25	36

	Number of Species Observed	Number of Species Recorded in Mozambique	Percent
Number of species restricted to the East African Coast biome (Parker, 2001)	13	25	52
Number of species restricted to the Zambezian biome (Parker, 2001)	5	26	19.2

Source: Enviro-Insight, 2012.

As shown in *Figure 8.74*, the observed number of species is within the limit (the curve is approaching saturation) of the number of species expected to occur, and provides a realistic indication of the thoroughness and general coverage of the Survey Area during the survey period.

Figure 8.74 Species Accumulation Curve (Based on 101 Sample Point Count)



Source: Enviro-Insight, 2012.

An analysis (1) based on bird data generated from the 101 point counts showed that the sombre greenbul (*Andropadus importunus*) followed by the dark-capped bulbul (*Pycnonotus tricolor*) were the most prominent species in the Survey Area. Other noteworthy species include the collared sunbird (*Hedydipna collaris*), black-backed puffback (*Dryoscopus cubla*), Cape turtle dove (*Streptopelia capicola*) and green-backed camaroptera (*Camaroptera brachyura*) (*Table 8.29*). These species are widespread and are numerically abundant in

(1) The analysis uses abundance values (absolute counts) and their distribution (the distribution of observations) to estimate the percentage contribution of each species' average abundance value in the Survey Area, as well as its fidelity (represented by the consistency of its occurrence across the point counts) based on the similarities between samples (using calculated similarity coefficients). Therefore, species with high average abundance values and high consistency values across all point counts will achieve higher contributions, and are thus prominent or typical species in the area.

habitat types of both open woodland (dark-capped bulbul and Cape turtle dove) and dense woodland (sombre greenbul and collared sunbird) structure. They are the most dominant species in the Survey Area and are common in the woodlands of the East African coast.

Table 8.29 also shows the dominance of shorebird species recorded during the austral summer period. These include high numbers of crab plover, dimorphic egret and Palaearctic waders. More frequently observed wading birds include the greater sand plover (*Charadrius leschenaultii)*, common whimbrel (*Numenius phaeopus)*, white-fronted plover (*Charadrius marginatus)*, grey plover (*Pluvialis squatarola)*, common ringed plover (*Charadrius hiaticula)*, sanderling (*Calidris alba)* and terek sandpiper (*Xenus cinereus*).

Table 8.29 Prominent Bird Species Observed within the Survey Area

Species	Av. Abundance	Consistency	% Contribution
Sombre greenbul	0.86	2.79	20.66
Dark-capped bulbul	0.76	1.69	12.47
Collared sunbird	0.5	1.23	9.07
Black-backed puffback	0.54	0.79	5.86
Cape turtle dove	0.31	0.56	4.16
Green-backed camaroptera	0.24	0.54	3.96
Tawny-flanked prinia	0.38	0.4	2.95
Emerald-spotted wood dove	0.28	0.39	2.9
Zitting cisticola	0.25	0.35	2.58
Crab plover	4.74	0.31	2.32
Yellow-rumped tinkerbird	0.19	0.31	2.26
Scarlet-chested sunbird	0.3	0.31	2.26
Palaearctic wader complex	5.77	0.27	2.03
Tropical boubou	0.28	0.27	2.02
Purple-banded sunbird	0.23	0.2	1.45
Yellow-breasted apalis	0.25	0.16	1.22
African paradise flycatcher	0.18	0.16	1.16
Yellow-throated longclaw	0.17	0.15	1.11
Yellow-bellied greenbul	0.17	0.14	1.05
Dimorphic egret	0.28	0.14	1

Source: Enviro-Insight, 2012.

Table 8.30 lists the species with the lowest recorded abundance values in the Survey Area. Many of these species were only recorded once during the point count surveys. However, the majority are believed to be widespread in the Survey Area, but always occur in low densities.

Table 8.30 Avian Species within the Survey Area with Low Abundance Values*

Species	Average Abundance
African pygmy kingfisher	0.01
Black crake	0.01
Black cuckoo	0.01
Black sparrowhawk	0.01
Black-eared seed-eater	0.01
Blue-mantled flycatcher	0.01
Broad-tailed paradise whydah	0.01

Species	Average Abundance
Common sandpiper	0.01
Common squacco heron	0.01
Diderick cuckoo	0.01
European golden oriole	0.01
Hadeda ibis	0.01
Lesser moorhen	0.01
Little egret	0.01
Lizard buzzard	0.01
Madagascar pond heron	0.01
Marsh warbler	0.01
Orange-winged pytilia	0.01
Red-backed shrike	0.01
Tambourine dove	0.01
Three-banded plover	0.01
Woodland kingfisher	0.01
Woolly-necked stork	0.01
Yellow-throated petronia	0.01

Key:
* Average abundance of less than 0.02 (n=101).

Source: Enviro-Insight, 2012.

A significant proportion of the low abundant species include medium-sized *Accipitrine* taxa (sparrowhawks and goshawks) and water birds (eg rallids). These species are probably overlooked due to their elusive behaviour. They are often difficult to detect in the dense structure of habitat in which they occur. The remaining species occur naturally at low densities.

8.9.6 *Avian Associations and Community Structure*

A total of 157 (1) species/taxa and 2,963 individuals representing three dissimilar avifaunal communities were recorded from the 101 point counts conducted:

Community 1 – Associated with Intertidal Beaches

Community 1 represents a community restricted to the intertidal beaches. It is characterised by large concentrations of plovers, waders and terns, accompanied by the crab plover and dimorphic egret. Other noteworthy species include the hamerkop (*Scopus umbretta*), African sacred ibis (*Threskiornis aethiopicus*), African openbill (*Anastomus lamelligerus*) and woolly-necked stork (*Ciconia episcopus*). However, these taxa occur in lower densities. The western reef heron (*Egretta gularis*) is an uncommon resident and only recorded occasionally.

(1) Herewith referring to those species observed during the point counts (excluding those noted during random transect walks).

Community 2 – Associated with Coastal Woodland and Azonal Habitat

Community 2 represents a diverse community denoted by four discrete associations confined to coastal woodland and its associated azonal habitat.

Community 2A – Associated with Saline Wetland Habitat

This community is confined to salt marshes and shares part of its composition with Community 1. It is typified by waders and birds that show high affinities for inland bodies of water.

Indicator species for this community include Kittlitz's plover (*Charadrius pecuarius*), wood sandpiper (*Tringa glareola*), little stint (*Calidris minuta*), ruff (*Philomachus pugnax*), marsh sandpiper (*Tringa stagnatilis*) and black-winged stilt (*Himantopus himantopus*).

The wattled crane and saddle-billed stork (*Ephippiorhynchus senegalensis*) occur in low densities.

Community 2B – Associated with Fresh-water Wetland Habitat

This community is confined to fresh-water *dambos* and drainage lines. The dense grassy cover of the fresh-water wetlands are inhabited by a bird composition that is atypical to Community 1 and Community 2A. The only similarity between this community and Community 2A occurs at the family level (herons, storks), where the different taxa show similar morphologies and function. The rallids (rails, crakes and flufftails) are unique to this community.

Indicator species for this community include cryptic taxa such as the zitting cisticola (*Cisticola juncidis*), croaking cisticola (*C. natalensis*), Zanzibar red bishop (*Euplectes nigroventris*), common waxbill (*Estrilda astrild*) and the yellow-throated longclaw (*Macronyx croceus*).

Species unique to this community include rallids and gamebirds; such as the red-chested flufftail (*Sarothrura rufa*), African rail (*Rallus caerulescens*), African crake (*Crecopsis egregia*) and blue quail (*Coturnix adansonii*). The Madagascar pond heron (*Ardeola idae*) and black coucal (*Centropus grillii*) occur in low densities.

Community 2C – Associated with Open Woodland Habitat

This community is largely sedentary on the open woodland and savannah grassland habitat types. It is a species-rich community consisting of so-called bushveld or savannah taxa. A definitive feature of this community is the formation of multispecies flocks (or bird parties), whereby different foraging species join the flock as it advances through the woodland canopy.

Indicator species for this community include the tawny-flanked prinia (*Prinia subflava*), flappet lark (*Mirafra rufocinnamomea*), fork-tailed drongo (*Dicrurus *adsimilis*), pale batis (*Batis soror*), black-crowned tchagra (*Tchagra senegalus*), red-faced crombec (*Sylvietta whytii*) and white-browed scrub robin (*Cossypha heuglini*).

The majority of species pertaining to this community are regionally widespread in sub-Saharan Africa.

Community 2D – Associated with Closed Woodland and Forest Habitat

This community is confined to the closed-canopy *Berlinia orientalis* woodland, the forest fragments and bush clumps. A character shared among most species pertaining to this community is their liquid, complex vocalisations and the tendency to forage in the lower strata or among the leaf litter.

Indicator species for this community include the yellow-rumped tinkerbird (*Pogoniulus bilineatus*), eastern nicator (*Nicator gularis*), red-capped robin-chat (*Cossypha natalensis*), bearded scrub robin (*Cercotrichas quadrivirgata*), square-tailed drongo (*Dicrurus ludwigii*), black-throated wattle-eye (*Platysteira peltata*) and African broadbill (*Smithornis capensis*).

Fischer's greenbul (*Phyllastrephus fischeri*), barred long-tailed cuckoo (*Cercococcyx montanus*), narina trogon (*Apaloderma narina*) and the short-tailed batis (*Batis* sp. nr. *B. mixta reichnowi*) also occur in low densities.

Community 2E – Associated with Closed and Open Woodland Habitat

This community consists of unspecialised and generalist species that are present in open as well as closed-canopy woodland. However, the difference is that the distribution of the abundance values of these species varies depending on the floristic structure of the woodland. For example, the sombre greenbul is commonly encountered in open and closed woodland, but is more common in closed-canopy vegetation. The taxa pertaining to this community are collectively known as edge species, and will often use modified habitats such as agricultural areas for foraging.

Typical species with high abundance values in structurally open woodland are the Cape turtle dove, dark-capped bulbul, emerald-spotted wood dove (*Turtur chalcospilos*), brown-crowned tchagra (*Tchagra australis*), scarlet-chested sunbird (*Chalcomitra senegalensis*) and brown-headed parrot (*Poicephalus cryptoxanthus*).

Typical species with high abundance in structurally closed-canopy woodland include the black-backed puffback, collared sunbird, purple-banded sunbird (*Cinnyris bifasciatus*), African paradise flycatcher (*Terpsiphone viridis*) and green-backed camaroptera.

The cluster analysis also shows that modified palm savannah and coastal thickets are prevalent in Community 2E. Hole-nesting species will temporarily vacate their preferred habitat to use dead palm trees for breeding or roosting purposes.

From the analysis it is also evident that the mangrove forests are occupied by an undifferentiated bird community, even though this habitat type is floristically well defined. However, the mangroves do hold significant numbers of sunbirds, with five different species co-occurring (eg purple-banded, grey, olive, scarlet-chested and collared sunbirds). The sunbirds are the main pollinators of some of the mangrove species.

Community 3 – Seabird Populations

The inshore seabird population within the Study Area was found to be severely species-poor and comprised mainly of marine tern species. The dominant terns include the swift tern (*Sterna bergii*), lesser crested tern (*Sterna bengalensis*), little tern (*Sterna albifrons*) and the common tern (*Sterna hirundo*). The Caspian tern (*Sterna caspia*) occurs in low densities.

An adult male greater frigatebird (*Fregata minor*) and a juvenile red-footed booby (*Sula sula*) sighted near Cabo Delgado Peninsula were regarded as vagrant individuals. These individuals were probably stray birds from the Aldabra Atoll breeding colonies (approximately 640km north-east of the Afungi Project Site).

8.9.7 Species of Conservation Concern

Important Habitat

The intertidal zone provides habitat for at least 22 wading bird species, of which 13 are Palaearctic migrants and five are *Sterna* (tern) species.

During the survey, a total of 1,651 birds were counted on 38ha of coastline of the Afungi Project Site. This indicates that the coastline supports approximately 44 birds/ha during the austral summer (December). *Table 8.31* shows that the intertidal zone supports a high number of shorebirds (with up to 32 percent of the global crab plover population appearing in winter within the Survey Area). Field observations also indicate that the exposed coral at Cabo Delgado (across Palma Bay from the Survey Area) is an important high-tide roosting site for these bird species.

One of the wader species present along the coastline of the Survey Area is the Eurasian curlew (*Numenius arquata*). It is classified as Near Threatened (IUCN, 2012), owing to a moderately rapid decline at several key breeding populations in the northern hemisphere. Its non-breeding habitat is threatened by disturbances of its intertidal foraging habitat and the development of infrastructure on high-tide roosting areas.

Table 8.31 ***Density Estimates of Waders and Terns within the Coastline of the Survey Area****

Taxon Group	Number of Individuals (on 38ha)	Density (birds/ha)
Crab plover	479	12.7
Palaearctic wader complex	794	21.1
Dimorphic egret	28	0.7
Various tern species	116	3.1

Key:
*Estimates obtained during December, 2011.

Source: Enviro Insight, 2012.

Globally Threatened Species

Four globally Threatened and seven Near Threatened bird species were recorded within the Study Area (IUCN, 2010). Of these, five species were observed within the Survey Area (*Table 8.32*) and images of these are provided in *Figure 8.75*. Of these five species, the Madagascar pond heron, wattled crane and the southern banded snake-eagle are likely to be susceptible to habitat changes brought on by development; due to high habitat fidelity (wattled crane and Madagascar pond heron) and limited closed woodland habitat (southern banded snake-eagle). The remaining species (those confirmed in the Survey Area) occupy large home ranges and occur over large areas of similar habitat. These species are therefore at a lower risk.

Table 8.32 ***Global Conservation Status of Avian Species within the Survey Area***

Species	Common Name	Conservation Status*	Status within the Study Area	Occurrence within Survey Area
Anthreptes reichenowi	Plain-backed sunbird	Near Threatened	Uncommon, only recorded from mature woodland	Not recorded, status uncertain, probably absent
Ardeola idae	Madagascar pond heron	Endangered	Fairly common non-breeding (austral winter) visitor from Madagascar	Confirmed from selective pools within fresh-water wetlands
Bucorvus cafer	Southern ground hornbill	Vulnerable	Uncommon resident north of Afungi, close proximity to Tanzanian border	Not recorded, likely to be absent
Circaetus fasciolatus	Southern banded snake-eagle	Near Threatened	Common resident north of Palma	Uncommon resident on Afungi (1-2 pairs)
Falco concolor	Sooty falcon	Near Threatened	Uncommon non-breeding (austral summer) visitor	Rare

Species	Common Name	Conservation Status*	Status within the Study Area	Occurrence within Survey Area
Glareola ocularis	Madagascar pratincole	Vulnerable	Status uncertain – observed overhead from open grassy areas; roosting and foraging areas unknown	Not recorded
Grus carunculatus	Wattled crane	Vulnerable	Uncommon and possible breeding resident in the Rovuma Delta	Confirmed from the salt marsh habitat and wetlands dominated by short Cyperaceae
Numenius arquata	Eurasian curlew	Near Threatened	Common non-breeding visitor along the coastline	Common on the sandy beaches
Polemaetus bellicosus	Martial eagle	Near Threatened	Uncommon foraging visitor (probably from nearby reserves or game management areas)	Not recorded
Rynchops flavirostris	African skimmer	Near Threatened	Common along the Rovuma River	Unlikely to occur within the Survey Area
Terathopius ecaudatus	Bateleur	Near Threatened	Common foraging visitor (probably breeds in nearby reserves or game management areas)	Common foraging visitor

Key:
* The conservation status is based on the IUCN Red List of Threatened Species (2011).

Figure 8.75 ***Bird Species of Global Conservation Interest***

Left: Wattled crane – Vulnerable. Centre: Southern banded snake-eagle – Near Threatened. Right: Madagascar pond heron – Endangered.

Source: Enviro-Insight, 2012.

Biome and Range – Restricted Species

The Afungi Project Site provides habitat for five bird species with Zambezian affinities and 13 with affinities to the East African coastal woodlands (Parker, 2001). The majority of these species are widespread and common in the region, as shown in *Table 8.33*.

Table 8.33 ***Biome Restricted Species***

Scientific Name	Common Name	Biome Type	Habitat	Status within Study Area
Falco dickinsoni	Dickinson's kestrel	Zambezian	Palm savanna	Rare, although breeding in Survey Area
Circaetus fasciolatus	Southern banded snake-eagle	East African Coast	Dense *Berlinia orientalis* woodland – limited by large trees used during hunting	Common resident north of Palma
Poicephalus cryptoxanthus	Brown-hooded parrot	East African Coast	Open woodland with fruit trees	Common in palm savanna (breed in dead palms)
Halcyon senegaloides	Mangrove kingfisher	East African Coast	Mangrove forest and adjacent dense woodland	Common summer visitor
Lybius melanopterus	Brown-breasted barbet	East African Coast	Most habitat types and mangrove trees with mistletoes	Common breeding resident
Phyllastrephus fischeri	Fischer's greenbul	East African Coast	Closed *Berlinia orientalis* woodland/forest	Uncommon breeding resident – common in mature woodland and thicket within the northern part of the Study Area

Scientific Name	Common Name	Biome Type	Habitat	Status within Study Area
Telophorus quadricolor	Gorgeous bush shrike	East African Coast	Mainly coastal thicket, also dense woodland	Common breeding resident
Prionops scopifrons	Chestnut-fronted helmet-shrike	East African Coast	Mature broad-leaved woodland and *Berlinia* forest	Common in mature forests adjacent to the Afungi Project Site – absent in the Survey Area
Batis soror	Pale batis	East African Coast	All woodland habitat types	Vary common breeding resident
Anthreptes reichenowi	Plain-backed sunbird	East African Coast	Mature woodland	Probably absent in the Survey Area – only observed within the northern Study Area
Cinnyris veroxii	Grey sunbird	East African Coast	Closed woodland and mangrove forest	Common breeding resident
Pyrenestes minor	Lesser seedcracker	East African Coast	Mature woodland and adjacent *dambos*	Uncommon breeding resident
Euplectes nigroventris	Zanzibar red bishop	East African Coast	Wetlands	Common breeding resident
Lamprotornis corruscus	Black-bellied starling	East African Coast	Closed woodland	Uncommon breeding resident
Turdus libonyana	Kurrichane thrush	Zambezian	Dense woodland	Common breeding resident
Calamonastes stierlingi	Stierling's barred warbler	Zambezian	Open woodland	Uncommon breeding resident
Cinnyris talatala	White-bellied sunbird	Zambezian	Varied	Common breeding resident
Vidua obtusa	Broad-tailed paradise whydah	Zambezian	Broad-leaved woodland	Common breeding resident

Source: Parker, 2001.

Figure 8.76 Biome Restricted Avian Species Observed within the Survey Area

Top left: Chestnut-fronted helmet-shrike. Top right: Mangrove kingfisher. Bottom left: Brown-breasted barbet. Bottom right: Brown-headed parrot.

Source: Enviro-Insight, October 2011–April 2012.

Locally Threatened Species

These are species that do not meet the IUCN criteria but are listed by Parker (2005) since their numbers are declining in Mozambique. Three species occur in the Afungi Project Site:

- Locust finch (*Paludipasser locustella*): a cryptic species that is highly unpredictable and irregular in occurrence. It is rare in northern Mozambique, and the observations from the Study Area stem from nomadic individuals. It was observed on the Rovuma floodplain, although it can occur on the inundated or moist grassland areas within the Survey Area. It is threatened by wetland disturbances.

- Blue quail: a common species in moist grassland bordering *dambos* and fresh-water wetlands. It is nomadic and can be absent during unfavourable conditions (eg dry years). It is threatened by wetland disturbances.

- Red-headed quelea (*Quelea erythrops*): a fairly common resident and nomad within the Survey Area. It was frequently observed in small groups from dense grassy fresh-water wetlands, especially during the dry season. It is threatened by wetland disturbances and the cage-bird trade.

Apart from the abovementioned species, the following species is worthy of discussion and is likely to occur in the Survey Area:

- African pitta (*Pitta angolensis*): an elusive, intra-African breeding migrant restricted to dense thickets and forested habitat types. It is likely to be a passage migrant to the Study Area. The patches of well-developed *Berlinia orientalis* woodland on the northern part of the Survey Area provide a suitable habitat for this species. It is threatened by deforestation and fragmentation.

Important Non-threatened Species

The following species are worthy of discussion since the Survey Area supports either significant numbers of these species or provides a migration corridor for species on their passage between breeding and non-breeding habitats:

- Crab plover: this species is currently listed as Least Concern since the global population appears to be stable (IUCN, 2012). It is a non-breeding visitor to the east coast of Africa, with the bulk of the population wintering along the Kenyan, Tanzanian and Mozambican coastline (Hockey, 2005; Hockey & Aspinall, 1996).

- Instantaneous counts of non-breeding individuals along the coastline of the Survey Area (479 individuals from 12 counts equalling 12.71birds/ha) suggest that approximately 32.6 percent of the entire global population (estimated at 50,000 individuals by Hockey & Aspinall, 1996; Rose & Scott, 1997) winter on the coastline of the Survey Area (as counted in December 2011). It is interesting to note that Hockey and Aspinall (1996) estimate the Mozambican population to be 500 individuals, while 30ha of suitable habitat in the Survey Area sustains 479 individuals.

- Mangrove kingfisher: this species is currently listed as Least Concern, even though the population trend appears to be declining. This decline is not believed to be sufficiently rapid to approach the vulnerable threshold (IUCN, 2012); however, it is listed as vulnerable in South Africa (Barnes, 2000). It is a local migrant that breeds during the austral summer in coastal woodlands and spend the austral winter in mangrove forests (Turpie, 2005).

- The mangrove kingfisher is fairly common within the Survey Area, and the high number of observations during the late summer season highlights the importance of the mangrove forests during local migration.

8.9.8 *Avifauna Sensitive Habitat*

The avifaunal sensitivity of any piece of land is based on its inherent ecosystem service (eg wetlands) and overall preservation of biodiversity. In addition, the sensitivity of any piece of land is a key consideration when identifying impacts; this is discussed in the Avian Impact Assessment in *Section 12.11*.

<u>Ecological Function</u>
The extent to which a site is ecologically connected to its surrounding areas is an important determinant of its sensitivity. Systems with a high degree of landscape connectivity or with extensive drainage systems between them are perceived to be more sensitive and will be those contributing to important avifaunal flyways or overall preservation of bird diversity.

<u>Avifaunal Importance</u>
Avifaunal importance relates to species diversity, endemism (unique species or unique processes) and the presence of topographical features or primary habitat units with the intrinsic ability to sustain conservation-important species.

<u>Sensitivity Scale</u>

- **High**: High sensitivity ecosystems either have a low inherent resistance or low resilience towards disturbance factors, or are highly dynamic systems considered being important for the maintenance of ecosystem integrity (eg pans, salt marsh habitat). Most of these systems represent ecosystems with high connectivity with important bird flight paths or high bird diversities, while providing suitable habitats for a number of threatened or rare species.

- **Medium**: Medium sensitivity ecosystems are slightly modified systems that occur along gradients of disturbances from low to medium intensity. They have some degree of connectivity with other ecological systems or ecosystems with intermediate levels of species diversity, and may include potential ephemeral habitats for threatened species.

- **Low**: Low sensitivity ecosystems include areas of disturbed/transformed systems with little ecological function. They are generally very poor in species diversity or feature a dominant composition of unspecialised and widespread species.

High Sensitivity Avifaunal Habitat Types

The following habitat types are of High avifaunal importance/High ecological function (see sensitivity map, *Figure 8.77*):

<u>Estuarine Salt Marshes and Fresh-water Wetlands</u>

The salt marsh and fresh-water wetland habitat types represent High sensitivity as they provide critically important avifaunal habitats due to their unique composition of bird species. Both habitat types are spatially limited and restricted. The characteristics of the wetlands and their value towards bird conservation can be summarised as follows:

- Fresh-water wetlands show a linear configuration, which functions as important dispersal corridors for a variety of bird species. These linear networks maintain a high connectivity with other habitat types within the Survey Area and facilitate the movement of bird species between the different habitat types.

- Fresh-water wetlands sustain habitat-specific bird compositions that are regionally unique.

- Fresh-water wetlands and salt marshes sustain additional micro-habitat types (eg open pools, *Cyperus* stands, mudflats) which, in turn, elevate avifaunal species richness. More importantly, these micro-habitat types are colonised by a variety of species, often aquatic-associated species of different guilds (eg fish-eating species, wading birds and waders) that are absent from the adjacent woodlands.

- Fresh-water wetlands and salt marsh vegetation provide habitats for two globally threatened species: the Madagascar pond heron and wattled crane.

<u>Large Intact Forest/Closed Woodland Remnants</u>
These habitat units are considered as High sensitivity due to their distinct floristic structure, patchy occurrence and dense midstrata and understorey. These areas are preferred by elusive bird taxa, many being uncommon and thinly distributed in sub-Saharan Africa. They play an important role as stepping stones for intra-African migrants that disperse along the East African coast. They also provide habitats for Near Threatened species such as the southern banded snake-eagle and a high diversity of East Coast biome-restricted species.

Medium–High Sensitivity Avifaunal Habitat Types

The following habitat types are of Medium–High avifaunal importance.

<u>Intertidal Zone and Mangrove Forests</u>
The intertidal zone and mangrove forests are widespread beyond the borders of the Survey Area. However, both units are important since they support large numbers of migratory bird species during certain times of the year.

The intertidal zone is an important wintering habitat for large numbers of Palaearctic waders, including a significant proportion of the global crab plover population, which winters within the Survey Area.

The mangroves assist bird migration and experience influxes of tropical species during certain times of the year (eg mangrove kingfisher). The upper reaches are also ecologically well connected with fresh-water wetlands.

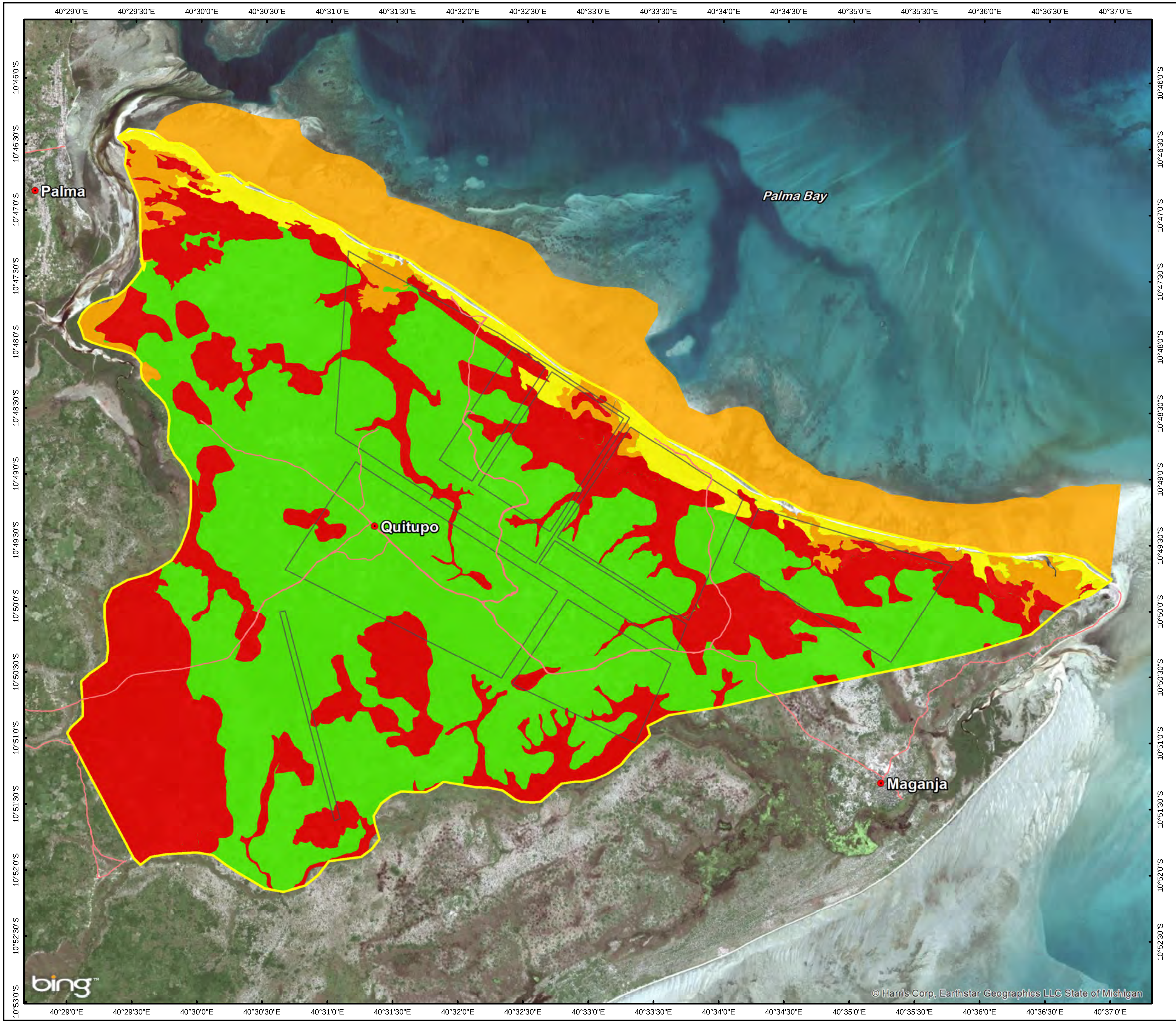
Medium Sensitivity Avifaunal Habitat Types

The following habitat types are of Medium avifaunal importance.

<u>Modified Palm Savannah and Coastal Thicket</u>
These habitat types are slightly modified and present a high density of palm trees. The palm trees (when dead) provide a seasonal breeding and roosting habitat for cavity-roosting/breeding bird taxa – a guild composition that is often severely constrained by the patchy distribution of suitable nesting/roosting space.

Low Sensitivity Avifaunal Habitat Types

<u>Open Woodland</u>
This is the dominant habitat type within the Survey Area, due to large areas having been converted for agriculture. This habitat type is mainly colonised by widespread species and is considered of Low sensitivity.



Legend

- Villages / Settlements
- Local Roads
- Onshore Project Footprint
- Afungi Project Site

Avifauna Sensitivity

- Low
- Medium
- Medium-High
- High

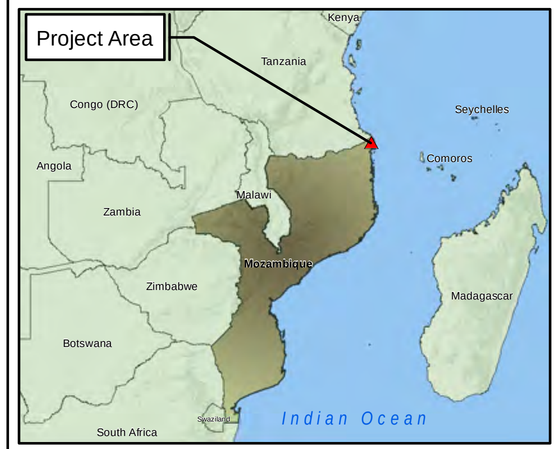


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Figure 8.77: Sensitivity Map Illustrating the Important Avifaunal Habitat

CLIENT:

Anadarko Moçambique Área 1, Lda

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DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 50 000

DRAWING: Sensitivity Map Illustrating the Important Avifaunal Habitat.mxd

REV: A

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Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
Enviro-Insight, 2012.
Inset Map: Esri Data & Maps

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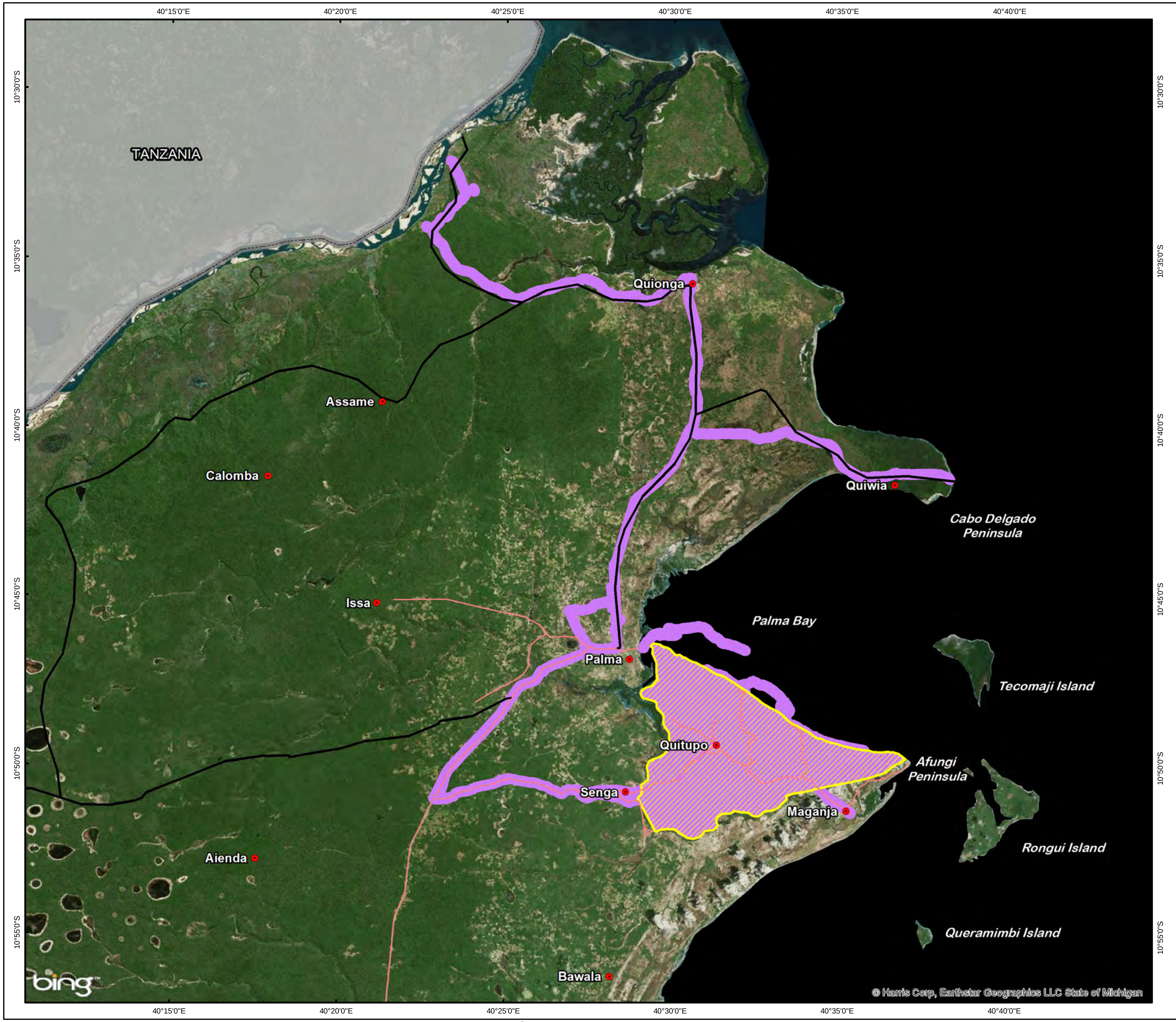
8.10 *MAMMALS*

8.10.1 *Geographical Context*

The mammalian study was conducted within the general vicinity of the Afungi Project Site and main travel corridors to Cabo Delgado Peninsula and the Rovuma River. The Study Area was evaluated to establish a regional context for many of the mammalian taxa, as numerous mammalian species are migratory. The Study Area was investigated by means of qualitative survey methods (direct observations and habitat interpretation) and the resulting data was used to emphasise the importance of the mammalian assemblages in the local context (Survey Area) within the region (Study Area). The Survey Area incorporates the Afungi Project Site and its immediate surroundings, and represents the focus area of the mammalian baseline study. In this area, all mammalian survey methods were employed (interviews, spoor tracking, camera traps, Sherman traps, predator call-ups, direct observations, night drives, habitat and GIS analysis). *Figure 8.78* shows the Survey Area and Study Area for the mammalian study.



Legend

- Villages / Settlements
- Local Roads
- Regional Roads
- Afungi Project Site
- Study Area
- Survey Area

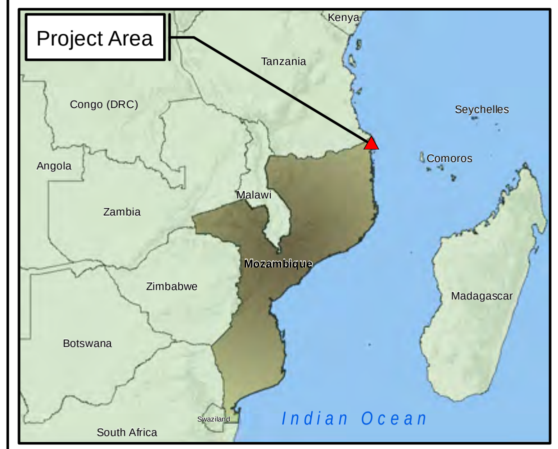


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Figure 8.78:
Mammalian Study and Survey Areas

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Impacto Projectos e Estudos Ambientais

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Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
Enviro-Insight, 2012
Inset Map: Esri Data & Maps

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8.10.2 *Mozambique Regional Mammalian Fauna*

Although Mozambique has a relatively rich diversity of mammalian fauna, much of the intact populations are largely confined to conservation areas (Mozambique Council for Environmental Affairs, 2009). However, the wilderness areas in the western and northern areas of Cabo Delgado Province are known to support large viable mammalian populations, notably of larger mammals, including various Red Data species. Major threats to mammal biodiversity in the region include subsistence hunting and habitat destruction resulting from slash-and-burn agriculture practices, livestock overgrazing and informal settlement sprawl. Such impacts are common to southern African systems that do not afford the protection of recognised national parks.

With regard to larger mammals, many of the threatened species in Mozambique are either hunted for subsistence use, are susceptible to habitat loss or are key factors in human/wildlife conflict. Subsistence use and habitat degradation are similarly key factors affecting the population dynamics of Red Data small mammals in the region.

Mozambique has 232 recorded species of mammal (MICOA, 2009). However, many factors contribute to the difficulty in accurately predicting local assemblages of mammal species. Mozambique is a very large country with highly variable population densities and localised environmental pressures. Therefore, the habitat integrity of a given area and subsequent mammalian diversity needs to be assessed on a site-specific basis. Mammal lists, both Red Data and otherwise, were obtained through the IUCN Red List (2012), Skinner and Chimimba (2007) and MICOA (2009) to provide a predictive focal point for the survey. Thus, the population dynamics of the Survey Area could be compared with the literature and the presence of predicted Red Data species could be evaluated.

8.10.3 *Cabo Delgado Province Mammalian Fauna*

Unlike many areas within Mozambique, Cabo Delgado Province exhibits comparatively broad mammalian density and diversity. The Study Area exhibits strong linkage to many important conservation areas, including the Niassa Conservation Area and Quirimbas National Park, which provide migration corridors for mammals [Ntumi, Ferreira & Van Aarde (2009), Timberlake et al. (2010) and Agreco (2008) National Census of Wildlife]. These areas play significant roles in the national conservation of Red Data mammalian species.

8.10.4 *Primary Mammalian Fauna Groups*

In total, 40 mammal species were recorded during three survey periods. The winter (dry season) survey yielded 34 species, with the same number of species recorded for the summer (wet season) surveys. There were only three species from each season that were not recorded in the other survey period, showing a pattern of very low seasonal differentiation, which is discussed below. The full list of mammal species and their Red Data/protected status is shown in *Table 8.34*.

Table 8.34 Mammals Observed within the Survey Area

Common Name	Scientific Name	IUCN Status
PRIMATES		
Greater galago	*Otolemur crassicaudatus*	LC
Grant's African galago	*Galago granti*	LC
Vervet monkey	*Cercopithicus pygerythrus*	LC
Baboon	*Papio cynocephalus*	LC
CARNIVORA		
African civet	*Civettictis civetta*	LC
African clawless otter	*Aonynx capensis*	LC
African lion	*Panthera leo*	VU
Honey badger	*Mellivora capensis*	LC
Large-spotted genet	*Genetta maculata*	LC
Large-grey mongoose	*Herpestes ichneumon*	LC
Leopard	*Panthera pardus*	NT
Marsh mongoose	*Atilax paludinosus*	LC
Serval	*Lepttailurus serval*	LC
Side-striped jackal	*Canis adustas*	LC
Slender mongoose	*Galerella sanguinea*	LC
Spotted hyaena	*Crocuta crocuta*	CD
RODENTIA		
Bushveld gerbil	*Tatera leucogaster*	LC
Gambian giant rat	*Cricetomys gambianus*	LC
Multimammate mouse	*Mastomys* spp.	LC
Pygmy mouse	*Mus minutoides*	LC
Doormouse	*Graphiurus* spp.	LC
Red bush squirrel	*Paraxerus palliatus*	LC
Red veld rat	*Aethomys*	LC
Striped bush squirrel	*Funisciurus flavivittis*	LC
Spiny mouse	*Acomys spinnosimus*	LC
Tree squirrel	*Paraxerus cepapi*	LC
Water rat	*Dasymys incomptus*	LC
RUMENANTIA		
Bushbuck	*Tragalephus scriptus*	LC
Common duiker	*Sylvicapra grimmea*	LC
Impala	*Aepyceros melampus*	LC
Warthog	*Phacochoerus africanus*	LC
Waterbuck	*Kobus ellipsiprymnus*	LC
WHIPPOMORPHA		
Hippopotamus	*Hippopotamus amphibius*	VU
LAGOMORPHA		
Scrub hare	*Lepus saxitillis*	LC
PROBOSCIDEA		
African elephant	*Loxodonta africana*	VU
MACROSCELIDIDAE		
Four-toed elephant shrew	*Petrodromus tetradactyla*	LC
EULIPOTYPHLA		
Musk shrew	*Cocidura* spp.	LC/DD
Unknown shrew	*Crocidura* spp.	DD
Total number	**38**	

Key:
CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern and DD: Data Deficient, according to IUCN Red Data List, 2012.

Due to the inherently large variations in the mammalian taxa, each group must be assessed separately in the context of Survey Area. Mammalian groups are defined and discussed below.

Herbivores

Very Large Herbivores: Elephant and Hippopotamus

Very large herbivores found in the region include the African elephant (*Loxodonta africana*) and hippopotamus (*Hippopotamus amphibious*). Although additional information on these species is provided in the Threatened and Endangered Mammal Species section, a brief summary is provided here.

African Elephant

The African elephant is the largest terrestrial mammal species on earth, with females weighing up to 3,500kg and males weighing up to 6,000kg. Herd dynamics vary geographically (differences being due to forage availability, hunting pressure, local climate and terrain) but in the Study Area, medium-size herds (10 to 15 individuals) as well as pairs (males) are commonplace; this information was acquired from local communities as well as direct observation. Throughout their range in sub-Saharan Africa, elephants are subjected to pressure from poaching (for both ivory and meat), sanctioned exterminations (agricultural and human conflict) and habitat reduction. The Study Area as a whole may represent an important migratory link between the Niassa reserve and habitats to the south.

Hippopotamus

The hippopotamus is a very large herbivorous species that can weigh up to 3,000kg (very large males). The species is highly social, existing in pods of up to 100, although within the region, the numbers of a given herd would seldom exceed 20. Displaced individuals, mostly males, will often migrate to other suitable areas seeking new habitats and herds. Although primarily aquatic, hippos will walk in excess of 20km at night in search of foraging grounds. The hippopotamus is listed as a vulnerable species in Mozambique due to unsustainable pressures from both local communities and authorities. Historically, the species is responsible for many human fatalities as well as agricultural conflicts. Within the Study Area, the Rovuma River provides a habitat for most of the hippopotamus in the area. However, some individuals are known to migrate temporarily into the Afungi Project Site in search of new habitats. This area is not considered to be a stronghold for the species in the Study Area or region.

Large Herbivores

Large herbivores found in the region include impala (*Aeypeceros melampus*), kudu (*Tragalephus strepticeros*), warthog (*Phacochoerus africanus*) and sable antelope (*Hippotragus niger*), which have been recorded by Timberlake et al. (2010). Due to constant subsistence use as well as some small-scale habitat clearing, very few large herbivores remain within the Survey Area or the peninsula as a whole. Regionally, most of the large herbivore activity is located to the north on Cabo Delgado Peninsula, near the Rovuma River or inland to the west of the Study Area. The western interior regions of Cabo Delgado Peninsula and the Rovuma River all show large tracts of intact habitat and lower human densities. However, bushbuck (*Tragalephus scriptus*), a large/medium-sized ungulate, were sighted frequently throughout the Survey Area. The reason for this could be the refuge provided by the dense habitats.

Small Herbivores

Small herbivores occur throughout the Survey Area and were sighted frequently, albeit in relatively low densities. Grey duikers (*Sylvicapra grimmea*) and suni (*Neotragus moschatus*) were sighted on numerous occasions during all the survey periods, with frequent records of spoor and scat. As a taxonomic group, small ungulates are far more resilient than their larger counterparts, primarily due to their ability to take refuge in a wider range of habitats and their lower densities. Small herbivores are often among the last of the mammalian taxa to be eliminated in heavily disturbed or heavily used areas. However, these species are targeted by local communities as a food source.

Carnivores

Large Carnivores

Larger carnivores exhibit a strong presence throughout the region, including within the Survey Area. Relevant species include spotted hyena (*Crocuta crocuta*), African lion (*Panthera leo*), leopard (*Panthera pardus*) and African wild dog (*Lycaon pictus*), which has been recorded in the region by Timberlake et al. (2009). There is likely an inadequate supply of food to support viable populations of lions and wild dogs within the Survey Area. However, leopards have a highly variable diet and spotted hyenas are opportunistic predators; both species were recorded on numerous occasions within the Survey Area and throughout the region. Reports from the towns of Maganja and Senga indicate lions are periodically present, but not resident to the Survey Area; these incursions are at best sporadic. On a regional scale, lions were recorded on Cabo Delgado Peninsula and are said to infiltrate the area regularly. This has been witnessed by local communities as well as Project staff. From a health and safety perspective, the lions in the region occasionally resort to man-eating, as was the case in 2008/2009 when two lions killed 28 people over a period of 12 months.

Meso-carnivores

This taxonomic group was observed to be by far the most numerous within both the region and the Survey Area. Relevant species include honey badger (*Mellivora capensis*), side-striped jackal (*Canis adustas*), African clawless otter (*Aonynx capensis*), serval (*Leptailurus serval*), water mongoose (*Atilax paludinosus*), large grey mongoose (*Herpestes ichneumon*) and African civet (*Civettictis civetta*). This strong presence could be explained by a number of factors. First, the African dog (*Canis africanus*) is uncommon in the area. This species severely depletes prey supplies throughout Mozambique and serves as an apex predator throughout most of the central and southern parts of the country. Second and most important, the food supply (especially within the feeding spectrum of meso-carnivores) is still highly functional. Wetland areas exhibit an extremely high density of amphibians, the mangrove areas show massive densities of large crabs, all of which are preyed upon by the above-mentioned species. Finally, meso-carnivores often react positively to the presence of humans (in the absence of large densities of African dogs) and will readily forage on anthropogenic food sources. Side-striped jackals, servals, water mongooses and African civets were all seen frequently in dens or foraging next to human settlements both in the region and within the Survey Area.

Small Carnivores

Small carnivores include species of mongoose, the genet (*Genetta* spp.), polecat (*Ictonyx striatus*) and African weasel (*Poecilogale albinucha*) (Mozambique protected species). Of these species, slender mongooses (*Galerella sanguinea*) and spotted genets were seen frequently throughout the region and within the Survey Area. These species are usually highly resilient and respond positively to human presence, as they readily use anthropogenic food sources or feed on the rodents that are attracted to human settlements. These species are not dependent on specific habitat requirements; therefore, most habitat types are suitable to meet the ecological requirements of these species. Dietary requirements are equally broad, which increases the adaptability of the group and therefore the overall resilience.

Primates

Species from this taxonomic group include the vervet monkey (*Cercopithecus aethiops pygerythrus*), yellow baboon (*Papio cynocephalus*), thick-tailed bushbaby (*Otolemur crassicaudatus*) and Grant's galago (*Galago grantii*). These species of primates were frequently sighted, both within the Survey Area and the region as a whole. The Sykes' monkey (*Cercopithecus albogularis*) was expected in the region but was not recorded. By Mozambican standards, the diurnal primate species observed were extremely confident in their behaviour, showing strong interest in humans and human settlement. Nocturnal primates such as thick-tailed bushbabies and Grant's galagos were fairly abundant, probably due to the lack of means for the local inhabitants to harvest them (ie no torches). The regional landscape-level likelihood of occurrence for primates was not mapped, due to the complete broad-spectrum habitat usage of the group.

Small Mammals

Species from these taxa include mammal species below 1kg in weight. This includes most species of rodent, lagomorph, sengi and shrew. The Survey Area exhibited a low abundance and density of small mammals, which only showed significant presence within close proximity to wetland areas. The reasons for this are conjecture, although some assumptions can be made, which include:

- poorly developed basal layer in much of the study area, providing poor refugia and forage;
- relatively low diversity of small mammal habitats throughout the site;
- suboptimal and homogeneous dominant substrate; and
- rich density of meso-predators.

8.10.5 Species of Conservation Concern

Globally Threatened Species

Confusion still persists regarding which is the most appropriate information source to use when discussing species of conservation concern. The most common method is to examine lists generated by Mozambican conservation authorities as well as the list of IUCN globally threatened and regionally threatened species. In addition, the Convention for the Trade in Endangered Species (CITES) can be consulted regarding the use and exploitation of mammalian species. By examining all available sources of information, a list of relevant threatened species for a particular area can be finalised. The combined list of IUCN global and Mozambican threatened species, their Red Data status and site-specific information, as well as the probability of occurrence in the Survey Area, is shown in *Table 8.35*. In addition, species protected by the Mozambican Ministry of Agriculture and Rural Development Regulation of Forestry and Wildlife (2002) must be considered.

Table 8.35 Probability of Occurrence of Red Data Mammals in the Study Area

Common Name	Scientific Name	IUCN[1]	Likelihood[2]	Site-specific Information
Globally Threatened Species in the Region				
CARNIVORA				
African wild dog	*Lycaon pictus*	EN	Moderate	Confirmed north on Cabo Delgado Peninsula and the Rovuma River
Brown hyena	*Parahyaena brunnea*	NT	Nil	Not within known distribution
Cheetah	*Acionynx jubatus*	VU	Low	Suboptimal habitat
Leopard	*Panthera pardus*	NT	Confirmed	Confirmed in Palma and in the Afungi Study Area
Lion	*Panthera leo*	VU	Medium	Confirmed on Cabo Delgado Peninsula
PROBOSCIDEA				
Elephant	*Loxodonta africana*	NT	Confirmed	Confirmed in areas adjacent to and south of the Rovuma River
PERRISIDACTYLA				
White rhinoceros	*Ceratotherium simum*	NT	Nil	Locally extinct
Black rhinoceros	*Diceros bicornis*	CR	Nil	Regional stronghold several hundred kilometres to the west
WHIPPOMORPHA				

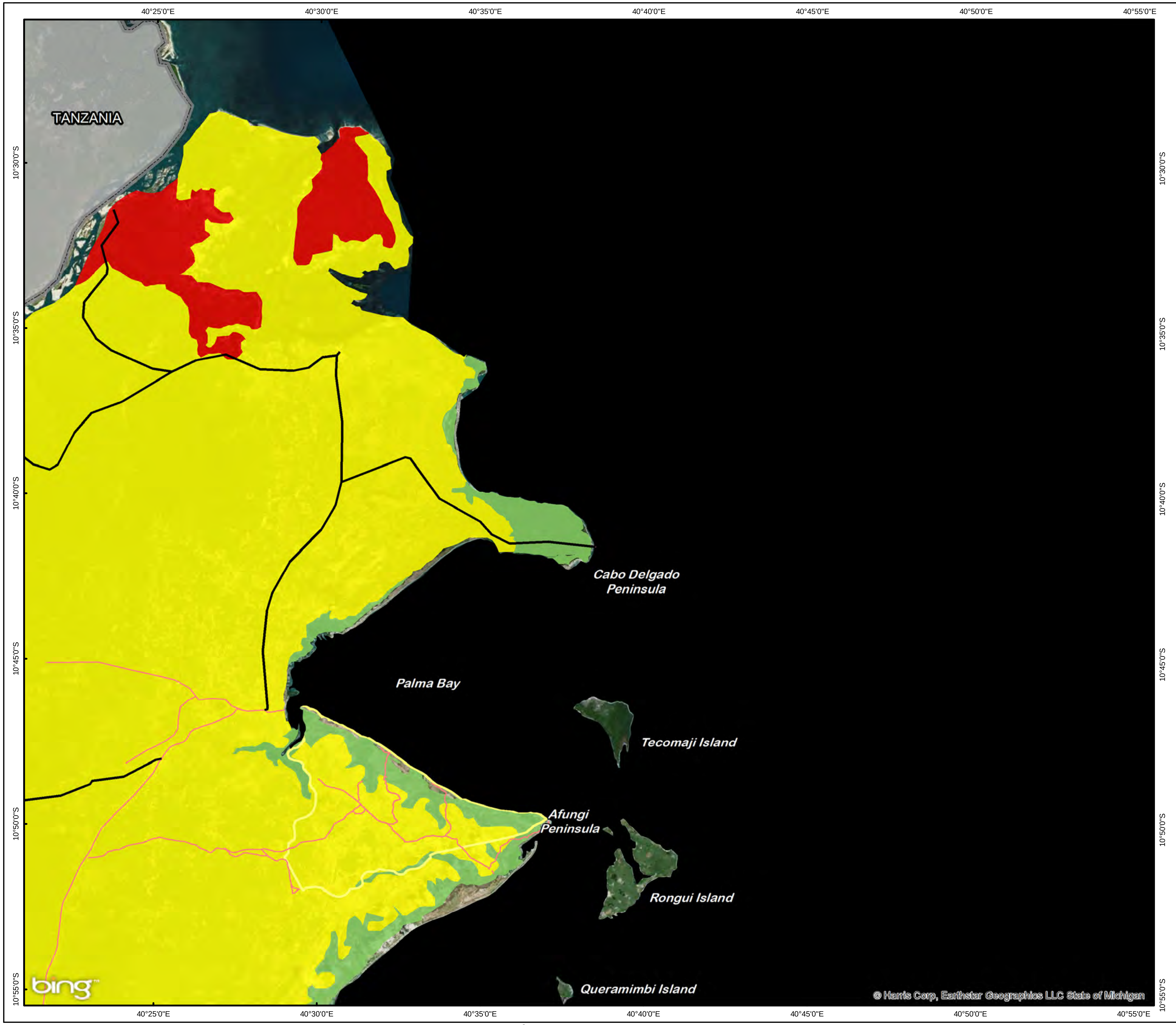
Common Name	Scientific Name	IUCN[1]	Likelihood[2]	Site-specific Information
Hippopotamus	*Hippopotamus amphibius*	VU	Confirmed	Confirmed in the Survey Area although considered to be vagrant. Common in the Rovuma River and within inland wetlands
RODENTIA				
Vincent's bush squirrel	*Paraxerus vincenti*	EN	Low	Not within known distribution
Checkered sengi	*Rhynchocyon cirnei*	NT	Low	Not within known distribution
Delectable soft-furred mouse	*Praomys delectorum*	NT	Low	Not within known distribution
Malawi galago	*Galagoides nyasae*	DD	Low	Not within known distribution
Dusky elephant shrew	*Elephantulus fuscus*	DD	Medium	May occur in region
Arend's golden mole	*Carpitalpa arendsi*	VU	Low	Not within known distribution
PHOLIDOTA				
Pangolin	*Manis temminckii*	NT	Medium	Consistently confirmed by local communities as a utilisable species
RUMENANTIA				
Giraffe	*Giraffe camelopardalis*	LC	Nil	Locally extinct
Mountain reedbuck	*Redunca fulvorufula*	LC	Nil	Not within known distribution
Roan antelope	*Hippotragus equinus*	LC	Medium	Unlikely to occur in area due to sustained hunting pressure
Sitatunga	*Tragalephus speki*	NT	Nil	Unlikely to occur in area due to sustained hunting pressure
Tsessebe	*Damaliscus lunatus*	LC	Low	Unsuitable habitat

Key:
CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern and DD: Data Deficient, according to IUCN Red Data List, 2012.
Low: infrequent incursions are possible, but overall unlikely to occur within the Survey Area.
Medium: regular periodic incursions into the Survey Area, although non-resident.
High: resident in the Survey Area on a permanent to semi-permanent basis.
Confirmed: observed in the Survey Area (includes observation of tracks).
Nil: no chance of occurring within the Survey Area due to inadequate habitat or the area being outside of all known distributions.

The landscape scale of the Red Data potential of the overall Study Area is illustrated in *Figure 8.79*. This map shows the likelihood of occurrence for sensitive Red Data species, based on the following factors:

- known distribution of Red Data species in the region;
- habitat potential (ecological requirements); and
- connectivity to surrounding wilderness and conservation zones.

Four of the recorded mammal species are listed as IUCN Red Data in Mozambique (namely African lion, African elephant, hippopotamus and leopard), and nine species are listed as protected by the Mozambican Forestry Act of 1999/2002 (African civet, African clawless otter, large grey mongoose, marsh mongoose, slender mongoose, large-spotted genet, honey badger, serval and side-striped jackal). Only the leopard can be considered to be a permanent resident of the Afungi Project Site. The other species, although resident in the region, will at most make periodic incursions to the Afungi Peninsula. Of the Mozambican protected species, most have been addressed in detail in the above section, describing the prevailing mammalian assemblages in the region.



Legend

- Regional Roads
- Local Roads
- Afungi Project Site

Likelihood of Occurrence

- Low-Medium
- Medium
- High

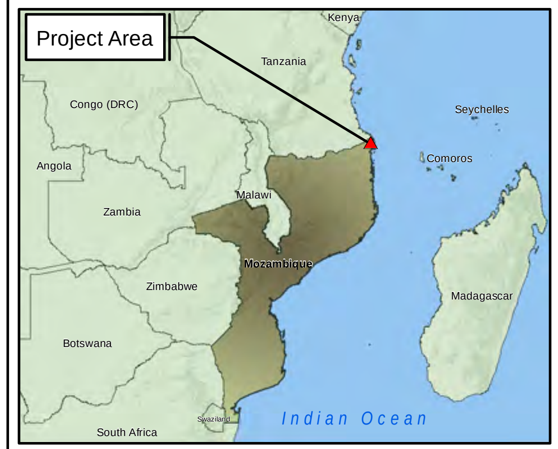


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Figure 8.79 Regional Likelihood of Occurrence for Combined Red-Data Species

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 160 000

DRAWING: Regional Likelihood of Occurrence for Combined Red-Data Species.mxd

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Projection: UTM Zone 37 S Datum: WGS84
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Inset Map: Esri Data & Maps

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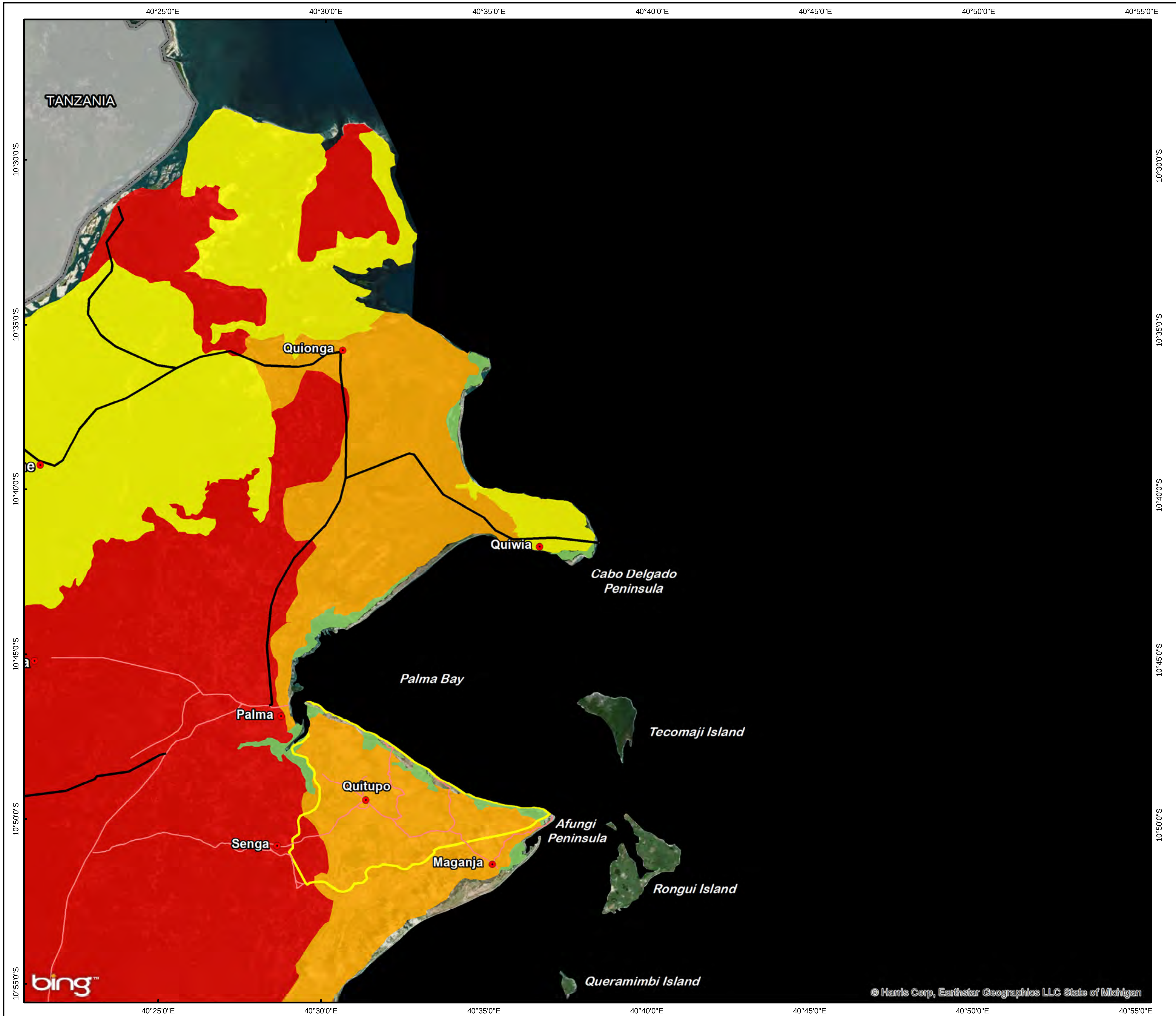
8.10.6 *Mammalian Sensitivity*

Regional Mammalian Sensitivity

On a regional landscape scale, Afungi Peninsula as a whole exhibits Low and Medium–High sensitivity (*Figure 8.80* below). There are a number of key reasons for this. From a geographical perspective, a peninsula is bordered by ocean on three sides, thus reducing its capacity as a migratory pathway. This creates a form of island scenario (from a migratory point of view), isolating the area from migratory corridors. Areas to the north, such as the Rovuma delta and areas inland, form valuable components of historical migratory routes to areas such as the Niassa Conservation Area (Anderson & Pariela, 2005). The prevailing habitat of Afungi Peninsula is predominated by relatively non-sensitive habitat types and is lacking very large tracts of the more sensitive Vegetation Units, such as primary wetlands leading into grassland *dambos* and forests. Although these units are present, they are not as prevalent as in the areas further north. Finally, Afungi Peninsula shows a much stronger degree of transformation from human land use than other areas in the region.

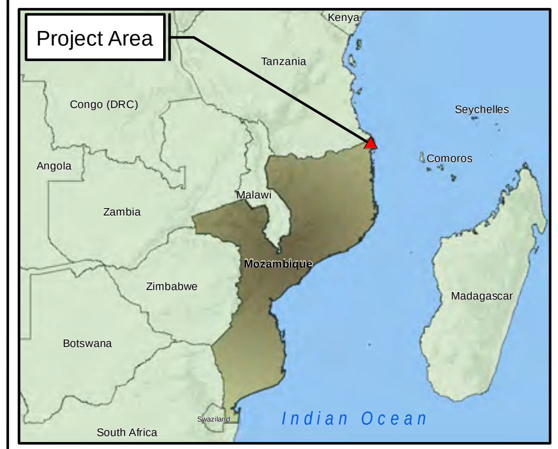


Legend

- Villages / Settlements
- Local Roads
- Regional Roads
- Afungi Project Site

Regional Mammal Sensitivity

- Low
- Low-Medium
- Medium-High
- High



MAIN MAP SCALE:

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Kilometers

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Figure 8.80
Regional Mammalian Sensitivity

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
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DRAWING: Regional Mammalian Sensitivity.mxd

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Relationship between Vegetation Units and Mammalian Sensitivity

As noted in *Section 8.7*, the Afungi Project Site contains seven Vegetation Units. *Table 8.36* provides an overview of how the various mammalian species use these Vegetation Units, and the accompanying text provides additional details.

Table 8.36 Description of the Vegetation Units in a Mammalian Context

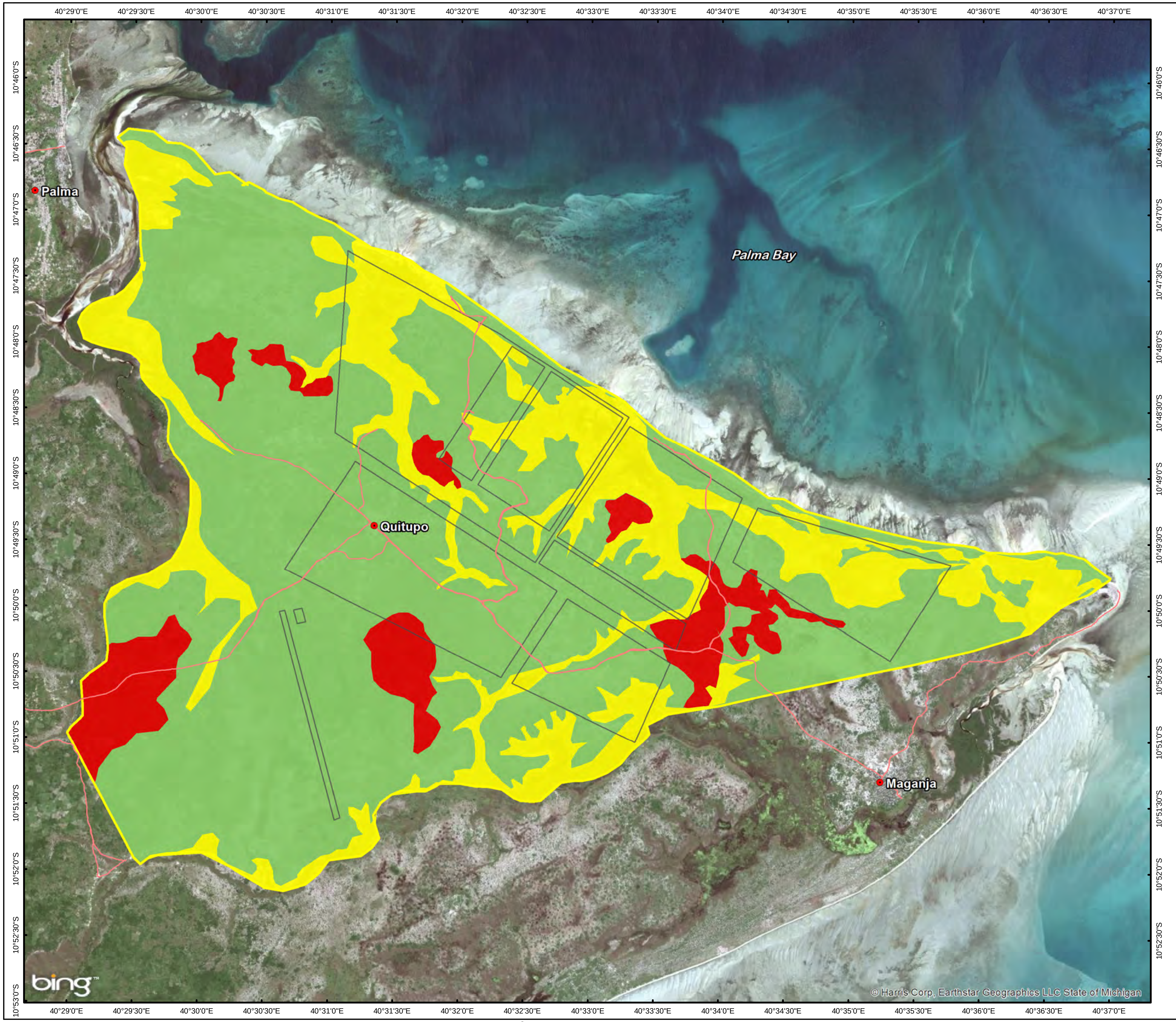
Vegetation Unit	Sensitivity	Remarks
1	**Low**	This habitat is represented by a thin littoral zone lining the coastline of the Survey Area. The primary structure is an artificial vegetation assemblage, due to the cultivation of coconut palms in the region. Mammal species sampled include small carnivores (most likely scavenging fish, crustaceans or anthropogenic food sources) and diurnal primates. Due to a lack of available forage, poor refugia potential and high human habitation, this habitat type is considered to be of Low mammalian sensitivity.
2	**Medium**	The mangrove stands in the study site are characterised by variable structure, zero basal herbaceous layer and high salinity substrates. These ecological conditions basically eliminate grazing potential for any ungulates, as well as small mammals. However, there exists an extremely productive macro-invertebrate density (crabs), which gives rise to very frequent foraging incursions from meso-predators such as jackal, serval, water mongoose, otter, civet and genet. Therefore, this habitat type is considered to be of Medium mammalian sensitivity.
3	**Medium**	This ecotone (1) is characterised by high salinity substrate as well as areas of tidal flats and open woody (mangrove) stands. It shows almost non-existent refuge or grazing potential and therefore eliminates the potential of most mammalian species to persist on a permanent basis. The area is, however, a prime habitat for macro-invertebrates (crabs), which provide forage potential for meso carnivores and small carnivores such as African clawless otter, genet, mongooses, jackals, servals and civet. Being an important ecotone, the overall mammalian sensitivity is Medium.
4 & 6	**Medium**	Vegetation Units 4 and 6 have been discussed together, due to their similarities and relevant cross-applicability to mammalian fauna. The short closed grasslands and short open woodlands form a type of a mosaic that feed into each other extensively. This vegetation type is structurally referred to as mixed open woodlands and/or short closed grassland, which often occurs as a dominant mosaic within the Survey Area. It makes up the bulk of what may commonly be referred to as dominant duneveld. Although it is one of the most widespread of the habitat types, these units are not highly sensitive from a mammalian perspective, due to the relatively sterile sandy substrate, variable slash-and-burn agricultural regimes and variable basal layers. Therefore, this habitat type is considered to be Medium mammalian sensitivity.
5	**High**	These areas are characterised by permanent, semi-permanent or seasonally inundated grassy wetlands, giving way to swampy forested islands. These marshy areas show grazing potential for small and larger ungulates as well as the strong meso-predator assemblage found within the area, which most likely frequents the area due to the extremely high density of prey populations

(1) An ecotone is a transition zone between two habitats.

Vegetation Unit	Sensitivity	Remarks
		(amphibians, rodents and reptiles). Especially where the *dambos* lead into permanent wetlands and associated closed forests, the overall mammal sensitivity of this habitat type is considered to be High.
7	**Medium to High**	This is a fragmented habitat that structurally resembles closed or semi-closed woodland. Although highly fragmented within the Survey Area, the vegetation type is prevalent in and around the Palma region and near the Rovuma River. Although this habitat provides refugia for many of the taxonomic groups, including meso and small carnivores, small ungulates and arboreal primates, the forage potential is generally low. The mammalian sensitivity of this habitat varies between Medium (fragmented secondary regrowth) and High, depending on the complexity of the vegetation and the proximity to permanent wetlands.

Mammalian Sensitivity within the Survey Area

The majority of the Afungi Project Site is of Medium and Low mammalian sensitivity, due to the overwhelming presence of Medium and Low sensitivity mammalian habitat types. Areas of Low sensitivity include the mangrove regions and the wetland *dambos*, which showed forage potential for many of the prevalent mammalian taxonomic groups. However, a single group (meso-predators) use these areas and therefore, the habitat is not considered sensitive. The intact closed woodland habitats occurring to the west of the Project Footprint Area and the permanent wetlands and drainage areas interspersed throughout are considered of High sensitivity. Both these areas are characterised by habitat integrity as well as structural diversity. The primary woodlands are interspersed by low hills and ecotonal forest woodlands, whilst the wetlands often lead into canopy forest and/or grassy *dambos* and provide corridor linkages throughout the area. These areas are illustrated in red in *Figure 8.81* below.



Legend

- Villages / Settlements
- Local Roads
- Onshore Project Footprint
- Afungi Project Site

Mammal Sensitivity

- Low
- Med
- High

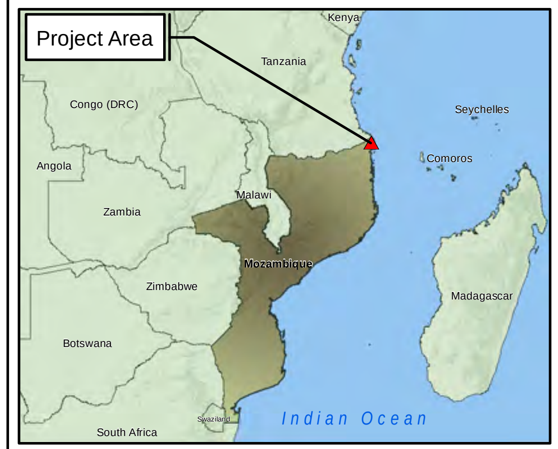


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Figure 8.81:
Mammal Sensitivity within the Afungi Project Site

CLIENT:

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eni

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
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DRAWING: Mammal Sensitivity within the Afungi Project Site.mxd

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Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
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Inset Map: Esri Data & Maps

SIZE: A3

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Local Knowledge and Interviews

The following summary information was obtained from the interviews from the towns of Quitupo, Senga and Maganja and a number of smaller communities and hunters throughout the Study Area and Survey Area. Due to the descriptive nature of the answers, it is not possible to represent the data graphically.

- Extensive subsistence use of mammals by local communities takes place throughout the Survey Area, the Afungi Peninsula and the region as a whole.

- Although some incursions by larger ungulate species do take place south of the Rovuma River, most mammal species found or actively hunted in the Survey Area are small mammals (rodents, shrews), meso-sized species (mongooses, genets, rabbits), arboreal species (bushbabies, squirrels, tree rats) or small antelope [primarily duiker (*Sylvicapra grimmea)* and suni (*Neotragus moschatus*)].

- Larger antelope species, primarily bushbuck and greater kudu, impala, roan antelope (*Hippotragus equines*) and sable antelope (*Hippotragus niger*), are primarily located within and north of Cabo Delgado Peninsula, as well as in the western corridors towards Niassa Province.

- All antelope species are coveted as a source of food within the Survey Area. Hunting methods primarily involve the use of snares and, in some cases, bows and arrows. In corroboration with the baseline data, the local inhabitants state that few larger antelope exist within the actual Survey Area, with larger species being found to the north and west.

- The Red Data species most often seen is the African elephant, which are prominent north of Cabo Delgado Peninsula. Hippopotamus show a permanent presence in the Rovuma River and the larger wetlands to the west and south-west of the Survey Area.

- Hippopotamus are seen as a threat to crops and human lives. However, hippopotamus rarely make incursions into the Survey Area.

- Large carnivores are often seen within the region and within the Survey Area. Red Data species such as leopard (IUCN Near Threatened) and lion (IUCN Vulnerable) are infrequently encountered within the Survey Area, but more often encountered within Cabo Delgado Peninsula and the areas surrounding the Rovuma River. Lions in the Palma area have historically preyed on both humans and livestock, and the attitude towards lions is overwhelmingly negative. However, due to the large presence of tsetse fly in the area, livestock losses due to carnivores are not considered to be a primary concern. The most common large carnivore in the area is the spotted hyena, which is said to rely on anthropogenic food sources (such as livestock and human refuse).

- All the local communities interviewed use small mammals as a staple food source. Methods of acquisition vary slightly between communities, but encompass burning of the basal layer to isolate mice and burrows, which are dug out of burrow systems.

- Significant conflict exists between local communities and elephants. Elephants often raid croplands, although this was mostly confined to the areas immediately adjacent to or within Cabo Delgado Peninsula and the Rovuma River area. Six out of 16 (38 percent) of the interview events were aware that the unauthorised killing of problem elephants was illegal. In recent memory, no human has been killed by elephants throughout the region, despite numerous crop-raiding events. The National Wildlife Census (2008) corroborates these findings, showing the Study Area to be in the highest density zone in terms of elephant crop raids, yet showing zero fatalities from elephants throughout the survey period.

- The pangolin (*Manis temmincki*) is seldom seen by most of the communities on Afungi Peninsula. As with most of Mozambique, the animal itself is one of superstition. Only one of the communities actively seeks out the animal for traditional medicine. One the communities (Maganja) reveres the pangolin as its totem animal and it is forbidden by the local chief to harm the animal. Hunters from the community capture individual animals, but do not kill or consume them. Rather, any captured animals are sequestered for a period of time and are involved in prayer rituals before being released. However, all other communities and individuals interviewed kill and consume the pangolin and consider it to be a delicacy. Pangolins are not traded to market in larger towns for currency. The fact that pangolins are a protected species is not known by local communities.

A high level of confidence can be placed in these interview results, for several reasons:

- Species identifications were facilitated using relevant field guides. Interview subjects were asked to give the local name and well as to provide any additional information (habitat, behaviour, vocalisations), to the satisfaction of the specialist.

- Although only 16 sets of interviews were conducted, answers usually resulted from the general consensus of many members of the community, facilitated by elders and hunters (mostly males). The women in the village offered useful information on crop raiding by elephants and hippopotamuses.

- Finally, interview subjects were mainly restricted to males in the community, preferably hunters, elders or members who spend much time in the Study Area (women tending crops) and had the relevant knowledge to assist in the process.

8.10.7 Health and Safety Analysis

There are a number of mammalian species in the Afungi Project Site that can potentially be of considerable danger to humans, and pose a health and safety risk to the Project. This analysis (1) is based on the number of observations of dangerous mammals (or signs of dangerous mammals) onsite, as well as:

- suitable habitat conditions for potentially dangerous species;
- further analysis of results from local interviews; and
- analysis of historical human/wildlife conflict data.

The potentially dangerous species and the risk associated with each of three distinct areas are shown in *Table 8.37*.

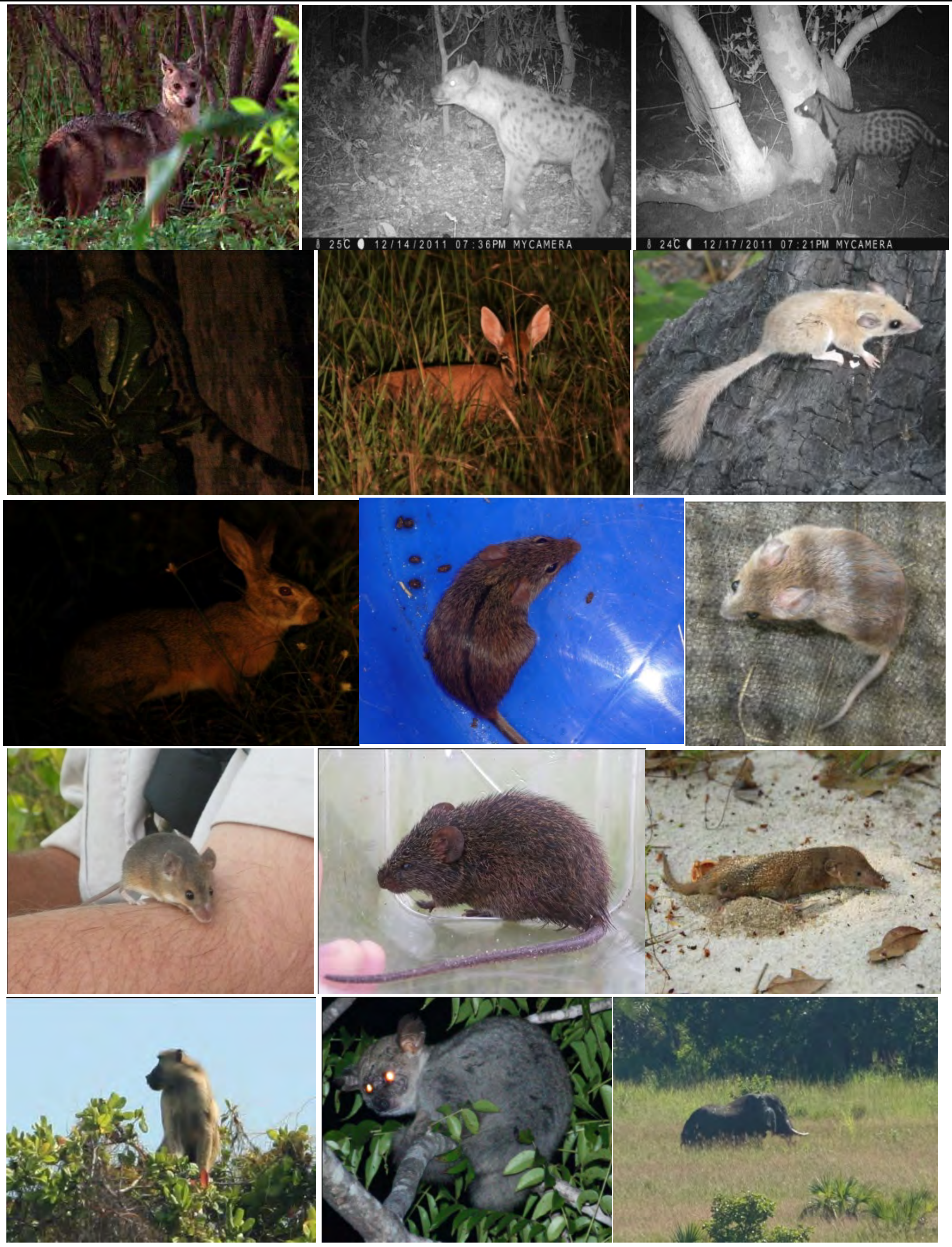
Table 8.37 Health and Safety Analysis for Potentially Dangerous Mammals

Species	**Afungi Project Site**	**Cabo Delgado Peninsula**	**Rovuma District**
African elephant	Low	Medium	High
Lion	Low	Medium	High
Leopard	Low	Low	Low
Spotted hyena	Low	Low	Low
Hippopotamus	Low	Low	High

Source: Enviro-Insight, 2012.

(1) Methodology for analysis is described in *Annex C*.

Figure 8.82 A Selection of Mammal Photographs Taken during the Field Surveys



Left to right, top to bottom: side-striped jackal, spotted hyaena, African civet, large-spotted genet, common duiker, dormouse, scrub hare, single-striped mouse, fat mouse, pygmy mouse, water rat, musk shrew, yellow baboon, thick-tailed bushbaby, African elephant.

Source: Enviro-Insight, 2011 and 2012.

8.11 *SUMMARY OF KEY ONSHORE ENVIRONMENTAL SENSITIVITIES*

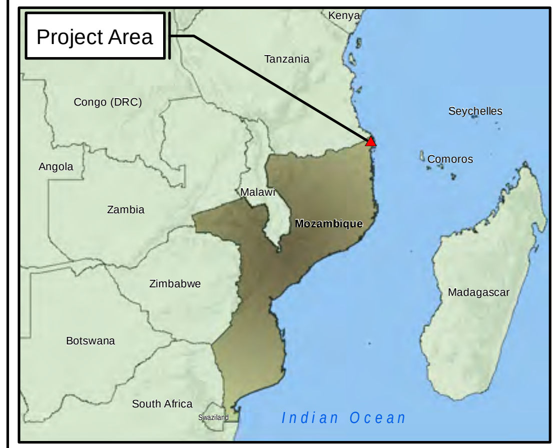
The following section provides an overview of the primary sensitivities associated with each of the specialist disciplines and baseline studies described in this chapter. This section provides a short summary of the main issues to take cognisance of when assessing potential impacts or developing mitigation measures. The sensitivity maps provided in *Sections 8.6* to *8.10* have been overlaid in *Figure 8.83* to highlight these overlapping habitat sensitivities.

Legend

- Villages / Settlements
- Local Roads
- Nearshore Components
- Onshore Layout
- Airstrip
- Afungi Project Site

Sensitivity Rating

- Very High
- High
- Medium-High
- Med
- Low
- 150m Buffer



MAIN MAP SCALE:

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Figure 8.83: Key Onshore Environmental Sensitivities

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: AS	PROJECT: 0133576
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DRAWING: Key Onshore Environmental Sensitivities.mxd

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SIZE: A3

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8.11.1 Sensitive Habitat Types

Flora

Three of the Vegetation Units fall within the High to Very High sensitivity category: Vegetation Unit 2 – Short Closed Marshland (Very High), Vegetation Unit 5 –: Short Closed Wetlands (Very High) and Vegetation Unit 7 – Short Closed Woodland (High). These Vegetation Units support the ecological functions of the animal communities discussed below.

Herpetofauna

Fresh-water wetland systems are classified as High sensitivity areas for herpetofauna as they serve as active breeding grounds for more than half the year. In turn, vertebrate predators rely on the extensive amphibian population as a source of food. The fresh-water wetlands are therefore a fundamental part of the herpetofauna community and all other vertebrate communities that rely on the herpetofauna assemblages. Several large reptile species, including the Vulnerable southern African python, exist in the fresh-water wetland systems. Additionally, a potentially new species of fossorial legless skink was discovered in these areas.

Contiguous trees are classified as Medium–High sensitivity as they provide a significant structural habitat for herpetofauna. In addition to the value this habitat provides to herpetofauna, predators use the thick stands of trees as foraging sites. Leaves and hollow logs act as refuge and shelter, and detritus tree material attracts insects and other invertebrates as valuable food sources. Only a few large stands of this landscape type still remain intact and, in conjunction with the refugia and foraging potential, increases the sensitivity classification of this area.

Avifauna

High sensitivity avian habitat types include the estuarine salt marshes and fresh-water wetlands of Vegetation Units 3 and 5, as well as the large intact forest/closed woodlands of Vegetation Unit 7. Medium–High sensitivity avifaunal habitat types include the mangrove forests associated with Vegetation Unit 2 and the intertidal zone. All these areas play an importance ecological function for resident and transient avian species within the Afungi Project Site.

The estuarine salt marshes and fresh-water wetland networks connect other habitat types within the Afungi Project Site and support the movement of bird species between habitats. They sustain habitat conditions and micro-habitat types that contribute to the diverse avifauna found in these areas, including for two globally threatened species: the Madagascar pond heron and wattled crane. Large intact forest/closed woodlands are considered High sensitivity as they play a role for intra-African migratory birds that disperse along the East African coast. They also provide habitats for several Near Threatened species. The intertidal zone and mangrove forests support large numbers of migratory bird species, serve as a winter habitat and are ecologically connected to fresh-water wetland networks, which gives them a Medium–High sensitivity rating.

Mammals

The Afungi Project Site as a whole exhibits Low to Medium mammalian sensitivity; however, the fresh-water wetlands associated with Vegetation Unit 5 exhibit a High mammalian sensitivity. These areas provide forage for grazing mammals and meso-predators reliant on the density of prey populations (amphibians, rodents and reptiles). The sensitivity of the closed woodlands of Vegetation Unit 7 varies between High and Medium; this sensitivity is dependent on the complexity of the vegetation and the proximity to permanent wetlands. This habitat provides refugia for many taxonomic groups (meso and small carnivores, small ungulates and arboreal primates). However, the forage potential is generally low.

8.11.2 Integrated Onshore Sensitivities

The various habitat types present within the Afungi Project Site are ecologically linked and are largely dependent on the surface-water flow regime. A commonality among the faunal groups discussed above is a high degree of reliance on Vegetation Units 5 and 7.

The short closed wetland areas associated with Vegetation Unit 5 are an integral component of the overall biodiversity of the Afungi Project Site. All fauna groups are reliant on the attributes these fresh-water wetlands provide (ie habitats for feeding, breeding, nesting, migration and refugia). Furthermore, amphibians (primarily frogs) occupy the base of the food chain for a majority of the species in the area. As the amphibian life cycle is tied to these wetland areas, it stands to reason that the overall well-being of the vertebrate community will therefore also rely upon the maintenance of the fresh-water wetland habitat.

The short closed woodlands of Vegetation Unit 7 provide another key habitat type used by all the faunal groups within the Afungi Project Site. However, the sensitivity of these areas is largely dependent on the size of the area, degree of fragmentation, and connectivity to other sensitive habitat types. Short closed woodlands occurring in the riparian areas adjacent to wetlands and large contiguous woodland areas provide more value to the faunal communities than do smaller or isolated woodland areas.

Certain species are reliant on sensitive habitat types provided by other Vegetation Units. As an example, the mangroves found in Vegetation Unit 2 are an essential foraging habitat for the sunbird taxa and the mangrove kingfisher. However, all fauna groups are reliant on the wetlands and woodlands of Vegetation Units 5 and 7. Therefore, these are considered the most sensitive habitat types within the Afungi Project Site.