

## Chapter 7

Environmental Baseline - Offshore and  
Near Shore

## CONTENTS

7	ENVIRONMENTAL BASELINE – OFFSHORE AND NEAR SHORE	7-1
7.1	INTRODUCTION	7-1
7.2	SUMMARY	7-1
7.2.1	<i>Offshore Environment</i>	7-1
7.2.2	<i>Near Shore Environment</i>	7-2
7.3	SOURCES OF INFORMATION	7-3
7.3.1	<i>Literature Sources</i>	7-3
7.3.2	<i>Baseline Surveys and Study Area</i>	7-3
7.4	REGIONAL CONTEXT – QUIRIMBAS ARCHIPELAGO	7-3
7.5	OFFSHORE ENVIRONMENT – PHYSICAL CONDITIONS	7-6
7.5.1	<i>Baseline Survey and Study Area</i>	7-6
7.5.2	<i>Major Circulation Patterns and Currents</i>	7-8
7.5.3	<i>Water Properties</i>	7-11
7.5.4	<i>Seabed Features</i>	7-16
7.6	OFFSHORE ENVIRONMENT – MAJOR BIOLOGICAL FEATURES	7-22
7.6.1	<i>Plankton</i>	7-22
7.6.2	<i>Benthos</i>	7-23
7.6.3	<i>Reef Structures</i>	7-26
7.6.4	<i>Fish</i>	7-30
7.6.5	<i>Whales and Dolphins</i>	7-31
7.6.6	<i>Seabirds</i>	7-35
7.7	NEAR SHORE ENVIRONMENT – PHYSICAL CONDITIONS	7-37
7.7.1	<i>Baseline Surveys and Survey Area</i>	7-37
7.7.2	<i>Bathymetry</i>	7-39
7.7.3	<i>Tides and Currents</i>	7-41
7.7.4	<i>Waves</i>	7-42
7.7.5	<i>Water Column – Properties</i>	7-43
7.7.6	<i>Sediment Properties and Seabed Features</i>	7-51
7.7.7	<i>Sediment Transport</i>	7-57
7.7.8	<i>Main Shoreline Types</i>	7-57
7.8	NEAR SHORE ENVIRONMENT – MARINE HABITATS	7-58
7.8.1	<i>Supratidal Sand Beach and Intertidal Sand/Mudflats</i>	7-58
7.8.2	<i>Mangroves</i>	7-63
7.8.3	<i>Seagrass</i>	7-66
7.8.4	<i>Coral</i>	7-69
7.8.5	<i>Shallow Coral Reefs and Outcrops</i>	7-71
7.8.6	<i>Fringing Coral Reef</i>	7-74
7.9	NEAR SHORE ENVIRONMENT – MAJOR BIOLOGICAL FEATURES	7-93
7.9.1	<i>Fish</i>	7-93
7.9.2	<i>Turtles</i>	7-95
7.9.3	<i>Whales and Dolphins</i>	7-96
7.9.4	<i>Seabirds</i>	7-97

## 7.1 INTRODUCTION

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

- *Section 7.2: Summary;*
- *Section 7.3: Sources of Information;*
- *Section 7.4: Regional Context – Quirimbas Archipelago;*
- *Section 7.5: Offshore Environment – Physical Conditions;*
- *Section 7.6: Offshore Environment – Major Biological Features;*
- *Section 7.7: Near Shore Environment – Physical Conditions;*
- *Section 7.8: Near Shore Environment – Marine Habitats; and*
- *Section 7.9: Near Shore Environment – Major Biological Features.*

## 7.2 SUMMARY

### 7.2.1 Offshore Environment

The offshore gas fields, Golfinho, Prosperidade and Mamba are located in deep oceanic water offshore of the extremely narrow continental shelf, in depths of around 1,000 to 2,300m. Deep canyons are found within the area, characterised by mostly unconsolidated sediment. Temperature, salinity<sup>(1)</sup> and dissolved oxygen profiles in the Offshore Study Area show a well-developed upper mixed layer underlaid by a strong thermocline. Water column turbidity levels are mostly low, <0.5mg/l, with elevated levels in the very near surface layers and a minor elevation in turbidity at depths corresponding to the base of the upper mixed layer/top of the thermocline. The sediments of the seabed are poorly sorted, indicating multiple sources of sediments and a low energy environment near the seabed.

Low and high-relief reef structures are present in deep waters, and are likely to be found throughout the area of the offshore gas fields. Biodiversity is highest on the high-relief reefs, although they do not apparently support high densities of fauna.

Pelagic and mesopelagic fish species are widely distributed. In the deep waters, a number of fish and benthic species have been observed appear to be new to science and have not previously been taxonomically described. Megafauna such as whales, dolphins and turtles, together with pelagic seabirds, are present in the region, and include species regarded as

(1) Salinity refers to the dissolved salt content in sea water.

Endangered, Vulnerable or Near Threatened according to the IUCN Red List of Threatened Species (IUCN, 2011). The distribution ranges of these fauna are truly vast compared to the distance scales of the gas fields that are proposed for development.

### 7.2.2 *Near Shore Environment*

The depth of the channel in the central area of Palma Bay extends to 50m. The islands of Tecomaji and Rongui sit on the edge of the continental shelf, where water depths of greater than 350m occur within 2.5km from the islands.

Palma Bay is a generally clear water environment with low turbidity levels. Temperatures and salinity are typically around 30°C and 35 practical salinity units (PSU) respectively. Surficial sediments are mainly sand or muddy sand. Sediment transport rates are small in the bay, due to the benign wave climate. Heavy metal concentrations observed were low. Small crater-like formations, 10m in diameter and 1 to 3m deep with rock pavement or rock with corals in their centres, have been observed in the approximate centre of Palma Bay.

The main shoreline types in Palma Bay are intertidal rock, steep supratidal sand beach, mangroves and intertidal sand/mudflats. The intertidal zone appears to be highly productive and biologically diverse. There are both extensive and minor stands of mangroves located in Palma Bay.

Seagrass beds and meadows, supporting a wide range of fauna including sea urchins, starfish, sea cucumbers, sponges, colonial ascidians and pen shells, are distributed throughout Palma Bay on sandy substrates from the mid-tide level in the intertidal zone to 6 to 8m depth. The species present are widely distributed on the East African coast, and particularly in the Quirimbas Archipelago.

Coral reefs in Palma Bay comprise *Porites*-dominated bommies with minor amounts of branching (*Acropora*) and other forms. They are distributed in and among the seagrass beds mainly in the west and south of Palma Bay; in diverse bommies in the bommie fields on the inshore side of Tecomaji, Rongui and Queramimbi islands; and in highly diverse reef and fringing reef at Cabo Delgado Peninsula and to the east of the islands. There are important structural reef features north of Tecomaji, between Tecomaji and Rongui and south of Rongui Island. These are biologically diverse, although evidence of damage (from extreme weather and fishing activities) is evident in each area. There are varying degrees of reef development between Tecomaji and Rongui, and the southern area between the islands has a relatively minor stretch of continuous reef, with more stretches of sand in the centre and on the northern side.

Fish species associated with reefs and seagrass beds are abundant and diverse. Five species of turtle are found in the Quirimbas Archipelago, all of which are protected species. The mainland beaches in Palma Bay are steep and the high tide levels extend to the top of the beach, making them unsuitable for turtle

nesting. A number of whale and dolphin species have been recorded in the near shore, and several species are known to enter Palma Bay eg humpback whales and bottlenose dolphins.

Palma Bay has been identified as a location with potential for aquaculture; namely, fish farming and seaweed production (INAQUA, 2011). In 2011 approximately 10ha of the bay was declared as a 'Marine Reserve' by Decree no. 71/2011 of 30 December. There are currently no known proposed or active aquaculture farms within the bay. This is detailed further in *Chapter 9*.

### 7.3 SOURCES OF INFORMATION

#### 7.3.1 Literature Sources

The information provided in this baseline chapter has been gathered from a wide range of sources. It draws upon a review and analysis of existing information, including data collected for EIAs from the exploration phase of the Project (for Area 1 and Area 4), and from other available reports and studies. These are referenced where applicable throughout the text. Most secondary data available are at a regional level ie the Quirimbas Archipelago, and are useful to describe the offshore environment.

#### 7.3.2 Baseline Surveys and Study Area

Location-specific information and data for the offshore and near shore (ie Palma Bay) are sparse and, therefore, intensive primary investigations of these areas have been carried out for this EIA Report. The types of marine surveys undertaken and the extent of the Survey Area are outlined in *Section 7.5.1* and *Section 7.7.1*, for the offshore and near shore respectively. The survey findings are described throughout this chapter. The survey methodologies applied by the marine specialists are presented in *Annex C*.

In this chapter, the near shore comprises the area from the mainland to approximately 1.5km east of Tecomaji and Rongui islands, ie roughly to the edge of the continental shelf/ drop-off into deep water. Offshore is considered to be from there eastwards. The Study Area comprises the near shore and offshore marine environment that may be affected by the Project, such as the near shore infrastructure, the subsea infrastructure, and the proposed activities in the Golfinho, Prosperidade and Mamba gas fields.

### 7.4 REGIONAL CONTEXT – QUIRIMBAS ARCHIPELAGO

Palma Bay is situated within the Quirimbas Archipelago. This is located in the East African Coral Coast Ecoregion of the Western Indian Ocean (WIO)

Province of the WIO biogeographic Realm <sup>(1)</sup> (Spalding *et al.* 2007). The East African Coral Coast Ecoregion is considered an area of relatively homogenous species composition, however, is clearly distinct from adjacent systems. It extends across approximately 1,700km (more than 15° latitude). The Quirimbas Archipelago forms a subset within the ecoregion and extends for approximately 400km from just south of the Rovuma River to Pemba.

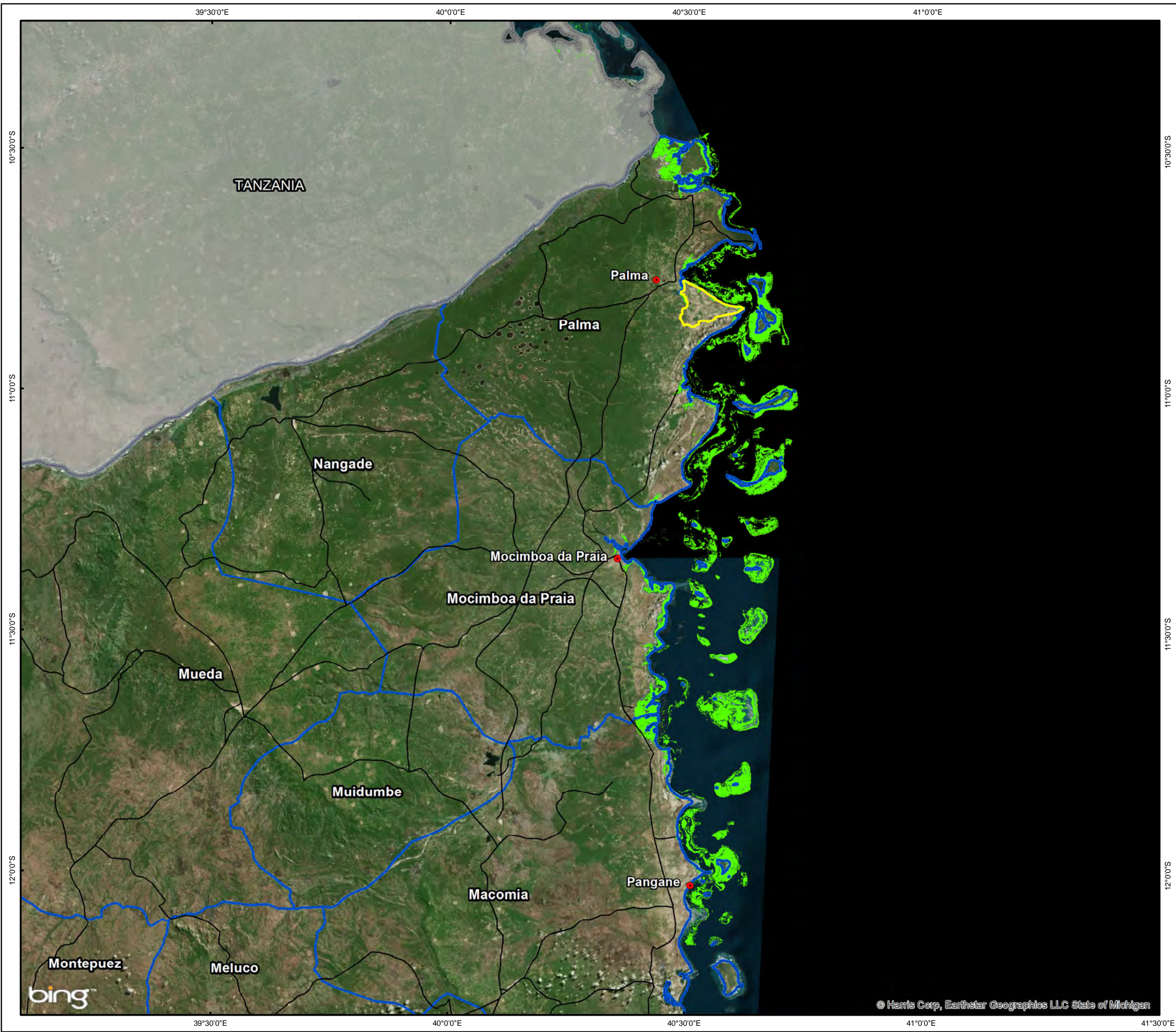
The Quirimbas Archipelago comprises 32 islands with associated coral reefs, seagrass beds, mangroves, sandy beaches and mudflats. Rodrigues *et al.* (2000) indicates that over 50 coral genera occur in reefs in the region while, detailed survey data obtained around Nacala, Pemba and Vamizi Island (approximately 10km south of Palma Bay) indicates the presence of 207 to 254 coral species (Obura, 2012). Species discovery analysis indicates that actual species numbers may be as high as 300. This is a highly diverse fauna and from this and comparisons of species richness distributions through the Western Indo-Pacific realm and oceanography, Obura (2012) concludes that the northern Mozambique Channel forms the core region from which there has been dispersal of corals to the adjacent ecoregions within the WIO biogeographic Province.

Extensive mangrove forests along the mainland shoreline and islands and seagrass beds in the shallow subtidal zone also contribute to the Archipelago's productivity. A total of 10 species of seagrass (Whittington *et al.*, 2000) and eight species of mangroves are known to occur in Cabo Delgado Province (CSA, 2007).

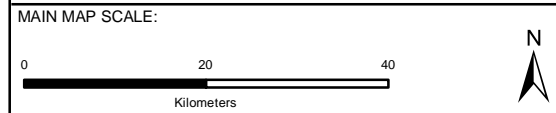
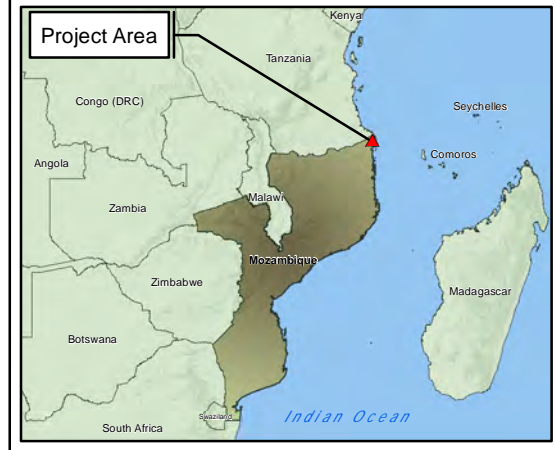
The broad distributions of potential habitats for coral reefs, seagrass beds and mangroves in the region are shown in *Figure 7.1*. This coarse data from remote sensing was mapped and subsequently subjected to ground-truthing by a marine ecologist, and the findings are described in *Sections 7.8.2 to 7.8.4*.

There are formally declared protected areas in the southern part of the region (Quirimbas National Park), while in southern Tanzania the Rovuma River mouth area lies within the Mnazi Bay–Rovuma Estuary Marine Park (MBREMP). See *Chapter 6* for further information on the designated and proposed protected areas of interest.

(1) A global hierarchy of 12 realms, 62 provinces and 232 ecoregions were established as the Marine Ecoregions of the World (MEOW) classification by Spalding, 2007.



- Legend**
- Towns
  - Regional Roads
  - ▭ Afungi Project Site
  - ▭ District Boundary
  - ▭ Boundary with Tanzania
  - Sensitive Marine Habitats (Coral, Seagrass and Mangroves)



TITLE:  
**Figure 7.1:**  
**Mapped Sensitive Habitats**  
**(Coral, Seagrass and Mangroves)**  
**in the Quirimbas Archipelago**

CLIENT:

**Anadarko**  
 Moçambique Área 1, Lda

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 830 000
DRAWING: Mapped Sensitive Habitats.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

Projection: UTM Zone 37 S Datum: WGS84  
 Source: Bing Maps ©2010 Microsoft Corporation.  
 Impacto/APC. Inset Map: Esri Data & Maps

SIZE:  
**A3**

**Baseline Survey and Study Area**

To gain information on the oceanography within the offshore environment, upper water column profiles of temperature, conductivity (salinity), dissolved oxygen concentrations, turbidity, chlorophyll fluorescence (chlorophyll a) and ultraviolet (UV) fluorescence <sup>(1)</sup> were measured in June 2012 on the Rylan-T cruise commissioned by AMA1 with Lwandle Technologies (Pty) Ltd (referred to as Lwandle) marine specialists present. The location of the conductivity–temperature–depth (CTD) sampling stations are confined to Area 1 as are shown in *Figure 7.2*.

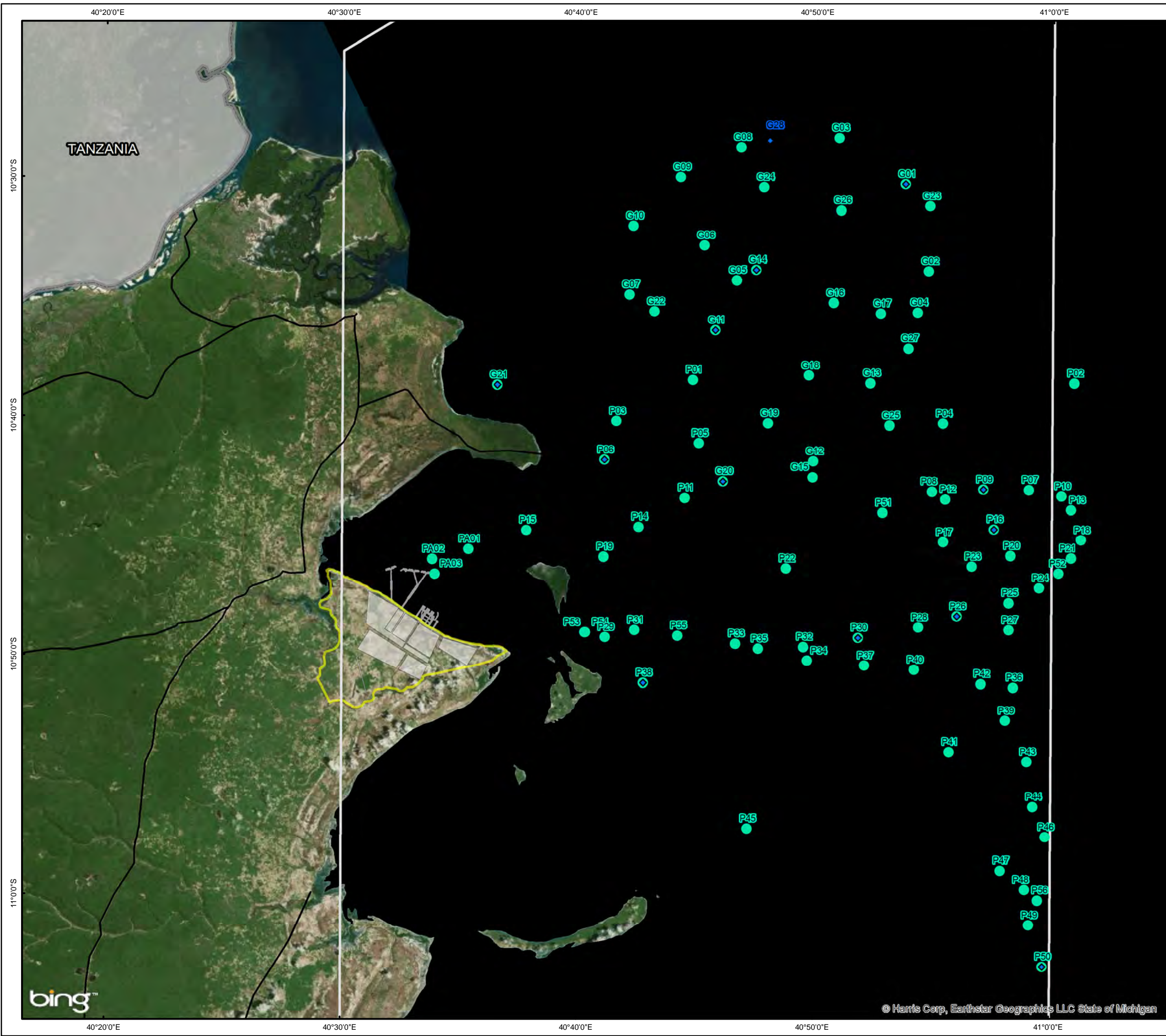
There is no published information or publicly available survey data on seabed features in the offshore gas fields. Surficial sediment sampling was conducted by box core (deepwater sites) and Day grab (shallow-water sites) in June 2012 by Lwandle, to determine sediment properties and the composition of the benthic community in the Golfinho and Prosperidade gas fields and the proposed pipeline corridor. The locations of sediment sampling stations are shown in *Figure 7.2*. Sediments were analysed for particle size distribution and texture, heavy metal concentrations and benthic data (eg species present, abundance, biomass etc).

Remotely Operated Vehicles (ROV) seabed video surveys have been conducted by AMA1 and eni in the Golfinho, Prosperidade and Mamba gas fields as part of their gas field exploration activities. The data has been analysed by Lwandle to examine the characteristics of the seabed and other features (eg deep water reef, fish etc).

The main features of the acquired data are discussed in *Sections 7.5.3 and 7.5.4*.

(1) A proxy for hydrocarbon concentrations.





### Legend

- Regional Roads
- Jetty
- Onshore Layout
- ▭ Afungi Project Site
- Seabed Sampling Stations
- ◆ CTD Stations
- Area 1

**Project Area**

SCALE: 0 5 10 15 Kilometers

TITLE:  
**Figure 7.2:**  
 Conductivity-Temperature - Depth (CTD)  
 and Sediment (including benthos)  
 Sampling Locations Offshore

CLIENT:  
  
 Anadarko  
 Moçambique Área 1, Lda

DATE: Oct 2013	CHECKED: KG	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 280 000
DRAWING: CTD and Sediment Sampling.mxd		REV: A

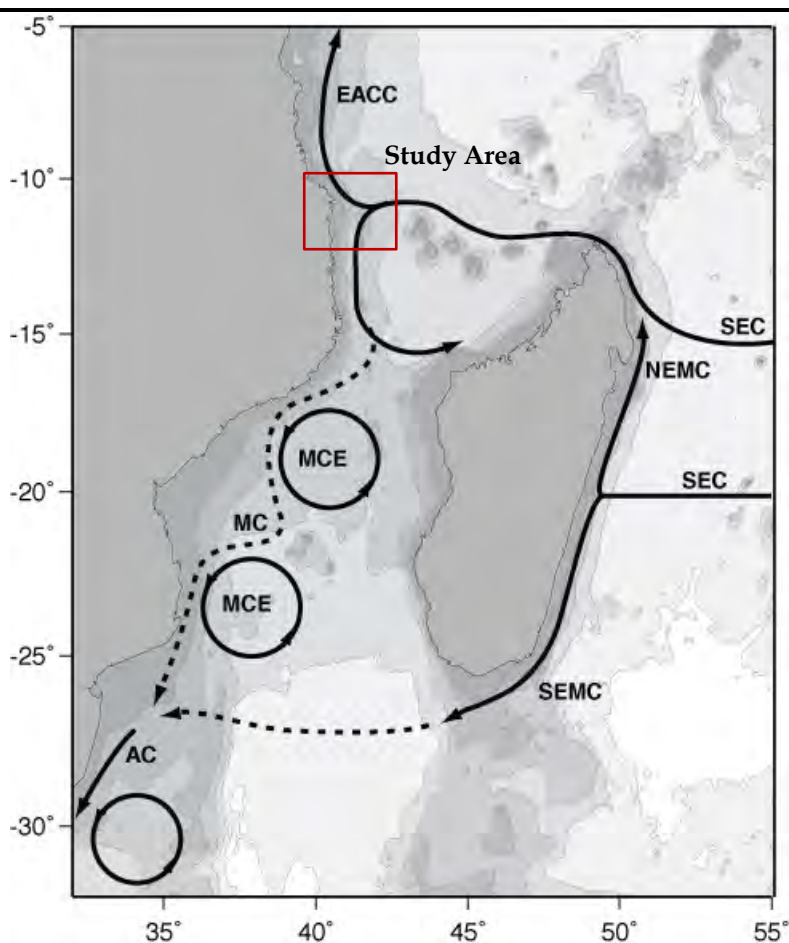
ERM  
 Great Westerford Building  
 240 Main Road  
 Rondebosch, 7725  
 Cape Town, SOUTH AFRICA  
 Tel: +27 21 681 5400  
 Fax +27 21 686 073

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

SIZE:  
A3

The equatorial water mass known as the South Equatorial Current (SEC) flows westward across the Indian Ocean and splits when it reaches Madagascar, into a southward-flowing branch, the South-east Madagascar Current (SEMC), and a northern branch, the North-east Madagascar Current (NEMC), which flows north to Cape Amber (the northernmost point of Madagascar), as shown in *Figure 7.3*. The NEMC branch veers westwards at Cape Amber towards the coast of Africa, where it bifurcates into northward and southward branches. The northward flow becomes the East African Coastal Current (EACC), while the southward flow becomes the Mozambique Current (MC).

*Figure 7.3* *Circulation Patterns in the Western Indian Ocean*



Key:

SEC = Southern Equatorial Current, NEMC = North-east Madagascar Current, SEMC = South-east Madagascar Current, EACC = East African Coastal Current, AC = Agulhas Current, MC = Mozambique Current, MCE = Mozambique Channel Eddies.

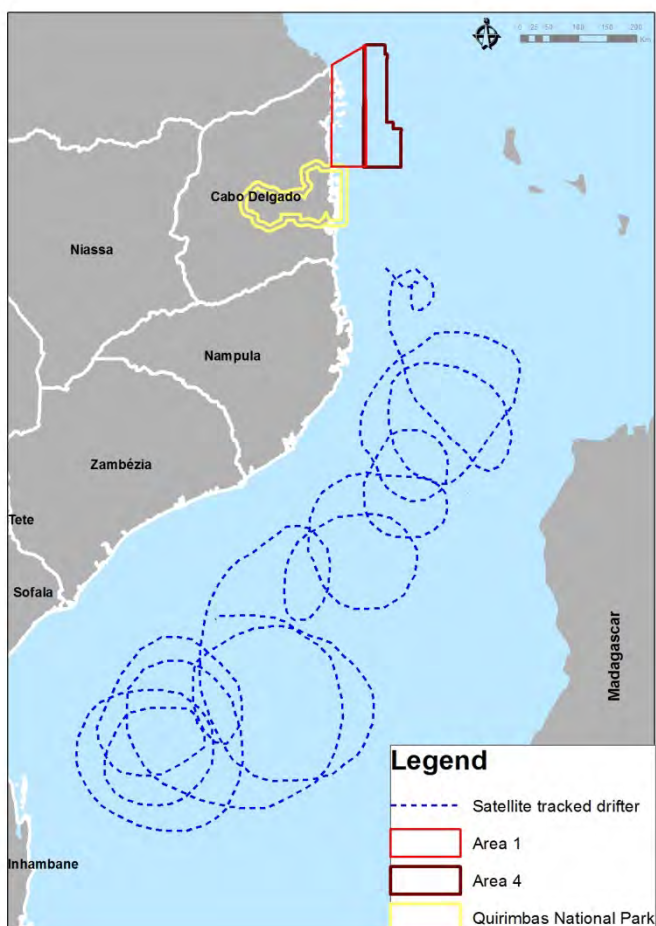
Source: Schouten et al., 2003.

Saetre and da Silva (1982, 1984) postulated that the current in the Mozambican channel occurs in the form of various large-dimension clockwise and counter-clockwise eddies, rather than a continuously flowing southward current. From this idea, the model of an overall southward-flowing MC was developed, but with several smaller semi-basin and regional circulation

patterns. Closer inshore, cooler pockets of water flow parallel to the coast, but in a direction opposite to the main flow of the MC (Figure 7.3). The offshore gas fields are located where the EACC and the MC branch out from the SEC.

De Ruijter et al. (2002) used satellite tracking of floating buoys to show southward flows clearly, but demonstrated that this is via a series of counter-clockwise eddies of around 300km in diameter, extending throughout the water column (Figure 7.4).

**Figure 7.4** *Patterns of Buoys Tracked by Satellite in the Mozambique Channel*



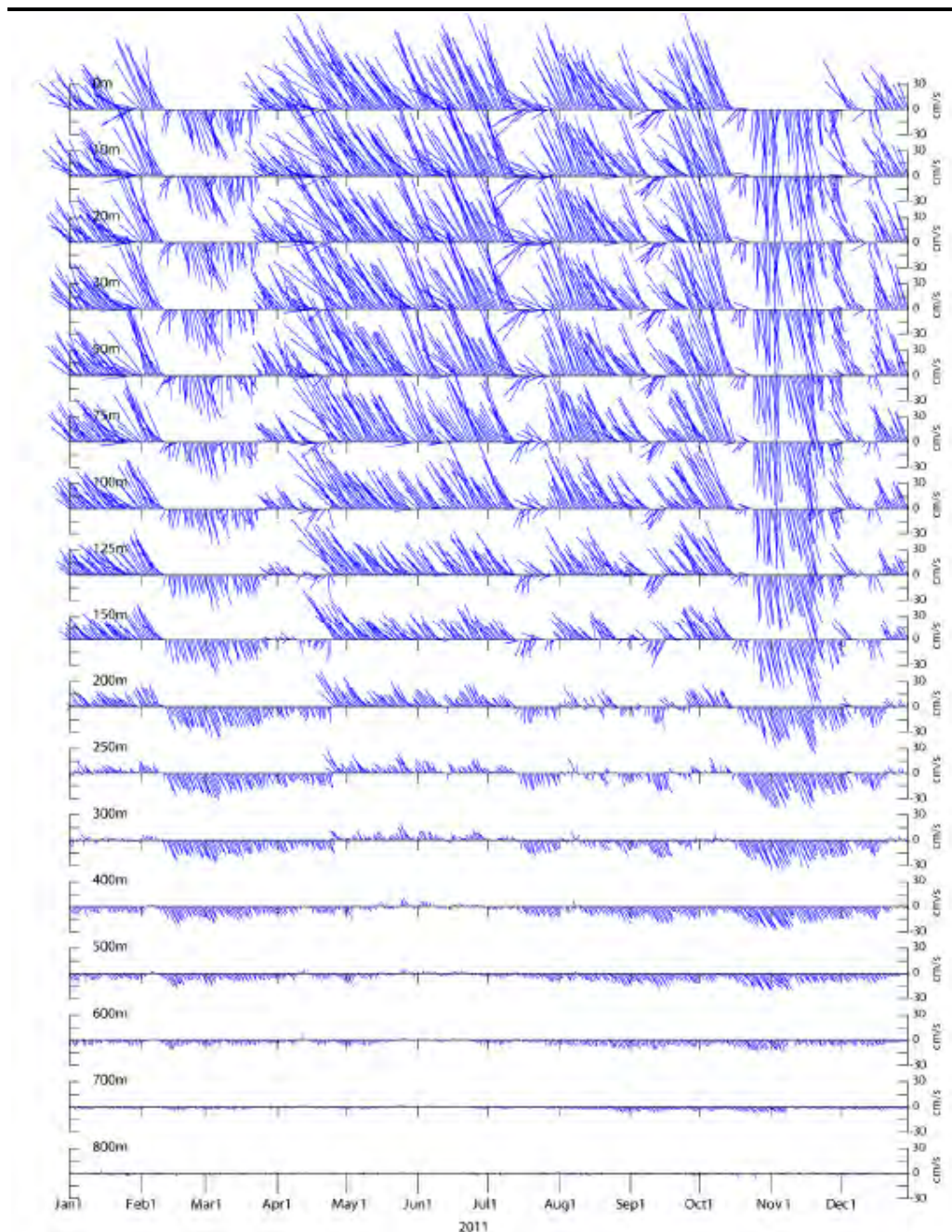
Source: De Ruijter et al., 2002.

Ridderinkhof et al. (2003) placed current-measuring devices along a narrow part of the channel (around 17°S), which clearly indicated a current of 1m/s in a southerly direction along the western side of the channel. These data, therefore, indicate an overall southward-flowing current of varying velocities via a series of anti-cyclonic eddies rather than a consistent southerly flow.

Similar variability is evident in current patterns of in the areas of the gas fields, offshore of northern Mozambique. Figure 7.5 shows the distribution of currents with depth at 10.53279°S, 040.70442°E, located in the Golfinho Gas Field. A strong current velocity gradient with depth is apparent, with current speeds of >70cm/sec at the surface and <15-20cm/sec towards the base of the

water column. There is also evidence of current directions changing from north/north-west to due south. Northerly flows are dominant between April and September (dry season) and southerly flows in other months. This is attributed to the location of the measured site in relation to the bifurcation <sup>(1)</sup> of the EACC and the MC (*Figure 7.3*). When this migrates north, currents flow mainly south, whereas northerly flow occurs when the bifurcation location moves south.

**Figure 7.5** *Vertical Current Velocity Profile at 10.53279°S, 040.70442° E in Golfinho*



Source: HYCOM data (2011) taken from ASA in CSA, 2012.

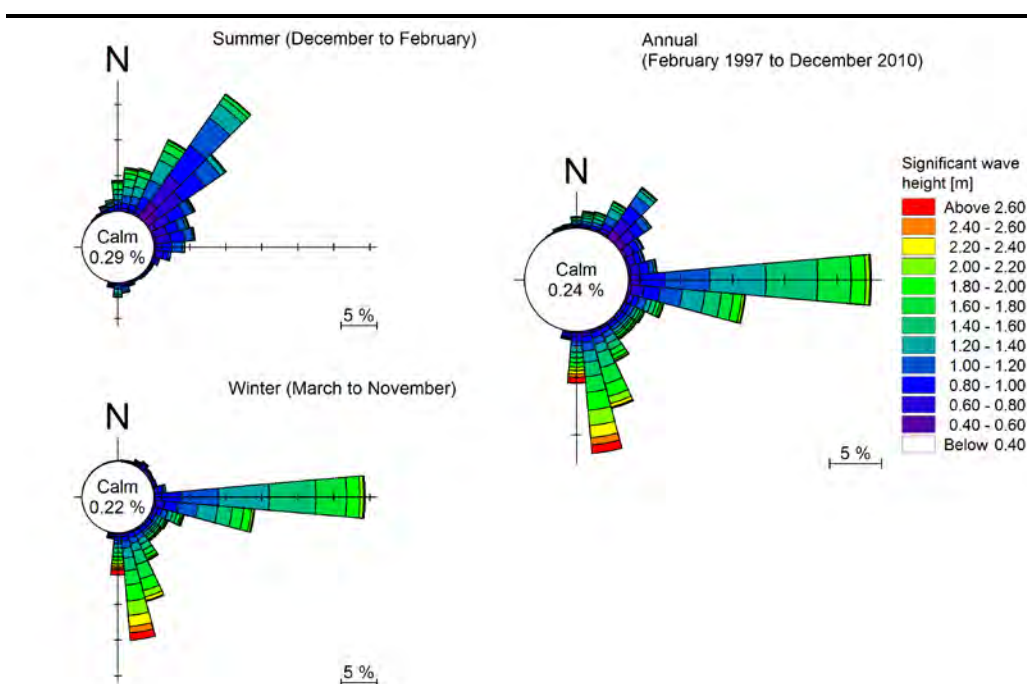
(1) Where the MC and EACC branch out from the SEC.

## Offshore Wave Conditions

The wave climate offshore of Palma Bay at the location S11.0°, E41.25° was extracted from the National Centre for Environmental Predictions (NCEP) hindcast model database for the period from 1997 to 2010.

Figure 7.6 illustrates these data and that offshore wave conditions have two distinct seasonal patterns. Wave conditions are predominantly from the north-east direction during the summer monsoon months, from December to February. During the winter months from March to November, the predominant swell directions are from the south and the east, with the largest significant wave heights coming from the south.

**Figure 7.6** Offshore Wave Rose - Seasonal (Left) and Annual (Right) Based on NCEP Wave Data (February 1997 to December 2010)



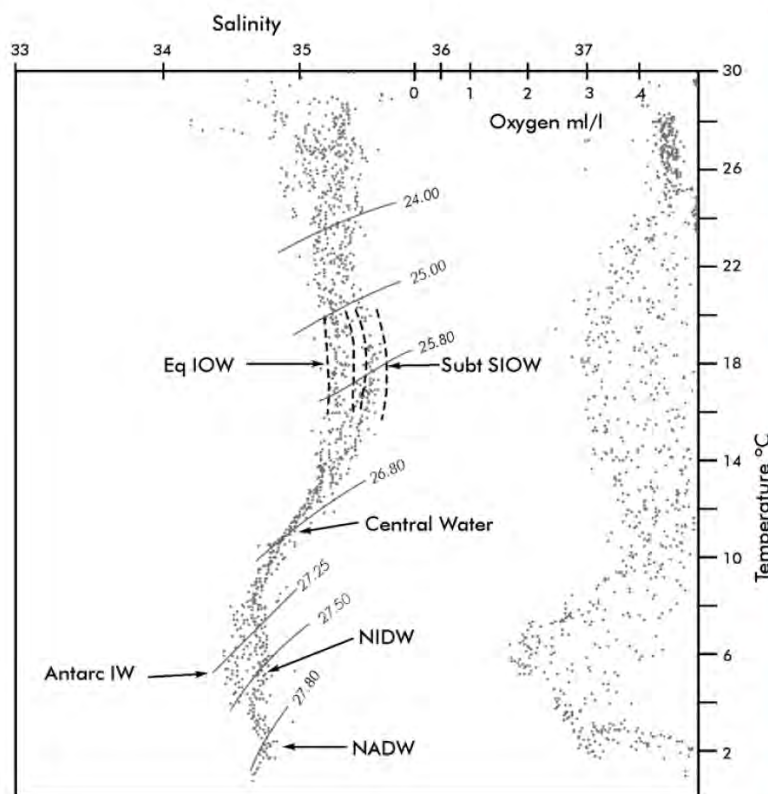
Source: PRDW, 2012. Data derived from Fugro, 2011, based on NCEP data.

### 7.5.3 Water Properties

#### Water Masses

Six water masses are evident in the MC, encompassing the offshore gas field area: Equatorial Indian Ocean Tropical Surface Water (EqIOW), Indian Ocean Subtropical Surface Water (Subt SIOW), Indian Ocean Central Water (CW), Antarctic Intermediate Water (Antarc IW), North Indian Deep Water (NIDW) and North Atlantic Deep Water (NADW) (Figure 7.7). Most of the water inshore of and on the continental shelf break, especially off northern Mozambique, is EqIOW (Lutjeharms, 2006).

**Figure 7.7** *Temperature-Salinity and Temperature-Oxygen Characteristics of the Water Masses in the Mozambique Channel*

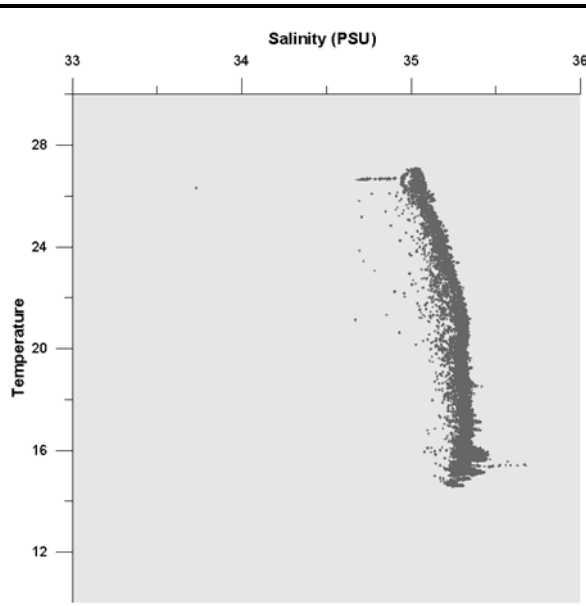


Key:  
 EqIOW = Equatorial Indian Ocean Tropical Surface Water, Subt SLOW = Indian Ocean Subtropical Surface Water, CW = Indian Ocean Central Water, Antarc IW = Antarctic Intermediate Water, NIDW = North Indian Deep Water, NADW = North Atlantic Deep Water.

Source: Lutjeharms, 2006.

The composite temperature/salinity (TS) plot for data from the offshore sampling stations obtained in June 2012 is illustrated in *Figure 7.7*. Comparison with the regional TS plot (*Figure 7.7*) indicates that the water mass is predominantly EqIOW, with a minor contribution of Subt SLOW towards the base of the measured water column (approximately 200m depth).

Figure 7.8 Temperature–Salinity for Offshore CTD Sampling Stations, June 2012

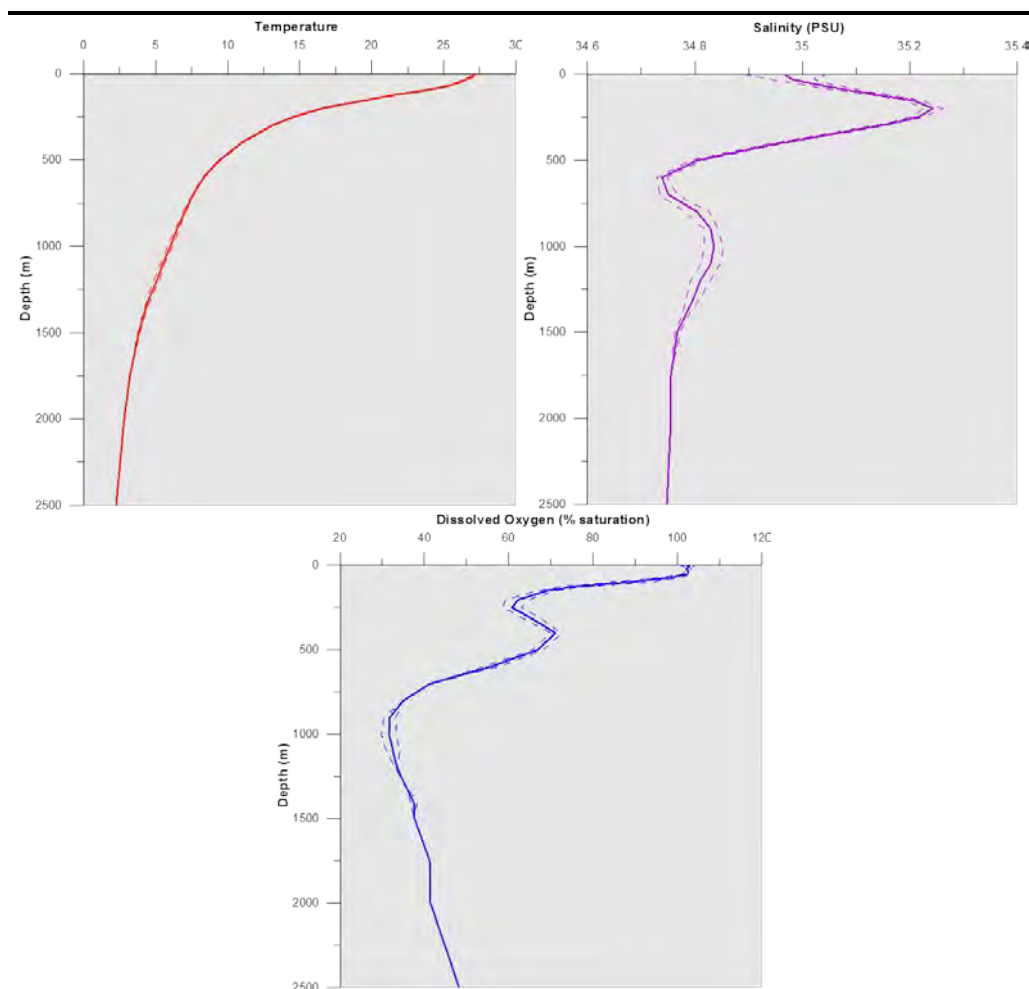


Source: Lwandle, 2012.

#### *Temperature, Salinity and Dissolved Oxygen*

There is no systematic and detailed information on the physical and chemical parameters of the waters in the north of the Mozambique Channel. Some scientific data were obtained during the cruise of the Dr Fridtjof Nansen between 1977 and 1978, and are described by Saetre and da Silva (1982). More recent data for the region are provided by Di Marco et al. (2002). Formalised water column profile data are available from the World Ocean Atlas (2009), and *Figure 7.10* shows vertical profiles of mean (+/- SE) values for temperature, salinity and dissolved oxygen concentrations for the one degree square area centred on 10.5°S, 41.5°E.

**Figure 7.9** *Vertical Profiles of Temperature, Salinity and Oxygen Offshore, Northern Mozambique*



Key:  
 Solid lines indicate mean values and dashed lines indicate Standard Errors of the mean.

Source: Lwandle, 2012. Data supplied by SADCO following extraction from the World Ocean Atlas 2009.

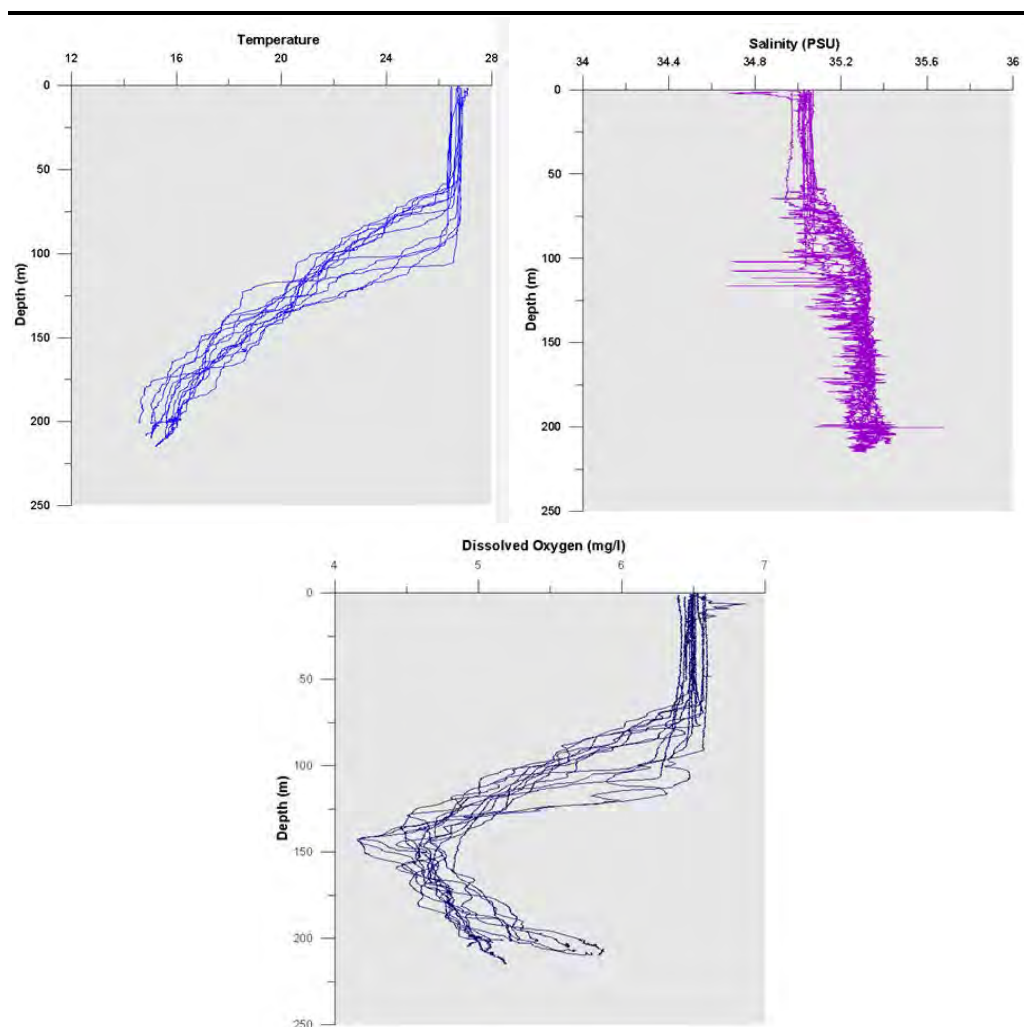
The observed patterns for temperature, depth and salinity are consistent with the regional distributions shown in *Figure 7.9*.

The vertical temperature profiles show a well-developed upper mixed layer of water at 27°C that extends to 60 to 120m depth. This overlies strong thermoclines, with temperatures dropping from 27°C to 14°C at depths of 220m at approximately 0.105°C/m. At the stations where the upper mixed layer was deepest, there were corresponding enhanced thermoclines indicating that surface wind/wave mixing was largely responsible for the observed patterns. The two-layer system evident in the temperature profiles is largely replicated in the composite salinity profiles, as shown in *Figure 7.10*. Relatively low salinity is apparent in the upper mixed layer depths, and salinity increases in the region of the thermocline. The dissolved oxygen profiles indicate uniformly high concentrations in the upper mixed layer



depths, a marked gradient in the region of the thermocline and gradually increasing concentrations below this (Figure 7.10). The entire measured depth range is considered to be well oxygenated.

**Figure 7.10** Composite Vertical Profiles of Temperature, Salinity and Oxygen for Offshore CTD Sampling Stations, June 2012

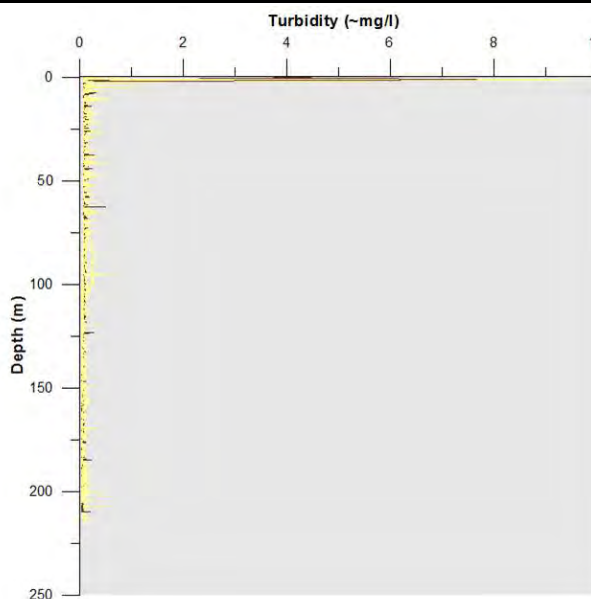


Source: Lwandle, 2012. Data collected during June 2012 survey.

### *Turbidity*

Water column turbidity levels measured during the offshore survey were mostly low, <0.5mg/l. However, quite strongly elevated levels were observed in the very near surface layers, with a minor elevation in turbidity at depths corresponding to the base of the upper mixed layer/top of the thermocline, as shown in Figure 7.11. This may be due to the accumulation of detritus at or close to density interfaces; however, there are no supporting data for this.

Figure 7.11 Composite Turbidity Profiles for Offshore CTD Sampling Stations, June 2012



Source: Lwandle, 2012. Data collected during June 2012 survey.

### *Hydrocarbons*

Fluorescence in the UV (10 to 400nm) wave length is used to detect hydrocarbon compounds in water. UV fluorescence profiles measured in the June 2012 offshore survey are all centred around zero, indicating that, if hydrocarbon compounds were present in the water column, they were at concentrations below the detection level of the sensors used (1 to 3ppm).

## 7.5.4 *Seabed Features*

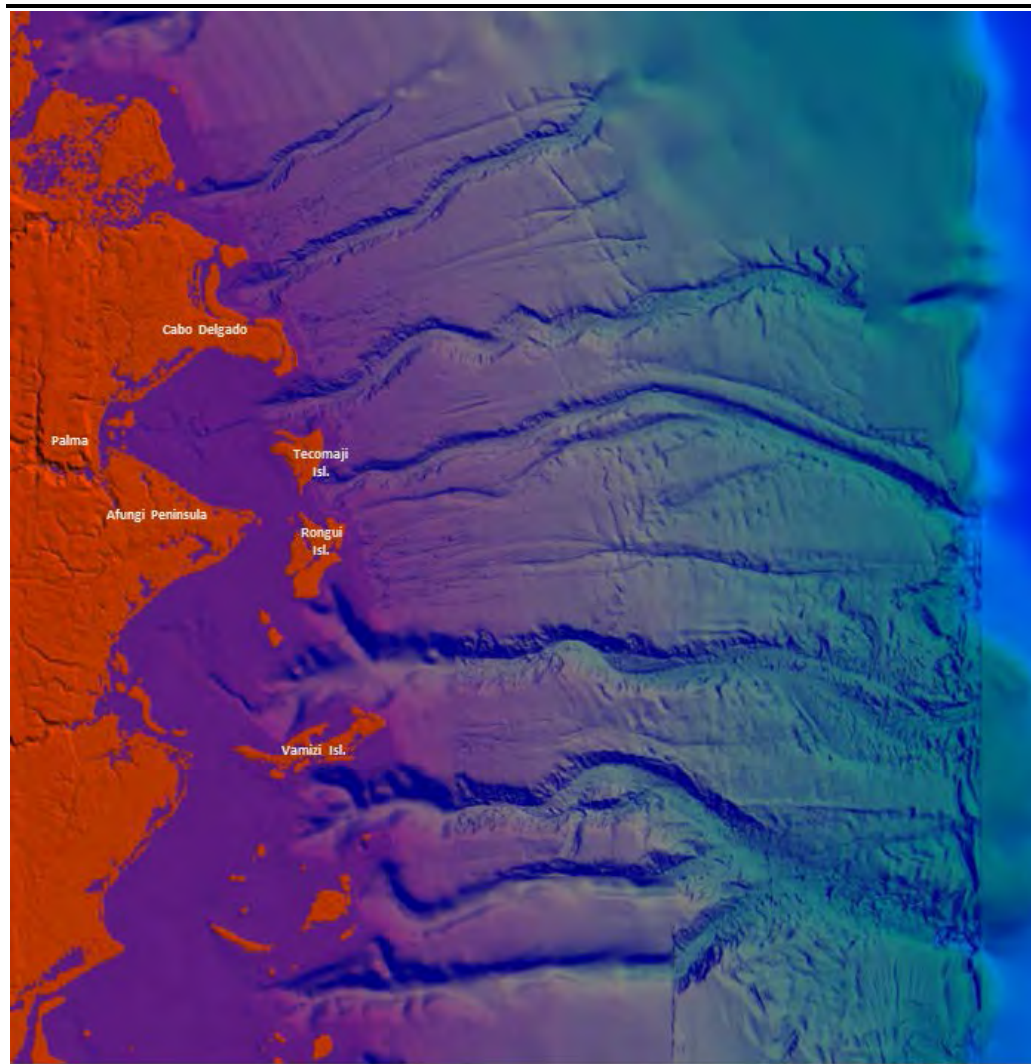
### *Topography*

The coastline of northern Mozambique is bordered by a narrow continental shelf. This shelf drops off into deep waters via a very steep slope. Both the shelf and slope are incised by a number of deep canyons that extend out to the abyssal plain <sup>(1)</sup> as shown in *Figure 7.12*. The seabed of the plain in the deep waters, outside of the canyons, comprises rough hummocks <sup>(2)</sup>, undulating sediment surfaces, rough seabed, older sediment outcrops, escarpments, slumped sediments and fault-like features. Typical seabed gradients are <4° dipping east north east (Fugro Survey Pte. Ltd., 2013).

(1) Smooth, almost level area of the deep-ocean floor in which the gradient is very low.

(2) A small but steep, irregular hill rising above the general level of the surrounding land; a low mound or ridge of earth, a knoll.

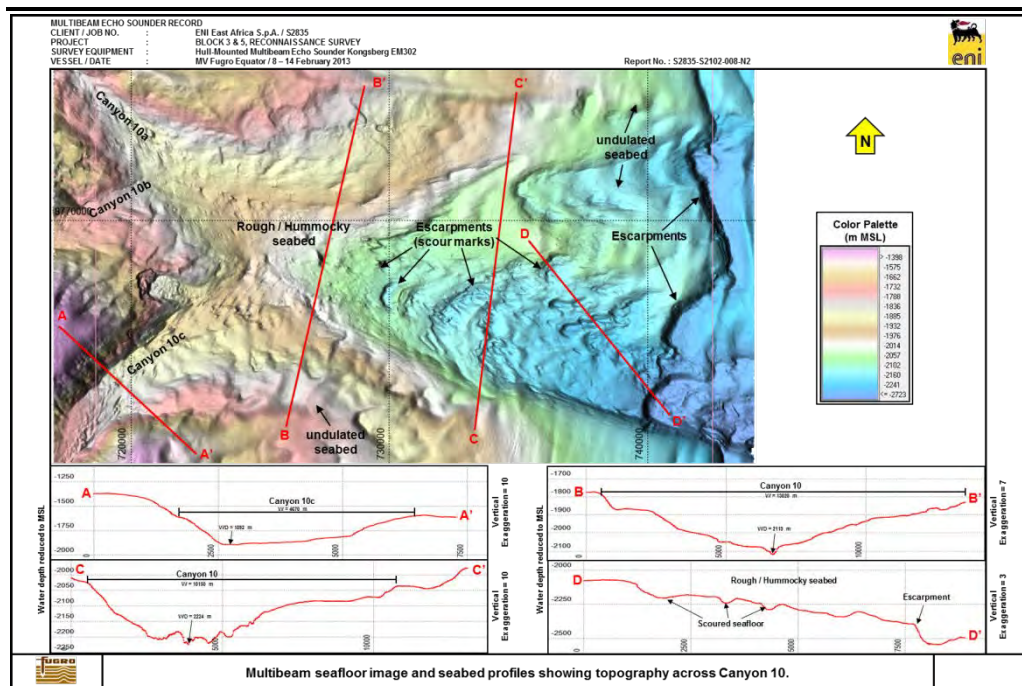
Figure 7.12 Regional Topography



Source: Eni, 2013.

The canyons are dramatic features with canyon walls having gradients of  $10^{\circ}$  to  $24^{\circ}$ . The canyons reach up to 14km in width and the seafloor within canyons can be 30 to 450m below the adjacent (overbank) seabed. Canyon floors comprise rough hummocky seabed (Fugro Survey Pte. Ltd., 2013). *Figure 7.13* shows an example of bed forms and gradients around a large canyon within the Mamba Gas Field.

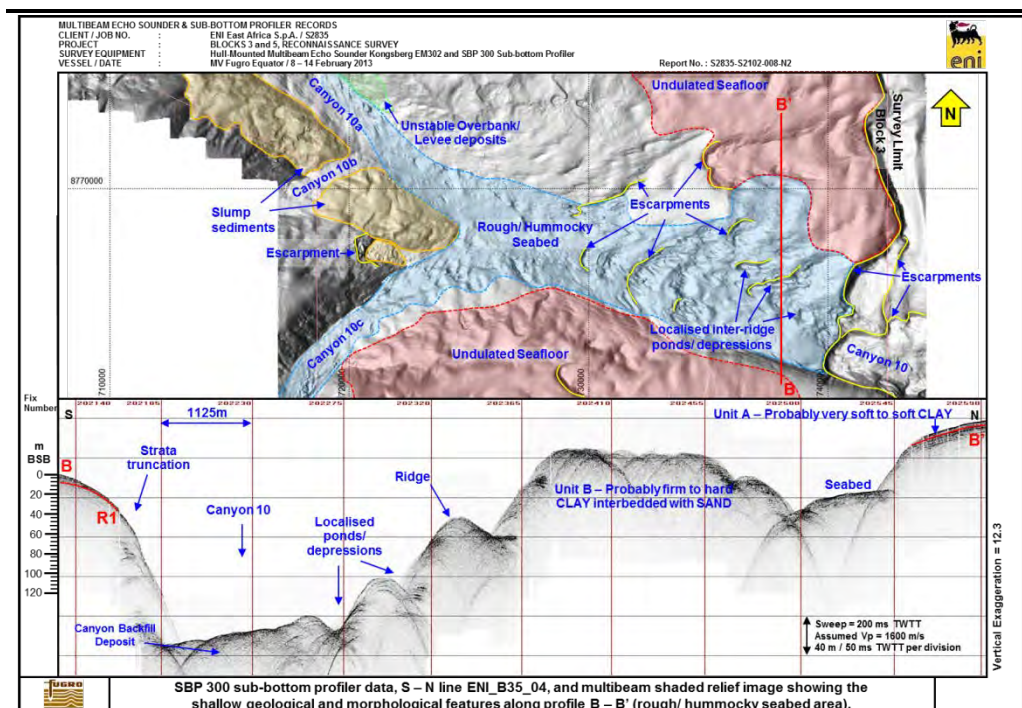
Figure 7.13 Seabed Features of a Canyon System and Adjacent Seafloor in Area 4 from a Multibeam Survey



Source: Fugro Survey Pte. Ltd., 2013

Sub-bottom profiling indicates the presence of soft and hard clays, the latter intercalated with sand, and coarse sediment layers (see Figure 7.14).

Figure 7.14 Sub-bottom Profiling Transects across a Canyon System and Adjacent Seafloor in Area 4



Source: Fugro Survey Pte. Ltd., 2013

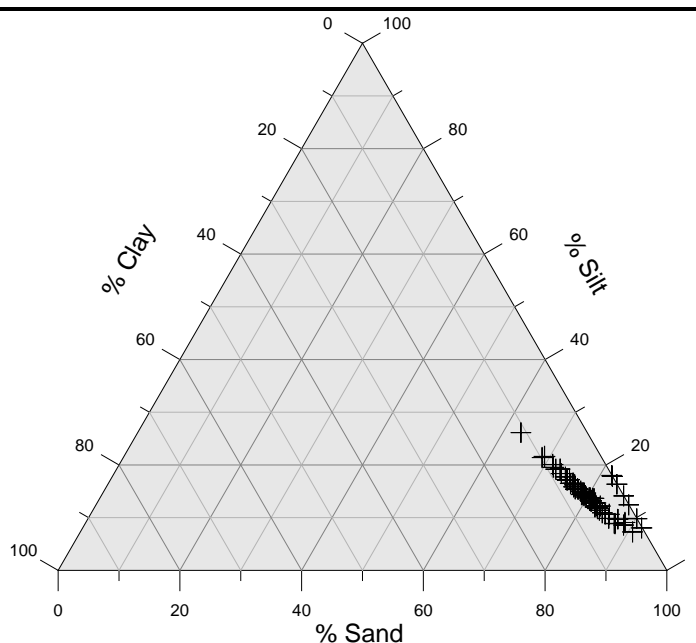
### Sediment Texture

Sediment samples taken at 75 sampling stations (see *Figure 7.15*) within the Offshore Survey Area were dominated by sand (77 percent), with silt (12 percent), mud (5 percent) and gravel (6 percent) comprising minor proportions. Sediments were mainly silty sand and mixtures of sand, as illustrated in *Figure 7.15*. Silt and clay are rare within the sediments.

In all samples, the sediments were poorly sorted, indicating multiple sources of sediments and a low energy environment near the seabed.

Microphotography of the sediments showed the presence of coral debris, quartzitic grains and illite (L Lenhoff, UWS, *in litt.*). Biogenic material (eg foraminifera) comprised a very minor proportion of the sediment samples examined.

**Figure 7.15** Ternary Diagram Showing Sediment Texture in the Offshore Survey Area, June 2012

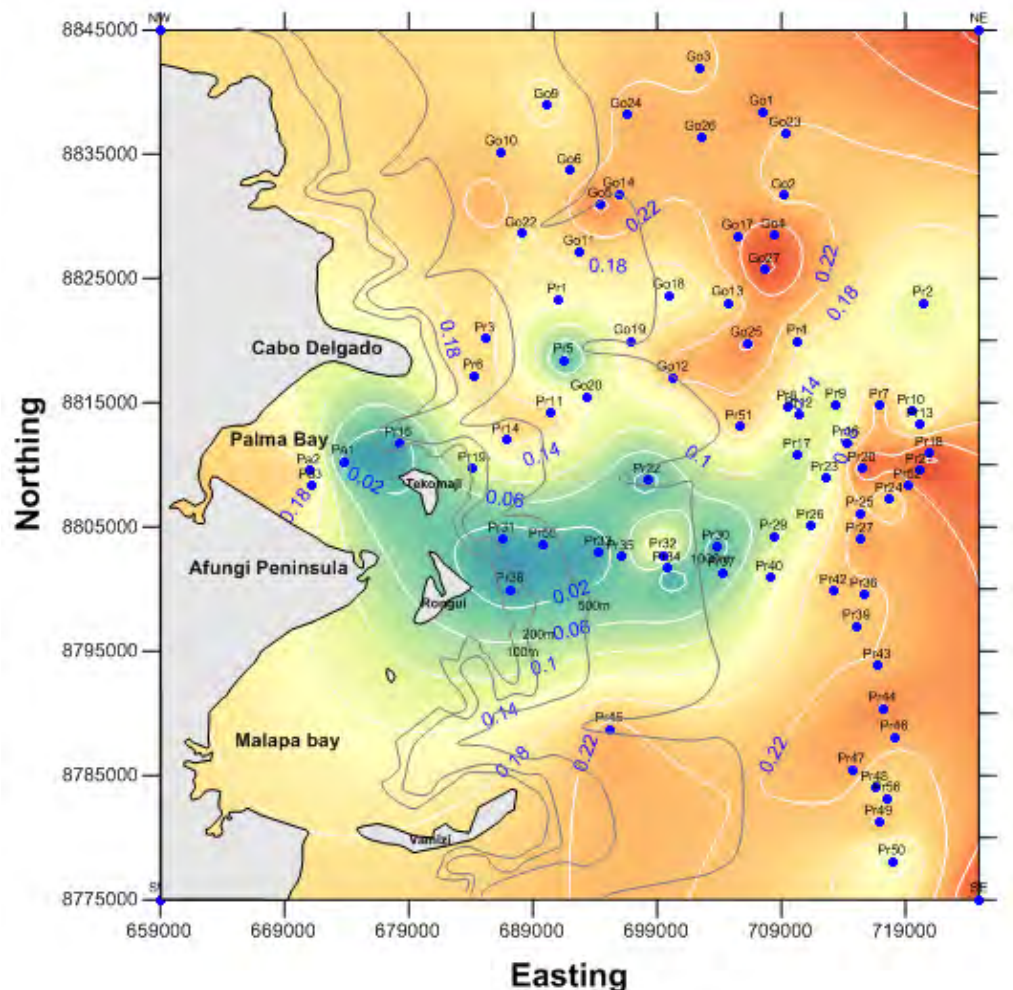


The black crosses indicate the various sediment types observed.

Source: Lwandle, 2012.

The distribution of the mud fraction in the Offshore Survey Area is shown in *Figure 7.16*. It is evident that, offshore of Palma Bay, higher proportions of mud occur in the deeper areas of the gas fields. Analysis of video footage of the Mamba gas fields, indicate that the sedimentary environment is similar to that of the deeper area of the Prosperidade Gas Field. This may be due to topography or higher current speeds associated with the steeper topography in the west of the Offshore Survey Area. Minimal mud was found in the offshore areas of Palma Bay and extending offshore between Tecomaji and Rongui islands.

Figure 7.16 Distribution of the Mud Fraction in Surficial Sediments in the Offshore Survey Area



Key:  
 Blue dots = locations of sediment sampling locations. White contours = distribution of the mud fraction in surficial sediments.

Source: Lwandle, 2012. Data collected during June 2012 survey.

### Heavy Metals

Heavy metal concentrations in the offshore sediments are low and fall within the environmental quality target (EQT) values specified for the western Indian Ocean (Table 7.1; UNEP & CSIR, 2009). This is expected, given the lack of industrialisation in the region.

Heavy metals in sediments are mostly associated with the fine fractions, as they partition onto clay minerals, iron and manganese oxide/hydroxide coatings on clay particles and organic substances (Calmano et al., 1993). The collected data show that this is the case, with the apparent exception of lead and manganese and a demonstrated exception of barium.

**Table 7.1** *Heavy Metal Concentrations (mg/kg) in Sediments from Offshore Survey June 2012 Compared to Sediment EQT Concentrations for the WIOLAB Region*

<b>Metal</b>	<b>Mean</b>	<b>Standard Dev</b>	<b>n</b>	<b>WIOLAB EQT</b>
Aluminium (Al)	27748.8	15381.6	77	
Cadmium (Cd)	Nd			0.68
Nickel (Ni)	15.4	7.8	77	15.9
Silver (Ag)	Nd			0.73
Arsenic (As)	2.5	1.4	28	7.24
Barium (Ba)	244.5	570.8	77	
Beryllium (Be)	1.1	0.2	33	
Cobalt (Co)	6.3	3.0	74	
Chromium (Cr)	28.1	11.2	77	52.3
Copper (Cu)	12.5	7.2	76	18.7
Iron (Fe)	18159.5	9003.9	77	
Lead (Pb)	4.8	1.5	57	30.2
Lithium (Li)	26.4	11.1	75	
Manganese (Mn)	315.6	243.8	77	
Molybdenum (Mo)	ND			
Selenium (Se)	ND			
Strontium (Sr)	1715.0	698	77	
Vanadium (V)	31.3	14.8	77	
Zinc (Zn)	33.8	16.4	77	124

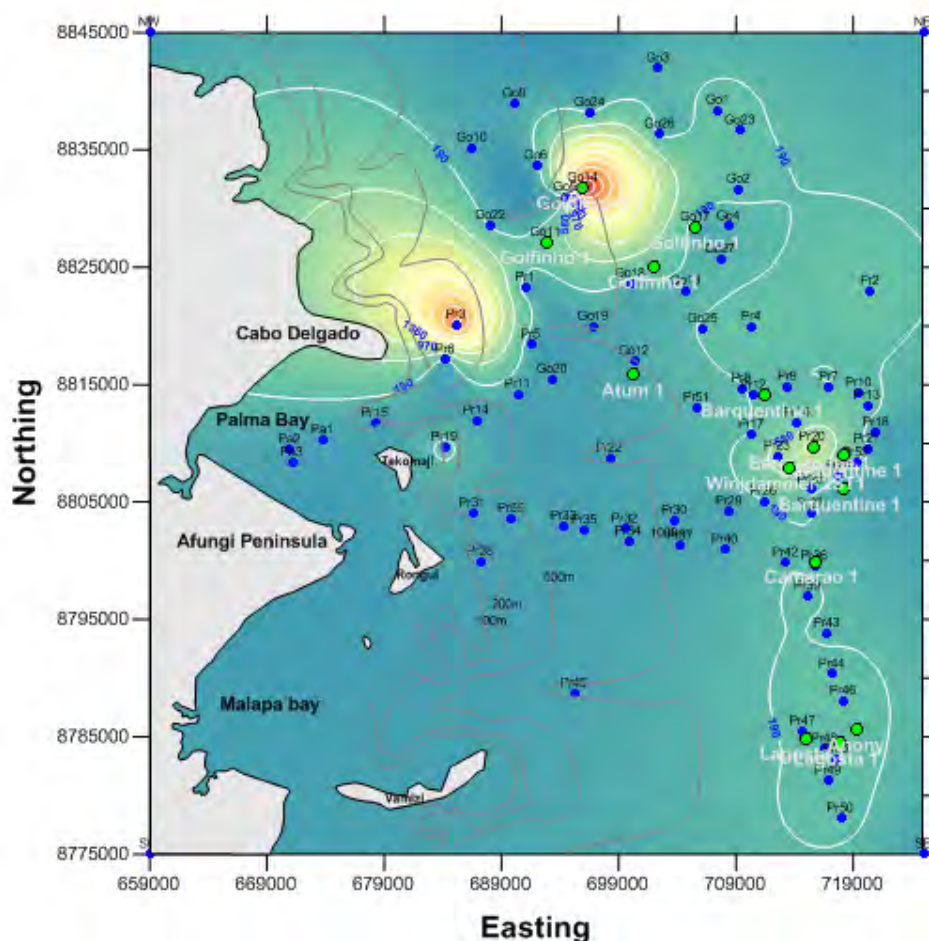
Key:

ND = below detection limit, EQT = environmental quality target concentration.

Source: Lwandle, 2012. Data collected during June 2012 survey.

Barium levels at a number of sampling stations in Area 1 were highly enriched relative to the apparent baseline conditions. A possible source of the barium is the barite used as a weighting agent in drilling fluids. This source is confirmed to an extent in the comparative distribution of sediment barium concentrations and known drilled well positions in the Golfinho and Prosperidade gas fields (see *Figure 7.17*). It is evident that barium concentration is strongly elevated at the Golfinho 1 well, and less so at the Barquentine and Lagosta well complexes. The strongly elevated concentration recorded at sample site Pr3 is not linkable to the well position data for these well complexes, but may be the result of previous exploration activities in this region.

Figure 7.17 Distribution of Barium Concentrations (mg/kg) in Sediments, June 2012, and Locations of Wells in Area 1



Key:  
 Blue dots = locations of sediment sampling locations. Green dots = known locations of drilled wells. White line = distribution of the barium concentrations in mg/kg.

Source: Lwandle, 2012. Data collected during June 2012 survey.

## 7.6 OFFSHORE ENVIRONMENT – MAJOR BIOLOGICAL FEATURES

### 7.6.1 Plankton

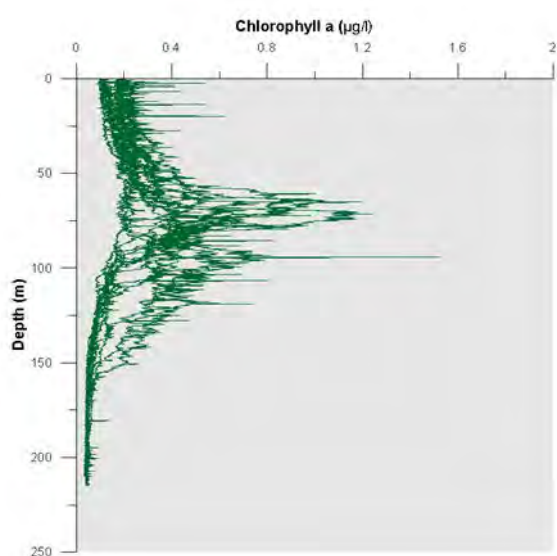
Plankton comprises two major components, phytoplankton and zooplankton. Generally, these two plankton components are the base that sustains the trophic web of marine life. Information about plankton in the Study Area is sparse. Saetre and da Silva (1979) reported on the plankton distribution and abundance results from acoustic surveys carried out during the Dr Fridtjof Nansen cruise in northern Mozambique waters. These authors suggested that plankton is abundant over the continental shelf, with a maximum abundance occurring along the continental edge or shelf break, with areas off the shelf exhibiting low plankton abundance. However, no details are available on species diversity. The frequent occurrence of tuna schools known in the area



was also found to substantiate the high productivity of plankton (Saetre & da Silva, 1979).

Water samples collected from the offshore CTD sampling stations in June 2012 (see Section 7.5.1) were analysed for chlorophyll fluorescence, and composite profiles (Figure 7.18) show low phytoplankton biomass in the upper water column overlying a subsurface chlorophyll maximum below 50m depth. This is consistent with a euphotic but nutrient-limited upper mixed layer, with nutrients diffusing through the thermocline from aphotic but relatively nutrient-rich deeper waters. This is an ubiquitous feature of open ocean chlorophyll distributions (eg Parsons et al., 1977).

**Figure 7.18** *Composite Chlorophyll Depth Profiles for the Offshore CTD Sampling Stations, June 2012*



Source: Lwandle, 2012. Data collected during June 2012 survey.

### 7.6.2 *Benthos*

One hundred and ten benthos taxa were observed in the samples analysed from the offshore sampling stations (see Figure 7.2). This included taxa from the major groups of Polychaeta, Crustacea, Mollusca and Echinodermata. Minor groups such as Sipunculida, Cnidaria and Nemertea were also represented. As shown in Table 7.2, polychaetes were the most taxonomically diverse group with 36 families represented.

**Table 7.2** *Total Numbers of Families and Species/Nominal Taxa per Higher Taxon Group (Phylum, Class, or Order) from all Sites Sampled in the June 2012 Survey*

Higher Taxa	Taxon Rank	Number of Families	Number of Taxa/Species
Sipunculida	Phylum	1	1*
Nemertea	Phylum	1	1*
Platyhelminthes	Phylum	1	1

Higher Taxa	Taxon Rank	Number of Families	Number of Taxa/Species
Polychaeta	Class	36	63
Gastropoda	Class	3	3
Bivalvia	Class	4	4
Aculifera	Class	1	1
Ophiuroidea	Class	1	3*
Holothuroidea	Class	2	2
Anthozoa	Class	1	1*
Amphipoda	Order	7	9
Cumacea	Order	1	2
Isopoda	Order	5	13
		(including the order Asellota)	
Tanaidacea	Order	8	9
Decapoda	Order	4	5

Several Tanaidacea (crustacea) species observed appear to be new to science and have not previously been taxonomically described. These specimens have been sent to an acknowledged expert on Tanaidacea taxonomy for confirmation of this. Whether these are unique to the area is unknown as the East African benthos has not been researched to the extent that any confident statements can be made on the geographic ranges of the sampled organisms. Generally deep water benthos species have distribution ranges that extend over multiple degrees of latitude (eg Rex et al., 2000) and it is unlikely that benthos observed in Area 1 are different in this respect. Distribution patterns in the sampled area are only weakly defined with the data available and there are similarly weak associations with key variables in the sediments.

The dominant fauna in terms of abundance and biomass are listed in *Table 7.3*.

**Table 7.3** *Benthos Abundance and Biomass from June 2012 Survey*

Abundance		
Higher Taxon	Taxon	Total abundance (0.1m <sup>2</sup> )
Polychaeta	<i>Aphelochaeta</i> spp. ( <i>Monticellina</i> spp.?)	52.78
	Syllidae	36.00
	<i>Aponuphis</i> spp.	33.84
	<i>Exogone</i> spp.	33.25
	<i>Paraprionospio</i> spp.	29.00
	<i>Aricidea</i> spp.	24.5
	<i>Nephtys</i> spp.	24.03
	Ampharetidae	23.03
Sipunculida	Maldanidae	19.03
	Sipunculida	18.75
Biomass		
Higher Taxon	Taxon	Total biomass (g/0.1m <sup>2</sup> )
Echinodermata	<i>Theleota ananas</i>	31.35
Mollusca	<i>Bullia</i> spp.	3.99
Sipunculida	Sipunculida	0.70
Mollusca	Bivalvia C (recruit) Veneridae	0.35
	Amphiuridae A	0.34
Polychaeta	Maldanidae	0.24
	<i>Aponuphis</i> spp.	0.17
Mollusca	Arcidae	0.10

Abundance		
Higher Taxon	Taxon	Total abundance (0.1m <sup>2</sup> )
Platyhelminthes	Platyhelminthes	0.10
Nemertea	Nemertea	0.09

In general, the benthos was sparsely distributed across the Offshore Survey Area with some stations recording zero counts. The offshore benthos survey indicates that the fauna are sparsely distributed throughout Area 1 but are diverse.

Typically low abundances were observed in the majority of the offshore sample sites, with elevated levels in Palma Bay and stations Pr3 and Pr 29. Polychaeta comprise most of the numerically abundant fauna with the only other group represented being Sipunculida (peanut worms). Benthic biomass were more uniformly distributed, with low biomass in the deeper water areas and markedly elevated levels within Palma Bay (although this is attributed to the presence of a single specimen of sea cucumber *Thelenota ananas* (Echinodermata, Holothuroidea (sea cucumber)) and two *Bullia* (Mollusca, Bivalvia) specimens. Results suggest abundance and biomass are reduced with increasing water depth.

Despite a moderately large number of samples it is probable that the species present were undersampled and that the derived taxonomic list for the area is likely to be incomplete.

*Figure 7.19* shows a number of benthos specimens observed offshore including the species identified that have not been previously been described taxonomically.

Figure 7.19 Benthos Specimens from Area 1, Offshore Mozambique

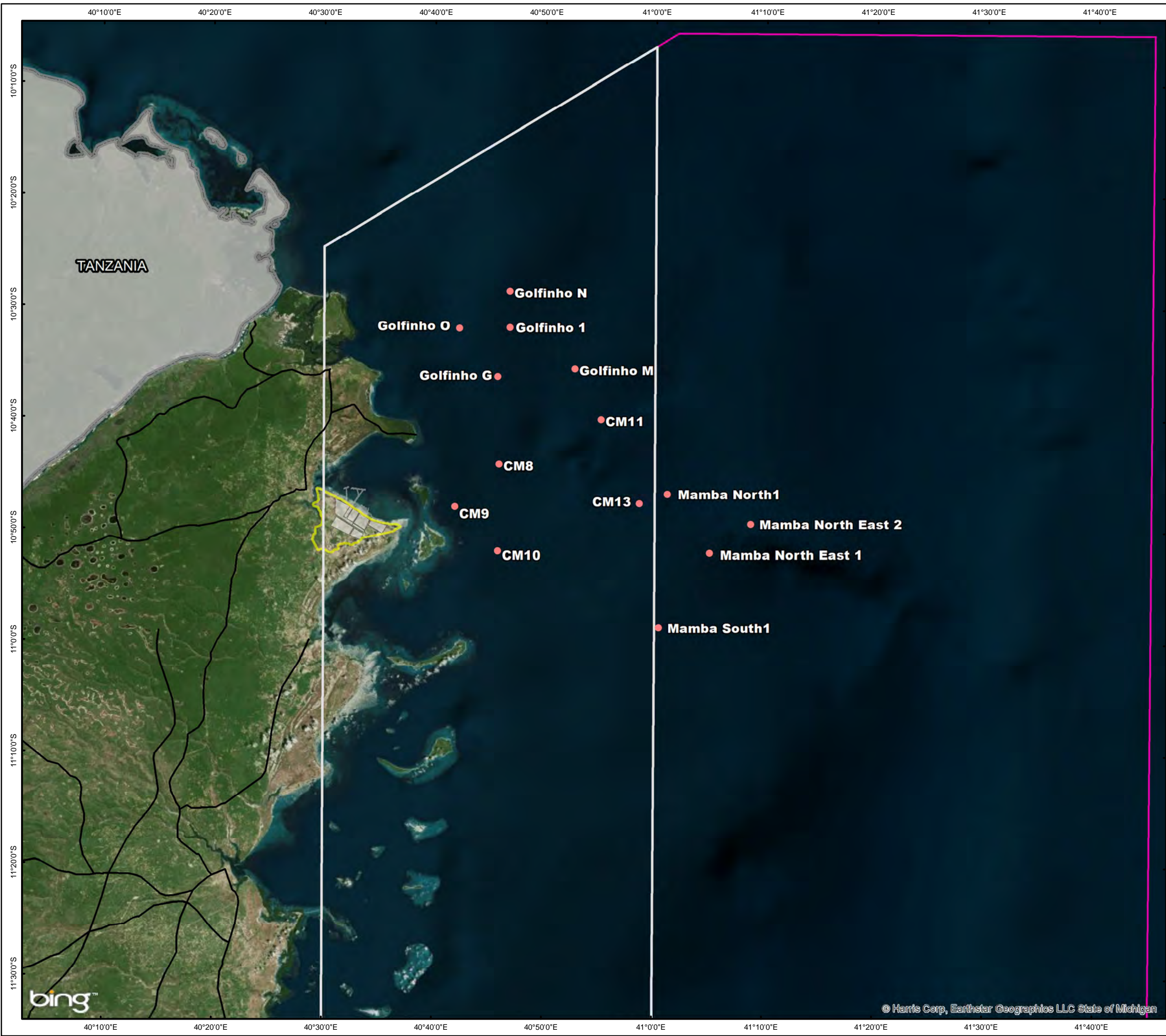


Note: Apseudes sp. and Parapseudes sp. (centre panels) are apparently new Tanaidacea (Crustacea) species.

Source: Lwandle, 2012.

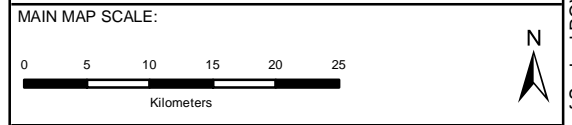
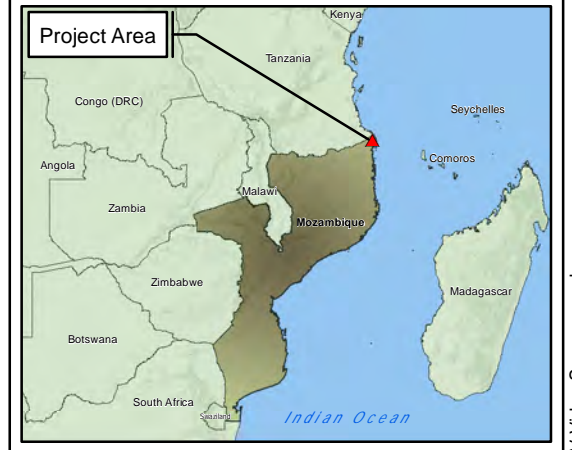
### 7.6.3 Reef Structures

There are no published scientific reports on the distributions or features of reefs in deep water off the northern Mozambique coast. CSA, as part of its gas field exploration and simulation modelling for drill cuttings and mud discharges, analysed ROV seabed video surveys around five sites in the Golfinho Gas Field in 2012. This work has been augmented by ROV video records from five current meter deployment sites off Palma Bay and a further four sites within the Mamba Gas Field. The locations of these are illustrated in Figure 7.20, and the water depths for each and types of transects deployed are listed in Table 7.4.



### Legend

- Regional Roads
- Jetty
- Onshore Layout
- ▭ Afungi Project Site
- Seabed ROV Video Surveys
- Area 1
- ▭ Area 4



TITLE:  
**Figure 7.20:  
 Locations of Seabed ROV Video Surveys**

CLIENT:

**Anadarko**  
 Moçambique Área 1, Lda

DATE: Oct 2013	CHECKED: KG	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 600 000
DRAWING: Locations of Seabed ROV Video Surveys.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. Lwandle Technologies, 2012. Inset Map: Esri Data & Maps

SIZE:  
**A3**

**Table 7.4 Seabed ROV Video Surveys in the Gas Fields Offshore of Palma Bay**

Site	Approximate Location (WGS 1984 UTM Zone 37S)		Water Depth (m)	No. of Transects	Transect Lengths and Layout
	X	Y			
Golfinho 1	694835	8835250	1010	17	400 m, grid
Golfinho G	692805	8827130	845	8	400 m, radial
Golfinho M	705570	8828395	1290	8	400 m, radial
Golfinho N	694820	8841230	1075	8	400 m, radial
Golfinho O	686515	8835175	730	8	400 m, radial
CM8	693024	8812646	655	4	~500 m, orthoganal
CM9	685690	8805685	390	4	~500 m, orthoganal
CM10	692767	8798344	515	4	~500 m, orthoganal
CM11	709885	8820012	1459	4	~500 m, orthoganal
CM13	716142	8806133	1510	4	~500 m, orthoganal
Mamba South 1	719325.230	8785615.230	1605	8	400 m, radial
Mamba North 1	720799.494	8807702.420	1710	10	400 m, radial
Mamba North East 1	727761.986	8797923.935	1863	9	400 m, radial
Mamba North East 2	734528.570	8802752.640	2019	7	400 m, radial

Source: Lwandle, 2012. Data from CSA (2012) and MSI (2012, *in litt.*) and eni, 2013.

These surveys detected low-relief reefs at Golfinho 1, G and O, CM 9, 10 and 13 and high-relief, rugose reefs at Golfinho 1 and CM10, indicating that reefs occur across the full depth range (390 to 1,510m) for which observations have been made. It is probable that they are found throughout the area of the offshore gas fields. Video records in the Mamba Gas Field show no evidence of reef structures in the vicinity of the four locations surveyed. Depths at these two well locations reach 1,685m and 2,000m respectively. The lack of reef structures cannot be extrapolated for the entire Mamba Gas Field, since the area of the seafloor was limited to the immediate surroundings of these two well locations.

Although the video records are not of high quality, it appears that biodiversity is higher on the high-relief reefs with that on the low-relief reefs being considerably lower. However, even the high-relief reefs do not apparently support high densities of fauna, which has been visually estimated to attain six to eight organisms per square metre (CSA, 2012). The observed fauna include Gorgoniid octocorals, Scleractinian cup corals and *Lophelia*, crinoids, sponges and Antipatharian (black) corals. It should be noted that only larger, easily visible organisms would have been identifiable in the video records, due to suboptimal video records. Some of the fauna observed are extremely slow growing eg black corals have estimated growth rates of <0.1mm per year (Roark et al., 2009). Thus, although biodiversity may be low and deepwater corals not well developed, these high-relief reefs are ecologically important features. *Figure 7.21* and *Figure 7.22* show examples of a high-relief reef at approximately 1,000m depth and a low-relief reef at 390m depth.

**Figure 7.21** ROV Images of High-relief Reef Structures at Approximately 1,000m Depth in Golfinho Gas Field



Image quality is insufficient for firm taxonomic classification.

Source: Lwandle, 2012. Images provided by AMA1.

**Figure 7.22** ROV Images of Low-relief Reef Structures at Approximately 390m Depth in Golfinho Gas Field

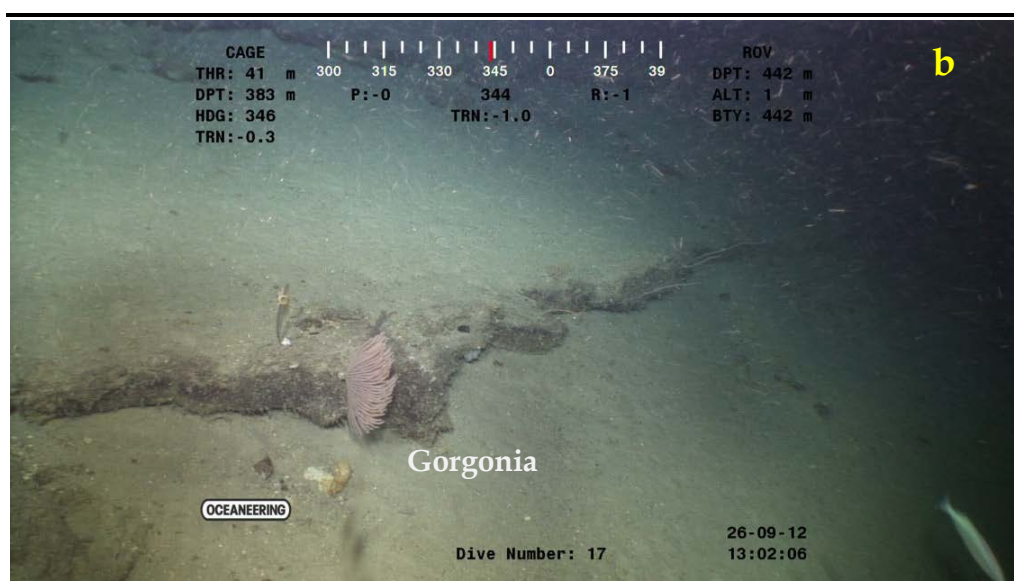


Image quality is insufficient for firm taxonomic classification.

Source: Lwandle, 2012. Images provided by AMA1.

Very little is known about the deepwater reefs in the waters off Mozambique, or off the east African continental shelf in general, as little to no research has been undertaken. Deepwater reefs, including coral and rugose reefs, typically act as biodiversity reserves, supporting habitat complexity distinct from that of the surrounding seabed. Species not unique to reefs often benefit by using these structures as a refuge eg for nursery grounds for fish. Deepwater reefs support a host of communities, however the extent of the function and importance of the deepwater reef structures in the Project Area are not fully understood.

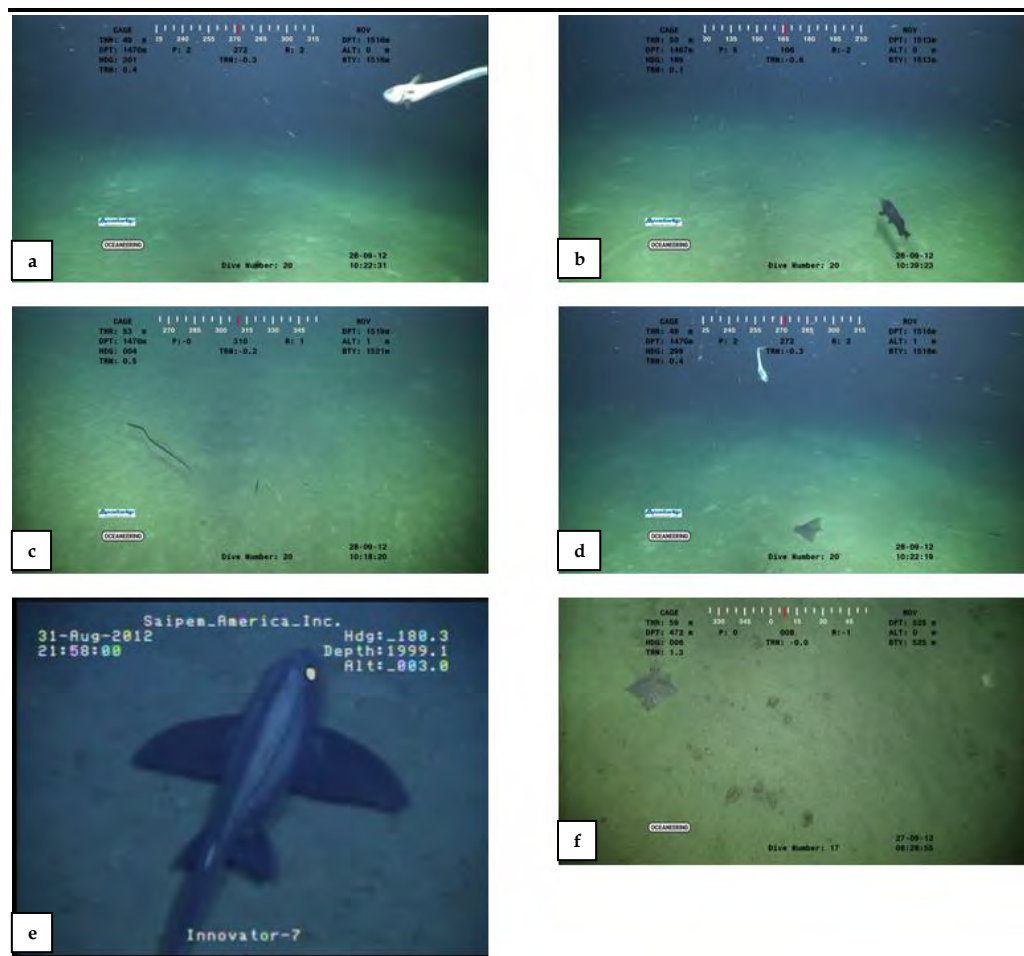
The fish fauna of northern Mozambique waters offshore of the continental shelf break are not well known, as is the case in much of the world's oceans, with knowledge mostly confined to the commercially important large pelagic tuna, mackerel and bonito (Scomberidae). Important species include yellowfin tuna (*Thunnus albacares*) and skipjack (*Katsuwonus pelamis*) which are categorised as Near Threatened and Least Concern respectively according to the IUCN Red List of Threatened species (IUCN, 2012). Information on other species that are probably present comes from tuna fishery bycatch data (Romanov, 2002). Bycatch records identify up to 45 taxa of fish fauna, depending on whether the tuna schools were free swimming or associated with whale sharks (*Rhincodon typus*) which are categorised as Vulnerable (IUCN, 2012) or whales (mainly Balaenoptera, such as sei whales). These include Dasyatidae (stingray), Mobulidae (manta ray), Lamnidae (mako), Carcharinidae, Sphyrnidae (hammerhead), Exocoetidae (flying fish), Belonidae (needlefish), Lampidae (opah), Spyraenidae (barracuda), Carangidae (many species), Coryphaenidae (dorado), Kyphosidae (chub), Gempylidae (cutlass fish), Ehippidae (batfish), Scombridae (wahoo, mackerel, tuna), Istiophoridae (sailfish, marlin), Xiphidae (swordfish), Nomeidae (bluebottle fish), Monacanthidae (filefish) and Diodontidae (puffer). All of the above have very wide distributions in the western Indian Ocean.

Mesopelagic fish that probably occur in the offshore area include *Benthoosema fibulatum*, *Symbolophorus evermanni*, *Diaphus garmani*, *D. nielsenii*, *D. perspicillatus* and *Lampanyctus* sp. (Saetre & da Silva, 1979). This group is well represented between 50 and 300km offshore, but appears to diminish in abundance beyond this range. Overall biomass has been estimated at 5,600 tonnes. Similar to the larger pelagic species, mesopelagics are generally widely distributed in the western Indian Ocean and worldwide.

Figure 7.23 shows a selection of deepwater demersal fish observed in the ROV video footage undertaken during offshore gas exploration activities. Given the quality of the video footage and that no specimens have been obtained, fish identification have been difficult. It is believed that some of the species observed eg the fish that resembles angel shark in the figure below, may be previously described taxonomically and possibly therefore new to science.



Figure 7.23 ROV images of Deepwater Demersal Fish in the Offshore Gas Fields



Sources: Images a - d and f from AMA1, 2013. Image e from eni.

Tentative classifications courtesy of David Japp (Capricorn Fishing CC, South Africa) and David Ebert (Pacific Shark Research Centre, Moss Landing Marine Laboratories, California State University):

- (a) Malacocephalus sp. (Rat Tail)
- (b) Alepocephalus sp. (*A. australis* (?), Slickhead)
- (c) Anguilliformes (Ophichthidae sp (?), snake eel)
- (d) Myliobatidae sp.
- (e) Not yet identified, resembles angel shark (Squatinae) but swimming motion and tail indicate that it may be a bony fish (Osteichthyes).
- (f) Raja sp. (*R. alba* or *R. dissimilis*).

## 7.6.5 Whales and Dolphins

According to Peddemors et al. (1997), at least 21 species of marine mammals have been recorded in the Mozambique Channel, 17 of which probably occur in the Study Area (Table 7.5). A sperm whale (*Physeter macrocephalus*) was recorded during the 2008 marine mammal monitoring programme undertaken as part of a seismic survey in the deepwater of Area 1, carried out between January and May 2008 (Marine Team Offshore<sup>(1)</sup>, 2008). This species

(1) The Marine Team Offshore refers to the team commissioned by AMA1 to undertake a marine mammal monitoring programme during a seismic survey in deepwater areas of Area 1 in 2008.

and several other species were observed by marine mammal observers in Area 4, during a seismic survey conducted between February and June 2010 (RPS Energy 2010). The species observed in the vicinity of the Mamba Gas Fields during the seismic campaigns are listed in *Table 7.5*.

In addition, a subsequent sighting of a sei whale (*Balaenoptera borealis*) has been observed in the Study Area (Mario Rassul, AMA1, pers. comm., 2011). Sei whales are considered to be Endangered, sperm whales Vulnerable, Indian Ocean humpback dolphins Near Threatened and the balance of the species are of Least Concern (eg humpback whales, which have been downgraded from Threatened status) or Data Deficient, according to the IUCN Red List of Threatened Species (IUCN, 2012).

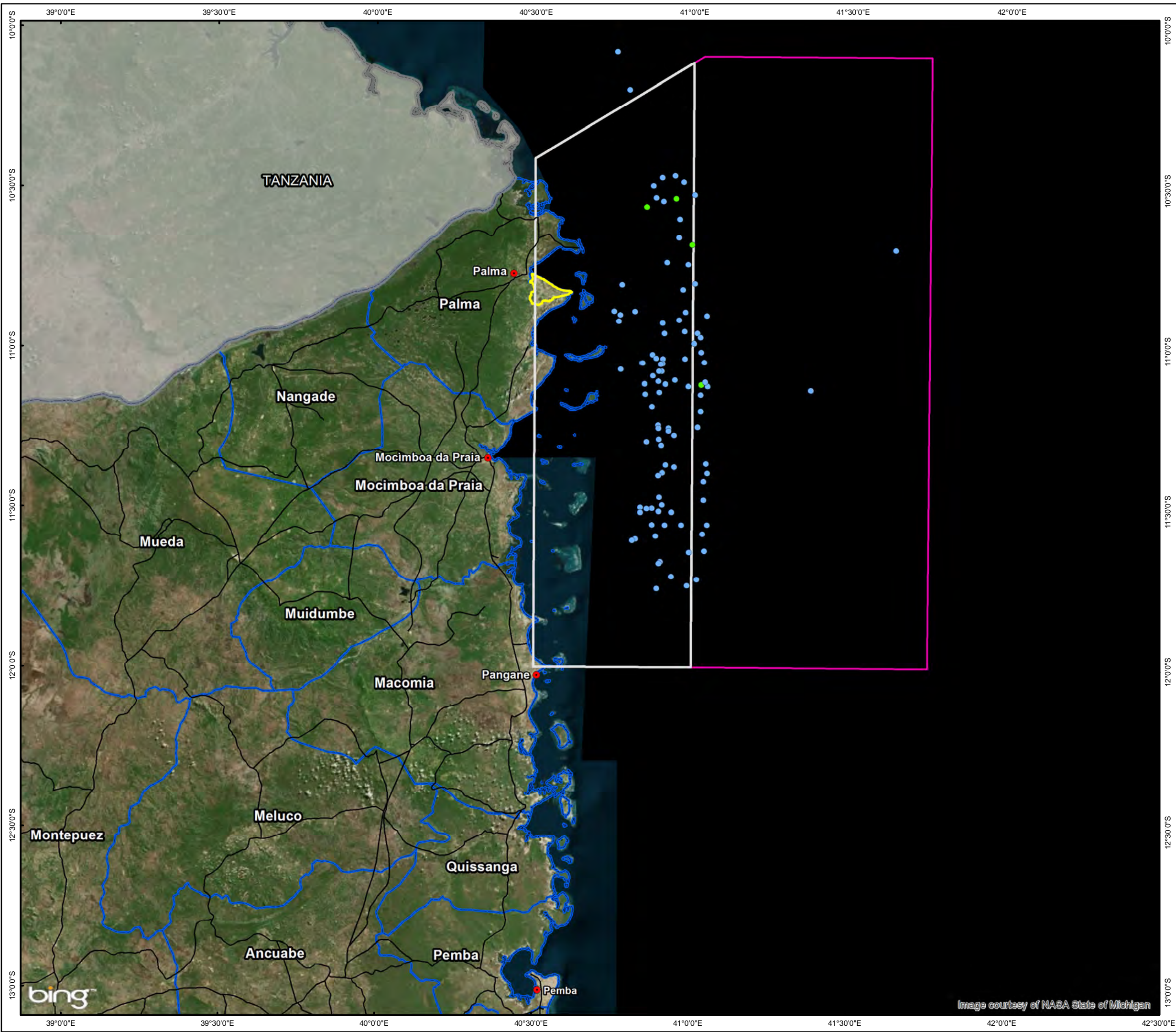
*Figure 7.24* shows the marine mammal sightings observed during the 2008 marine mammal observations undertaken during the offshore seismic surveys (Marine Team Offshore, 2008). *Table 7.5* indicates the periods when the various whale and dolphin species may be expected to occur offshore, based on previous observations.

**Table 7.5** *Marine Mammals in the Mozambique Channel, Expected Occurrences and Sightings*

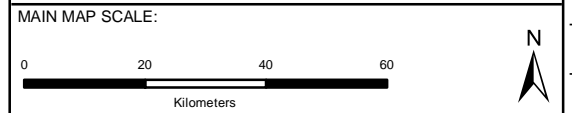
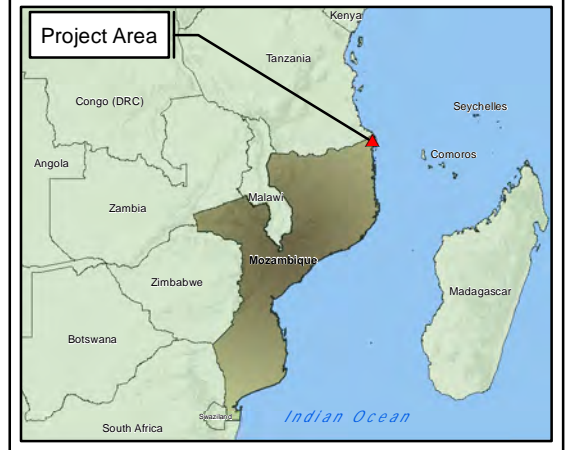
Common Name	Species	Conservation Status*	Resident/ Occurrences	Sightings in Area 4
Humpback whale	<i>Megaptera novaeangliae</i>	Least Concern	Seasonal: July–November	Yes
Minke whale	<i>Balaenoptera acutorostrata</i>	Least Concern	Seasonal: July–November	Yes
Common dolphin	<i>Delphinus delphis</i>	Least Concern	All year	Yes
Pygmy killer whale	<i>Feresa attenuata</i>	Data Deficient	All year	Yes
Short finned pilot whale	<i>Globicephala macrorhynchus</i>	Data Deficient	All year	Yes
Risso’s dolphin	<i>Grampus griseus</i>	Least Concern	All year	Yes
Pygmy sperm whale	<i>Kogia breviceps</i>	Data Deficient	All year	Yes
Blainville’s beaked whale	<i>Mesoplodon densirostris</i>	Data Deficient	All year	
Killer whale	<i>Orcinus orca</i>	Data Deficient	Seasonal	
Melon-headed whale	<i>Peponocephala electra</i>	Least Concern	All year	Yes
Sperm whale	<i>Physeter macrocephalus</i>	Vulnerable	All year/males migratory	Yes
Bryde’s whale	<i>Balaenoptera brydei</i>	Data Deficient	Unknown	Yes
False killer whale	<i>Pseudorca crassidens</i>	Data Deficient	All year	Yes
Indian Ocean humpback dolphin	<i>Sousa chinensis</i>	Near Threatened	All year	Yes - nearshore
Spotted dolphin	<i>Stenella attenuata</i>	Least Concern	All year	Yes
Striped dolphin	<i>Stenella coeruleoalba</i>	Least Concern	All year	
Long-snouted spinner dolphin	<i>Stenella longirostris</i>	Data Deficient	All year	Yes
Rough-toothed dolphin	<i>Steno bredanensis</i>	Least Concern	All year	
Bottlenose dolphin	<i>Tursiops truncatus</i>	Least Concern	All year	Yes
Long-beaked common dolphin	<i>Delphinus capensis</i>	Data Deficient	All year	

Common Name	Species	Conservation Status*	Resident/ Occurrences	Sightings in Area 4
Risso's dolphin	<i>Grampus griseus</i>	Least Concern	Unknown	Yes
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	Least Concern	All year	Yes
Sei whale	<i>Balaenoptera borealis</i>	Endangered	Seasonal (austral winter)	Yes

Source: Expected occurrences from Peddemors et al., 1997. Sightings in Area 4 from RPS Energy, 2010 during seismic surveys. \* The conservation status is based on the IUCN Red List of Threatened Species (2012).



- Legend**
- Marine Mammal Sightings
  - Turtle Sightings
  - Towns
  - Regional Roads
  - Afungi Project Site
  - Area 1
  - Area 4
  - District Boundary
  - Boundary with Tanzania



TITLE:  
**Figure 7.24:**  
 Marine Mammals (blue dots) and  
 Turtle Sightings (green dots) and  
 Detections

CLIENT:

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 1 250 000
DRAWING: Marine Mammals.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

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

SIZE:  
 A3

Six taxonomic families of seabirds (broadly defined as species that spend a large portion of their lives on or over sea water) are found in the offshore waters of northern Mozambique (*Table 7.6*). Some species of this group primarily inhabit continental slope habitats (eg albatrosses, petrels and their allies, boobies and gannets, and tropicbirds). Most seabird species in the Mozambique Channel, however, inhabit waters of the continental shelf and shelf edge and adjacent coastal and inshore habitats (Newman, 2002; Sinclair & Ryan, 2003).

Two species that are known to occur in the area, wandering albatrosses and Cape gannets (the latter probably being juvenile vagrants), are currently listed by the IUCN as Vulnerable, while the Indian yellow nose albatross is listed as Endangered, and the shy albatross and Jouanin's petrel as Near Threatened (IUCN, 2012).

Common and lesser crested terns were the most common seabirds sighted along the western edge of the Survey Area within waters of the continental shelf edge, during an offshore habitat characterisation survey undertaken for AMA1 (CSA, 2007).

**Table 7.6** *Offshore Seabirds of Northern Mozambique*

Common Name	Species	Conservation Status*	Seasonality	Local Presence
Wandering albatross	<i>Diomedea exulans</i>	Vulnerable	N/A	Uncommon visitor
Indian yellow-nosed albatross	<i>Thalassarche carteri</i>	Endangered	Winter	Common visitor
Shy albatross	<i>Thalassarche cauta</i>	Near Threatened	Winter Summer	Common visitor Uncommon visitor
Great-winged petrel	<i>Pterodroma macroptera</i>	Least Concern	N/A	Common visitor
Pintado petrel	<i>Daption capense</i>	Least Concern	Winter	Common visitor
Jouanin's petrel	<i>Bulweria fallax</i>	Near Threatened	N/A	Uncommon visitor
Wedge-tailed shearwater	<i>Puffinus pacificus</i>	Least Concern	N/A	Infrequent visitor
Flesh-footed shearwater	<i>Puffinus carneipes</i>	Least Concern	N/A	Uncommon visitor
Cory's shearwater	<i>Calonectris diomedea</i>	Least Concern	N/A	Common visitor
Audubon's shearwater	<i>Puffinus lherminieri</i>	Least Concern	N/A	Uncommon visitor
Wilson's storm petrel	<i>Oceanites oceanicus</i>	Least Concern	N/A	Common visitor
Black-bellied storm petrel	<i>Fregatta tropica</i>	Least Concern	Winter	Uncommon visitor
Cape gannet	<i>Morus capensis</i>	Vulnerable	N/A	Vagrant
Masked booby	<i>Sula dactylatra</i>	Least Concern	N/A	Common visitor
Red-footed booby	<i>Sula sula</i>	Least Concern	N/A	Uncommon visitor
White-tailed tropicbird	<i>Phaethon lepturus</i>	Least Concern	N/A	Common visitor
Red-tailed tropicbird	<i>Phaethon rubricauda</i>	Least Concern	N/A	Uncommon visitor
Lesser frigate bird	<i>Fregata ariel</i>	Least Concern	N/A	Rare visitor
Greater frigate bird	<i>Fregata minor</i>	Least Concern	N/A	Common resident
Sandwich tern	<i>Sterna sandwicensis</i>	Least Concern	Summer	Common visitor
Lesser crested tern	<i>Sterna bengalensis</i>	Least Concern	Summer	Common visitor
Common tern	<i>Sterna hirundo</i>	Least Concern	Summer	Common visitor
Sooty tern	<i>Sterna fuscata</i>	Least Concern	N/A	Uncommon visitor
Lesser noddy	<i>Anous tenuirostris</i>	Least Concern	N/A	Uncommon visitor
Pomarine jaeger	<i>Stercorarius pomarinus</i>	Least Concern	N/A	Common visitor
Parasitic jaeger	<i>Stercorarius parasiticus</i>	Least Concern	N/A	Common visitor
Long-tailed jaeger	<i>Stercorarius longicaudus</i>	Least Concern	N/A	Common visitor

Source: Harrison, 1983; Newman, 2002; Sinclair and Ryan, 2003.

\* The conservation status is based on the IUCN Red List of Threatened Species (2012).

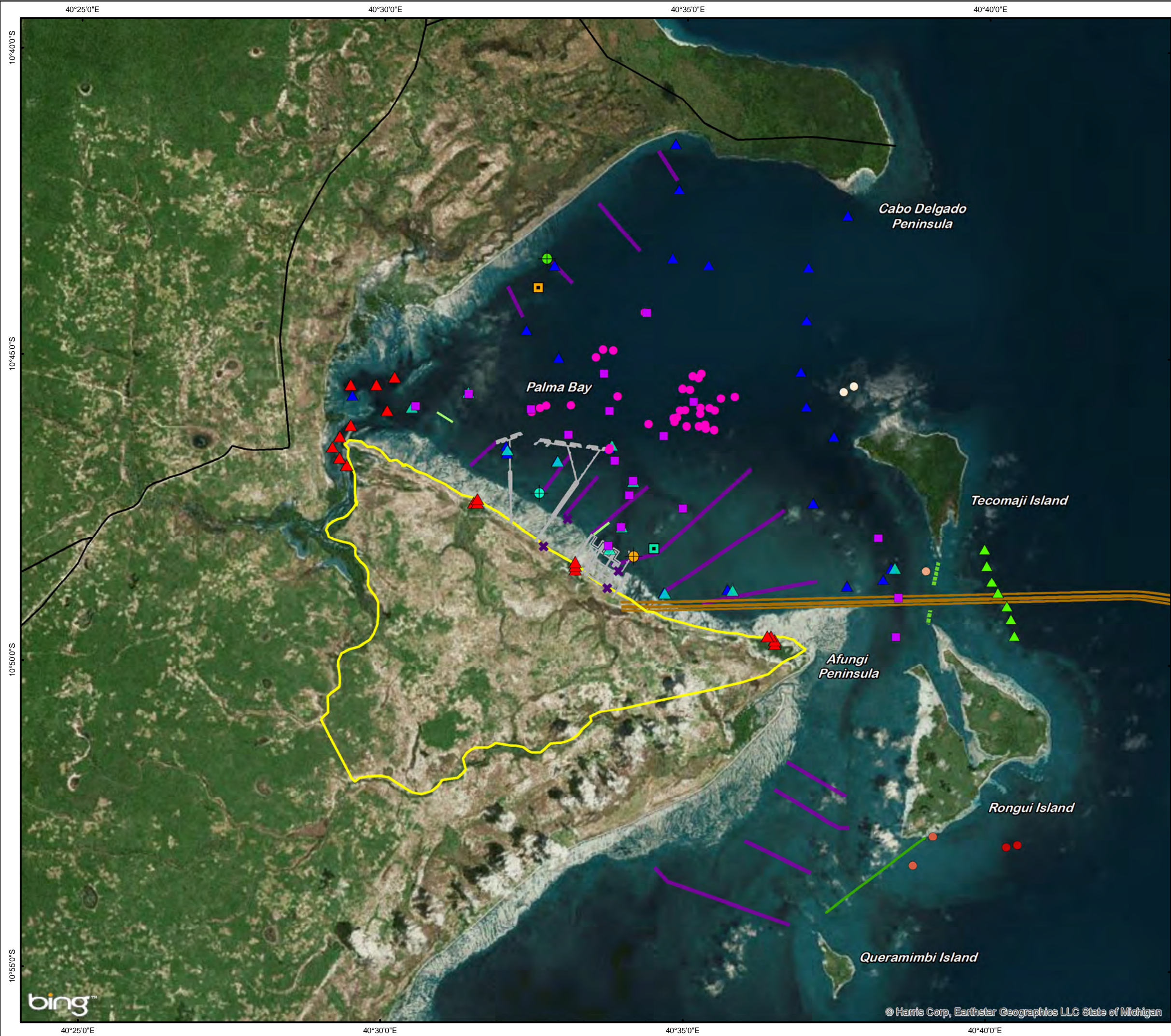
## 7.7 NEAR SHORE ENVIRONMENT – PHYSICAL CONDITIONS

### 7.7.1 *Baseline Surveys and Survey Area*

Location-specific information and data for Palma Bay are sparse. Therefore, as part of the LNG Facility site selection process, and subsequent environmental baseline data gathering and design data procurement, intensive investigations of the area have been carried out. These include bathymetric and sub-bottom profiling undertaken by UWS, metocean measurements within the bay and offshore undertaken by Metocean Services International (Pty) Ltd (MSI) and also dry season (November 2011) and wet season (March 2012) marine ecology surveys (Lwandle Technologies (Pty) Ltd). These are discussed below, with the main focus being on marine ecology surveys, which are augmented by contributions on the marine ecology of the region (Adriano Macia, Impacto) and fish and fisheries (Atanasio Brito, Impacto).

The marine ecology surveys were undertaken in the near shore environment, ie Palma Bay, by Lwandle. They comprised water column measurements of temperature, salinity, dissolved oxygen, turbidity and pH. In addition, water sampling was carried out to assess the concentration and distribution of dissolved inorganic nutrients, and surveys on seagrass, coral and sandy beach ecology were conducted. The findings are described in *Sections 7.7 to 7.8* of this chapter.

*Figure 7.25* provides a schematic view of the distribution of measurement stations and sites in relation to the marine facilities planned for the LNG Facility. The location of these stations and sites is collectively referred to as the Survey Area.



**Legend**

- ▲ Conductivity Temperature Depth
- ▲ Inorganic Nutrient Sampling Sites
- ▲ Inorganic Nutrient Sampling Sites - Estuaries

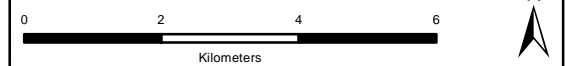
**Seagrass Bed Sampling Stations**

- ⊕ Afungi Test Site East (AFE)
- ⊕ Afungi Test Site West (AFT)
- ⊕ Palma West (PMW)
- Sand Craters
- Surficial Sediment Sampling Locations

**Coral Reef Sampling Sites**

- Far Field Bommie (FFB)
- Near Field Bommie (NFB)
- ▲ Seabed Observations at Deeper Waters between Tecomaji and Rongui Islands
- Tecomaji North Observations
- Tecomaji South Observations
- Rongui South Observation
- Rongui South Transect
- Boat Based Survey
- Tecomaji and Rongui Transect
- Rongui and Queramimbi Transect
- Seagrass Transects
- Regional Roads
- Proposed Nearshore Infrastructure
- Proposed Pipeline Corridor Route
- Afungi Project Site

MAIN MAP SCALE:



TITLE:

**Figure 7.25:  
Marine Ecology Survey Area -  
Nearshore**

CLIENT:



DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
----------------	-------------	------------------

DRAWN: AB	APPROVED: KG	SCALE: 1 : 110 000
-----------	--------------	--------------------

DRAWING: Marine 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

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



### *Bathymetry*

Bathymetry and topographic data have been obtained from the following sources:

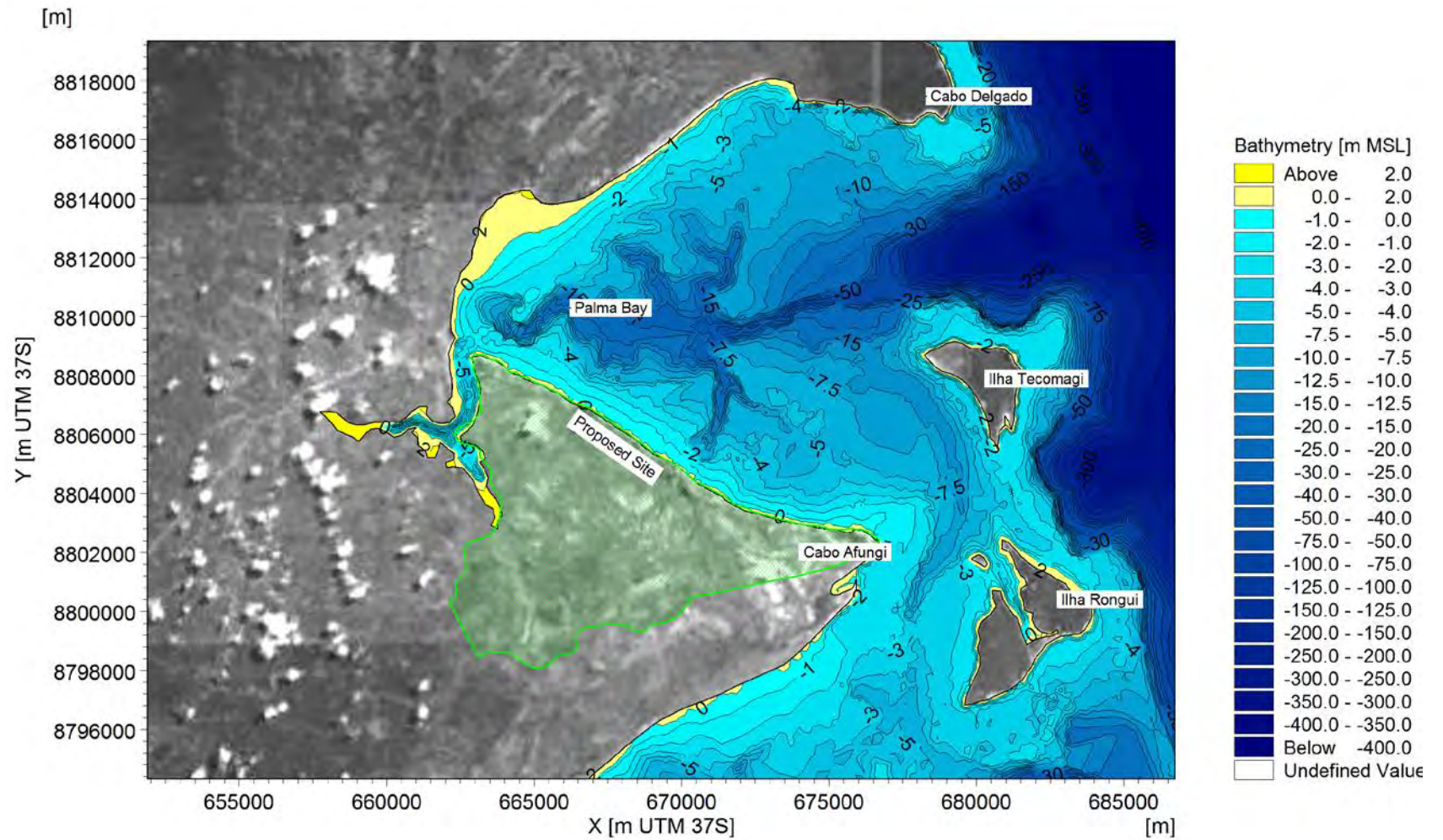
- single and multibeam bathymetric survey for Palma Bay undertaken by Underwater Surveys (Pty) (known as UWS) Ltd for Anadarko (P Vrey, pers. comm., 10 Feb 2012); and
- C-Map charts (DHI, 2011a).

All vertical levels in this report are relative to mean sea level (MSL). The horizontal projection is UTM Zone 37S. The vertical datum for the topography and the bathymetry has been analysed and corrected by PRDW with respect to measured tidal data in Palma Bay (PRDW, 2012). The general layout of Palma Bay and its bathymetry are shown in *Figure 7.26*.

The bathymetry of Palma Bay suggests that the bay is a drowned river/estuary system. There is a central channel linked to a continental shelf-edge canyon that exits the bay between the northern tip of Tecomaji Island and the Cabo Delgado Peninsula. The depth of the channel in the central area of the bay reaches up to 50m. Subsidiary channels join this, originating from the western shoreline of Palma Bay and from the northern shore of Afungi Peninsula.

The islands of Tecomaji and Rongui sit on the edge of the continental shelf, where there are water depths of greater than 350m within 2.5km of the islands.

Figure 7.26 Bathymetry of Palma Bay



Source: PRDW, 2012.

### 7.7.3

### Tides and Currents

Tidal water levels were measured by Underwater Surveys (Pty) Ltd at the mouth of the Palma estuary (10° 46' 31.83" S, 40° 29' 09.19" E) for almost three months, from 2 August 2011 to 25 October 2011. Analysis of the data by Lwandle has provided the following predicted tidal levels.

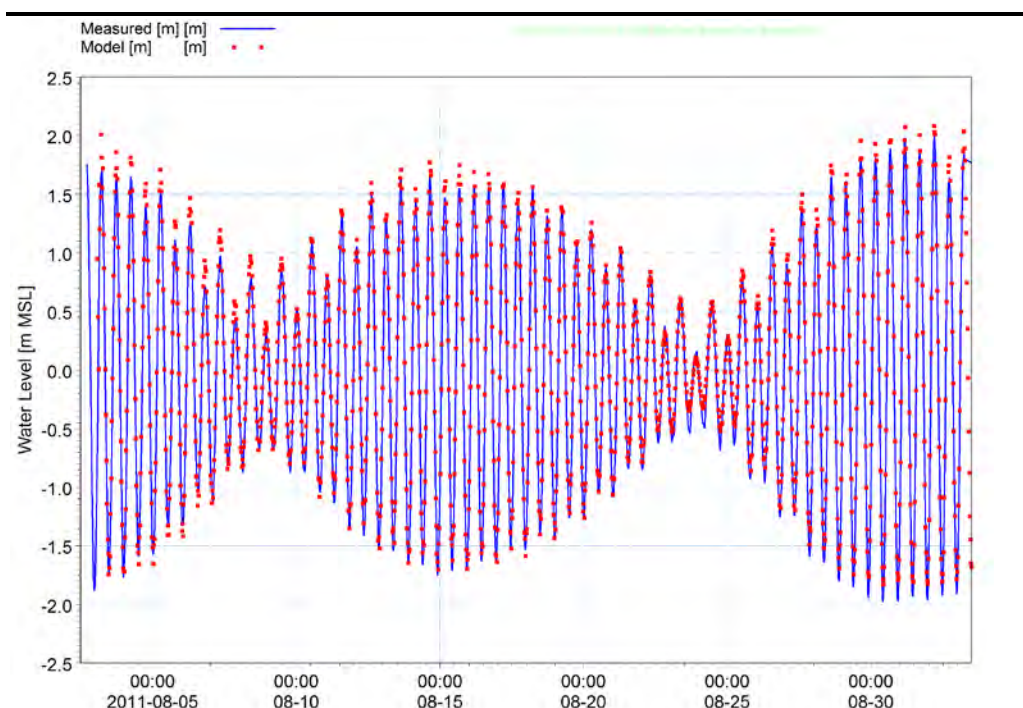
**Table 7.7** *Tidal Levels at Palma River Mouth*

Level	Height (m)
Highest Astronomical Tide (HAT)	2.21
Mean High Water Springs (MHWS)	1.80
Mean High Water Neaps (MHWN)	0.48
Mean sea level (MSL)	0.00
Mean Low Water Neaps (MLWN)	-0.52
Mean Low Water Springs (MLWS)	-1.77
Lowest Astronomical Tide (LAT)	-2.03

Source: Lwandle, 2012. Data derived from Underwater Surveys (Pty) Ltd.

Calibration of these measured water levels was undertaken by PRDW, using the Mike 21 Flow Model FM based on the flexible mesh approach (DHI, 2011b). Model results are plotted with measured data and shown in *Figure 7.27*.

**Figure 7.27** *Hydrodynamic Model Calibration: Model versus Measured Water Levels at Palma Bay*

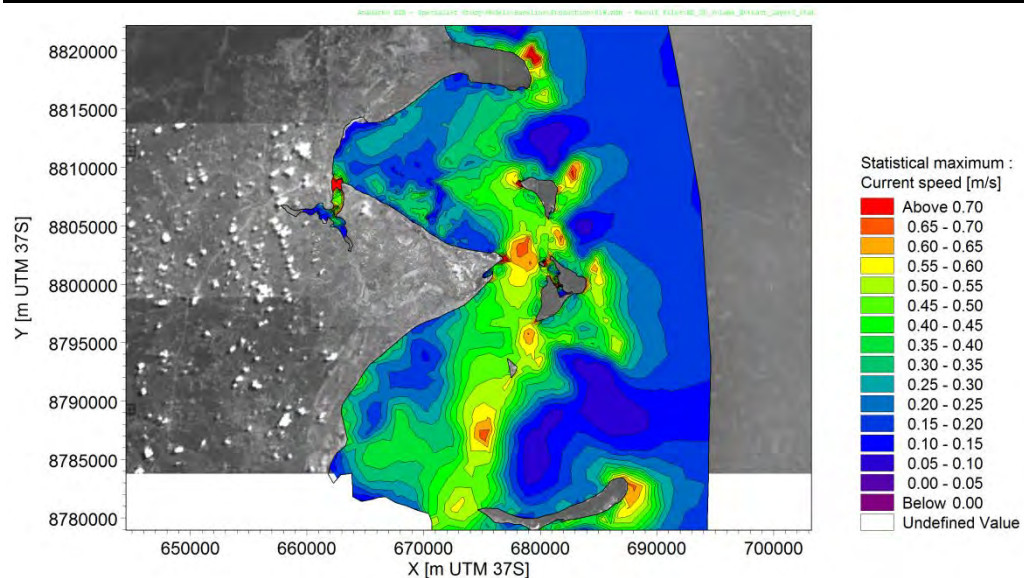


Source: PRDW, 2012.

In addition, PRDW undertook 3-D hydrodynamic modelling to characterise the current conditions in Palma Bay. As shown in *Figure 7.28*, maximum

current speeds can be seen in the relatively shallow water between the islands of Rongui and Tecomaji, where the maximum current speeds of 0.65 to 0.70m/s were observed. Statistical mean currents (not shown) for Palma Bay are low, between 0.05 and 0.2m/s.

**Figure 7.28** *Statistical Maximum Expected Surface Current Speeds for the South-easterly Monsoon Season*



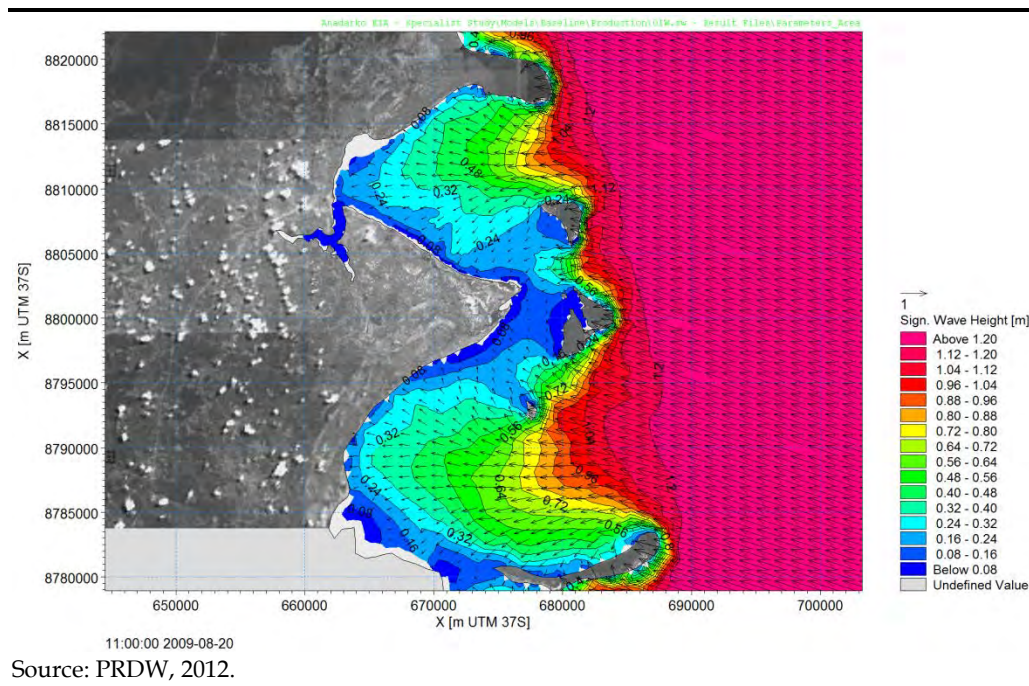
Source: PRDW, 2012.

#### 7.7.4 Waves

The wave climate described in *Section 7.5.2* for the offshore environment has been transformed to the near shore using modelling software by PRDW. Two representative conditions of a month each in duration were used to force the models, extracted from the National Oceanic and Atmospheric Administration (NOAA) National Centre for Environmental Prediction (NCEP) wave data (NCEP, 2010). These conditions can be seen as representing the two predominant seasonal patterns, namely a north-westerly (NW) monsoon and south-easterly (SE) monsoon.

Results from the wave transformation model are shown in *Figure 7.29* for a single wave condition (20 August 2009). It can be seen from the image that the limited depth within Palma Bay, coupled with the fringing reefs and the islands of Rongui and Tecomaji, offer protection in Palma Bay.

Figure 7.29 Wave Transformation in Palma Bay

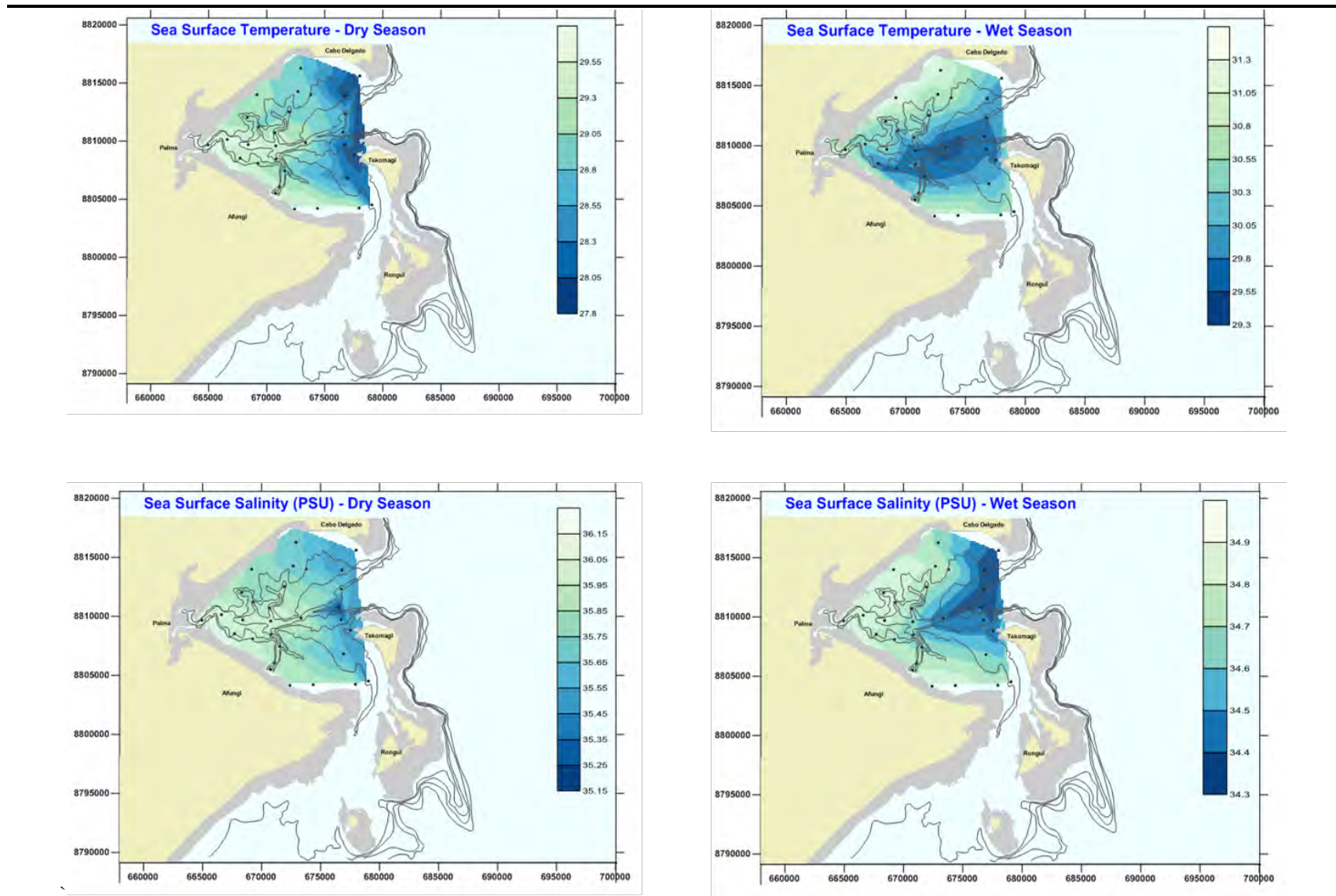


## 7.7.5 Water Column – Properties

### Temperature and Salinity

Sea surface temperature and salinity distributions measured in the dry (November) and wet (March) seasons in Palma Bay are shown in *Figure 7.30*. Surface temperatures ranged from 27.8 to 29.6°C in the dry season and from 29.4 to 31.3°C in the wet season. Higher temperatures were recorded in the inner reaches of the bay during both seasons. Sea surface salinities ranged from 35.14 to 36.13 PSU in the dry season and were lower at 34.34 to 34.89 PSU in the wet season, consistent with the increased rainfall and surface run-off typical of the wet season. However, as with the temperature distributions, the highest salinities occurred in the inshore areas of Palma Bay. The conjunction of the higher temperatures and higher salinity values implies reduced water turnover rates, with temperatures being increased by surface heating and salinities by evaporation.

Figure 7.30 Sea Surface Temperature and Salinity Distributions in Palma Bay in the Dry (November 2011) and Wet (March 2012) Seasons

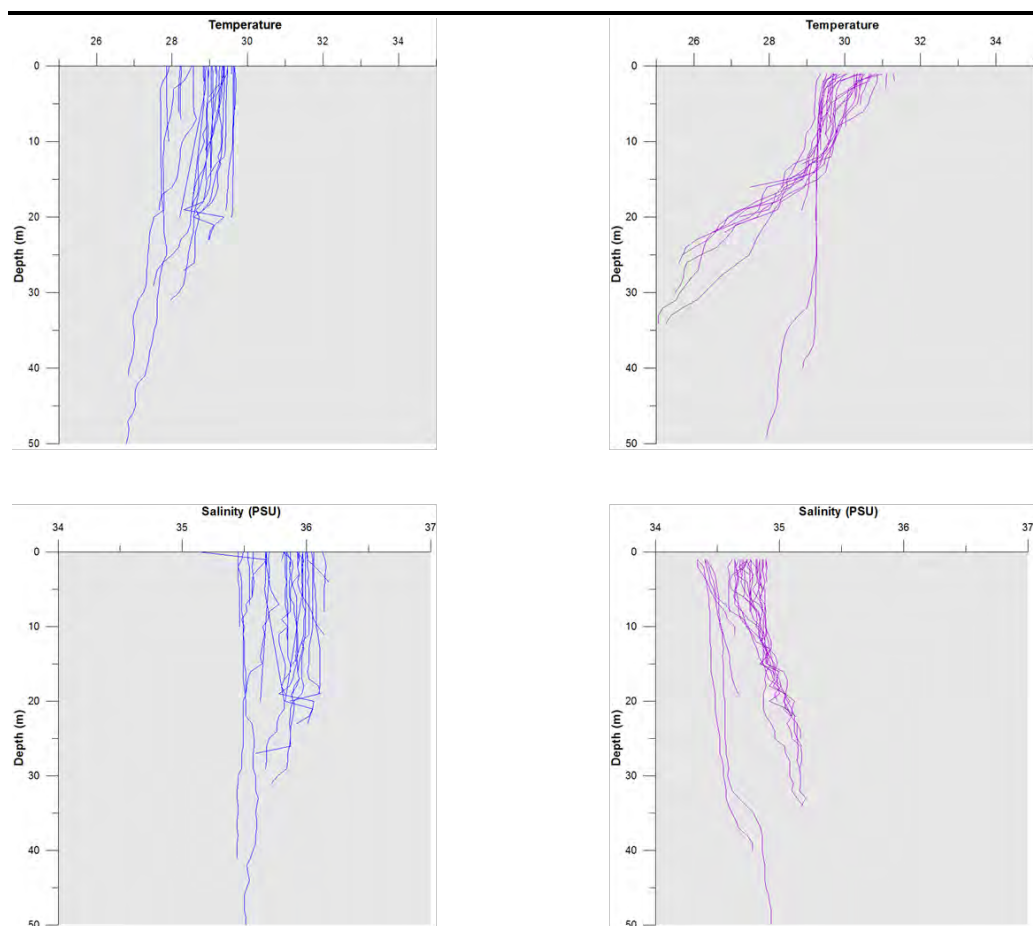


Source: Lwandle, 2012.

Distributions of temperatures and salinities across the water column show minimal vertical gradients in the dry season, but stronger gradients in the wet season (Figure 7.31). The wet season temperatures show the presence of relatively cool water at depth in the shallower profiles, and that bottom temperatures in these are lower than those measured at approximately 50m depth in the deeper areas in the entrance to Palma Bay. This implies that the cool waters that were present in the bay on the day of measurement were a remnant of a previous upwelling event. There are no concurrent data to identify upwelling mechanisms but, given the close proximity of the continental shelf break to the bay, upwelling events are probably at least episodic, if not frequent.

Upwellings are important for fuelling primary production in Palma Bay (and probably the inshore areas south towards Pemba) by increasing inorganic nutrient concentrations and promoting water exchange between the bay and the adjacent continental shelf and slope water body.

**Figure 7.31** *Vertical Profiles of Temperature and Salinity Measured in Palma Bay in the Dry Season (Left) and Wet Season (Right)*



Source: Lwandle, 2012.

### *Dissolved Oxygen*

The water column in Palma Bay is well oxygenated in both the dry and wet seasons (Figure 7.32). An oxygen minimum was observed in the deep channel

areas in the centre of the bay during both seasons. This is not solely linked to water depth, as deeper water on the eastern side of the bay has higher dissolved oxygen concentrations. This feature is interpreted as being due to local oxygen demand by, for example, the remineralisation of organic matter of probable seagrass origin in this area. The observed lower oxygen concentrations are consistent with the extended residence times of sea water in this portion of the bay, indicated by the temperature and salinity distributions (above).

### *Turbidity*

As is expected for an area that supports hard corals and seagrasses, Palma Bay is generally a clear water environment with low turbidity levels in the water column (*Figure 7.33*). Turbidity is caused by colloidal suspensions (particle size between 0.001 $\mu\text{m}$  and 0.1 $\mu\text{m}$ ), which usually gives water a murky appearance. Both turbidity and colour <sup>(1)</sup>, together with suspended solids, influence the clarity of water, ie the depth of light penetration or visibility in water.

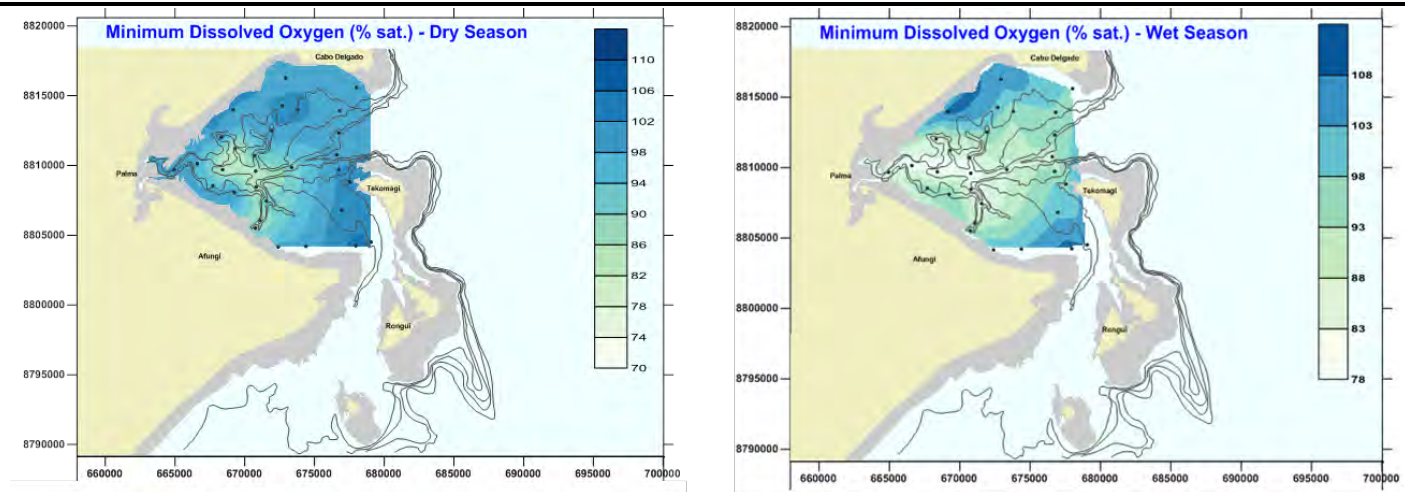
Turbidity distribution patterns were similar between each of the two seasonal surveys conducted, although the dry season maximum turbidities were higher than those of the wet season. The locations of the turbidity maxima are aligned with the dissolved oxygen minima (*Figure 7.32*), indicating that the material generating the elevated turbidities is mainly organic detritus.

Observations during dive surveys adjacent to the Afungi Peninsula indicate that, at high tides during onshore winds (north-north-easterly), turbidity levels can be high with diver visibility <0.5m. Water colour during these events is a light khaki green, probably linked to suspended organic particles.

(1) Colour is caused by substances that dissolve in water; as a result, the colour of the water changes.

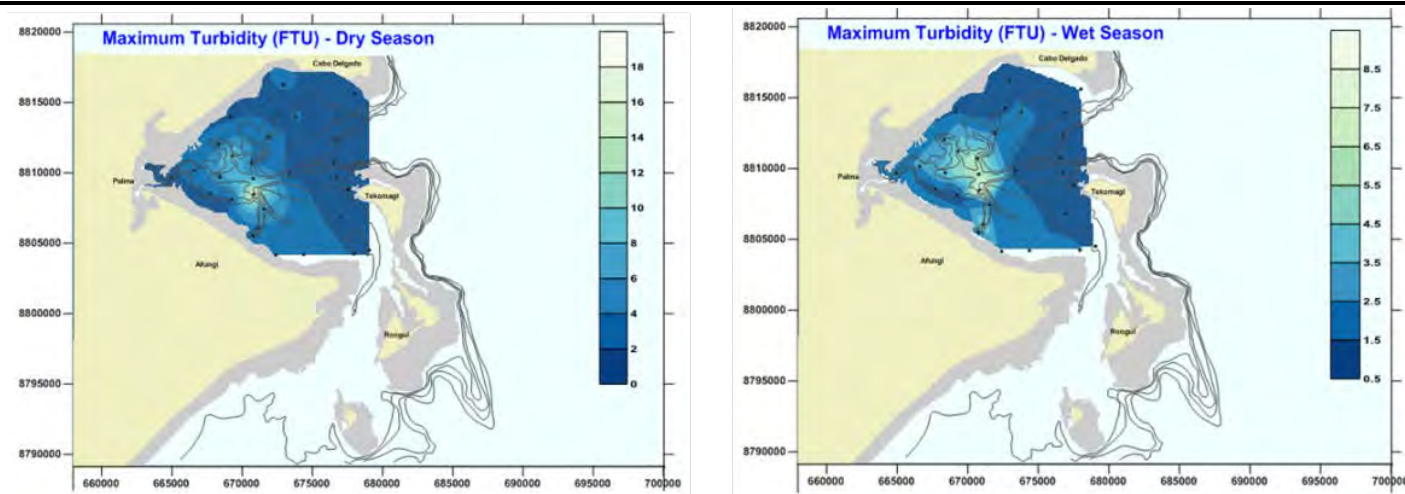


Figure 7.32 Distribution of Water Column Minimum Dissolved Oxygen Concentrations in Palma Bay in the Dry and Wet Seasons



Source: Lwandle, 2012.

Figure 7.33 Distributions of Water Column Maximum Turbidity (FTU) Levels in Palma Bay in the Dry and Wet Seasons



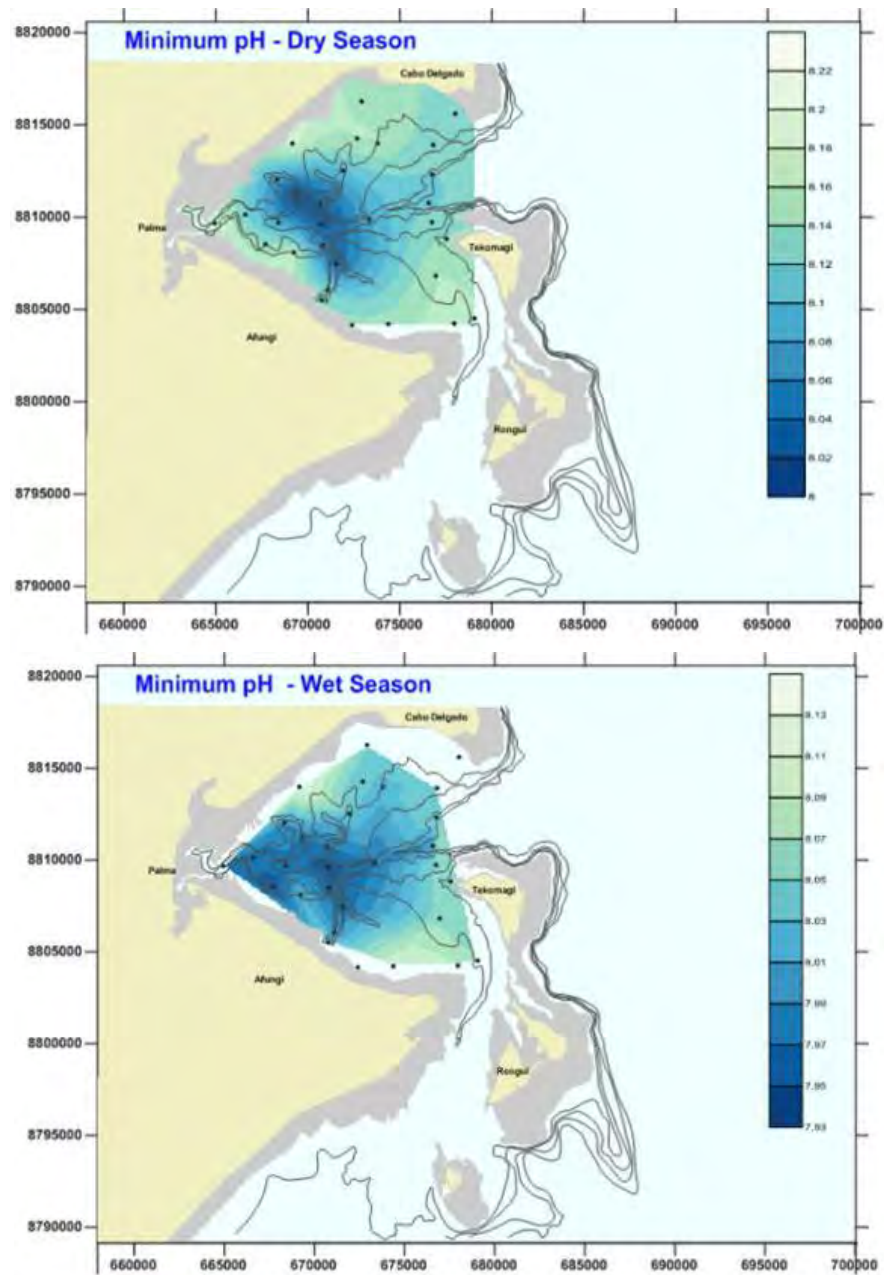
Source: Lwandle, 2012.

Legend: Units in Formazin Attenuation Unit (FPU)

pH

Median pH levels in the dry season were 8.15 and lower, at 8.03, in the wet season. In both seasons, minimum pH was recorded in the deeper waters in the inner part of Palma Bay (Figure 7.34). The wet season distributions, however, showed that the minima extended towards the shoreline at Palma and immediately north of this. The possible sources of acidity observed at this location may originate from rainwater draining through acid sulphate soils associated with the larger mangrove stands that occur at this location.

Figure 7.34 Distributions of Water Column Minimum pH Levels in Palma Bay in the Dry and Wet Season Surveys



Source: Lwandle, 2012.

## Nutrients

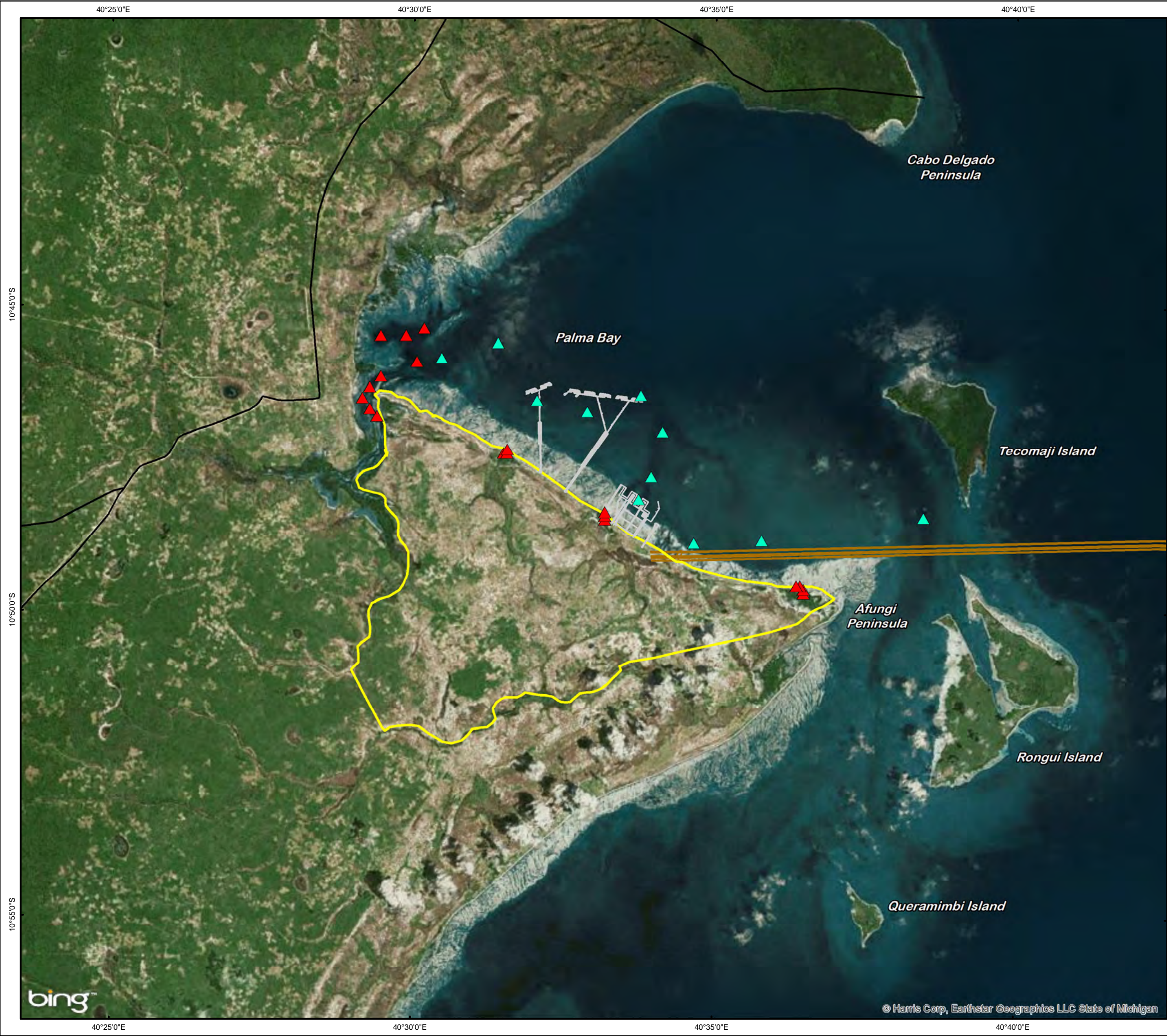
Measured inorganic nutrient concentrations were low, both in Palma Bay and the four estuaries draining the Afungi Peninsula, as shown in *Table 7.8*. This is consistent with the generally oligotrophic <sup>(1)</sup> character of tropical coastal waters. The locations within the bay and the four estuaries of Afungi Peninsula sampled are shown in *Figure 7.35*.

**Table 7.8** *Measured Inorganic Nutrient Concentrations (mg/l) in Palma Bay and Afungi Peninsula Estuaries Measured in the Wet Season Survey (March 2012)*

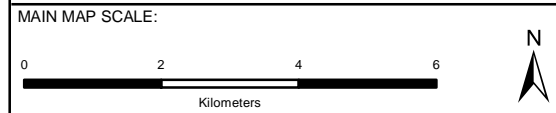
Sample	Nitrogen (NO <sub>3</sub> +NO <sub>2</sub> )	Silica	Phosphorus PO <sub>4</sub> -P
P-Bay001	0.018	0.17	<0.004
P-Bay002	0.012	0.18	<0.004
P-Bay003	0.037	0.16	<0.004
P-Bay004	0.009	0.21	<0.004
P-Bay005	0.02	0.14	<0.004
P-Bay006	0.027	0.18	<0.004
P-Bay007	0.032	0.2	<0.004
P-Bay008	0.03	0.13	<0.004
P-Bay009	0.037	0.1	<0.004
P-Bay010	0.037	0.21	<0.004
P-Bay011	0.041	0.26	<0.004
A-Est001	0.037	1.16	<0.004
A-Est002	0.039	0.79	<0.004
A-Est003	0.037	0.74	<0.004
A-Est004	0.037	0.49	<0.004
A-Est005	0.039	0.4	0.007
A-Est006	0.042	0.56	0.008
A-Est007	0.037	0.62	0.006
A-Est008	0.035	0.5	0.007
A-Est009	0.041	0.96	0.004
A-Est010	0.042	3.35	<0.004
A-Est011	0.03	3.4	0.006
A-Est012	0.033	5.86	0.005
A-Est013	0.03	6.13	0.004
A-Est014	0.034	6.7	<0.004
A-Est015	0.034	0.21	<0.004
A-Est016	0.034	0.26	<0.004
A-Est017	0.038	0.29	<0.004
A-Est018	0.016	0.24	<0.004

Source: Lwandle, 2012.

(1) A water body poor in nutrients and rich in oxygen.



- Legend**
- ▲ Inorganic Nutrient Sampling Sites - Estuaries
  - ▲ Inorganic Nutrient Sampling Sites
  - Regional Roads
  - Proposed Nearshore Infrastructure
  - Proposed Pipeline Corridor Route
  - Afungi Project Site



TITLE:  
**Figure 7.35:**  
 Inorganic Nutrient Sampling Sites,  
 Wet Season Survey, March 2012

CLIENT:

**Anadarko**  
 Moçambique Área 1, Lda

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 110 000
DRAWING: Inorganic Nutrient Sampling Sites.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

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

SIZE:  
 A3

Inorganic nitrogen and reactive silica concentrations recorded in the four estuary areas sampled (see *Table 7.9*) were statistically significantly higher than those measured in the open surface waters of Palma Bay (*Table 7.9*), but the gross differences were slight. Despite this, it is apparent that the estuaries contribute directly to productivity in Palma Bay through the enhancement of nutrient concentrations.

**Table 7.9** *Comparisons between Inorganic Nitrogen and Silica Concentrations in Surface Waters in Palma Bay and Afungi Peninsula Estuaries*

Nutrient	Palma Bay (n = 11)		Afungi Peninsula Estuaries (n = 18)		ANOVA	
	Mean (mg/l)	Standard Deviation	Mean (mg/l)	Standard Deviation	F	P
NO <sub>3</sub> +NO <sub>2</sub> -N	0.027	0.011	0.035	0.006	6.50	0.02
Si	0.176	0.044	1.814	2.241	5.79	0.02

Source: Lwandle, 2012.

### *Chlorophyll*

Chlorophyll (measured as chlorophyll fluorescence) distributions reflect generally low levels throughout Palma Bay in both the dry and wet seasons. Low chlorophyll levels accord with the oligotrophic status of these tropical waters. The distributions closely parallel those of turbidity (*Figure 7.33*), with the peak values being located in the inner part of the bay in the region of the dissolved oxygen minimum. Differences between the measured distributions in the two seasons are slight.

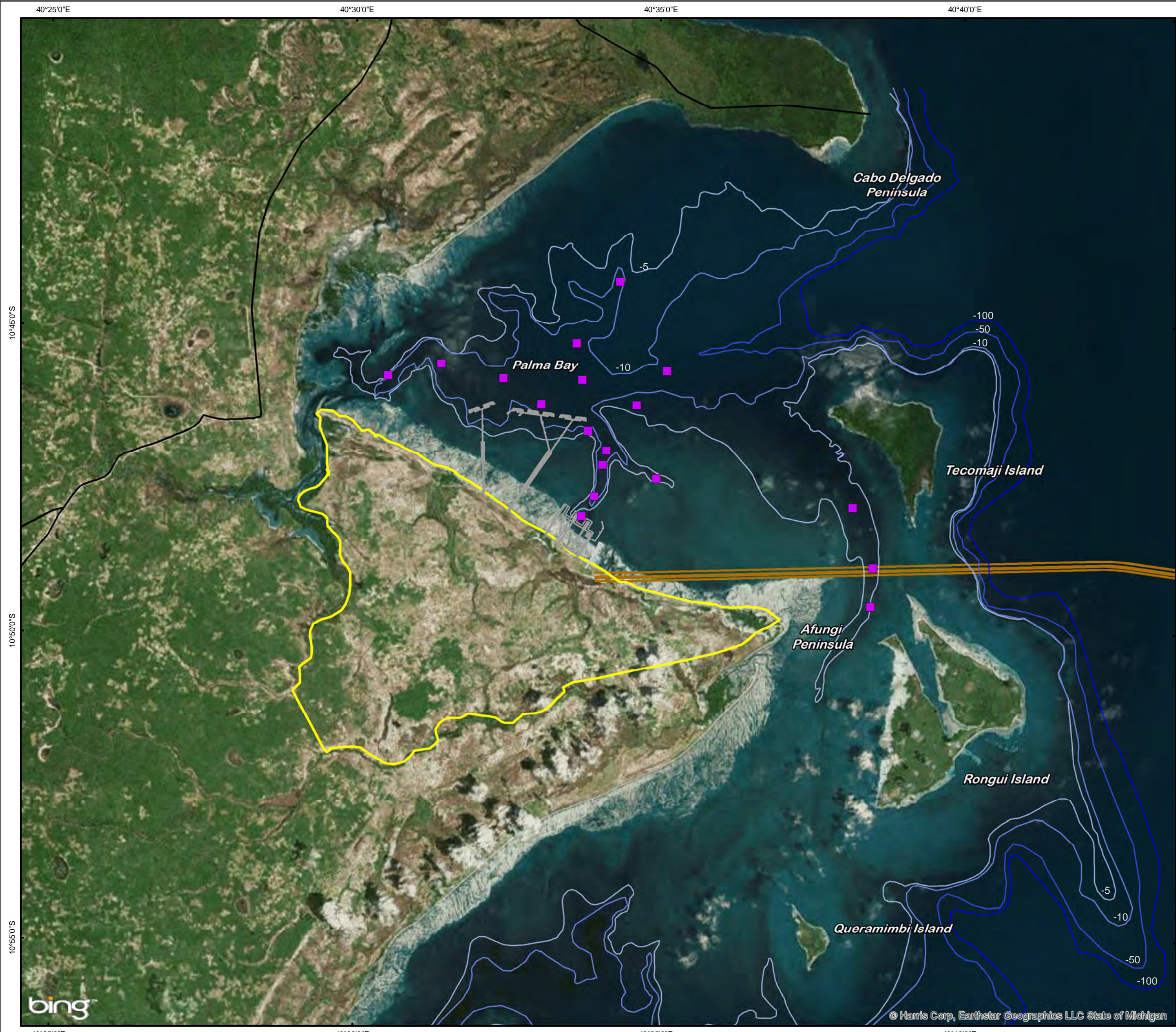
## 7.7.6 *Sediment Properties and Seabed Features*

### *Sediment Texture*

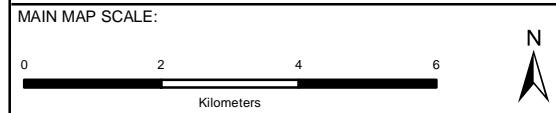
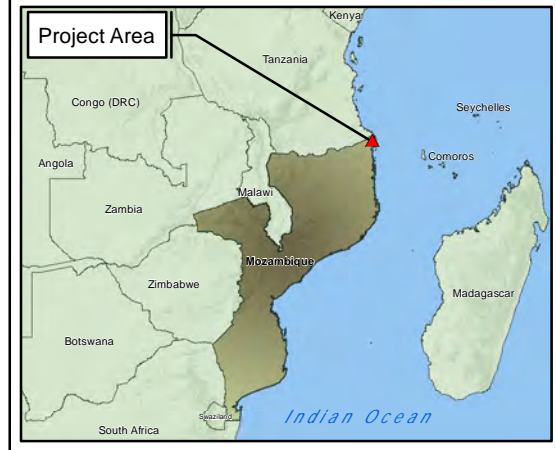
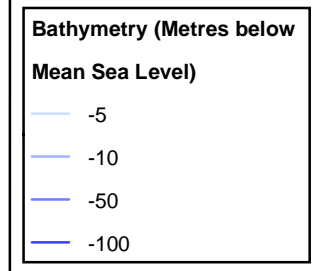
Surficial <sup>(1)</sup> sediment samples taken from the centre and southern parts of Palma Bay (*Figure 7.36*) indicate that sediments are mainly sand or muddy sand, as illustrated in *Figure 7.37*.

Gravel-sized sediments were present in some of the samples, but visual inspection indicated that most of these were shell fragments. In general, the sampled sediments were classified as poorly sorted, gravelly, muddy sand in terms of texture. This implies that the area is subject to episodic events in distributing sediments, such as cyclones with accompanying large waves and land run-off, as opposed to, for example, consistent wave action sorting and distributing sediments.

(1) The layer at the top of the sediment body, usually millimeters to centimeters thick.



- Legend**
- Surficial Sediment Sampling Locations
  - Regional Roads
  - Proposed Nearshore Infrastructure
  - Proposed Pipeline Corridor Route
  - Afungi Project Site



TITLE:  
**Figure 7.36:**  
 Surficial Sediment Sampling Locations,  
 Wet Season Survey, March 2012

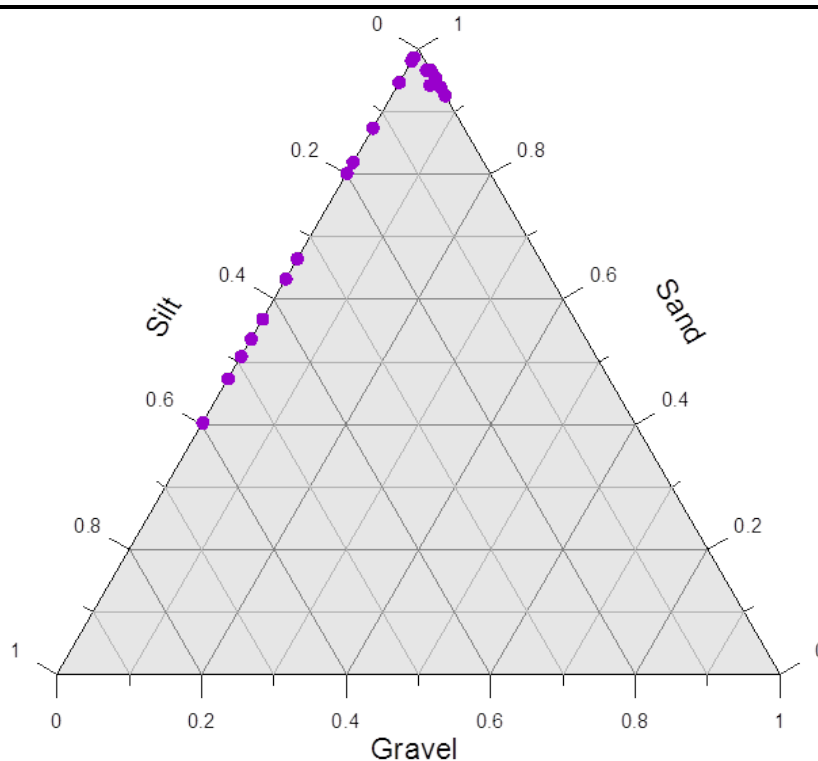
CLIENT:

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 110 000
DRAWING: Surficial Sediment Sampling Locations.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

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

**Figure 7.37 Ternary Diagram Showing Sediment Texture within Palma Bay for Samples Taken in the Wet Season (March 2012)**



Key:  
The purple dots indicate the various sediment types observed.

Source: Lwandle, 2012.

### Heavy Metals

Heavy metal concentrations in the sampled sediments were low and well within the environmental quality objectives identified for the WIOLAB region (Table 7.10). This is to be expected for a non-industrialised area with mainly sandy sediments.

**Table 7.10 Sediment Heavy Metal Median Concentrations (mg/kg) Compared to Sediment Environmental Quality Target (EQT) Concentrations for the WIOLAB Region**

Heavy Metal	Median	90 <sup>th</sup> Percentile	WIOLAB EQT
Aluminium (Al)	1535.69	4913.34	-
Arsenic (As)	1.86	3.53	7.24
Barium (Ba)	nd	nd	-
Beryllium (Be)	nd	nd	-
Cadmium (Cd)	nd	nd	0.68
Cobalt (Co)	0.86	1.20	-
Chromium (Cr)	6.37	23.33	52.30
Copper (Cu)	nd	nd	18.70
Iron (Fe)	1732.95	5320.12	-
Mercury (Hg)	nd	nd	0.13
Lithium (Li)	12.60	25.33	-
Manganese (Mn)	16.29	27.52	-

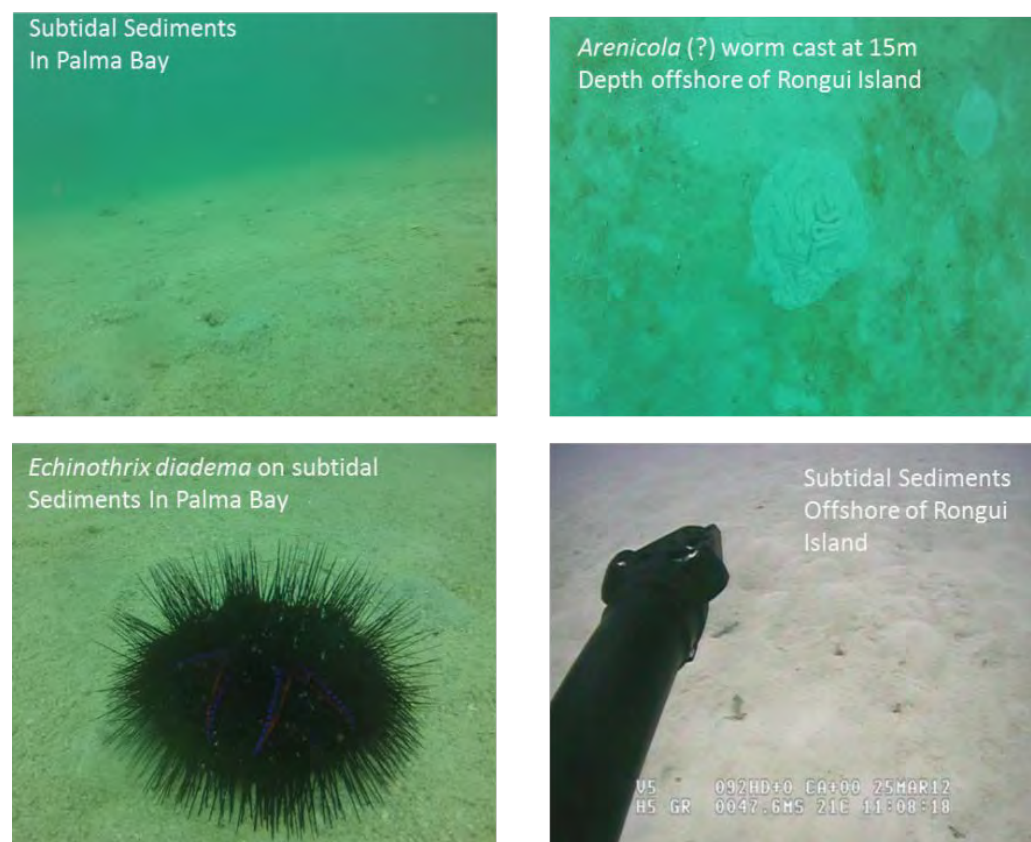
Heavy Metal	Median	90 <sup>th</sup> Percentile	WIOLAB EQT
Molybdenum (Mo)	1.97	2.11	-
Nickel (Ni)	3.29	5.68	15.90
Lead (Pb)	nd	nd	30.20
Antimony (Sb)	nd	nd	-
Tin (Sn)	6.09	6.09	-
Uranium (U)	5.97	10.65	-
Vanadium (V)	4.83	12.31	-
Zinc (Zn)	4.70	8.38	124.00

Source: CSIR, 2006.

### Seabed Features

The subtidal sediments both within Palma Bay and immediately offshore of the fringing reefs between Tecomaji and Rongui islands are heavily bioturbated (Figure 7.38). Worm holes are frequent and, from the size of the casts observed in the offshore area, large benthic fauna are known to occupy the sediments. In soft sediment, benthos size can be equated with longevity, and the presence of large fauna indicates that the host environment is physically and biologically stable.

**Figure 7.38** *Subtidal Sandy Sediments in Palma Bay (Left) and Offshore of Rongui Island (Right)*



Source: Lwandle, 2012.

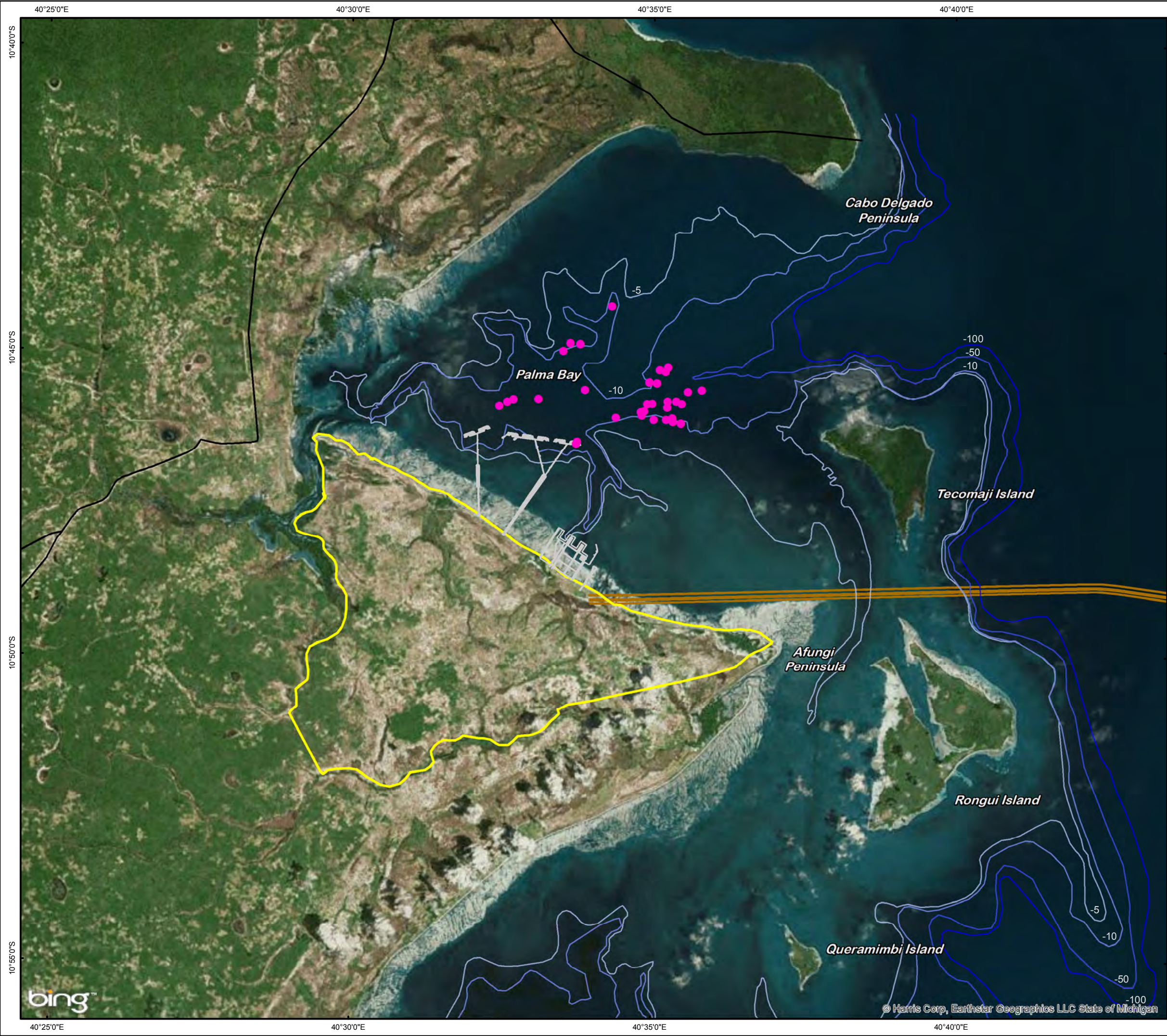


Small crater-like formations in the approximate centre of Palma Bay are noteworthy features that have been revealed by multibeam bathymetric survey (UWS, 2011). Thirty-three of these formations have been recorded and their distributions are shown in *Figure 7.39*.

Diver inspections on 14 of these small crater-like formations showed a more or less uniform structure of a sand crater of up to 10m in diameter and 1 to 3m deep, with rock pavement or rock with corals in their centres (inset in *Figure 7.39*). All of these latter features hosted numerous fish, ranging from cleaner wrasse (*Labroides dimidiatus*) to the very much larger javelin grunter (*Pomadasys kaakan*).

The craters appear to be maintained by turbulence such as scour associated with tidal flows, or they may be locations of fresh water outflows from aquifers (Neil Summers, AMA1 pers. comm. 2012). If the latter applies, then the outflows may be tidally pulsed, as no low-salinity water was detected by short-term (10 to 15 minutes) CTD recordings in the centres of seven of the craters inspected.

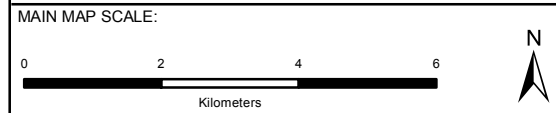
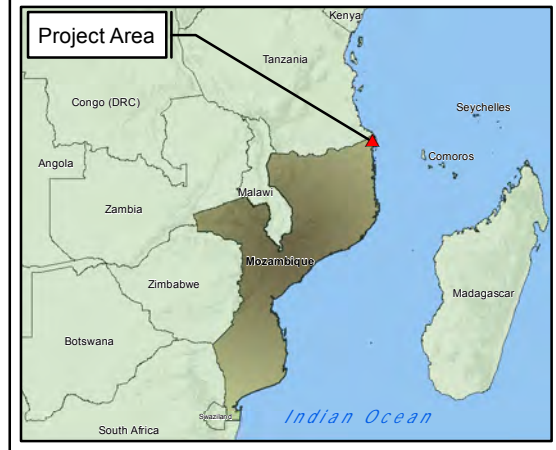
These features are enigmatic and deserve closer inspection, especially if they are a fresh water source to the bay as, if so, they can transfer land-derived contaminants and pollutants into the system. There are no data to show whether such features occur in other areas of the Mozambique or East African shallow littoral zone.



- Legend**
- Sand Craters
  - Regional Roads
  - Proposed Nearshore Infrastructure
  - Proposed Pipeline Corridor Route
  - Afungi Project Site

**Bathymetry (Metres below Mean Sea Level)**

- 5
- 10
- 50
- 100



TITLE:  
**Figure 7.39:  
 Distribution of 'Sand Craters' in  
 Central Palma Bay**

CLIENT:

**Anadarko**  
 Moçambique Área 1, Lda

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 110 000
DRAWING: Distribution of Sand Craters.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

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

SIZE:  
**A3**

10°40'0"S  
10°45'0"S  
10°50'0"S  
10°55'0"S

10°40'0"S  
10°45'0"S  
10°50'0"S  
10°55'0"S

40°25'0"E 40°30'0"E 40°35'0"E 40°40'0"E

40°25'0"E 40°30'0"E 40°35'0"E 40°40'0"E



© Harris Corp, Earthstar Geographics LLC State of Michigan

### 7.7.7 *Sediment Transport*

Moffat and Nichol (AMA1, 2012) assessed the sediment transport regime of Palma Bay, using a combination of a desktop assessment based on aerial photographs and a two-dimensional sediment transport numerical model using available wind and wave data. The findings of this study indicate that the sediment transport rates are small around the Project location, due to the benign wave climate (AMA1, 2012). The longshore sediment transport is from east to west.

### 7.7.8 *Main Shoreline Types*

The main shoreline types in Palma Bay, as shown in *Figure 7.40*, are:

- intertidal rock platform (on southern side of Cabo Delgado Peninsula);
- supratidal sand beach <sup>(1)</sup> (extending south towards Palma town);
- mangroves (in Palma estuary); and
- intertidal sand/mudflats (on north side of Afungi Peninsula).

Palma Bay is bounded in the north by Cabo Delgado Peninsula, the base of which is coral-derived limestone (coral rag). The shoreline is highly eroded rock (*Figure 7.40a*). This shoreline type extends to the western extremity of the peninsula. From there to immediately north of Palma town, the shoreline is sandy with a steep primary dune (*Figure 7.40b*). It is evident from the seagrass strand lines that high tide levels extend right to the top of these beaches. This shoreline type also occurs at the top of the intertidal zone on Afungi Peninsula.

An estuary is found adjacent to Palma town, and several others are observed along the northern and eastern shores of Afungi Peninsula. These support mangrove stands and associated biologically productive intertidal mudflats (*Figure 7.40c*), the most extensive of which are at Palma and on the eastern extremity of Afungi. Both the northern and south-eastern sides of Afungi Peninsula are characterised by extensive intertidal sand/mudflat areas (*Figure 7.40d*), which host a wide range of fauna and, at their lower extremities, seagrass.

(1) The supratidal zone is the area above the high tide water line that extends upland. The area is seldom covered by water unless during flooding or storms, but can receive water from wave splash.

Figure 7.40 Main Shoreline Types in Palma Bay



a = intertidal rock platform on southern side of the Cabo Delgado Peninsula.  
b = steep supratidal sand beach extending south towards Palma town.  
c = mangroves in Palma estuary.  
d = intertidal sand/mudflat on north side of Afungi Peninsula.

Source: Lwandle, 2012.

## 7.8 NEAR SHORE ENVIRONMENT - MARINE HABITATS

### 7.8.1 *Supratidal Sand Beach and Intertidal Sand/Mudflats*

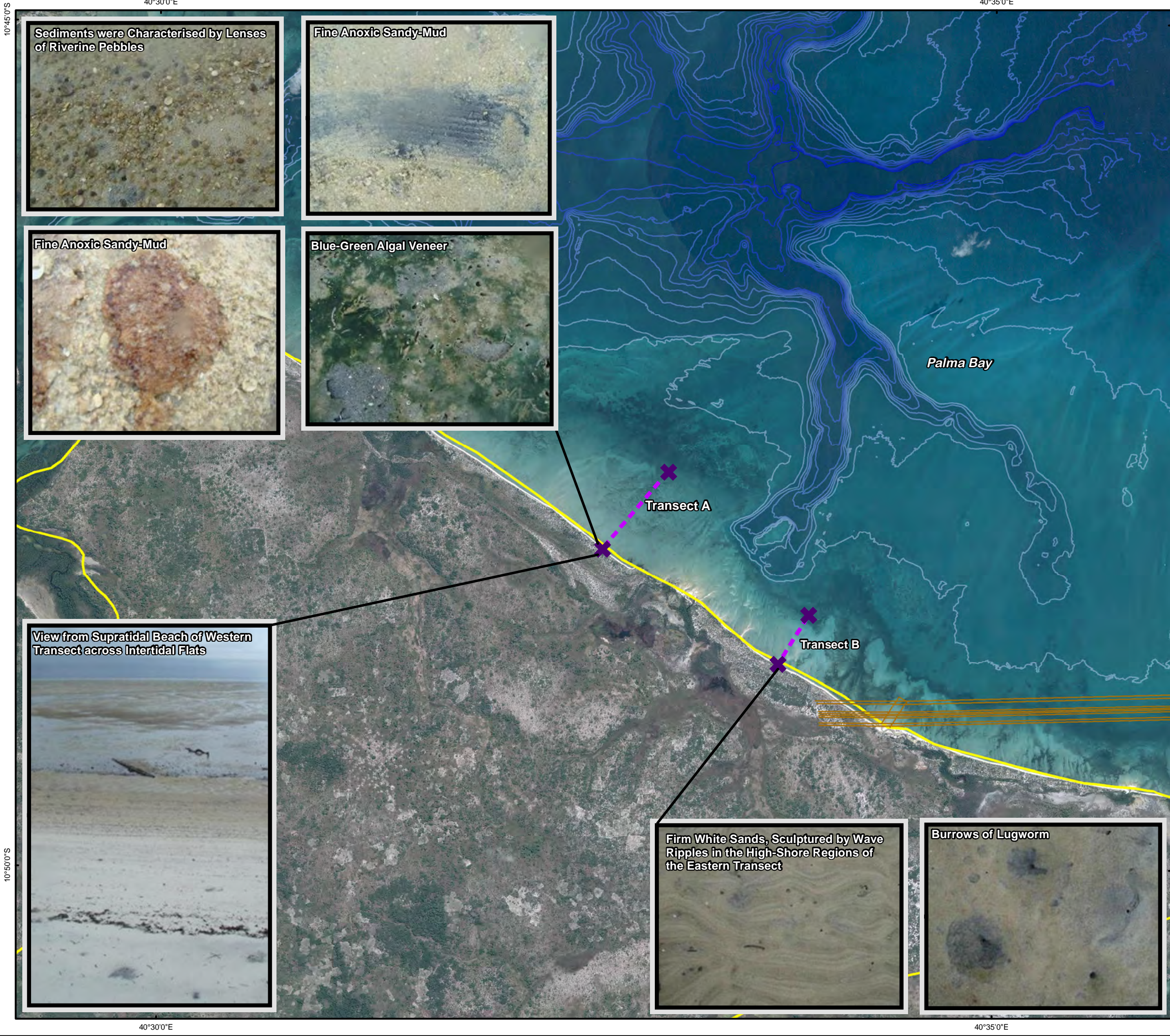
The extensive sandy beach and sand/mudflat on the northern shore of the Afungi Peninsula is extensive, physically and biologically diverse and productive. It hosts benthic microalgae, seagrass beds and a wide range of intertidal fauna, including those targeted by the artisanal fishery. The fauna is dependent on local primary productivity, supplemented to a greater or lesser degree by particulate organic matter brought onto the beaches by tides and longshore currents.

The supratidal and intertidal zones were inspected during the wet season survey in March 2012. Qualitative assessments of the major biological features

were made on two transects located on the shores adjacent to Afungi Peninsula, extending from the primary dune in the supratidal to the bottom of the intertidal zone (Figure 7.41).

On the western transect (Transect A), the narrow supratidal zone was characterised by relatively fine white sand (0.1 to 0.2mm), which in the upper intertidal zone gave way to lenses of smooth riverine pebbles (<20mm) interspersed with very fine sandy mud (Figure 7.41). From the middle intertidal zone onwards, sediments were dominated by muds, but became sandier towards the lower intertidal zone. The sediments were aerated to within only 1cm of the surface, the subsurface sediments being anoxic and containing hydrogen sulphide. At low tide, the entire middle and lower intertidal zone was covered by shallow pools of standing water.

The seagrass bed started at approximately 300m seaward of the high water mark, with the dominant species being *Halophila ovalis* and *Halodule uninervis* both of which are categorised as Least Concern (IUCN, 2012). Scattered between the sparse seagrass beds in the upper and mid-intertidal zones were areas of fine sandy mud, covered in a veneer of blue-green algae mixed with bacteria to form slime mounds (Figure 7.41). *Thalassia hemprichii* (also categorised as Least Concern (IUCN, 2012)) only became evident from seawards of the mid-tide level (Figure 7.42), increasing in density towards the lower intertidal zone as sediments became sandier.

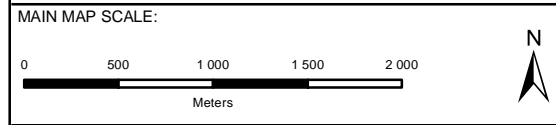
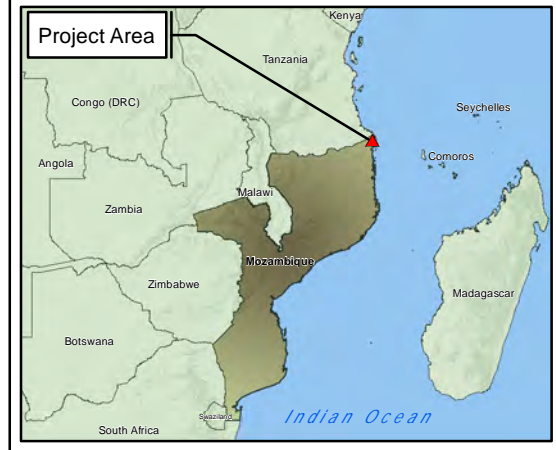


**Legend**

- Intertidal Transects
- Proposed Pipeline Corridor Route
- Afungi Project Site

**Bathymetry (Metres below Mean Sea Level)**

-2	-16
-4	-18
-6	-20
-8	-24
-10	-26
-12	-28
-14	-30



TITLE:  
**Figure 7.41:  
 Location of Intertidal Transects on  
 Afungi Peninsula**

CLIENT:  
**Anadarko**  
 Moçambique Área 1, Lda

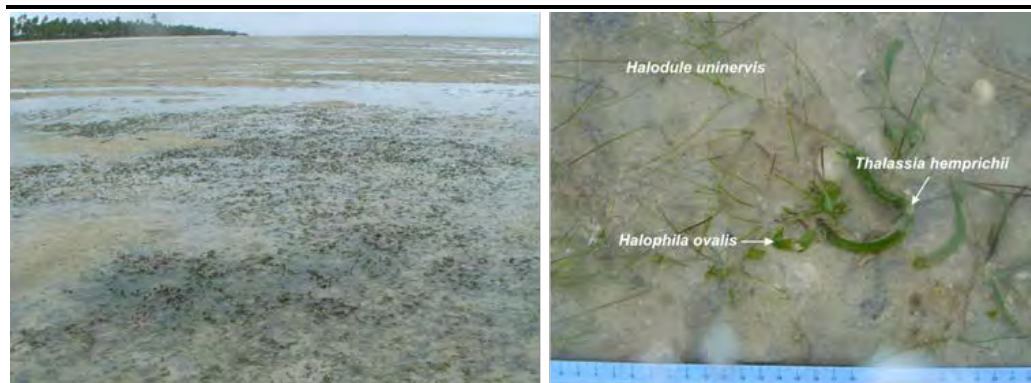
DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 40 000
DRAWING: Location of Intertidal Transects.mxd		REV: A

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

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

SIZE:  
**A3**

**Figure 7.42** *View Across the Intertidal Seagrass Bed on the Western Transect (Left), which Hosted Three Co-occurring Seagrass Species (Right)*



Source: Lwandle, 2012.

Associated with the seagrass was a diversity of gastropod molluscs [white moon shell (*Polinices mammilla*), necklace shells (*Natica* spp.), gold ring cowrie (*Cypraea annulus*), dog whelks (*Nassarius coronatus*) and mangrove whelks (*Terebralia palustris*)], holothurians (*Synapta maculata* and *Stichopus hermanni*), clusters of sand-boring anemones (*Cerianthus maua*) and isolated specimens of the single large anemone (*Stichodactyla* sp.), usually accompanied by juvenile damselfish (black and white). The burrowing sand crab (*Matuta lunaris*) and the shy crab (*Calappa hepatica*) were present in low numbers. Some of the species recorded are illustrated in Figure 7.43.

Of the bivalve molluscs observed, only the pen shell (*Pinna muricata*) was represented by live specimens, buried in the sand among the seagrass. Other bivalves collected were dead, but in good condition (indicating that they most likely occur as infauna in either the intertidal or shallow subtidal areas), including *Modiolus philippinarum*, the razor clam (*Solen cylindraceus*), true bubble shell (*Bulla ampulla*), *Anadara antiquata*, *Tellina virgata* and *Loripes clausus*. Various red, orange and black creeping and encrusting sponges, associated with seagrass and hard substrata, were also observed, as was an encrusting green ascidian. Macroalgae in the lower intertidal zone were represented by isolated clumps of *Acanthophora spicifera* and the creeping *Codium prostratum*. The funnel-shaped depressions and coiled castings of a lugworm (*Arenicola* sp.) were abundant on the sand flats in the mid and low intertidal zone.

Figure 7.43 Invertebrate Species Occurring in the Seagrass Beds



Top left: Dog whelks. Top right: Mangrove whelks. Bottom left: Large anemones. Bottom right: Sand crabs.

Source: Lwandle, 2012.

Although only 2.2km further east (see *Figure 7.41*), the eastern transect (Transect B) was biophysically substantially different from the western transect. The upper and middle intertidal zones of the eastern transect were dominated by firm white sands, sculptured by wave ripples (*Figure 7.41*), with muddy sand being entirely absent. Bioturbation was limited, and the anoxic sediments were within a few millimetres of the surface. The edges of drainage runnels, however, revealed a dense network of fine tubes of a polychaete species, to 10 to 15cm depths into the sediments.

The middle intertidal area at the eastern transect lacked the extensive shallow pools of water and the blue-green algal mats that characterised the western transect. The landward edge of the seagrass bed was located approximately 500m from the high water mark and the bed itself was not as extensive. *Halophila ovalis* and *Halodule uninervis* dominated in the sparse beds on the firm, flat sand in mid-intertidal zone, with *Thalassia hemprichii* again prevalent in the lower intertidal zone. Invertebrate diversity associated with the seagrass was similar to that recorded on the western transect. The urchin *Diadema* sp. was present in clusters in the lower intertidal zone. The burrows and castings of lugworms were restricted to this area and were primarily associated with the *Thalassia* beds. There appeared to be a higher abundance of pen shell (*Pinna muricata*) in the intertidal areas to the east of the channel, as these were being harvested by artisanal fishers, shucked and the shells



discarded in 'middens' (Figure 7.44). Evidence of harvesting of the false oyster (*Hyotissa hyotis*) and the lugworm was also observed.

**Figure 7.44** Evidence of Artisanal Harvesting of *Pinna muricata* (Left) and Lugworms (Right)



Source: Lwandle, 2012.

The species and genera that have been observed in the supratidal and intertidal zones of the beach on the northern shore of Afungi Peninsula and in the sediments have wide regional distributions.

### 7.8.2 Mangroves

Extensive mangrove stands with associated intertidal sand/mudflats are located immediately north and south of Palma town and on the eastern end of Afungi Peninsula, with minor stands associated with small estuaries distributed around Palma Bay, as shown in Figure 7.45. The largest estuary within Palma Bay is that at the south of Palma town. This supports a relatively extensive stand of mangroves and is fronted by apparently highly productive sand and mudflats. There is an equally extensive stand of mangroves adjoining this system to the north, based on fresh water flows from the extensive wetlands behind the western shore of Palma Bay. The estuary and associated mangroves on the eastern extremity of Afungi Peninsula is less extensive than those at Palma town but, according to the associated fauna, is equally productive.

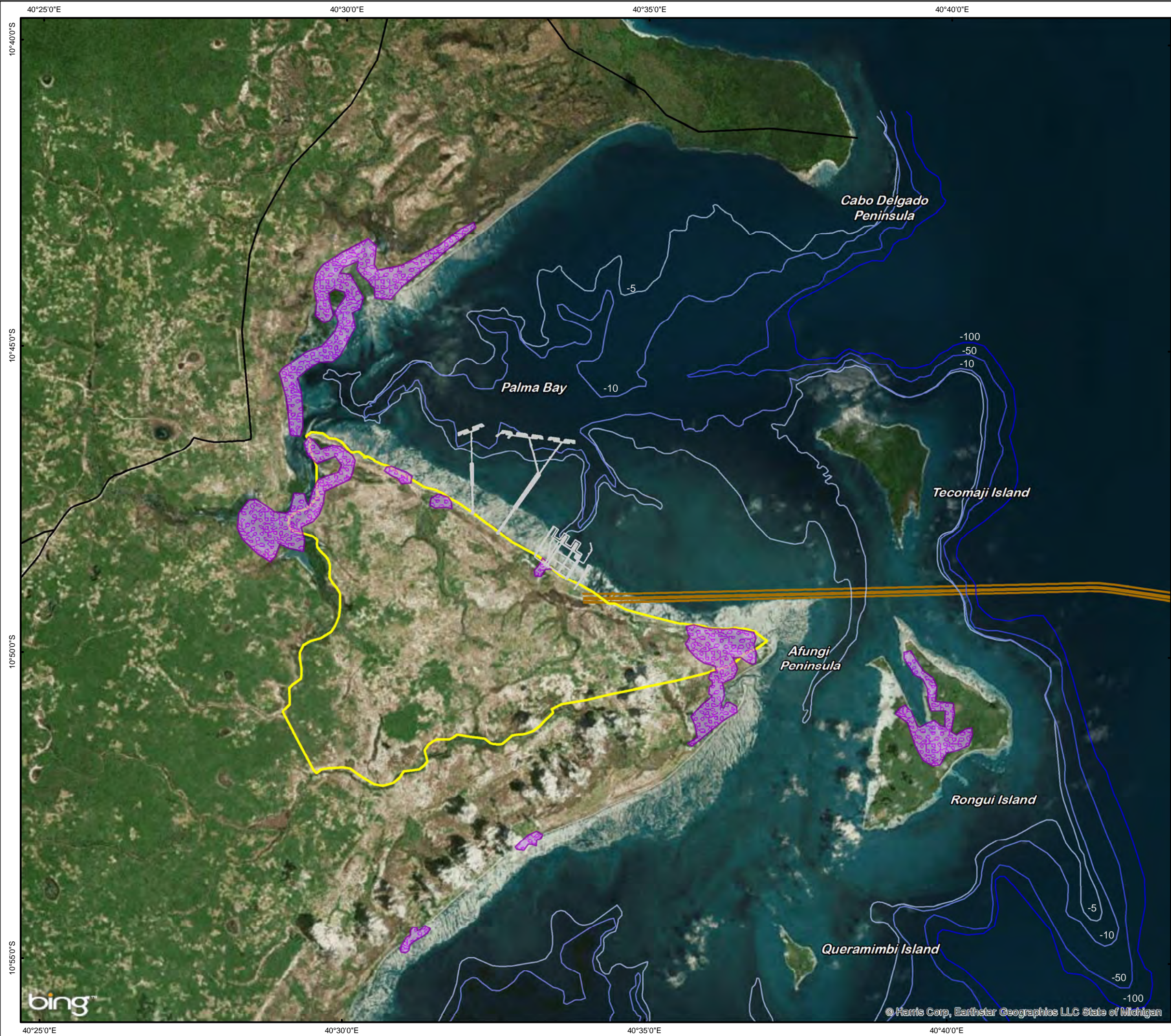
Eight species of mangrove tree species have been identified in Cabo Delgado Province, including Palma Bay. These include *Rhizophora mucronata*, *Ceriops tagal*, *Bruguiera gymnorrhiza*, *Avicennia marina*, *Lumnitzera racemosa*, *Sonneratia alba*, *Xylocarpus granatum* and *Pemphis acidula* (CSA, 2007). These mangrove species are categorised as Least Concern (IUCN, 2012)

The mangroves have a distinct pattern of zonation where, generally, *Sonneratia alba* is the seaward pioneer adapted to the open coastal and coral platforms, occupying sites that are tidally flooded daily. *Rhizophora mucronata* and *Xylocarpus granatum* are generally located on stream fringes, while *Bruguiera*

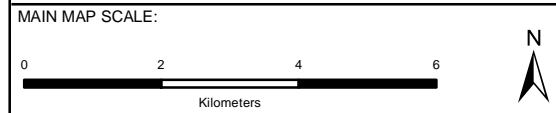
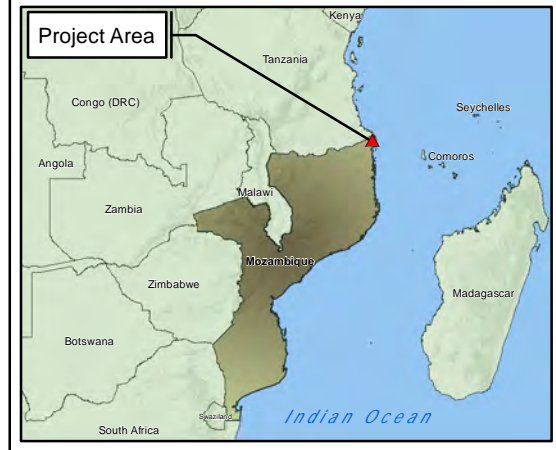
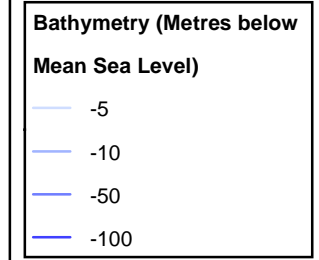
*gymnorrhiza* and *Ceriops tagal* occur behind these, sometimes forming broad belts. *Pemphis acidula* is a beach shrub or mangrove tree located around the high water mark along the northern coast. *Avicennia marina* is located landward of this and fringes the upper high water mark as trees or dwarf mangroves. These may give way to a dwarf *Avicennia marina* zone. Upshore of the mangroves are saline tidal flats fringed by succulent herbaceous species, such as *Arthrocnemum australasicum*, *Arthrocnemum indicum*, *Arthrocnemum perenne*, *Salicornia perriere*, *Chenolea diffusa* and *Suaeda monoica*, which occur in these saline areas (CSA, 2007).

Mangroves typically host a wide range of invertebrate meiofauna and macrofauna. Of the macrofauna, crustaceans and molluscs are the dominant groups. Crustacea include the families Ocypodidae (fiddler crabs), Sesarinae (marsh crabs), Portuninae (mangrove/mud crabs, *Scylla serrata*) and some Penaeid shrimps (*Fenneropenaeus indicus*, *Metapenaeus monoceros* and *Penaeus monodon*). Molluscs include mud creepers (*Terebralia palustris*), pencil bait (*Solen capensis*) and mud snails (*Cerithidea decollata*). Littorinidae are well represented with *Littoraria scabra*, *L. pallescens*, *L. intermedia* and *L. subvittata* all being common or abundant on mudflats associated with mangrove stands.

Large bivalves such as oysters (*Saccostrea forskali* and *S. cuculata*) and barnacles (*Balanus amphitrite*) typically attach to mangrove stems, branches or roots and rocks.



- Legend**
- Regional Roads
  - Proposed Nearshore Infrastructure
  - Proposed Pipeline Corridor Route
  - ▭ Afungi Project Site
  - ▭ Mangrove Stands



TITLE:  
**Figure 7.45:  
 Distribution of Mangrove Stands  
 in Palma Bay**

CLIENT:

**Anadarko**   
 Moçambique Área 1, Lda

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 110 000
DRAWING: Distribution of Mangrove Stands.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

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

SIZE:  
**A3**

Seagrass species observed in the bay include *Enhalus acoroides*, *Halodule uninervis*, *Halophila ovalis*, *Syringodium isoetifolium*, *Thalassia hemprichii* and *Thalassodendron ciliatum* <sup>(1)</sup>. *Thalassia* was widespread while *Enhalus* and *Thalassodendron* had a clumped distribution. The other species observed were more cryptic and relatively rare. Seagrass beds occur on sandy sediments extending from the middle intertidal zone of the beaches on the northern side of Afungi Peninsula, to approximately 8m depth in the centre of Palma Bay.

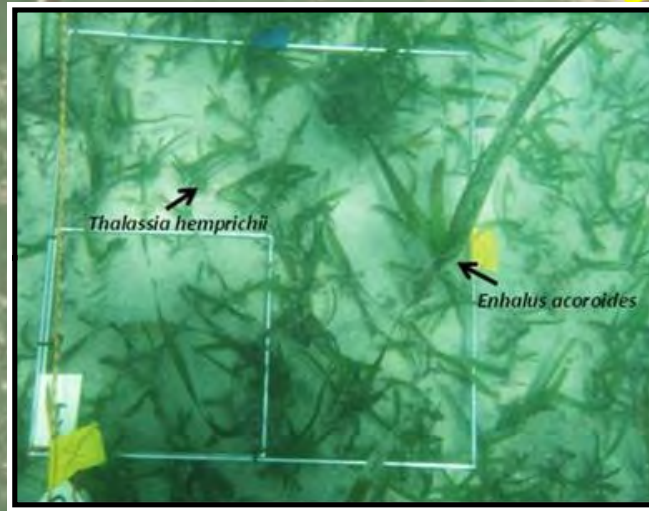
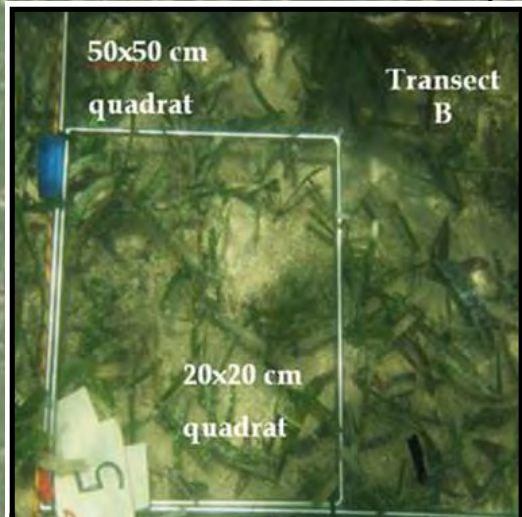
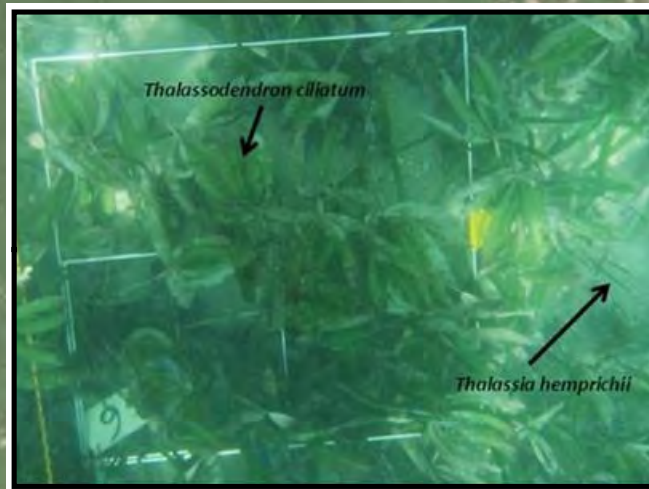
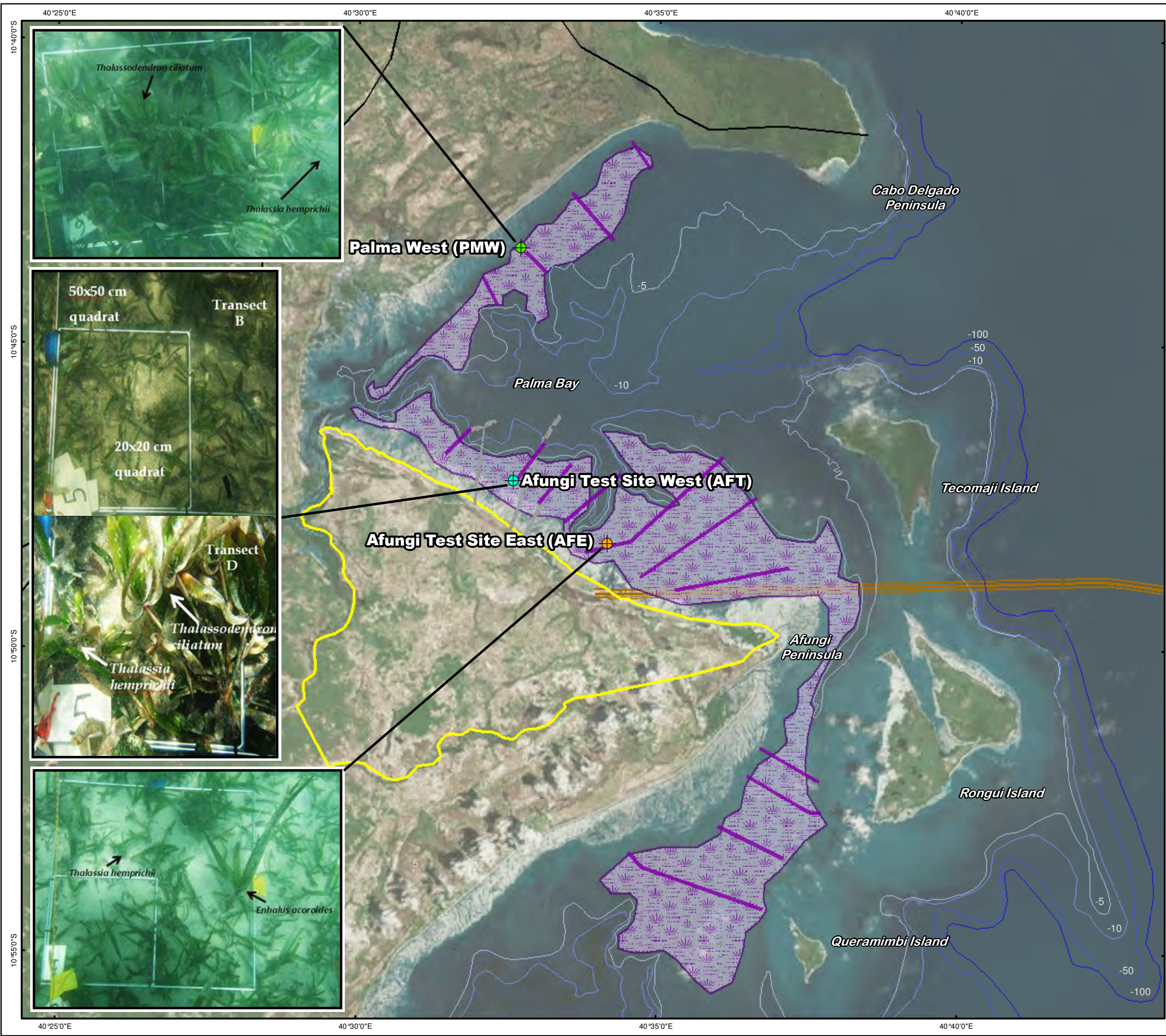
Three sampling sites were selected for the quantitative seagrass bed survey: two test or impact sites in the extensive Afungi seagrass bed bordering the proposed development area, and one reference site on the western shore of Palma Bay (Figure 7.46). The sites Afungi Test Site West (AFT) and Afungi Test Site East (AFE) are directly west and east of the area that will be dredged for the construction of the jetty and to deepen the entrance channel for vessels, and may thus be potentially affected by the dredging activity. The reference site Palma West (PMW) is located in the seagrass bed on the western shore of Palma Bay, more than 8km away from the location of the proposed developments.

The seagrass cover at the reference site PMW, north of Palma, was most dense, with a mean of 51 percent cover compared to 40 percent cover at AFT and only 28 percent at AFE. Average cover was relatively similar at PMW and AFT but was more patchy at AFE, ranging from 27 to 56 percent.

Site PMW was dominated by *Thalassodendron ciliatum* with lower understorey cover of *Thalassia hemprichii* (see Figure 7.46). The other two sites contained dense mixed beds of *Thalassia* and *Thalassodendron*. AFE was the only site where all four seagrass species observed were encountered, ie *Thalassia*, *Thalassodendron*, *Enhalus* and *Halophila*, though the latter three species had very low percentage cover. Figure 7.46 shows seagrass coverage at the various sites. The seagrass bed at AFE showed 30 percent cover of mostly *Thalassia hemprichii* and sparse cover of *Enhalus acoroides*. Dense cover of *Thalassodendron ciliatum* with understorey stands of *T. hemprichii* were evident at PMW.

The different morphologies of the two dominant seagrasses are shown in Figure 7.47. Based on this, the canopy height was lower at AFT and AFE, where the seagrass bed was an almost-exclusive *Thalassia* bed. At PMW, the seagrass bed was mixed but dominated by *Thalassodendron*, and therefore canopy height was higher, ranging between 24 and 28cm.

(1) These species are all categorised as 'Least Concern' according to the IUCN Red List of Threatened Species 2012 (IUCN, 2012).



**Legend**

- Seagrass Bed Sampling Stations
  - Afungi Test Site East (AFE)
  - Afungi Test Site West (AFT)
  - Palma West (PMW)
- Seagrass Transects
- Seagrass Habitat
- Regional Roads
- Proposed Nearshore Infrastructure
- Proposed Pipeline Corridor Route
- Afungi Project Site

**Bathymetry (Metres below Mean Sea Level)**

- 5
- 10
- 50
- 100

**Project Area**

**MAIN MAP SCALE:**

0 2 4 6 Kilometers

**TITLE:**

**Figure 7.46:**  
Distribution of Seagrass Habitat and Seagrass Bed Sampling Stations

**CLIENT:**

**Anadarko**  
Moçambique Área 1, Lda

DATE: Jan 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 110 000
DRAWING: Sea grass Habitat and stations.mxd		REV: A

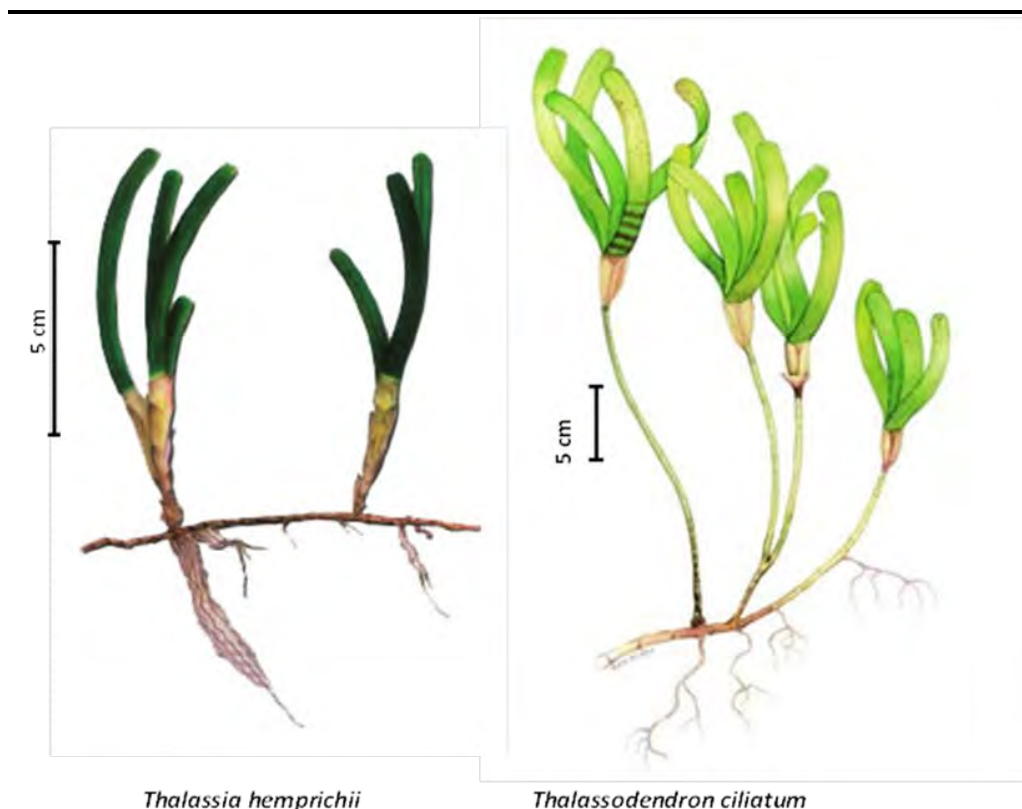
**ERM**  
Block A, Silverwood House  
Silverwood Close  
Steenberg Office Park, 7945  
Cape Town, SOUTH AFRICA  
Tel: +27 (0)21 702 9100  
Fax +27 (0)21 701 7900

**Impacto**  
Projetos e Estudos Ambientais

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

**SIZE:**  
A3

**Figure 7.47** *Morphology of the Seagrasses Thalassia hemprichii and Thalassodendron ciliatum*



Source: Lwandle, 2012.

*Thalassia* shoot densities were relatively similar at the two impact sites AFT and AFE, ranging from 20 and 35 shoots/0.0625m<sup>2</sup> (area of small quadrat) for AFT and AFE respectively. Shoot densities of other species were very low (<10 shoots/0.0625m<sup>2</sup>), reflecting their low cover at these sites. At PMW, shoot density of the two dominant species, *Thalassodendron* and *Thalassia*, was on average very similar across the transects, with a mean value of 12/0.0625m<sup>2</sup> for both species.

Seagrass biomass is divided into above ground biomass, ie leaves, stems and sheaths, and below ground biomass, ie roots and rhizomes. At the Afungi sites AFT and AFE, below ground biomass was typically greater than biomass above ground. In contrast, at PMW, the above ground biomass was greater than below ground biomass. These results reflect the morphological differences between the dominant seagrass species at each site. *Thalassia hemprichii* has shoots from 10 to 40cm (in this study always <20cm) with a thick (3 to 5mm) rhizome and a dense root system (Figure 7.47). Consequently, the below ground biomass can easily be greater than the above ground biomass. *Thalassodendron ciliatum*, in contrast, has a long stem and can reach up to 75cm (together with the leaves) (Figure 7.47). Its root system, however, is less dense and the relative mass of the below ground parts is thus less than that of the stem and leaves.

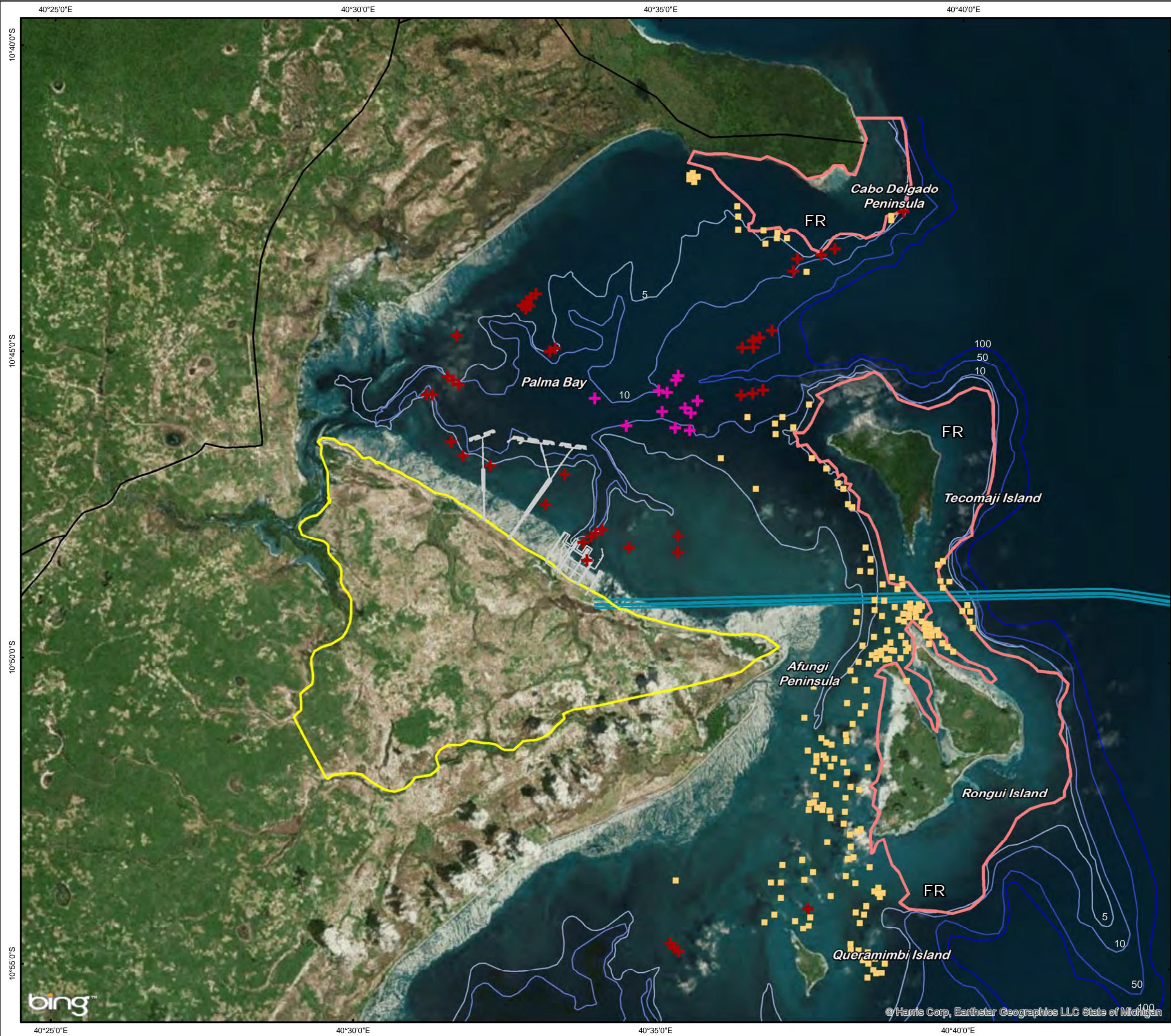
Many large invertebrates were commonly encountered in the seagrass beds in Palma Bay, including several species of sea urchins, starfish and sea cucumber, a large variety of sponges and colonial ascidians, and occasional hard coral. Particularly common was the pen shell (*Pinna muricata*), living partially buried in the sand with only the top third exposed. These often occurred in relatively dense clusters.

#### 7.8.4 *Coral*

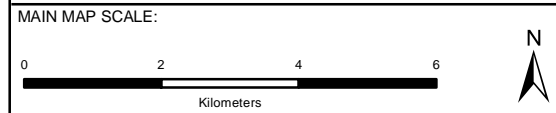
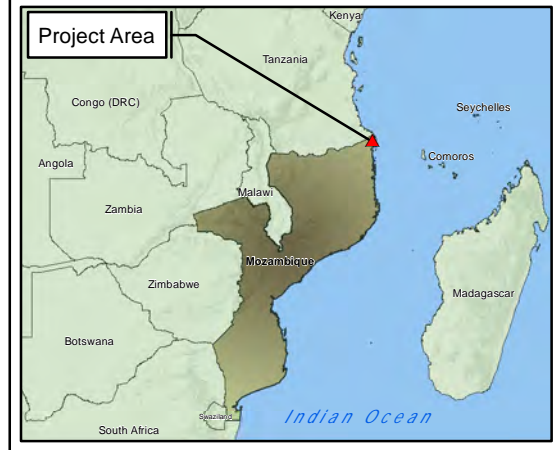
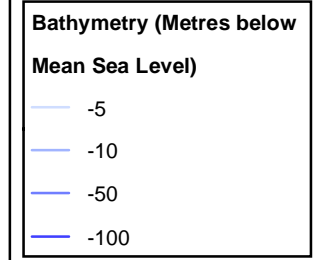
Corals are marine invertebrates in the class Anthozoa of the phylum Cnidaria, typically living in compact colonies of many identical individual polyps. The group includes the important reef builders that inhabit tropical oceans, which secrete calcium carbonate (CaCO<sub>3</sub>) to form a hard skeleton.

Much of the seabed within Palma Bay is soft sediment, specifically sand, with coral outcrops distributed around the bay. The most well-developed of these outcrops are located adjacent to Cabo Delgado Peninsula and around the islands in the mouth of Palma Bay (*Figure 7.48*). Coral reef structures in Palma Bay comprise fringing reefs and bommies. A coral bommie<sup>(1)</sup> is either an outcrop of coral reef, often resembling a column that is higher than the surrounding platform of reef, or an isolated piece of reef on sand. Fringing reefs usually occur parallel to shorelines. These coral habitats in Palma Bay are further discussed in *Sections 7.8.5 and 7.8.6*.

(1) Short for 'bombora' - an Aboriginal word meaning outcrop or reef.



- Legend**
- Small Coral Bommie
  - + Larger (Porites) Coral Bommie
  - + Sand Crater with Coral
  - Fringing Reef (FR)
  - Regional Roads
  - Proposed Nearshore Infrastructure
  - Proposed Pipeline Corridor Route
  - Afungi Project Site



TITLE:  
**Figure 7.48:  
Distribution of Coral Reef in Palma Bay**

CLIENT:

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 110 000
DRAWING: Distribution of Coral Reef.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

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



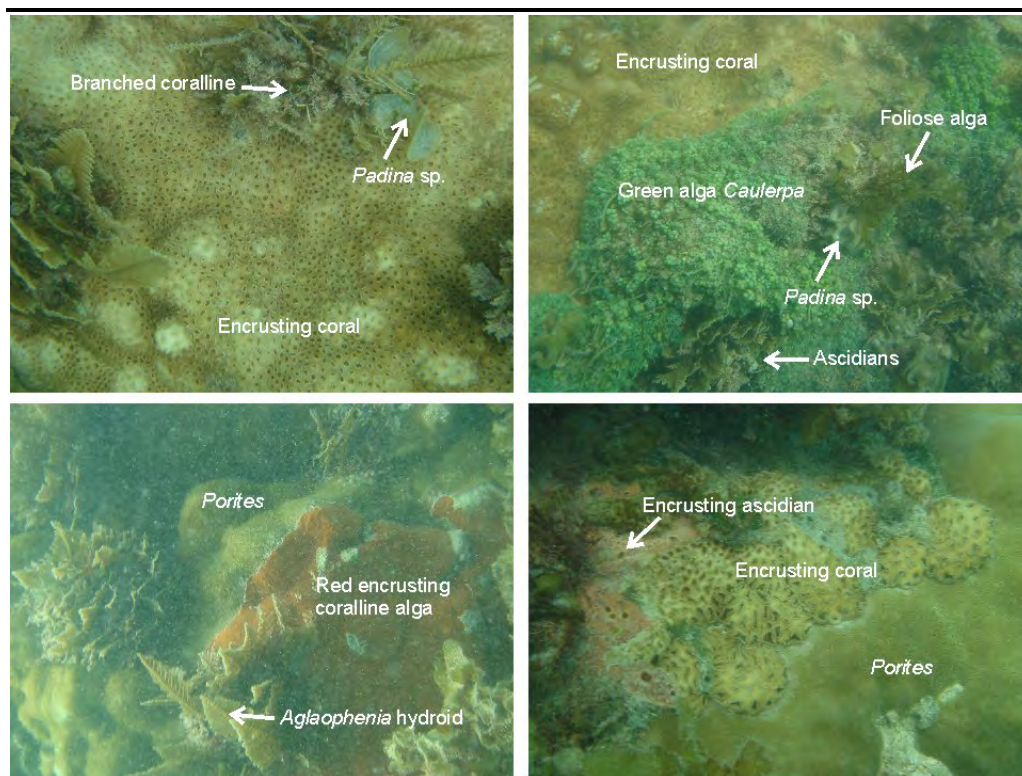
### Shallow Coral Reefs and Outcrops

Shallow coral reefs and outcrops are scattered throughout Palma Bay, as shown in Figure 7.48. Count, visual and photographic observations of coral reef features were undertaken at two locations within Palma Bay: a near-field site (NFB), which is situated sufficiently close to the proposed marine facilities area to be exposed to potential dredging effects, and a far-field site (FFB) in the same depth range, but at a distance unlikely to be impacted by the dredging (Figure 7.50).

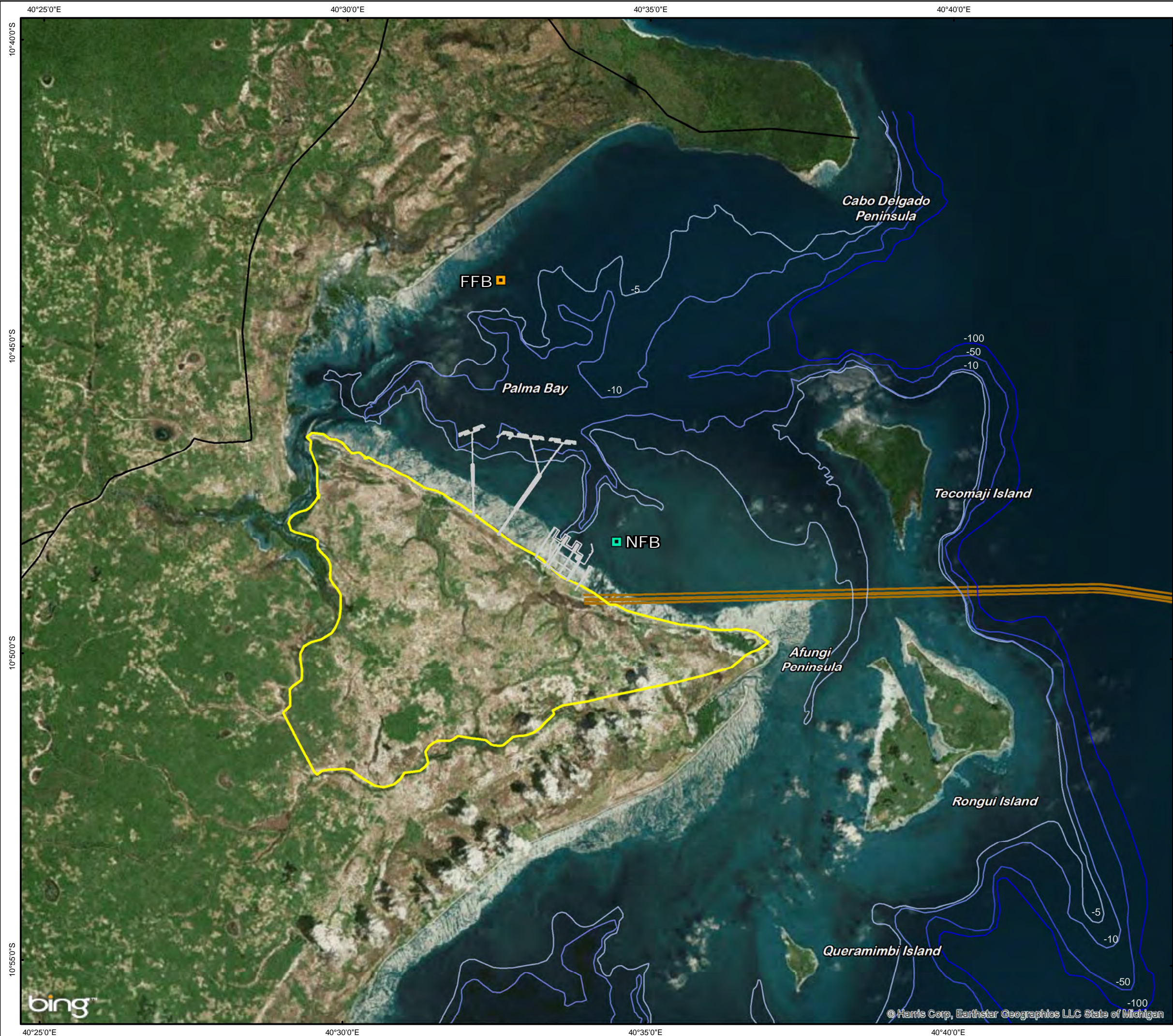
At both locations, the reef structures comprised individual *Porites*-dominated bommies, which rose to a height of 2 to 3m above the surrounding sandy seabed. Areas of dead coral on these bommies were dominated by silt-covered hydroid fuzz and red encrusting coralline algae.

At the far-field site near Cabo Delgado Peninsula, patches of reef not formed by live *Porites* coral were characterised by massive colonies including *Platygyra* spp. and *Lobophyllia hemprichii*. Macroalgae including *Sargassum* spp., *Padina* sp. and *Turbinaria* spp. were the dominant growth on dead coral. The hydroid *Aglaophenia cupressina* and red encrusting coralline algae, encrusting sponge, encrusting ascidians (*Didemnum* sp.) and encrusting, massive and branched coral forms were also present (Figure 7.49). Bommie density was approximately 3/1,000m<sup>2</sup>.

**Figure 7.49** *Encrusting and Erect Biota Present on the Far-field Porites Bommies*



Source: Lwandle, 2012.



**Legend**

**Coral Reef Sampling Sites**

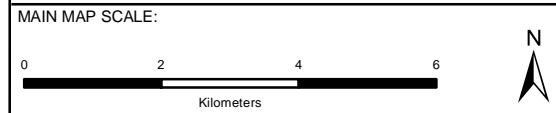
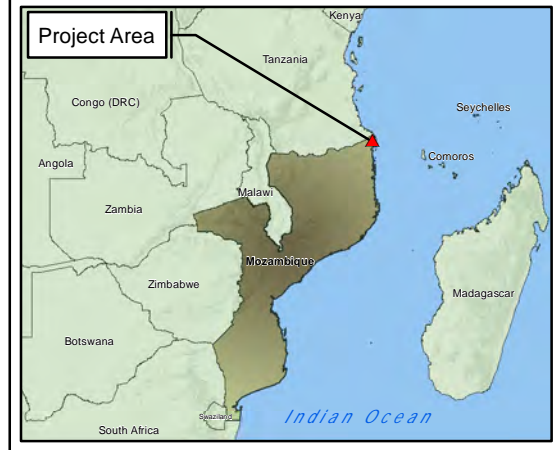
- Far Field Bommie (FFB)
- Near Field Bommie (NFB)

- Regional Roads
- Proposed Nearshore Infrastructure
- Proposed Pipeline Corridor Route

Afungi Project Site

**Bathymetry (Metres below Mean Sea Level)**

- -5
- -10
- -50
- -100



TITLE:  
**Figure 7.50:  
 Near (NFB) and Far (FFB) Field Coral Reef Sampling Site Locations**

CLIENT:

**Anadarko**

Mozambique Área 1, Lda

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 110 000
DRAWING: Near and Far Field Coral Reef.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

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

SIZE:  
**A3**

At the near-field site adjacent to the shores of Afungi Peninsula, the coral bommies were similar to those at the far-field site in structure, although the diversity of epiphytic coral growth forms was higher. In particular, a wide variety of massive and sub-massive forms were seen, with some larger branched colonies at the bases of the bommies (Figure 7.51). Hydroids, filamentous algae (*Halimeda* spp.), encrusting coralline algae and encrusting sponges provided the majority of cover on surfaces not occupied by live coral (Figure 7.52). Branched coralline algae and zoanthids were also observed. Bommie density at the near-field site was 42/1,000m<sup>2</sup>, a factor of 10 greater than the density measured at the far-field site.

Mobile benthos observed at the near-field site included urchins (*Diadema setosum*) and cushion stars (*Culcita schmideliana*). The fish fauna was also more diverse than at the far-field site, with lionfish and lizardfish recorded in addition to various damselfish, angelfish, butterflyfish and wrasses, some of which are shown in Figure 7.52.

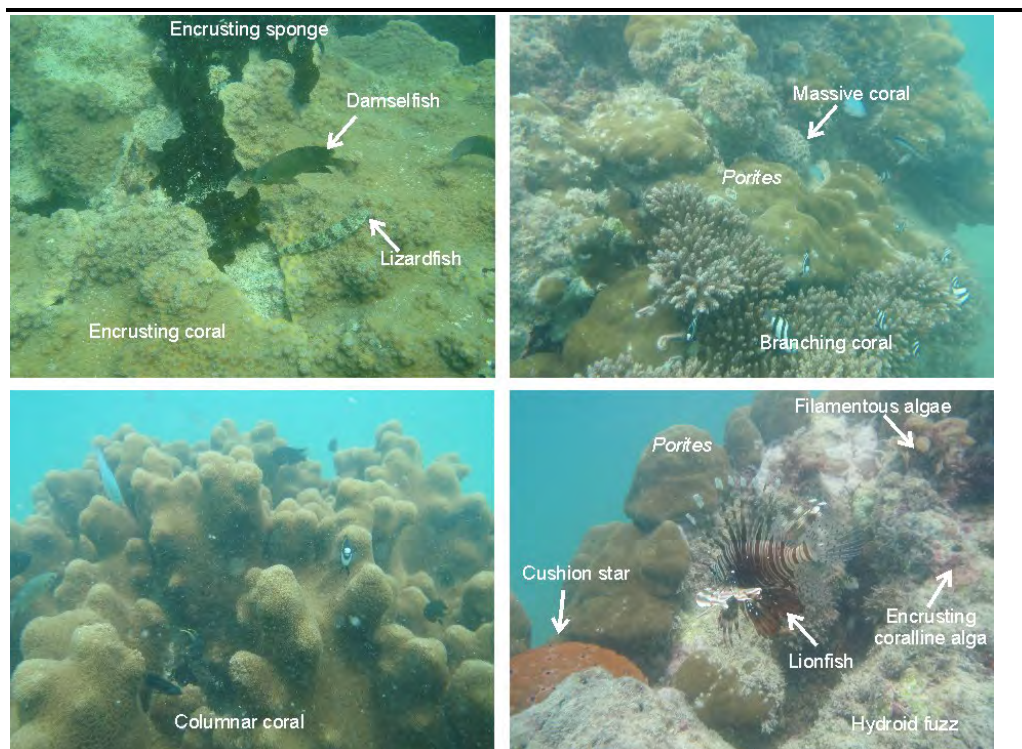
Most of the massive forms showed little apparent damage from the 1997 and 1998 El Niño coral bleaching events. In general, massive forms seemed to be the dominant coral growth form within the bay.

**Figure 7.51** *Diversity of Massive Coral Forms Present on the Near-field Porites Bommies*



Source: Lwandle, 2012.

Figure 7.52 *Biota Present on the Near-field Porites Bommies*



Source: Lwandle, 2012.

All of the bommie areas are fished intensively and there is evidence of damage from anchoring, lines, nets, baskets and even trampling. Damage includes detachment of large *Acropora* colonies and smashed *Lobophyllia* (massive coral). From this and probably other causes, a high proportion of the coral bommie reef structure is actually dead material comprising >60 percent of reef cover.

Isolated colonies of *Acropora* were associated with the bommies. In a marine habitat survey at three locations along the Cabo Delgado coastline from Vamizi Island south to Medjumbe Island CSA (2007) identified *Acropora aspera* amongst these. This species is categorised as Vulnerable according to the IUCN (2011) red list. The CSA (2007) data indicate that *A. aspera* was one of the dominant species at each of the three sites they sampled and although not specifically recorded in Palma Bay it is probable that it occurs there.

### 7.8.6 *Fringing Coral Reef*

As shown in *Figure 7.48*, the fringing coral reef areas are found around and between the three islands in and immediately south of Palma Bay – Tecomaji, Rongui and Queramimbi. The coral genera, species and growth forms recognised in Palma Bay are similar to those recorded throughout the Quirimbas Archipelago and in the Indo-Pacific region. They therefore represent a locally important biodiversity resource, as opposed to being unique at the regional, national or international scale. The fringing reefs around these islands were surveyed to provide comparative information to be used in the selection of a pipeline route. The sites/transects surveyed are

shown in *Figure 7.54*, and are listed in groups according to their geographical location below:

- North of Tecomaji Island:
  - Tecomaji North Observations;
  
- Between Tecomaji and Rongui islands:
  - Tecomaji South Transects,
  - Tecomaji to Rongui Transect,
  - Deeper Waters between Tecomaji and Rongui islands; and
  
- South of Rongui Island:
  - Rongui South Transects,
  - Rongui South Observations, and
  - Rongui to Queramimbi Transect.

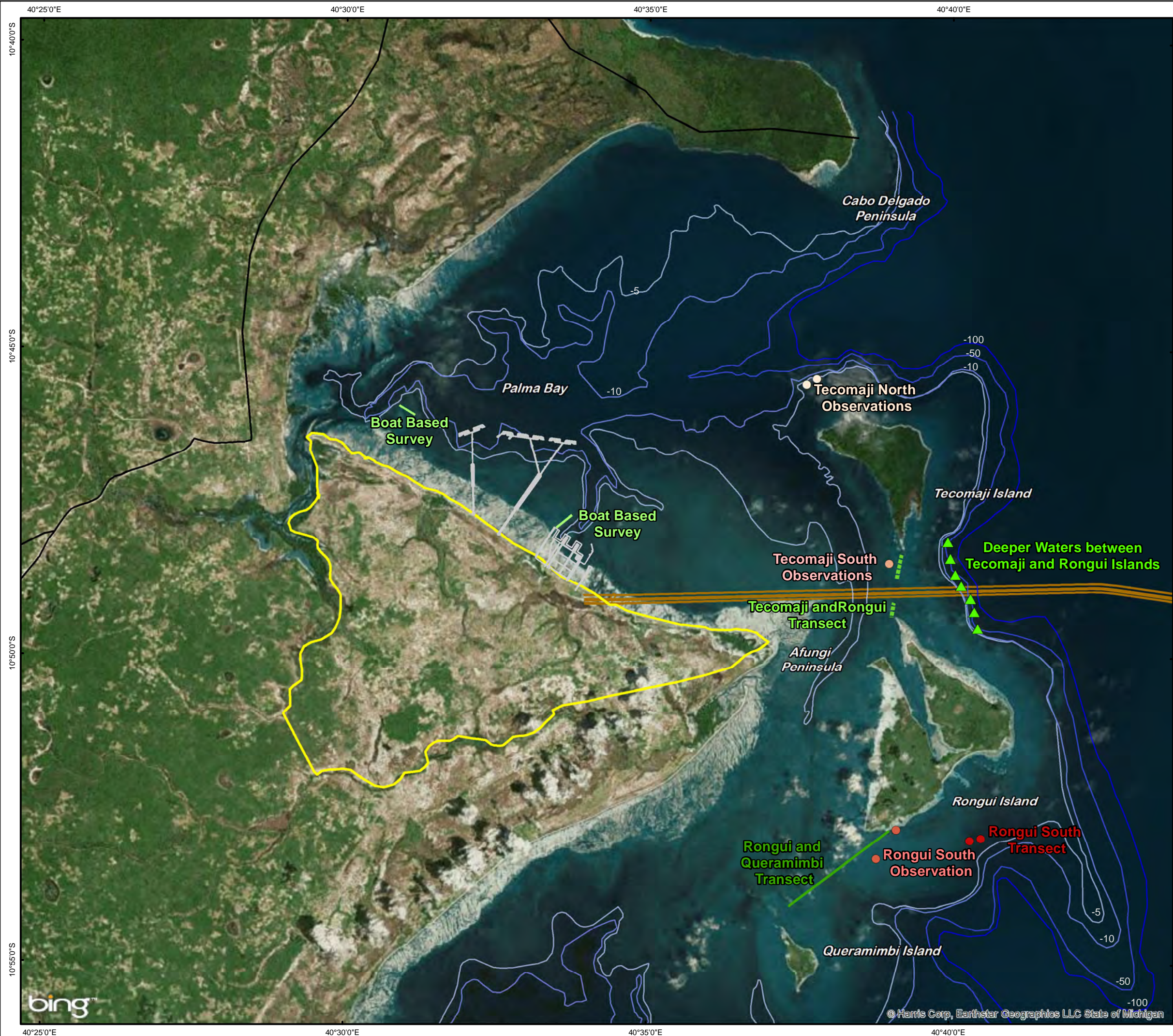
The fringing reef habitats are described according to these geographical areas in the sections below.

#### *North of Tecomaji Island*

##### Tecomaji North Observations

Visual and photographic observations of coral reef features were undertaken towards the seaward drop-off at two locations to the north of Tecomaji Island: Tecomaji North Deep at approximately 7m, and Tecomaji North Shallow at approximately 5m).

*Figure 7.53* and *Figure 7.55* illustrate examples of the biodiversity recorded in the Tecomaji North Shallow and Deep areas respectively. The reef at both of these sites was considerably more extensive than seen at the two inter-island inshore sites (discussed below), with coral cover increasing with depth. Although still present in patches at the shallow site, sand was less common, with the reef base comprising masses of dead coral rubble. In places, the coral rubble remained barren and devoid of obvious recolonisation by macrobenthos, whereas prolific overgrowth by a foliose algae and healthy regrowth of both massive and branched hard coral forms was also apparent in places. A high diversity of coral forms was observed north of Tecomaji. These included massive, branched, tabular, plate, solitary and encrusting species (*Figure 7.53*). Other macrobenthos present included the giant anemones (*Heteractis magnifica* and *Sarcophyton* spp.), giant clams (*Tridacna* sp.), zooanthids, ascidians (*Didemnum molle*) and a crown-of-thorns (COT) starfish (*Acanthaster planci*). The presence of COT starfish is of significance as it is a corallivore, ie a carnivorous predator that preys on reef coral polyps, and has been implicated in coral reef degradation. Ichthyofauna was also diverse, with a variety of larger Chaetodontid (butterflyfish) and Pomacanthid (angelfish) species being prevalent, as well as the ever-present damselfish, anemonefish and small wrasses.

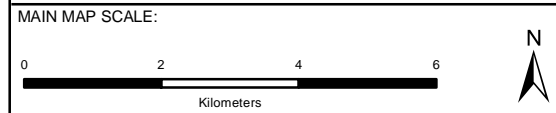
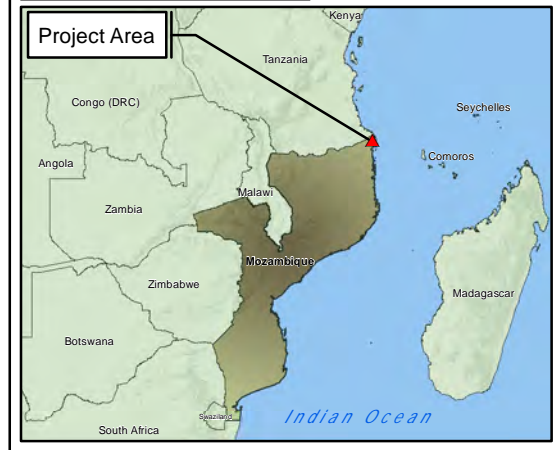


**Legend**

- ▲ Seabed Observations at Deeper Waters between Tecomaji and Rongui Islands
- Tecomaji North Observations
- Tecomaji South Observations
- Rongui South Observation
- Rongui South Transect
- Boat Based Survey
- Tecomaji and Rongui Transect
- Rongui and Queramimbi Transect
- Regional Roads
- Proposed Nearshore Infrastructure
- Proposed Pipeline Corridor Route
- Afungi Project Site

**Bathymetry (Metres below Mean Sea Level)**

- -5
- -10
- -50
- -100



TITLE:  
**Figure 7.53:  
 Boat, Diver and ROV Fringing Coral Reef Survey Sites**

CLIENT:  
**Anadarko**  
 Moçambique Área 1, Lda

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 110 000
DRAWING: Boat Diver and ROV Fringing.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

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

SIZE:  
**A3**

**Figure 7.54** *Tecomaji North Shallow Area Showing the Coral Regrowth and Some Examples of Species Mentioned in the Text*



**Figure 7.55** *Tecomaji North Deep Area Showing Coral Rubble, Macro-algal Growth and Some Examples of the Coral Diversity*



Source: Lwandle, 2012.

*Between Tecomaji and Rongui Islands*

Tecomaji South Transects

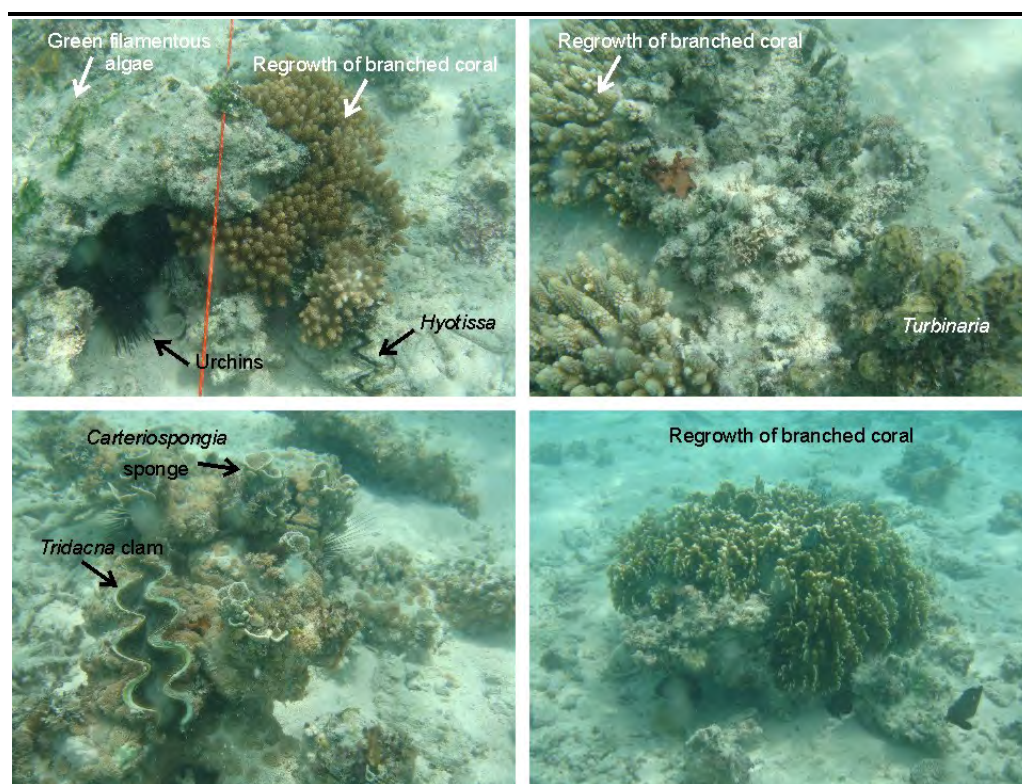
Sand, and sand with coral debris, dominated most of the transects surveyed south of Tecomaji Island, essentially similar to the Rongui south transects. A further similarity between this location and south of Rongui is the increased representation of massive and branched corals on the inner Transect #3.

The area around the Tecomaji South Transect #1 was dominated by sand and expanses of coral rubble. The hard substrata in the area are low-relief clusters of what appeared to be a dead coral base, covered by a carpet of encrusting coralline algae, hydroid fuzz and tufts of green filamentous algae, with a veneer of loose sand. Regrowth of branching coral forms is evident in places,



indicating recovery following the coral bleaching event in the late 1990s (see later text). The dead base-reef was comparatively barren, with partial cover by areas of soft coral and the anemone *Heteractis magnifica*. Other sessile invertebrates included upright (*Carteriospongia foliacens*) and encrusting sponges, and ascidians (*Didemnum molle*). The giant clam *Tridacna* sp. and *Hyotissa hyotis* were both present, usually deeply embedded within the old coral structure. Mobile invertebrates included cushion stars (*Culcita schmideliana*), urchins (*Diadema setosum*), which usually occurred on sand and sheltered under small coral overhangs, and the sea cucumber *Synapta maculata*. Macroalgae were primarily represented by the brown alga *Turbinaria ornata*. Fish fauna was comparatively scarce, and limited to anemonefish associated with *H. magnifica* and a few species of damselfish associated with the new branched coral growth.

**Figure 7.56** *Tecomaji South Transect #1 - Biodiversity*



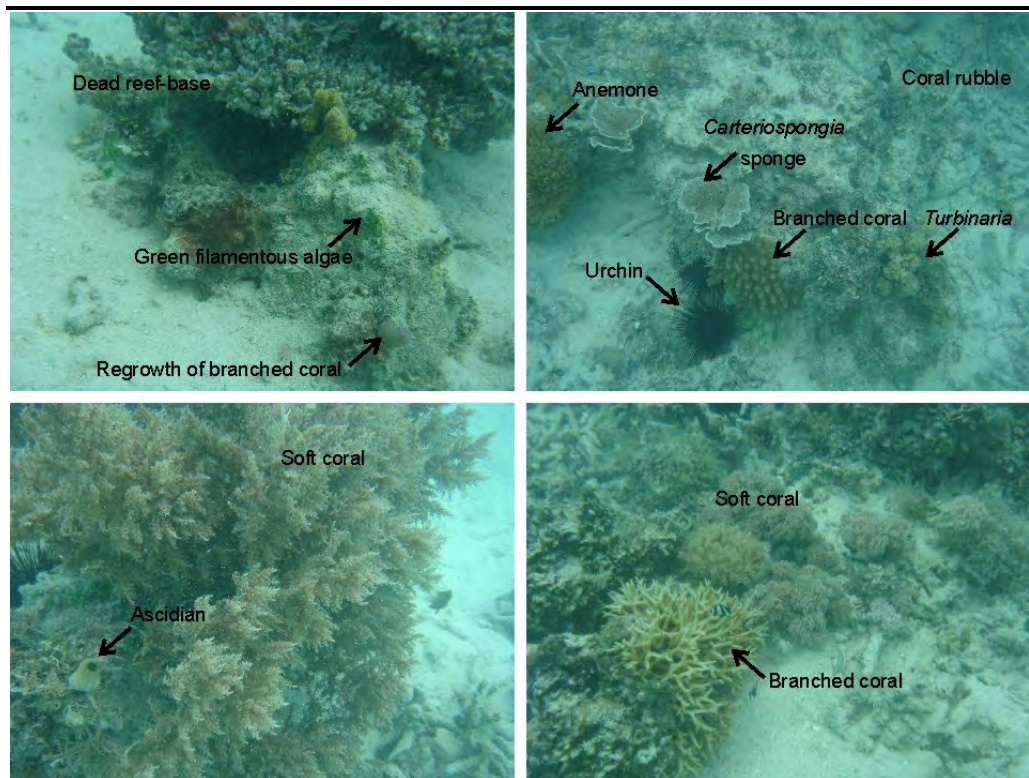
Source: Lwandle, 2012.

The Tecomaji South Transect #2 was very similar to Transect #1, being dominated by sand and expanses of coral rubble, with regrowth occurring on a dead coral base. A notable difference was that Transect #2 had a higher abundance and diversity of soft corals, and regrowth of hard corals included some stands of delicately branched species. Hydroid fuzz, filamentous green algae and a foliose brown alga species (possibly *Lobophora variegata*) formed the principal living cover. The giant anemone (*Heteractis magnifica*), upright sponge (*Carteriospongia foliacens*), brown alga (*Turbinaria ornata*) and ascidians (*Didemnum molle*) were also recorded. Molluscs were represented by the bivalves *Hyotissa hyotis* and *Atrina vexillum*. Fish fauna was again relatively

sparse and associated primarily with the small clumps of coral regrowth and stands of soft coral.

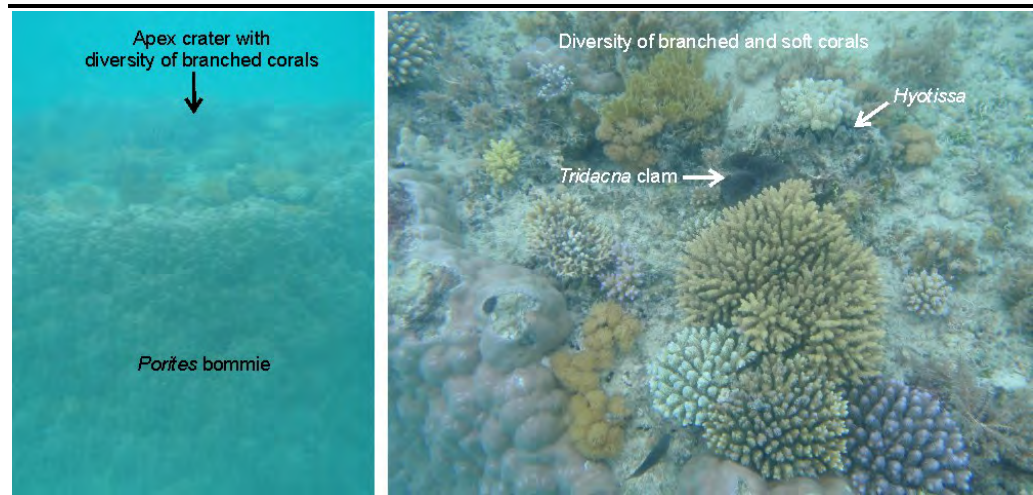
At Transect #3, the most prominent feature was a massive *Porites* bommie, which rose to a height of some 3m above the surrounding sandy seabed. The steep, almost monospecific sides gave way to a flat crater at the apex, which provided a habitat for a wide diversity of small, relatively young colonies of branched corals, soft corals, hydroids and the associated fish fauna, comprising primarily damselfish. Giant clams (*Tridacna* sp.), the bivalve *Hyotissa hyotis* and the tropical crayfish *Palinurus versicolor* were also present, the latter having found shelter in a small crevice in the walls of the bommie.

Figure 7.57 Tecomaji South Transect #2 - Biodiversity



Source: Lwandle, 2012.

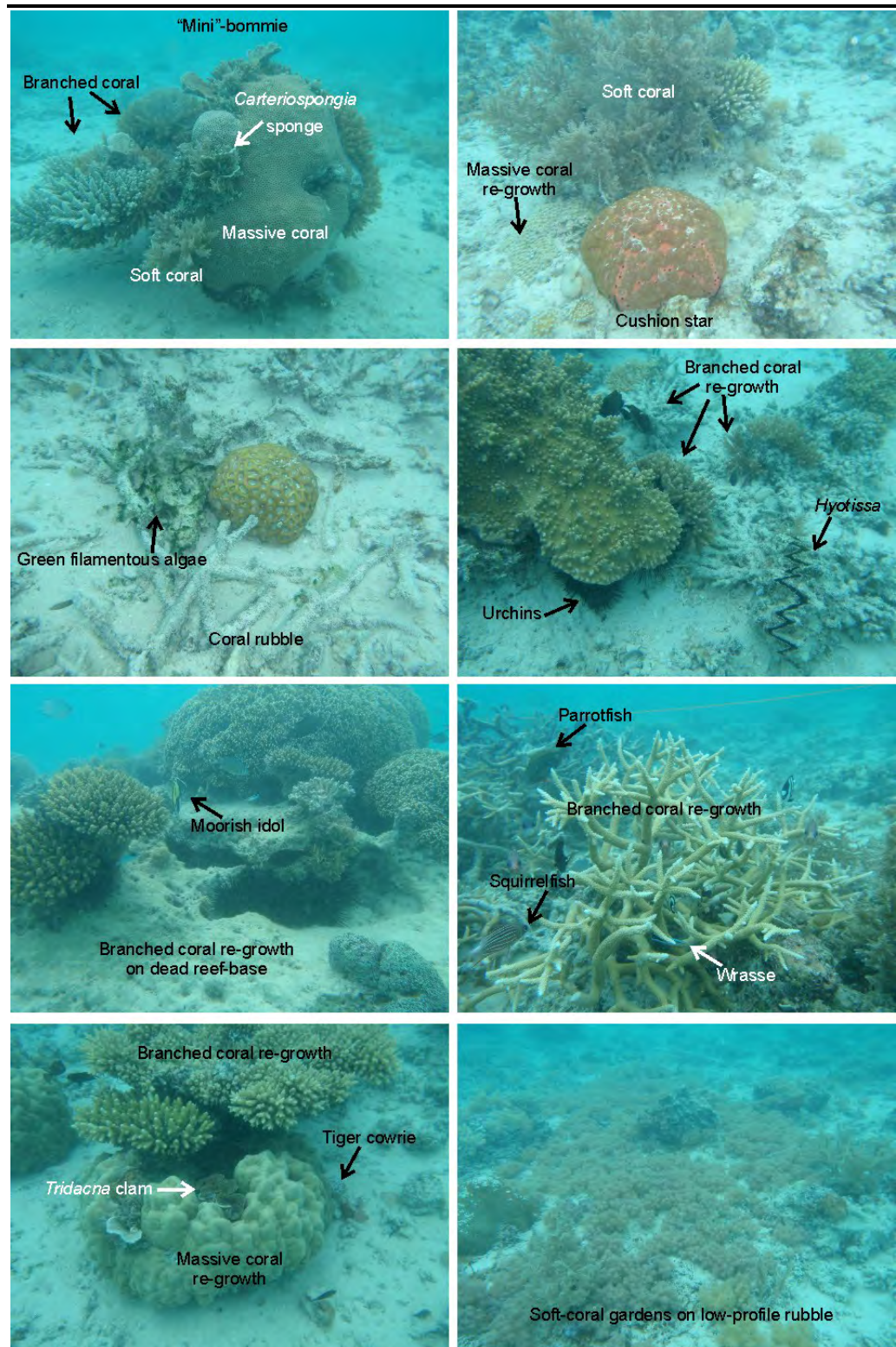
Figure 7.58 Tecomaji South Transect #3 – Biodiversity



Source: Lwandle, 2012.

The area around the coral bommie was dominated by expanses of sand interspersed with coral rubble. Isolated mini bommies of dead coral-base provided substrata for colonisation by a variety of soft corals, upright sponge (*Carteriospongia foliacens*) and giant anemones (*Heteractis magnifica*), and the regrowth of a diversity of branched and massive coral forms (Figure 7.58 above). Sessile invertebrates included giant clams (*Tridacna* sp.), the bivalve *Hyotissa hyotis* and fan worms, whereas mobile invertebrates included urchins (*Diadema setosum*), a tiger cowrie (*Cypraea tigris*) and cushion stars (*Culcita schmideliana*). Areas of low-profile coral rubble provided a substrate for expansive fields of soft corals and dense carpets of a prostrate foliose alga (possibly *Lobophora variegata*) and green filamentous algae. Ichthyofauna included a diversity of damselfish, anemonefish, crown squirrelfish, wrasses, bullhead parrotfish, butterflyfish, pufferfish and moorish idols.

Figure 7.59 Tecomaji South Transect 3# Showing the Mini Bommies, Coral Regrowth and Some Examples of Species Mentioned in the Text



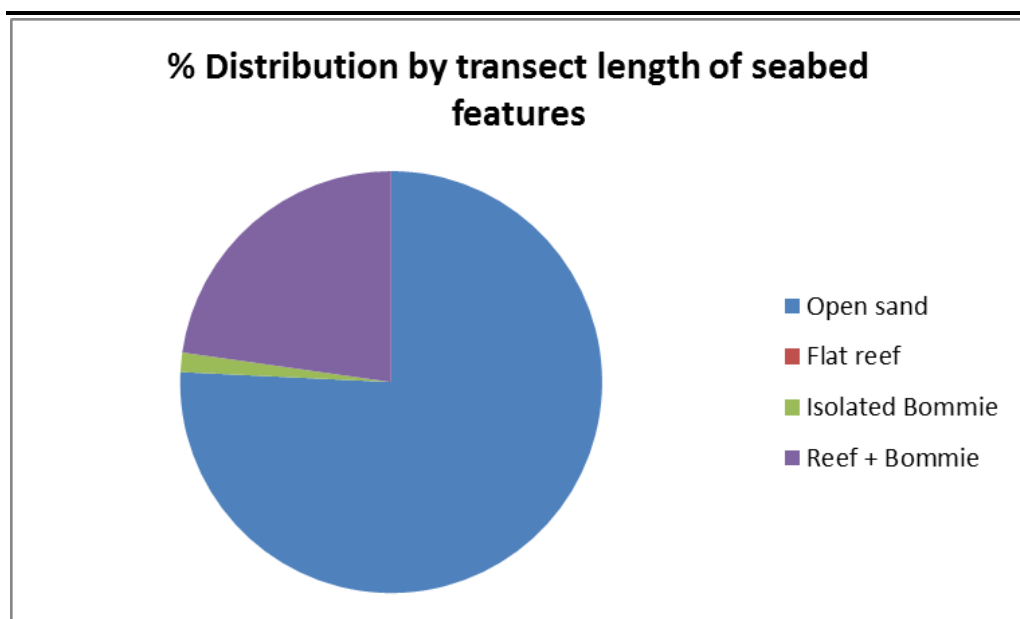
Source: Lwandle, 2012.

### Tecomaji-Rongui Transect

Nineteen observations of seabed types were made across the 2.04km transect between Tecomaji and Rongui. Figure 7.60 shows the distributions of seabed

types observed. The dominant types are open sand seafloor and coral reef with bommies, which were observed on the southern end of the transect. The latter was distributed in two sections of approximately 340m and 180m lengths. Sand seafloor completely dominated the transect, with a semi-continuous stretch extending more than 1.1km across the centre of the transect. Isolated bommies were concentrated on the northern portion of the surveyed area close to Tecomaji Island.

**Figure 7.60** *Proportional Distribution of Seabed Types on the Tecomaji–Rongui Inter-island Transect*



Source: Lwandle, 2012.

#### Deeper Waters between Tecomaji and Rongui Islands

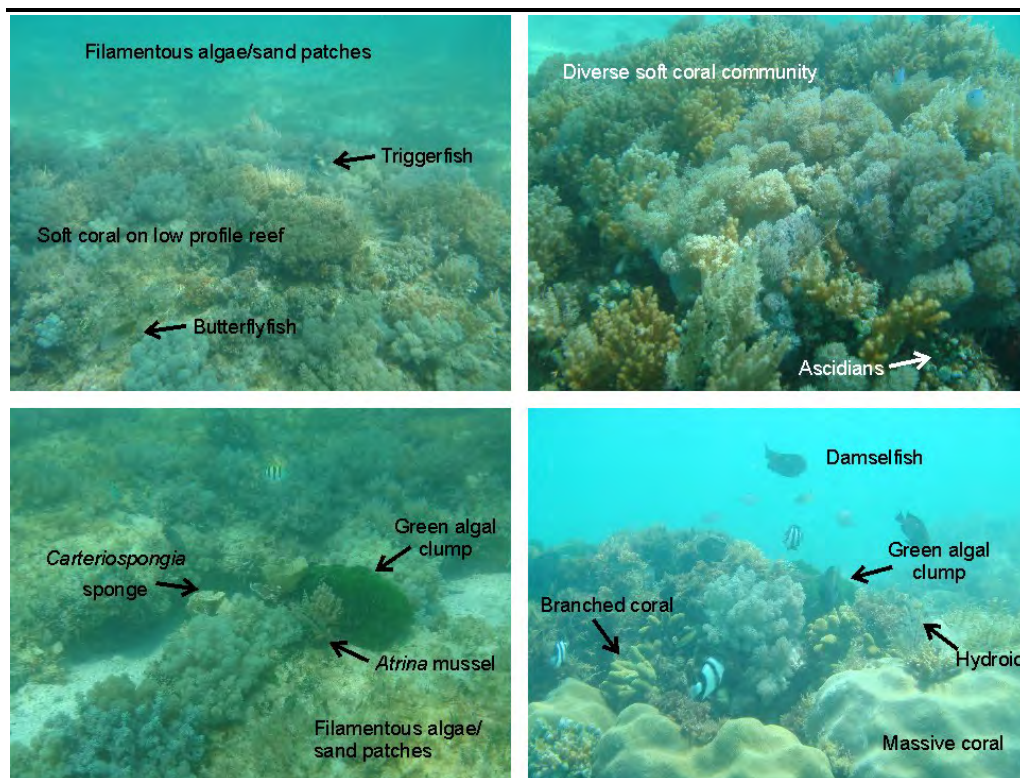
During the wet season survey (March 2012), ROV video footage was obtained between the approximate depths of 5 and 70m at seven locations between Tecomaji and Rongui islands (*Figure 7.54*). This area was selected for inspection as it was being considered as a possible suitable area to route the gas pipelines. The video recording was examined and the seafloor was broadly classified according to whether it comprised well-developed reef, patchy sand and reef, or sand in 5m-depth bands (depth record taken from ROV pressure sensor). In general, shallower depths had varying degrees of coral reef cover, with this giving way to mainly sand, or sand with patchy reef with soft corals and crinoids, below approximately 35m depth. Two transects of the seven varied from this (Transects #TR001 and #TR007). In those transects, sand was dominant from relatively shallow depths (#TR001) or, along with patchy reef, completely dominant (#TR007). This reflects the overall distribution of seafloor types in the shallower areas between these islands.

Rongui South Transects

The distributions of coral and sand on these transects are essentially similar to those in the Tecomaji South Transects. Sand, and sand with coral debris, dominated most of the transects surveyed south of Rongui in terms of proportions of these seabed types along the 100m lengths surveyed. This is consistent with the results of the inter-island surveys, which show that distances between coral bommies are usually >20m. Macroalgae were also common. When attached to corals this is symptomatic of coral senescence or mortality, and the observations are consistent with the high proportions of coral debris observed in the transects. The differences between the individual transects are slight, but massive and branching corals have a higher representation on the inner Transect #3.

The photos of Transect #1 show that the hard substrate areas of this transect were primarily characterised by low-profile, platform-like 'reef' (possibly dead coral-based reef) with some higher-profile outcrops. These reefs were interspersed between lawns of filamentous blue-green algae, and green algae and patchy sand veneer (Figure 7.61). Cushion stars (*Culcita schmideliana*) were present on the sandy substrate. The low-profile reef was dominated by thick stands of a wide diversity of soft corals. Other benthic organisms living between the soft corals included ascidians (*Didemnum molle*), hydroids, encrusting and upright (eg *Carteriospongia foliacens*) sponges and mussels (*Atrina vexillum*). Areas of higher relief provided habitat for isolated clumps of branching and massive (primarily *Porites* sp.) hard corals, hydroids and clumps of the green alga (*Bryopsis* sp.). Dominant ichthyofauna included a variety of damselfish species, with some triggerfish and butterflyfish also present.

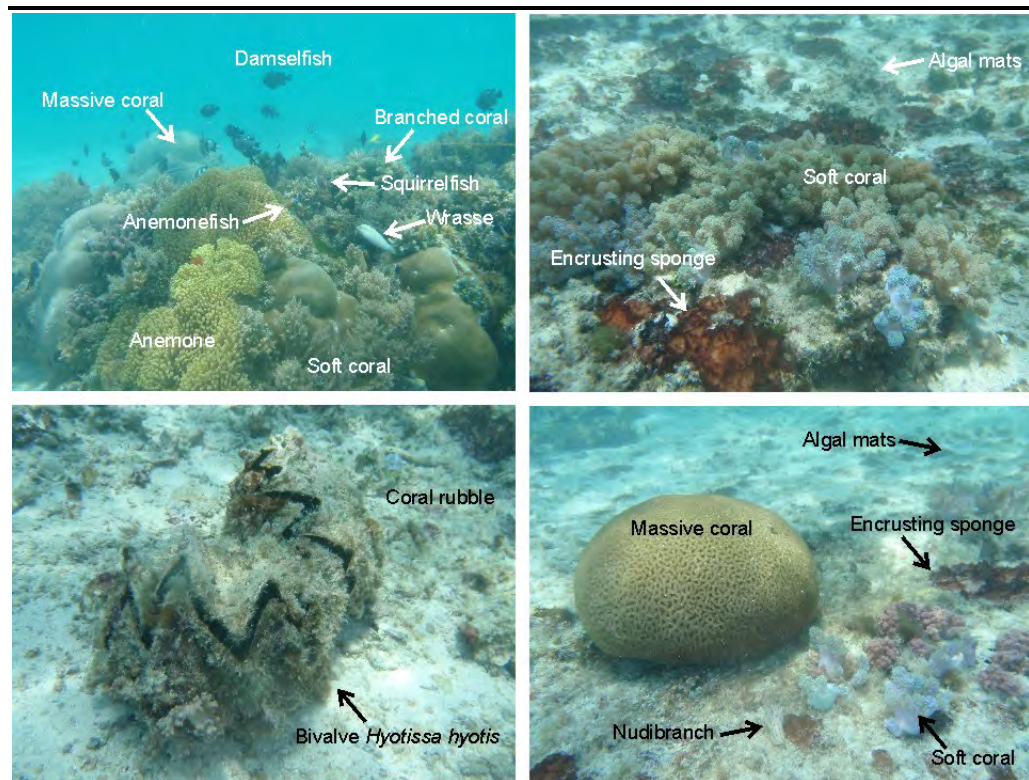
Figure 7.61 Biodiversity Recorded along Rongui South Transect #1



Source: Lwandle, 2012.

At Transect #2, the reef structures scattered throughout the expanses of sand and coral rubble had a profile of up to 1m and were characterised by a diversity of both hard and soft corals (Figure 7.62). Hard corals included both massive and branched forms. Mats of the sea anemone *Heteractis magnifica* were common, and associated with these were a diversity of damselfish and anemonefish. Other benthos included ascidians (*Didemnum molle*), zoanthids, hydroids, encrusting and upright (*Carteriospongia foliacens*) sponges. Algae on the reef were represented by clumps of green (*Bryopsis* sp.) and brown algae (*Turbinaria ornata*). Mobile benthos associated with the reef area included a starfish (*Leiaster* sp.) and a nudibranch. The sand and coral rubble areas were characterised by patchy coverage of brown algal mats and encrusting sponge and stands of soft corals. The Gryphaeid bivalve *Hytissa hyotis* and an isolated colony of a massive (brain) coral (probably a *Goniastrea* sp.) were present in the sand-dominated areas. A diversity of reef fish was associated with the coral outcrops including butterflyfish, goldies, wrasses, pufferfish and crown squirrelfish.

Figure 7.62 Biodiversity Recorded along Rongui South Transect #2

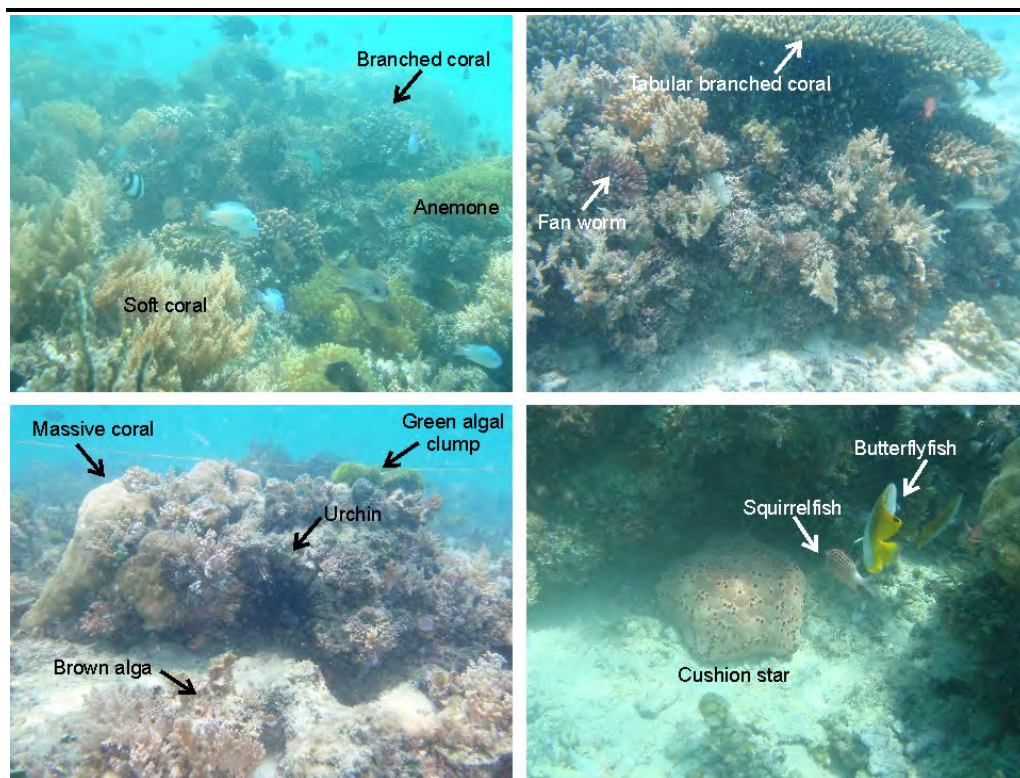


Source: Lwandle, 2012.

The reefs around the innermost Transect #3 were more extensive, with an increasing abundance and diversity of branched and massive corals, with small tabular forms being noted (Figure 7.63). The sea anemone *Heteractis magnifica* and its associated ichthyofauna was again common. Other benthos included ascidians, hydroids, upright and encrusting sponges, fan worms, cushion stars, urchins (*Diadema setosum*) and the bivalves *Atrina vexillum* and *Hyotissa hyotis*. The fish fauna around this transect was more diverse and abundant relative to the two other transects. Algae were represented by the typical clumps of *Bryopsis*, encrusting corallines, erect brown alga (*Turbinaria ornate*) and a foliose alga (possibly *Lobophora variegata*).



Figure 7.63 Biodiversity Recorded along Rongui South Transect #3



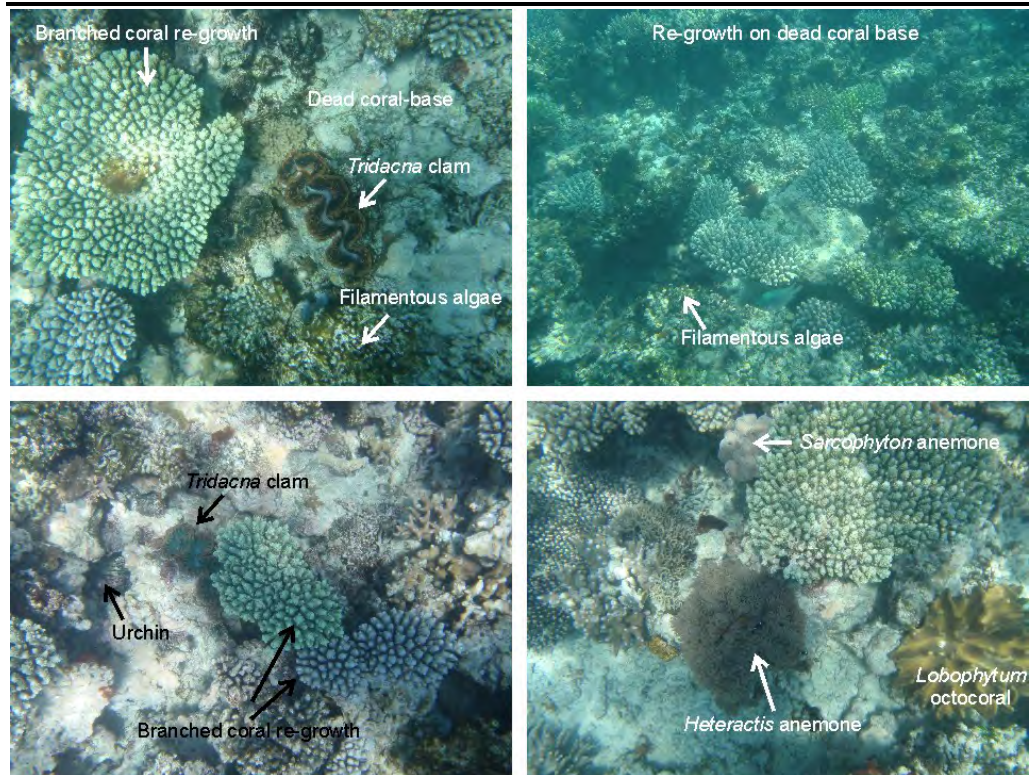
Source: Lwandle, 2012.

### Rongui South Observations

Visual and photographic observations of coral reef features were similarly undertaken at two locations offshore, namely the Rongui South video transects and west of the southern point of Rongui Island (Rongui South Deep at approximately 6m and Rongui South Shallow at approximately 4m), as shown in Figure 7.54.

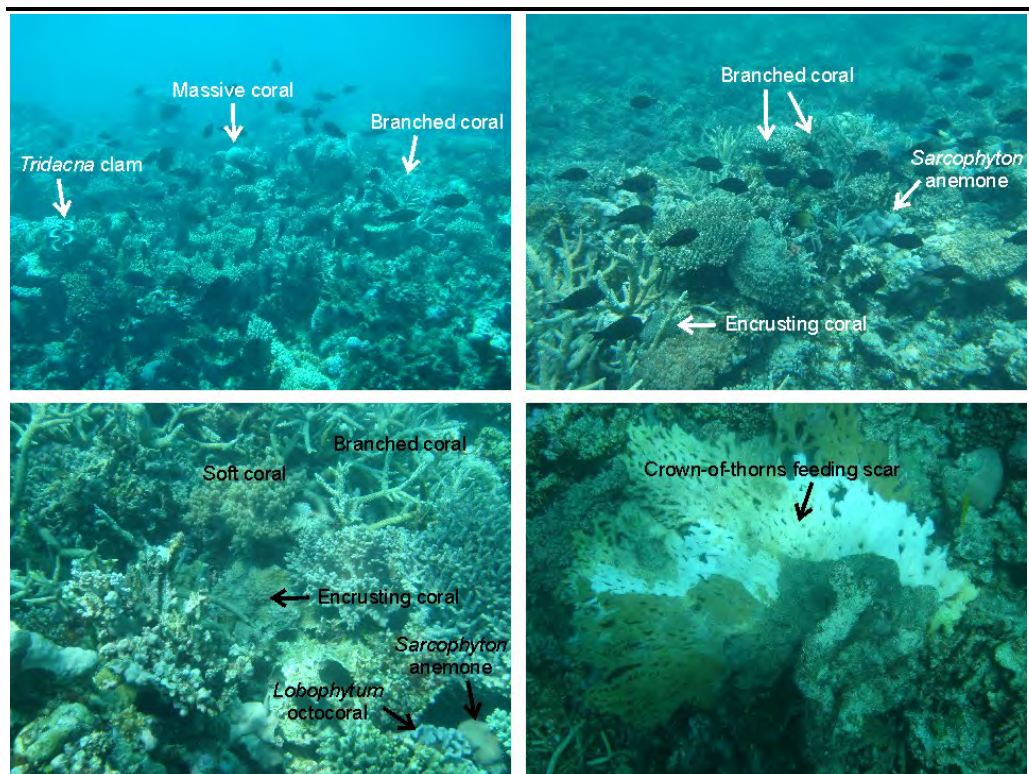
Figure 7.64 and Figure 7.65 provide images of biodiversity recorded in the Rongui South Shallow and Deep areas respectively. The reef towards the seaward drop-off was significantly more extensive than at the inshore transect sites, with sand being virtually absent, but the reef was dominated by large expanses of coral rubble. In some areas, the dead coral was overgrown by mats of filamentous algae and crustose coralline algae, although much of the rubble remained barren. The erect brown alga (*Turbinaria ornata*) was also present.

**Figure 7.64** *Rongui South Shallow Area Showing Coral Rubble, Filamentous Algal Growth and Some Examples of Benthic Diversity*



Source: Lwandle, 2012.

**Figure 7.65** *Rongui South Deep Area Showing Coral Regrowth and Some Examples of Benthic Diversity*



Source: Lwandle, 2012.

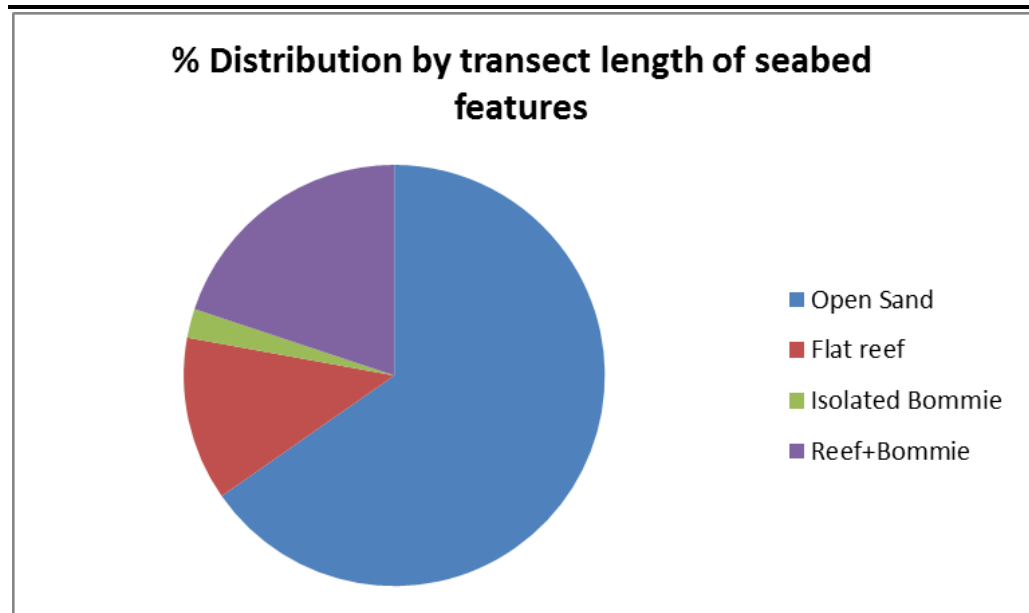
Regrowth of branched, massive and encrusting coral forms, as well as a diversity of soft coral and encrusting sponge, was evident throughout the area. Other macrobenthos present included giant anemones (*Heteractis magnifica* and *Sarcophyton* spp.), encrusting octocorals (*Sinularia* spp. and *Lobophytum* spp.), giant clams (*Tridacna* sp.) and urchins (*Diadema setosum*). The upright sponge (*Carteriospongia foliacens*) and cushion star (*Culcita schmideliana*) were primarily recorded in the shallower area. The bleached tips of some branching coral forms and bleached bands on tabular corals suggest that predation by COT starfish occurs to some extent in the area. As in the deeper areas off Tecomaji North, the fish fauna was characterised by a variety of larger Chaetodontids (butterflyfish) and Pomacanthids (angelfish), as well as damselfish, anemonefish and small wrasses. A pipefish was also seen.

#### Rongui-Queramimbi Transect

Fifty individual observations of coral reef and associated or isolated coral bommies were made along the 3.8km transect between Rongui and Queramimbi islands. The proportions of the seabed types recorded between the two islands are shown in *Figure 7.66*. The bulk of the transect was sand, interspersed with coral bommies, but the most extensive continuous feature on the transect was the approximately 730m-long stretch of coral reef with bommies. Despite being numerous, isolated bommies comprise a small fraction of the surveyed transect length. Two flat coral reef areas, probably with coral rubble <sup>(1)</sup>, made up stretches of approximately 220m lengths on the southern side of the transect. Inter-bommie distances (bommie spacing) were variable, ranging from approximately 240m to 10m or less. *Figure 7.67* shows a typical view of bommie spacing as visible from the survey boat.

(1) Unconsolidated fragments of broken dead coral.

**Figure 7.66** *Proportional Distribution of Seabed Types on the Rongui-Queramimbi Inter-island Transect*



Source: Lwandle, 2012.

**Figure 7.67** *Surface View of Coral Reef Distribution South of Rongui Island*



The dark patches of reef are interspersed with lighter areas of sand.

Source: Lwandle, 2012.

## *Disturbance/Damage to Fringing Coral Reefs*

A major and prominent feature of the fringing coral reef areas surveyed around the islands was the substantial amount of coral debris and dead coral-base present. There are three possible causes for this:

- destructive fishing methods using dynamite <sup>(1)</sup>;
- reef damage through cyclones or heavy storms; and
- coral bleaching.

Dynamite fishing is extremely effective in shallow-water areas, where it is used to stun fish, which are then collected from the surface or the seabed. The explosions are highly damaging to the benthic reef communities, with branching coral forms being particularly vulnerable. The blasts usually affect an area of 4 to 5m in diameter and can reduce mature coral growth to rubble within a few seconds (Richmond, 1997). Considering the comparatively small areas usually affected by dynamite fishing compared to the extent of the coral rubble around Tecomaji and Rongui islands, it is unlikely that the coral damaged observed can be attributed to this fishing method.

Tropical storms (cyclones, hurricanes or typhoons) are the most severe form of mechanical disturbance of coral reefs. In a study conducted on the Great Barrier Reef in Australia following the Category 4 Tropical Cyclone, Ingrid, it was found that winds in excess of 33m/s caused catastrophic damage on inshore and offshore reefs. While offshore reefs had the deepest depth of damage, inshore reefs had the greatest rates of coral breakage and dislodgement. For example, on a severely affected inshore reef, hard coral cover and taxonomic richness decreased while massive coral cover remained unaltered (Fabricius et al., 2008). Harmelin-Vivien (1994), however, points out that cyclone-induced damage to reef communities is highly variable and related to factors including cyclone characteristics, location of the reef to the storm path, reef topography, characteristics of the pre-storm communities, their location and depth on the reef and the time elapsed since the previous disturbance.

The most recent cyclones to affect the Mozambique coastline were Cyclone Jokwe (Category 3 storm), which raged across central and northern Mozambique in March 2008, and Cyclone Favio (Category 4 storm), which struck the central province of Inhambane in February 2007. Of these, Cyclone Jokwe may have affected the Study Area, with similar (although probably not as extreme) effects as described by Fabricius et al. (2008).

North of Tecomaji Island and south of Rongui Island, the occasional specimen of COT starfish was observed. This starfish has gained notoriety as a threat to coral reef ecosystems, particularly in the Great Barrier Reef off the coast of

(1) The use of dynamite in fishing is forbidden in Mozambique; however, the Fisheries Council of Palma confirmed the use of dynamite around the corals in Palma Bay and elsewhere (2012).

Australia. It feeds on live coral polyps by climbing onto a reef structure and then extruding its stomach onto the coral. This releases digestive enzymes that allow the starfish to absorb nutrients from the liquefied coral tissue. Overpopulation of COT has been blamed for widespread reef destruction, although it has been pointed out that the starfish has an important and active role in maintaining coral reef biodiversity, driving ecological succession by preventing fast-growing corals from overpowering the slower-growing coral varieties. However, when coinciding with other factors negatively affecting the reef ecosystem, such as coral bleaching or coral specific diseases, overpopulation of COT can cause permanent and devastating damage.

In 1995, the reefs of Mozambique experienced a COT starfish outbreak, which in the following three years resulted in 80 percent coral mortality in the Bazaruto area and reduction of coral cover to 2 to 5 percent in the Inhambane area (Motta et al., 2002). Towards the end of this infestation, the western Indo-Pacific was subject to a wide-scale El Niño Southern Oscillation (ENSO) between 1997 and 1998. The elevated sea temperatures associated with this ENSO resulted in regional coral bleaching, the extent and impacts of which showed a strong north-south gradient. The bleaching and mortality started in the south in February/March 1998, terminating in the north in May that year (Schleyer et al., 1999; Motta et al., 2000; Motta et al., 2002; Obura et al., 2000). The northern Mozambican reefs, previously known for their great biodiversity, suffered most, with coral mortality on some patch reefs as high as 99 percent being reported. Reefs in sheltered bays, which experience higher levels of nutrients and turbidity from land run-off, as well as variance in surface water temperatures, were least affected (Motta et al., 2000; Obura et al., 2000).

Following the event, there were significant increases in foliose, turf, calcareous and coralline algae growing on the newly dead coral surfaces which, in turn, influenced the abundance of herbivorous fish populations. Subsequent coral monitoring surveys conducted in Mozambique as part of the Coral Reef Degradation in the Indian Ocean (CORDIO) programme have found evidence of recovery on some reefs on which soft corals are the primary colonisers (Motta et al., 2000, Motta et al., 2002).

The coral species that suffered the highest bleaching and mortality were typically fast-growing branching species with high sexual or asexual reproduction rates and competitive overgrowth (eg *Acropora*, *Pocillopora*, *Stylophora* and *Seriatopora*, which showed up to 100 percent bleaching). Many of the surviving species were the slower-growing massive, sub-massive and encrusting forms, which rarely dominate reef communities (Obura et al., 2000). Obura et al. predicted that the bleaching event would have profound impacts on the structure and growth rates of the Mozambican coral reefs for many years, with the possibility of eventual collapse of the reef structure (Motta et al., 2000). Any future ENSO events may thus have very different impacts on the evolving reef community structure, due to overall species changes in these coral communities. Large-scale El Niño events may be 'selecting' specific gene pools that are more resistant to temperature impacts.

Video footage and photographic data collected from the coral reefs in the Palma Bay area, confirm the above findings to a large degree. Soft corals appeared to be the primary colonisers in damaged shallow reef areas, although there was also evidence of substantial recovery of branching forms on both the reef flats and towards the drop-offs. The coral rubble comprised primarily broken branched coral forms (which are, however, also the most sensitive to cyclone damage), and collapse of the reef structure was evident at the sites surveyed towards the drop-offs.

## 7.9 NEAR SHORE ENVIRONMENT – MAJOR BIOLOGICAL FEATURES

### 7.9.1 *Fish*

There are no survey data available for fish within Palma Bay. However, being part of the Quirimbas Archipelago, it is probable that the fish species recorded for coral reef and seagrass biotopes to the south of Palma Bay will occur in the bay.

Of the larger pelagic species, Spanish mackerel (*Scomberomorus commerson*) have been recorded off Cabo Delgado (Saetre & da Silva, 1979). It is noteworthy that juvenile Spanish mackerel (2 to 3cm in length) were caught off the Cabo Delgado coast in April 1978 during the Dr Fridtjof Nansen survey, indicating spawning activity for this species during this period of the year at that location or nearby. Surface schools of yellowfin tuna (*Thunnus albacares*) have been observed in the region and are fished at industrial and artisanal scales (see *Chapter 9* for information on fisheries). Other large pelagic species in the coastal waters include sailfish (*Istiophorus platypterus*), marlin (*Makaira indica*, *M. mazara*, *Tetrapterus angustirostris*, *T. audax*), wahoo (*Acanthocium solandri*), albacore (*Thunnus alalunga*), skipjack tuna (*Katsuwonus pelamis*), bonito (*Gymnosarda unicolor*), narrow-banded Spanish mackerel (*Scomberomorus japonicus*), swordfish (*Xiphias gladius*), great barracuda (*Sphyraena barracuda*), giant trevally (*Caranx ignobilis*) and bluefin trevally (*Caranx melampygus*).

Sharks caught in these waters include the bull shark (*Carcharhinus leucas*), blacktip shark (*C. limbatus*), dusky shark (*C. obscurus*), hammerhead sharks (*Sphyrna* spp.) and tiger shark (*Galeocerdo cuvier*).

These larger pelagic species described above are wide ranging and will certainly occur in the area, even if confined to deeper waters at the entrance to Palma Bay. The summary below focuses on coral reef and seagrass bed associated species likely to be present in the bay area (Impacto, 2008). Data related to fish associated with coral reefs and seagrass beds are based mainly on data derived from the Darwin/Frontier Mozambique Quirimbas Archipelago Marine Research Programme (DFMQAMRP) (April 1996 to December 1997).

## *Fish Associated with Coral Reefs*

The species diversity of fish associated with coral reefs is high. Pereira (2000) has drawn up a checklist of reef-associated fishes of Mozambique that lists 601 species comprising 27 families.

Detailed surveys of the southern Quirimbas islands have been carried out under the auspices of the DFMQAMRP. The researchers identified 375 reef-associated fish species from 57 families (*Table 7.11*). The number of reef-associated fish species in the northern Quirimbas (eg Palma Bay) is likely to be higher.

**Table 7.11** *Number of Species per Family of Reef Fishes Recorded for the Southern Quirimbas Archipelago Islands*

<b>Family</b>	<b>Common Name</b>	<b>No. of Species</b>
Acanthuridae	Surgeon fishes	22
Antennaridae	Frog fish	1
Anthiinae	Fancy sea basses	3
Apogonidae	Cardinal fishes	10
Aulostomidae	Trumpet fishes	1
Balistidae	Trigger fishes	12
Belonidae	Needle fish	2
Blenniidae	Blennies	6
Bothidae	Lefteye flounders	2
Caesionidae	Fusiliers	8
Callionymidae	Dragonets	2
Carangidae	King fishes	11
Carcharhinidae	Requiem sharks	3
Chirocentridae	Wolf herrings	1
Chaetodontidae	Butterfly fishes	21
Cirrhitidae	Hawk fishes	4
Clupeidae	Herrings, shads	2
Cynoglossidae	Tongue fishes	1
Dactylopteridae	Flying gurnards	1
Dasyatidae	Sting rays	2
Echeneidae	Shark suckers	2
Engraulidae	Anchovies	1
Entriscidae	Shrimp fish	1
Fistulariidae	Cornet fishes	2
Gerreidae	Mojarras	2
Gobiidae	Gobies	5
Grammistidae	Soap fishes	1
Haemulidae	Rubberlips and grunters	10
Hemiramphidae	Halfbeaks	3
Holocentridae	Squirrel fishes	8
Kyphosidae	Drummers	1
Labridae	Wrasses	45
Lethrinidae	Emperors	15
Lutjanidae	Snappers	13
Microdesmidae	Worm fishes	1
Monacanthidae	File fishes	5
Mullidae	Goat fishes	16
Muraenidae	Moray eels	2
Nemipteridae	Threadfin breams	2
Ostraciidae	Box fishes	2
Pegasidae	Sea moths	1



Family	Common Name	No. of Species
Pinguipedidae	Sand perches	2
Platacidae	Bat fishes	2
Platycephalidae	Flatheads	3
Plotosidae	Cat fishes	1
Pomacanthidae	Angel fishes	12
Pomacentridae	Damsel fishes	20
Priacanthidae	Bigeyes	2
Rhynchobatidae	Guitar fish	1
Scaridae	Parrot fishes	18
Scombridae	Mackerel	1
Scorpaenidae	Scorpion fishes	6
Serranidae	Groupers	21
Solenostomidae	Pipe fishes	1
Siganidae	Rabbit fishes	4
Stegostomatidae	Zebra sharks	1
Syngnathidae	Seahorses	5
Synodontidae	Lizard fishes	2
Teraponidae	Tiger fishes	2
Tetraodontidae	Puffer fishes	13
Tetrarogidae	Wasp fishes	1
Triglidae	Sea robins	1
Zanclidae	Moorish idol	1

Source: Whittington et al., 1998.

#### *Fish Associated with Seagrass Beds*

Gell (1997) identified 195 species of fish from 52 families caught by seine nets and basket traps over seagrass beds in the Quirimbas Archipelago. The family Lethrinidae accounted for the largest proportion of fish (31.5 percent, while family Siganidae accounted for 22 percent and Scaridae represented 11 percent. There were 29 species of wrasse (Labridae) identified, and the family accounted for over 9 percent of all fish caught.

Although the dominant species varied considerably from day to day and even between hauls, nearly 70 percent of the catch samples by weight were accounted for by the following five species: *Siganus sutor* (Siganidae, 25.1 percent), *Lethrinus lentjan* (Lethrinidae, 23.9 percent), *Leptoscarus vaigiensis* (Scaridae, 8.8 percent), *Lethrinus variegatus* (Lethrinidae, 8 percent) and *Gerres oyena* (Gerreidae, 3.5 percent).

#### 7.9.2

#### *Turtles*

Five species of marine turtle have been documented to occur along the Mozambican coast, as follows:

- green (*Chelonia mydas*);
- hawksbill (*Eretmochelys imbricata*);
- loggerhead (*Caretta caretta*);
- leatherback (*Dermochelys coriacea*); and
- olive Ridley (*Lepidochelys olivacea*).

All of these species are considered to be vulnerable to extinction by the IUCN (2011). The leatherback and hawksbill turtles are considered Critically Endangered, the loggerhead and green turtles Endangered and the olive Ridley Vulnerable.

The distribution of sea turtles in the region, documented by CSA (2007), indicates that turtles were four times more abundant in the waters of Quirimbas National Park than on the northern part of the Archipelago, outside the Park. The turtles observed outside the Park were most numerous in the deep waters around the Macaloe and Medjumbe islands, located more than 100km south of Palma Bay.

Recent studies undertaken by the Maulane Group in conjunction with the London Zoological Society on the islands of Vamizi, Rongui and Macaloe, indicate that green and hawksbill turtles nest on the islands (Hill & Garnier, 2003). Turtle nesting occurs throughout the year. On Vamizi Island, turtle nesting peaks in January and August, while on Macaloe Island, the turtles have their nesting peak between November and May.

Mainland beaches in Palma Bay are steep and the high tide levels extend to the top of the beach (eg *Figure 7.40*). These beaches are therefore unsuitable for turtle nesting, as nests will have a high probability of flooding. Turtle nesting has been recorded on Rongui Island (Hill & Garnier, 2003) and is also reported to occur on Tecomaji Island (Luke Verburgt, Enviro-Insight, pers. comm., 2012).

### 7.9.3 *Whales and Dolphins*

Seventeen species of whales and dolphins have been recorded in near shore waters in the region (*Section 7.6.5*). Three of these are known to enter Palma Bay, namely humpback whales, humpback dolphins and bottlenose dolphins. The balance may episodically occur in the bay or around the fringing islands.

Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) are common in the region and enter sheltered coastal waters inshore of the offshore islands. Indo-Pacific humpback dolphins (*Sousa chinensis*) also occur in these areas and are considered to be restricted to shallow water (<50m, Best, 2007). Humpback whales (*Megaptera novaeangliae*) are seasonal visitors to the inner continental shelf areas for calving and breeding. This species is generally present in northern Mozambique waters between July and November (see *Table 7.5*).

All whales and dolphins are generally wide ranging (Best, 2007), and it is expected that all the species listed in *Table 7.5* may enter shallow coastal waters. Sperm whales are probably the exception here, as they appear to be confined to deep water offshore of the continental shelf break.

Humpback whales are seasonally present in northern Mozambique between July and November, using the region and further north to Kenya for calving

and mating (Best, 2007). Humpback dolphins are an inshore species, and pairs and groups of up to 15 to 20 individuals were observed recently (2011/2012) in Palma Bay (Lwandle field surveys; Luke Verburgt, Enviro-Insight, pers comm.). It is probable that individuals or groups are resident in the system, but the overall distribution of the population is widespread along the African coast, extending from at least the equator to 35°S (Best, 2007). A school of 30 to 40 bottlenose dolphins have been observed in the mouth of Palma Bay (between Cabo Delgado Peninsula and Tecomaji Island) (Lwandle field surveys) and it is considered to be highly probable that they are frequent visitors to the bay. As with humpback dolphins, bottlenose dolphins are widely distributed along the African coast. However, unlike them, they also extend into deeper water, having been recorded from the Walters Shoal, south of Madagascar (Best, 2007).

#### 7.9.4 *Seabirds*

The coastal seabirds recorded from the region are listed in *Table 7.12*. Nineteen species are known to occur in the coastal area, but it is likely that some offshore species (*Table 7.12*) extend into the coastal waters because of the very narrow continental shelf, eg frigate birds. These seabirds may occur in Palma Bay.

Common and lesser crested terns were the most common seabird sighted within waters of the continental shelf edge during a 2007 CSA offshore habitat characterisation survey (CSA, 2007).

**Table 7.12** *Coastal Seabirds of Northern Mozambique and their 2011 IUCN Listing Status*

Common Name	Species	Seasonality	IUCN Listing Status
Lesser frigate bird	<i>Fregata ariel</i>	n/a	LC
Greater frigate bird	<i>Fregata minor</i>	n/a	LC
Grey-headed gull	<i>Larus cirrocephalus</i>	n/a	LC
Lesser black-backed gull	<i>Larus fuscus</i>	n/a	LC
Little tern	<i>Sterna albifrons</i>	n/a	LC
Caspian tern	<i>Sterna caspia</i>	n/a	LC
Gull-billed tern	<i>Sterna nilotica</i>	n/a	LC
Sandwich tern	<i>Sterna sandvicensis</i>	Summer	LC
Lesser crested tern	<i>Sterna bengalensis</i>	Summer	LC
Swift (greater crested) tern	<i>Sterna bergii</i>	n/a	LC
Common tern	<i>Sterna hirundo</i>	Summer	LC
Sooty tern	<i>Sterna fuscata</i>	n/a	LC
Whiskered tern	<i>Chlidonias hybridus</i>	n/a	LC
White-winged tern	<i>Chlidonias leucopterus</i>	Summer	LC
African skimmer	<i>Rynchops flavirostris</i>	n/a	NT
Pink-backed pelican	<i>Pelecanus rufescens</i>	n/a	LC
Eastern (great) white pelican	<i>Pelecanus onocrotalus</i>	n/a	LC

Common Name	Species	Seasonality	IUCN Listing Status
Reed cormorant	<i>Phalacrocorax africanus</i>	n/a	LC
White-breasted (great) cormorant	<i>Phalacrocorax carbo</i>	n/a	LC

Key:

LC = Least Concern; NT = Near Threatened; VU = Vulnerable.

Source: Newman, 2002; Sinclair and Ryan, 2003; IUCN, 2011.

During the marine ecology dry (November 2011) and wet (March 2012) surveys undertaken by Lwandle, seabird sightings were limited to swift and common terns. The intertidal shore-based birds observed during the avifaunal surveys undertaken by Enviro-Insight are detailed in *Chapter 8*.