









TOTAL E&P PNG LIMITED

PAPUA LNG

Upstream Environmental Impact Statement

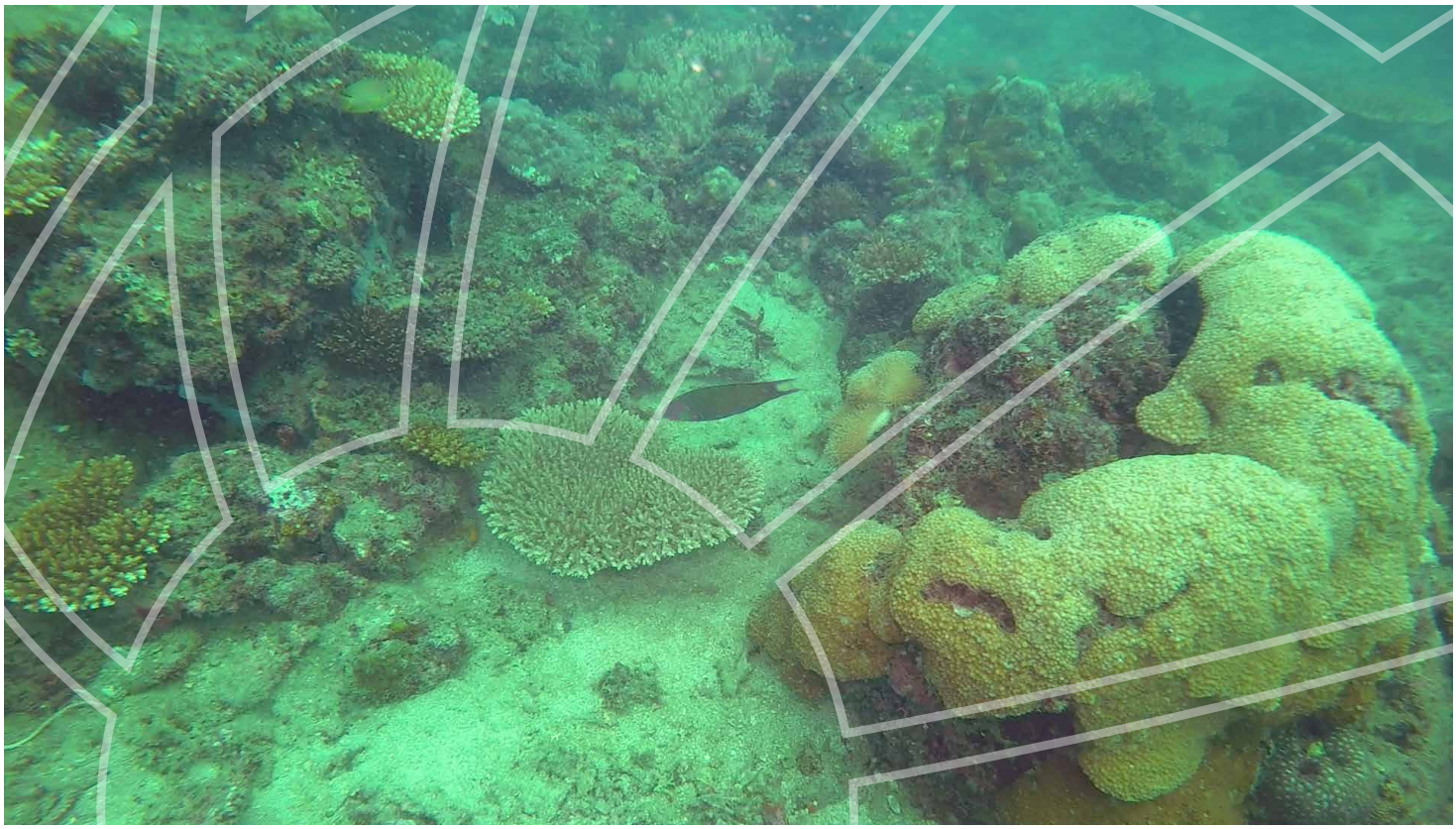
Volume 2: Environmental and Social Baseline

Part 12
Marine Biodiversity Baseline Report

TOTAL
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BMT WBM

"Where will our knowledge take you?"



Papua LNG Project

Marine Biodiversity Baseline Report

August 2017

Prepared for Total Exploration and Production PNG Limited

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Papua LNG Project - Marine Biodiversity Baseline Report

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TECHNICAL REPORTS SERIES

Report Number	Description
6	***Papua LNG ESBS – Marine Biodiversity***

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Executive Summary

Background

Total E&P PNG Limited (TEP PNG), a wholly owned subsidiary of TOTAL S.A (TOTAL) is the largest partner in a joint venture to develop the Elk-Antelope gas field, located in Petroleum Retention License 15 (PRL-15) in Gulf Province, Papua New Guinea. This project, known as the Papua LNG Project, will comprise upstream production well development and associated infrastructure at the gas field within PRL-15, construction of an upstream central processing facility (CPF) and delivery of gas and condensate via onshore and offshore export pipelines to a LNG plant site at Caution Bay, Central Province, 20 km northwest of Port Moresby.

This technical report provides the findings of a baseline study in relation to marine biodiversity values in the study area. This technical report forms part of the Environmental and Social Baseline Study (ESBS) for the Project Environmental Impact Statement/Environmental, Social and Health Impact Assessment (EIS/ESHIA). The study area encompasses three sub-areas, namely (1) Orokolo Bay, including nearshore (i.e. to the 15 m depth contour) and offshore waters adjacent to the Purari River delta, (2) the nominal offshore export pipeline corridor through the Gulf of Papua (offshore export pipeline corridor), and (3) relevant parts of Caution Bay (Caution Bay).

The key objectives of the ESBS for marine biodiversity are to:

- Identify national, international and corporate regulatory and policy frameworks for assessment of impacts to marine biodiversity, including the technical elements required to conduct an EIS/ESHIA.
- Review previous studies relevant to marine biodiversity within and adjacent to the study area.
- Collect new data through targeted field investigations to fill gaps in previous studies and ensure sufficient data to meet EIS requirements.
- Describe the environmental baseline of the study area in relation to marine biodiversity.
- Identify threatened, rare or otherwise noteworthy species likely to be present in the study area.
- Identify marine invasive species, including invasive native and alien species.
- Identify any areas of sensitive marine habitat.

The Project is regulated under the *Environment Act 2000*, the *Oil and Gas Act 1998*, with aspects of the Marine Pollution Acts. This report provides baseline ecological information which adheres to International environmental guidelines, including the International Finance Corporation (IFC) Performance Standards and TOTAL company environmental performance specifications.

Study Approach

The ESBS was prepared based on a review of desktop information, including literature associated with previous environmental studies in the study area and surrounds, together with field-based data collection to address key information gaps. The key existing information that was available consists of the following:

- Orokolo Bay– historical (1979) fish assemblage data for Orokolo Bay, including adjacent Purari River mouth, for which there is only limited contemporary marine ecological information.
- Offshore export pipeline corridor – limited baseline benthic habitat descriptions where the corridor coincides with the corridor studied for the PNG LNG Project EIS.

- Caution Bay – baseline descriptions and mapping of benthic habitats, descriptions of patterns in reef and soft sediment benthos and fish communities, and identification of species of conservation value known or likely to occur, collected as part of the PNG LNG Project EIS (prior to development of that project).

In order to supplement information gaps, two targeted field surveys were undertaken during nominal dry (20 June to 9 July 2016) and wet (12 and 31 January 2017) seasons. The surveys involved:

(1) Mapping of benthic habitats (including by use of acoustic survey), with a focus on sensitive receptor sites (e.g. reefs, seagrass).

(2) Surveys of benthic macroinvertebrates to assess patterns in community structure among and within key habitats such as reefs, mangroves and soft sediments.

(3) Surveys of reef fish assemblages in Caution Bay.

(4) Assessments of marine species listed as threatened or protected under the International Union for the conservation of Nature (IUCN) Red List and/or *Fauna (Protection and Control) Act 1966* or potentially relevant to a Critical Habitat assessment under IFC Performance Standard 6.

Field surveys were not intended to provide a complete coverage of the entire study area but provide a representation of the marine biodiversity values for the study area sufficient for the purposes of the EIS/ESHIA. Unlike terrestrial surveys, the marine field surveys focused on identifying habitats that support valuable biodiversity, fisheries, and communities. They were not taxonomically resolved or designed to investigate the presence of species new to science.

Study Findings

Orokolo Bay and most of the offshore export pipeline corridor are located within the Gulf of Papua Ecoregion. The marine ecological character of these areas, particularly at Orokolo Bay, is heavily influenced by fluvial input and seasonal changes in wind and sea state, with rainfall relatively uniform throughout the year. Caution Bay is located in the Southeast Papua New Guinea Ecoregion and experiences a relatively low level of riverine discharge (comparative to Orokolo Bay).

The key findings of the baseline characterization are as follows:

Biotopes and Communities in Orokolo Bay

- Riverine discharges of nutrients, sediments and freshwater, together with wave generated sediment resuspension, are critical drivers of coastal ecosystem values and productivity in the Gulf of Papua.
- No seagrass meadows or high density macroalgae beds are known or likely to occur in Orokolo Bay. High turbidity (low benthic light) and bed instability due to wave action (especially during the southeast trade winds season) do not provide suitable habitat conditions for seagrass and algae.
- One rocky reef was recorded in Orokolo Bay (Site M6), located on the eastern side of the bay offshore from the Vailala River. The reef supported a mixed assemblage of filter-feeding soft corals, sponges, ascidians and echinoderm species that are tolerant of the high turbidity and lower salinity found at this location.
- Benthic substrates of Orokolo Bay are comprised mostly of silts and sandy silts, as occurs throughout the nearshore waters of the Gulf of Papua. Benthic fauna assemblages were dominated by deposit-feeding taxa (mostly small polychaete worms and burrowing crustaceans), and were structurally similar to those found in the wider Gulf of Papua area and other turbid water tropical environments.

Biotopes and Communities in the Offshore Export Pipeline Corridor

- The benthic biotopes of the offshore export pipeline corridor were comprised of flat and featureless sandy and silty substrates. Epifauna assemblages (i.e. those living on the seabed) had low taxonomic richness and sparse cover.
- The corridor does not provide suitable habitat for seagrass (insufficient light), and no reefs have been recorded.

Biotopes and Communities in Caution Bay

- Caution Bay supports a mosaic of coral reef, seagrass and 'unvegetated' soft sediment biotopes that have high biodiversity values despite being located near a major urban center and subject to a range of pressures.
- Seagrass meadows fringe the coastline (*Enhalus acoroides*, *Syringodium isoetifolium* and *Cymodocea* spp.) and the northern part of the bay (*Halophila* spp.). Seagrass meadows appeared to be in good condition throughout the bay, but in the absence of historical mapping (i.e. for past decades), long term trends in seagrass extent cannot be determined.
- Coral reefs occur immediately seaward of coastal seagrass communities and within the central part of the bay. Fringing reef communities occur on the outer parts of the bay, associated with Vari and Idihi islands.
- Studies conducted in the 2000s indicate that many coral reefs in Caution Bay were degraded by fishing pressure. The present study found that outer reef environments (e.g. Vari Vari Island and Idihi Island communities) had high coral cover and reef structure was intact. Nearshore reefs have lower cover than offshore reefs, and while empirical historical baseline data are lacking, it appears that reef benthic assemblages are in a state of recovery. Caution Bay is at potential risk from outbreaks of the crown-of-thorns sea star (*Acanthaster planci*), a native species that has caused significant impacts to nearby coral reef ecosystems.

Prioritization of Biodiversity Values

In total, the study area is expected to support 35 threatened/important species. This includes:

- Five species listed as Critically Endangered on the IUCN Red List, two of which are considered Likely to occur in part of the study area while three are considered Possible to occur. These species are elasmobranchs (cartilaginous fish), including sharks, rays and sawfish, as well as sea turtles.
- Eight species listed as Endangered, six of which are Known to occur in the study area and two which are considered Likely to occur. These species include elasmobranchs, sea turtles and sea cucumbers.
- Thirteen species listed as Vulnerable, five of which are Known to occur in the study area, six of which are considered Likely to occur, and two of which are considered Possible to occur.
- Nine listed as Near Threatened, two of which are Known to occur in the study area, six of which are considered Likely to occur, and one of which is considered Possible to occur.

The remainder of the threatened/important species are not considered as threatened on the IUCN Red List but are relevant due to endemism, restricted-range status, migratory and/or congregatory status, or restricted from trade under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) or the *International Trade (Fauna and Flora) Act 1979*. Two of the species that could possibly occur in the study area are Protected under the *Fauna (Protection and Control) Act 1966*.

The conservation status of these species and their occurrence in the study area is summarized in Table 1, grouped based on threatened status.

An assessment was carried out to define the sensitivity of biotopes and other features based on vulnerability and replaceability (Table 2). Features of high and moderate sensitivity were coral reefs and seagrass meadows, turbid waters near river mouths, the ornate rock lobster migration path and spawning ground, the Cape Suckling green turtle aggregation site, and other sandy beaches possibly supporting turtle nesting.

There are no protected areas within the study area (the nearest is a terrestrial area in Port Moresby), although it is noted that under the Coral Triangle Initiative, Papua New Guinea is committed to protecting and managing coral reef ecosystems.

Table 1 Summary of Threatened/Important Species

Name	Relevant threatened/ important status	Supporting habitat	Known
IUCN Critically Endangered and Endangered Species			
Pristis pristis Largetooth sawfish	CITES Appendix I IUCN Critically Endangered Migratory	Coastal waters near large river mouths	• Orokolo Bay: ***Likely*** • Offshore export pipeline corridor: ***Possible*** • Caution Bay: ***Unlikely***
Pristis zijsron Green sawfish	CITES Appendix I IUCN Critically Endangered Migratory	Shallow coastal waters near large river mouths	• Orokolo Bay: ***Possible*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Unlikely***
Glyphis garricki Northern river shark	IUCN Critically Endangered	Coastal waters near large river mouths	• Orokolo Bay: ***Possible*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Unlikely***
Anoxypristis cuspidata Narrow sawfish	CITES Appendix I IUCN Endangered Migratory	Coastal waters near large river mouths	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Possible*** • Caution Bay: ***Unlikely***
Glyphis glyphis Speartooth shark	IUCN Endangered	Coastal waters near large river mouths	• Orokolo Bay: ***Likely*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Unlikely***
Eusphyra blochii Winghead shark	IUCN Endangered	Coastal waters through to edge of continental shelf	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Likely*** • Caution Bay: ***Likely***
Holothuria lessoni Golden sandfish	IUCN Endangered	Coastal waters, estuaries, reef flats, seagrass meadows	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Known***
Holothuria nobilis Black teatfish	IUCN Endangered	Coastal waters, estuaries, reef flats, seagrass meadows	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Known***
Holothuria scabra Sandfish	IUCN Endangered	Coastal waters, estuaries, reef flats, seagrass meadows	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Known***
Thelenota ananas	IUCN Endangered	Coastal waters, estuaries, reef flats, seagrass meadows	• Orokolo Bay: ***Known*** • Offshore export pipeline

Name	Relevant threatened/ important status	Supporting habitat	Known
Prickly redfish			corridor: ***Unlikely*** • Caution Bay: ***Known***
Eretmochelys imbricata Hawksbill turtle	CITES Appendix I IUCN Critically Endangered Migratory	Coastal waters near coral reefs and seagrass meadows	• Orokolo Bay: ***Unlikely*** • Offshore export pipeline corridor: ***Likely*** • Caution Bay: ***Likely***
Dermochelys coriacea Leatherback turtle	Protected CITES Appendix I IUCN Critically Endangered Migratory	Pelagic waters	• Orokolo Bay: ***Unlikely*** • Offshore export pipeline corridor: ***Possible*** • Caution Bay: ***Unlikely***
Chelonia mydas Green turtle	CITES Appendix I IUCN Endangered Migratory	Coastal waters near seagrass meadows Low-gradient sandy beaches	• Orokolo Bay: ***Possible*** • Offshore export pipeline corridor: ***Likely*** • Caution Bay: ***Likely***
IUCN Vulnerable and Near Threatened Species			
Carcharhinus leucas Bull shark	IUCN Near Threatened	Coastal waters through to edge of continental shelf	• Orokolo Bay: ***Likely*** • Offshore export pipeline corridor: ***Likely*** • Caution Bay: ***Likely***
Carcharhinus macloti Hardnose shark	IUCN Near Threatened	Coastal waters through to edge of continental shelf	• Orokolo Bay: ***Likely*** • Offshore export pipeline corridor: ***Likely*** • Caution Bay: ***Known***
Hemiscyllium hallstromi Papuan epaulette shark	IUCN Vulnerable Endemic	Coastal waters near coral reefs and seagrass meadows	• Orokolo Bay: ***Unlikely*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Likely***
Glaucostegus typus Giant shovelnose ray	IUCN Vulnerable	Coastal waters through to edge of continental shelf	• Orokolo Bay: ***Likely*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Likely***
Aetobatus narinari Spotted eagle ray	IUCN Near Threatened	Coastal waters, especially near coral reefs	• Orokolo Bay: ***Likely*** • Offshore export pipeline corridor: ***Possible*** • Caution Bay: ***Likely***
Manta birostris Giant manta ray	CITES Appendix II IUCN Vulnerable Migratory	Pelagic waters	• Orokolo Bay: ***Unlikely*** • Offshore export pipeline corridor: ***Possible*** • Caution Bay: ***Unlikely***
Manta alfredi Reef manta ray	CITES Appendix II IUCN Vulnerable Migratory	Nearshore through to pelagic waters	• Orokolo Bay: ***Possible*** • Offshore export pipeline corridor: ***Possible*** • Caution Bay: ***Likely***
Mobula eregoodootenkee Pygmy devilray	CITES Appendix II IUCN Near Threatened Migratory	Nearshore through to pelagic waters	• Orokolo Bay: ***Possible*** • Offshore export pipeline corridor: ***Possible*** • Caution Bay: ***Possible***
Epinephelus coioides Orange-spotted grouper	IUCN Near Threatened	Coastal waters near large river mouths	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Possible*** • Caution Bay: ***Likely***

Name	Relevant threatened/ important status	Supporting habitat	Known
Epinephelus fuscoguttatus Brown-marbled grouper	IUCN Near Threatened	Coastal waters near coral reefs and seagrass meadows	• Orokolo Bay: ***Likely*** • Offshore export pipeline corridor: ***Possible*** • Caution Bay: ***Likely***
Actinopyga echinites Deepwater redfish	IUCN Vulnerable	Coastal waters, estuaries, reef flats, seagrass meadows	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Known***
Actinopyga mauritana Surf redfish	IUCN Vulnerable	Coastal waters, estuaries, reef flats, seagrass meadows	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Known***
Actinopyga miliaris Hairy blackfish	IUCN Vulnerable	Coastal waters, estuaries, reef flats, seagrass meadows	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Known***
Holothuria fuscogilva White teatfish	IUCN Vulnerable	Coastal waters, estuaries, reef flats, seagrass meadows	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Known***
Stichopus hermannii Curryfish	IUCN Vulnerable	Coastal waters, estuaries, reef flats, seagrass meadows	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Known***
Dugong dugon Dugong	Protected CITES Appendix I IUCN Vulnerable Migratory	Coastal waters near seagrass meadows	• Orokolo Bay: ***Unlikely*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Possible***
Orcaella heinsohni Australian snubfin dolphin	CITES Appendix I IUCN Near Threatened Migratory	Coastal waters near large river mouths Coastal waters near seagrass meadows	• Orokolo Bay: ***Likely*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Likely***
Sousa sahulensis Australian humpback dolphin	CITES Appendix I IUCN Vulnerable Migratory	Coastal waters near large river mouths	• Orokolo Bay: ***Likely*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Likely***
Caretta caretta Loggerhead turtle	CITES Appendix I IUCN Vulnerable Migratory	Coastal waters near coral reefs and seagrass meadows	• Orokolo Bay: ***Unlikely*** • Offshore export pipeline corridor: ***Likely*** • Caution Bay: ***Likely***
Lepidochelys olivacea Olive ridley turtle	CITES Appendix I IUCN Vulnerable Migratory	Coastal waters near coral reefs and seagrass meadows	• Orokolo Bay: ***Unlikely*** • Offshore export pipeline corridor: ***Likely*** • Caution Bay: ***Likely***
Laticauda guineai Guinea's sea krait	IUCN Near Threatened Endemic	Coastal waters near coral reefs	• Orokolo Bay: ***Does not occur*** • Offshore export pipeline corridor: ***Possible*** • Caution Bay: ***Likely***
Scomberomorus commerson Narrow-barred Spanish mackerel	IUCN Near Threatened Migratory	Coastal waters through to edge of continental shelf	• Orokolo Bay: ***Likely*** • Offshore export pipeline corridor: ***Likely*** • Caution Bay: ***Likely***

Name	Relevant threatened/ important status	Supporting habitat	Known
IUCN Least Concern, Data Deficient and Not Evaluated Species			
Scomberomorus multiradiatus Papuan seerfish	Restricted-range Migratory	Coastal waters through to edge of continental shelf	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Likely*** • Caution Bay: ***Likely***
Tursiops aduncus Indo-Pacific bottlenose dolphin	CITES Appendix II Migratory	Pelagic waters	• Orokolo Bay: ***Likely*** • Offshore export pipeline corridor: ***Likely*** • Caution Bay: ***Likely***
Tursiops truncatus Common bottlenose dolphin	CITES Appendix II Migratory	Pelagic waters	
Delphinus delphis Short-beaked common dolphin	CITES Appendix II Migratory	Pelagic waters	
Stenella longirostris Spinner dolphin	CITES Appendix II Migratory	Pelagic waters	
Stenella attenuata Pantropical spotted dolphin	CITES Appendix II Migratory	Pelagic waters	
Natator depressus Flatback turtle	CITES Appendix I Migratory	Coastal waters near coral reefs and seagrass meadows	• Orokolo Bay: ***Possible*** • Offshore export pipeline corridor: ***Likely*** • Caution Bay: ***Likely***
Crocodylus porosus Saltwater crocodile	CITES Appendix II Migratory	Coastal waters near large river mouths	• Orokolo Bay: ***Known*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Possible***
Enhalus acoroides	Least Concern (decreasing)	Shallow waters (<5 m depth) with high water clarity	• Orokolo Bay: ***Does not occur*** • Offshore export pipeline corridor: ***Does not occur*** • Caution Bay: ***Known***
Panulirus ornatus Ornate lobster	Migratory and/or congregatory	Usually occurrence in shallow waters (<8 m depth) near coast Migration in waters 40-80 m deep through northern gulf to Yule Island Spawning near Yule Island	• Orokolo Bay: ***Possible*** • Offshore export pipeline corridor: ***Known*** • Caution Bay: ***Likely***
Cantoria annulata Banded watersnake	Restricted-range	Coastal waters near mangroves and nipa palm wetlands	• Orokolo Bay: ***Possible*** • Offshore export pipeline corridor: ***Unlikely*** • Caution Bay: ***Unlikely***

Table 2 Habitat Features in Study Area with Moderate to High Sensitivity

Marine habitat value/area	Sensitivity rating	Comments/applicable criteria
Coral reefs	***High***	Potentially supports coral species with *extreme* vulnerability. Provides habitat utilized by non-coral species with *moderate*, *high* and *extreme* vulnerability, although not considered to be critical to survival and/or lifecycle functions of these species.
Seagrass meadows	***Moderate***	Supports seagrass species with *moderate* vulnerability. Provides habitat utilized by non-seagrass species with *moderate*, *high* and *extreme* vulnerability, although not considered critical to survival and/or lifecycle functions of these species.
Highly turbid waters adjacent to large rivers	***Moderate***	Provides primary feeding habitat for species with *high* (*O. heinsohni*, *S. sahulensis*) and *extreme* vulnerability (*G. glyphis* and *P. pristis*).
P. ornatus migratory path	***High***	Area within migration route for migratory species (*P. ornatus*) that occurs only within the Gulf of Papua and Southeast Papua New Guinea ecoregions.
P. ornatus spawning ground	***High***	Area within spawning ground for migratory species (*P. ornatus*) that occurs only within the Gulf of Papua and Southeast Papua New Guinea ecoregions.
C. mydas aggregation site	***High***	Area used by congregatory species (*c. mydas*) that is of *extreme* vulnerability but is representative within other parts of the ecoregions of the study area and surrounds.
Turtle nesting beaches	***Moderate***	Potentially provides habitat important to lifecycle functions of a species with *moderate*, *high* or *extreme* vulnerability (green turtle).

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1 Introduction

1.1 Project Overview

Joint venture partners, Total E&P PNG Limited (TEP PNG) (40.13%), ExxonMobil (37.03% - through SPI (208) Limited (35.48%) and SPI Security Holdings Limited (4.55%)), and Oil Search Limited (22.84% - through PAC LNG Assets Limited (6.75%), Pac LNG International Limited (5.10%), Pac Overseas Limited (5%), Pac LNG Holdings Limited (3.49%) and Pac LNG Investments Limited (2.50%)) are planning the development of the Elk-Antelope gas fields located in Gulf Province, Papua New Guinea. The gas fields are located within Petroleum Retention License 15 (PRL-15). The Project will include infrastructure development inside PRL-15, and the construction of gas and condensate pipelines (export pipeline) to a liquefied natural gas (LNG) plant site at Caution Bay, 20 km northwest of Port Moresby.

The Project area comprises the physical footprint of the various Project components and associated infrastructure as detailed below (Figure 1-1).

- Production, processing and related facilities (within PRL-15):
  - Wellpads and the associated gathering system (including flowlines and trunkline).
  - Central processing facility (CPF).
  - Logistics base and river offloading facilities, accommodation camps, airstrip, roads and bridges.
  - Quarries, communications infrastructure.
  - Initial section of the onshore export pipeline.
- Onshore pipeline (outside PRL-15):
  - Remainder of the onshore export pipeline to landfall on the Gulf coast including valve stations.
  - Temporary laydown areas and camps.
  - Quarries, communications infrastructure.
- Transport (river) corridors:
  - River transport routes— the Purari, Urika-Ivo and Wame-Varoi rivers.
- Offshore pipeline:
  - Offshore section of the export pipeline to a LNG Plant site at Caution Bay.

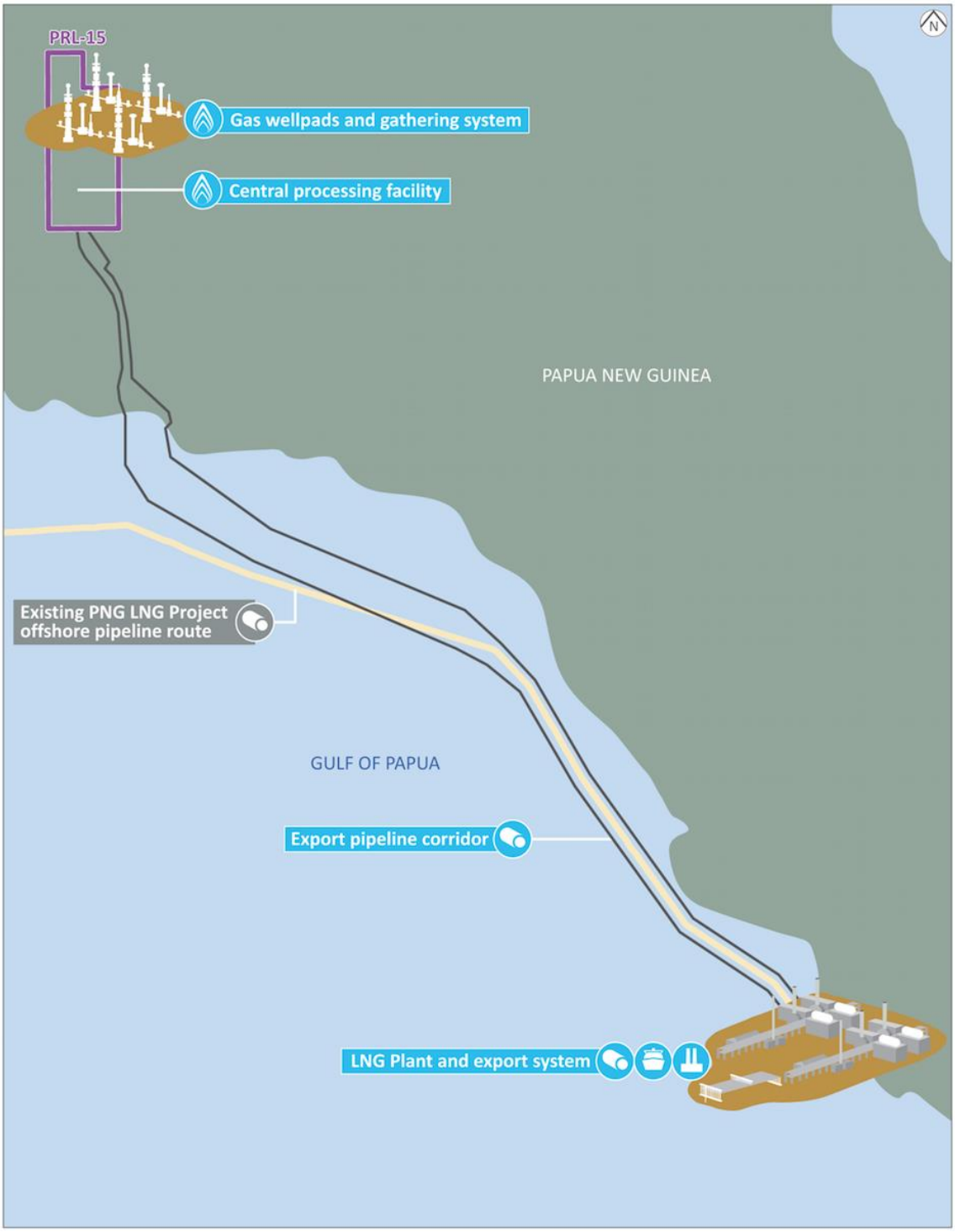


Figure 1-1 Schematic of the Project

1.2 Study and Objectives

This technical report describes the baseline marine biodiversity characteristics of areas potentially influenced by the Project. This report is part of the Marine Biodiversity Study for the Environmental Impact Statement, and the Environmental, Social and Health Impact Assessment (EIS/ESHIA) for the Project. In particular, this report forms part of the Environmental and Social Baseline Study (ESBS) component of the EIS/ESHIA.

The study key objectives for the Marine Biodiversity Study are to:

- Map intertidal and subtidal habitats in the study area, and identify sensitive areas.
- Characterize epibenthic communities in the study area.
- Describe marine fauna and flora species that inhabit the study area.
- Determine the presence and (where practicable) status of species of conservation significance recorded or potentially present within the study area.
- Collect information on priority biodiversity values suitable for use in impact and critical habitat assessment, development of mitigation and management measures, and monitoring programs.
- Support assessment of project-related impacts on aquatic biological resource uses (ecosystem services).
- Plan and execute baseline studies to collect sufficient data to underpin assessment of potential Project impacts to:
    - satisfy International Finance Corporation (IFC) environmental and social performance standards.
    - meet Papua New Guinea requirements under the *Environment Act 2000*.
    - meet TOTAL General Specifications, including GS EP ENV 112: Environmental Baseline and Monitoring Studies: Offshore and Nearshore Sites.

Within the context of these study objectives, this technical report achieves the following:

- Identifies the national, international and corporate regulatory and policy frameworks for assessment of impacts to marine ecology, including the technical elements required to conduct an EIS/ESHIA.
- On the basis of a review of previous studies and data collected through field surveys, describes baseline marine biodiversity conditions with reference to relevant guidelines.
- Identifies threatened, rare or otherwise noteworthy species likely to be present within the study area.
- Identifies marine invasive species, including invasive native and alien species.
- Identifies any areas of sensitive marine habitat to inform the assessment of Critical Habitat in accordance with IFC Performance Standard 6.

The Marine Biodiversity ESBS technical report specifically considers the following components:

- Benthic habitats, including flora species.
- Marine benthic macroinvertebrates.

- Fish (elasmobranchs and bony fish).
- Marine mammals (delphinids, dugong, whales).
- Marine reptiles (sea snakes, sea turtles).

Note that other reports consider coastal avifauna species and mangroves; see Upstream Terrestrial Biodiversity Baseline Report (ERIAS Group, 2017a; Part 6 of ESBS Dossier) and Upstream Freshwater and Estuarine Biodiversity Baseline Report (BMT WBM, 2017b; Part 5 of ESBS Dossier).

2 Regulatory Framework and Standards

The Project is regulated primarily under the *Environment Act 2000* and the *Oil and Gas Act 1998* together with aspects of the suite of recently introduced Marine Pollution Acts. In addition, TEP PNG will be guided by company environmental performance specifications and international guidelines for the purposes of the EIS/ESHIA. Therefore, there are three sets of performance standards/guidelines applicable to the EIS/ESHIA:

- Papua New Guinean Legislation, including Conservation and Environmental Protection Authority (CEPA) operational procedures and codes of practice under the *Environment Act 2000*.
- International environmental guidelines, including the IFC Performance Standards.
- TEP PNG company standards and commitments.

2.1 Papua New Guinean Authorities and Legislation

The following Papua New Guinean legislation is considered relevant for the purposes of the Project EIS/ESHIA:

- *Environment Act 2000*, including Regulations and operational procedures/information guidelines.
- *Oil and Gas Act 1998*.
- Marine Pollution Acts,[1] including:
  - *Marine Pollution (Preparedness and Response) Act 2013*.
  - *Marine Pollution (Sea Dumping) Act 2013* and Marine Pollution (Sea Dumping) Regulation.
  - *Marine Pollution: Ships and Installations Act 2013*.
- *Fauna (Protection and Control) Act 1966*.
- *International Trade (Flora and Fauna) Act 1979*.
- *Conservation Areas Act 1971*.

These instruments identify critical aspects of the EIS process and/or protection to particular aspects of the Papua New Guinea environment. These areas are discussed in more detail below.

2.1.1 Permit and Environmental Impact Assessment Requirements

An EIS in Papua New Guinea is required under the *Environment Act 2000* in order to assess and understand the potential environmental impacts of significant activities prior to the issue of an Environment Permit. In particular, an EIS is required for Level 3 Activities identified under the Environment (Prescribed Activities) Regulation 2002. The Project is a Level 3 Activity in accordance with Sub-Category 18 of the Regulation. The *Environment Act 2000* and EIS process is administered by CEPA.

Under the *Oil and Gas Act 1998* the issue of licenses for petroleum projects, including Petroleum Development Licenses (PDLs), Pipeline Licenses (PLs) and Petroleum Processing Facility Licenses (PPFLs) require consideration of environmental aspects and management actions. A PDL can only be issued where the Minister administering the Act is satisfied that the project provides for

[1] The Marine Pollution Acts have been enacted to meet Papua New Guinea's obligations under the International Convention for the Prevention of Pillution from Ships (MARPOL)

the protection of the environment and welfare of people in the project area. In practice, the Minister relies on the EIS developed under the *Environment Act 2000* in making this assessment. The Minister administering the Act is the Minister of the Department of Petroleum and Energy.

The *Marine Pollution (Sea Dumping) Act 2013* requires a Sea Dumping Permit for the purposes of placement of certain waste material within marine waters. This includes dredged material but only where material meets the contaminant guidelines set under the Regulation. Non-compliant material must be disposed of on-land. An application for a Sea Dumping Permit is considered separately to the application for an Environment Permit, though the assessment of dredged material contamination levels can be undertaken as part of an EIS. This process is administered by the National Maritime Safety Authority (NMSA).

The discharge of pollutants from installations and ships in the marine environment is prohibited under the *Marine Pollution (Ships and Installations) Act 2013* unless approved under an Environment Permit under the *Environment Act 2000*, assessed by CEPA.

In preparing an EIS and applying for an Environment Permit, a proponent is required to follow the process set out in operational procedures and guidelines prepared by CEPA. These include the following:

- Information Guideline GL-ENV/02/2004: *Guideline for Conduct of Environmental Impact Assessment & Preparation of Environmental Impact Statement*.
- Information Guideline GL-ENV/03/2004: *Guideline for Submission of an Application for an Environment Permit to Discharge Waste.*
- Technical Guideline IB-ENV/04/2004: *Water & Land Discharges*.

In addition to the requirements of these guidelines, the *Marine Pollution (Prevention and Response) Act 2013* requires proponents for new petroleum-related facilities to undertake a marine pollution risk assessment as part of an EIS. This allows for marine pollution risks to be assessed as part of an Environment Permit application. A detailed marine pollution contingency plan must then be developed prior to operation of the installation.

2.1.2 Protected Species and Areas

Species of conservation significance in Papua New Guinea consist of those listed as Restricted or Protected as declared by ministerial gazette under the *Fauna (Protection and Control) Act 1966*. The current list of species is based on a list compiled by Kula and George (1996) and primarily consists of terrestrial mammals, reptiles and birds. The list also includes some aquatic mammals, reptiles and fish.

The *Fauna (Protection and Control) Act 1966* also provides for the declaration of Wildlife Management Area (WMAs) which serve as a form of protected area in Papua New Guinea. Conservation Areas are another form of protected area declared under the *Conservation Areas Act 1971*. In addition, a proposed *Protected Areas Bill* is being considered by the Government of Papua New Guinea which would repeal aspects of the above legislation and introduce a new framework for protected areas (including marine protected areas). Protection of the species listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is also provided under the *International Trade (Fauna and Flora) Act 1979*. This Act list Schedule 1 (threatened), Schedule 2 (potentially threatened) and Schedule 3 (trade-restricted) species in accordance with the Convention.

In addition, CEPA operational procedure GL-ENV/02/2004 introduces the requirement to consider 'special purpose areas'. While not defined under the procedure or other legislation, these areas have been interpreted as significant and/or sensitive environmental features that are not formally recognized under legislation but are still relevant to the EIS decision-making process.

Papua New Guinea is also a member of the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF), a multilateral partnership to coordinate management of the coral triangle biodiversity 'hotspot'. As part of this initiative, Papua New Guinea is committed towards protection of coral reef, including through the development of legislative instruments governing coral reef.

2.2 International Standards and Guidelines

TEP PNG has committed to preparing an EIS/ESHIA for the Project consistent with a number of international standards and guidelines. These are:

- Equator Principles and World Bank Safeguards.
- IFC Performance Standards.
- Organization for Economic Cooperation and Development (OECD) Common Approaches.
- International Petroleum Industry Environmental Conservation Association (IPIECA) Guidelines.
- Any international convention ratified by the Government of Papua New Guinea (that has not been given effect under legislation listed above).

In addition to these guidelines, it is also noted that the International Union for the Conservation of Nature (IUCN) has established an international approach for recognizing threatened species and ecosystems. This has been adopted for the ESHIA in accordance with IFC Performance Standards.

2.2.1 Environmental Impact Assessment Requirements

Preparation of an ESHIA for the purposes of environmental due diligence is required under the World Bank Safeguards, Equator Principles and OECD Common Approaches. The IFC Performance Standards provide specific guidance on the ESHIA process.

IFC Performance Standard (PS) 1 establishes the framework for preparing an ESHIA in order to assess and manage the impacts from a particular activity. The remaining Performance Standards (PS2 to PS8) provide more detail on the assessment and management of impacts in particular areas, including pollution/discharges to the environment (PS3) and biodiversity conservation (PS6). The IFC Performance Standards are supplemented by Environmental, Health and Safety (EHS) guidelines which provide examples of good international industry practice (GIIP) for certain activities.

In accordance with the IFC PS an ESHIA is required to consider the risk of an activity to the environment within the activity's 'area of influence'. This includes consideration of the impacting processes in the relevant industry-specific EHS Guidelines.

Under PS 3, the ESHIA is required to describe the ambient environment conditions in the area of influence, including the assimilative capacity. This then forms the basis of assessing potential pollution impacts and for the setting of impact criteria. Performance Standard 6 requires the ESHIA to include a distinction between 'modified', 'natural' and 'critical' habitat in order to appropriately quantify and manage impacts to biodiversity and ecosystems services.

The IPIECA has prepared a number of guidelines for the petroleum industry to advise proponents on best practice related to ESHIA processes. These guidelines include a focus on biodiversity and ecosystem services, oil spill preparedness, and water. The key features of these guidelines include: locating and assessing sensitive areas (including protected areas, sensitive habitats and rare, threatened or endangered species) as part of project planning; assessing baseline ecological conditions to inform the occurrence of and vulnerability to alien invasive species; and assessing the potential impacts of abstraction of and discharge to naturally-occurring water sources, including cumulative impacts and the effects of climate change.

2.2.2 Threatened Species and High Value Areas

The IUCN has published a Red List of Threatened Species and a Red List of Ecosystems. These lists represent the most comprehensive global system for listing species and/or ecosystems that are under threat. This system is used as the basis for designating threatened species and ecosystems under the IFC PS, especially PS 6. NOTE: No ecosystems in Papua New Guinea have yet been assessed for the Red List of Ecosystems.

Species and ecosystems are listed on the Red Lists as Least Concern, Near Threatened, Endangered, Critically Endangered and Extinct (for species) or Collapse (ecosystems). There are also categories for Not Evaluated and Data Deficient related to species that have not been sufficiently evaluated to be placed into a different category.

PS 6 also includes references to endemic, restricted-range, migratory and congregatory species. These are considered further in Section 5.6.3.

2.3 TOTAL Company Standards and Commitments

TOTAL has developed the following general specifications for the purpose of environmental baseline studies and impact assessment that are relevant to the Project EIS/ESHIA:

- GS EP ENV 120: Environmental impact assessment of E&P activities.
- GS EP ENV 111: Environmental Baseline and Monitoring Studies: Onshore Sites.
- GS EP ENV 112: Environmental Baseline and Monitoring Studies: Offshore Sites.

GS EP ENV 120 provides details on the process for undertaking an environmental impact assessment and preparing an environmental management plan. The instrument adopts the ISO14001 approach for impact assessment and management. Some relevant specific requirements of the specification include:

- Identification of the physical, biological and socio-economic context of a project, including sensitivities of the environment.
- Assessment of impacts within an ‘area of influence’.
- Use of a modeling study (if relevant) to assess liquid effluent discharges dispersion.

The specifications also identify a methodology for impact assessment and contents of an environmental management plan (including oil spill contingency plan).

GS EP ENV 111 and GS EP ENV 112 specify the type of data to be collected for baseline purposes. These include physico-chemical properties of marine sediment and water, rare and endangered species, and flora and fauna bioindicators.

3 Study Area

The Project occurs across the northern and eastern ends of the Gulf of Papua, as shown in Figure 1-1. Studies are being undertaken across much of this area as part of the EIS/ESHIA. For the purposes of this study, the 'study area' includes only the marine elements of the Project and surrounding area.[2]

Figure 3-1 provides an overview of the study area. This includes the following three subsets:

- Coastal and nearshore environments at Orokolo Bay and offshore the Purari delta, located at and adjacent to the upstream segment of the offshore export pipeline corridor and offshore potential riverine transport routes along the Wame-Varoi, Urika-Ivo and Purari rivers (Orokolo/Purari). This area is located in the Gulf Province.
    - Orokolo Bay refers to the bay embayment between the eastern-most mouth of the Purari River and the mouth of the Vailala River.
    - Purari delta represents the area between the Purari and Wame-Varoi river mouths.
- Offshore environments in the Gulf of Papua at and adjacent to the offshore segment of the export pipeline corridor (offshore export pipeline corridor study area). The western sediment of the offshore pipeline is located offshore from the Gulf Province whereas the eastern segment is located offshore from the Central Province.
- Coastal and nearshore environments at and adjacent to Caution Bay at the downstream end of the export pipeline (Caution Bay study area). This area is located in the Central Province region.

The waters in the study area include nearshore and offshore waters. For the purposes of this report, 'nearshore' waters are those between the mean high tide level and the 15 m water depth contour. 'Offshore' waters represent all waters seaward of the 15 m depth contour. Coastal environments are those within or immediately adjacent to the intertidal area.

Figure 3-2 through Figure 3-4 show offshore the Purari delta, Orokolo Bay, and Caution Bay.

[2] 'Surrounding area' refers to areas immediately adjacent to the study area that are considered relevant in assessing regional occurrence of marine biotopes and populations of relevant species.



Title:

Marine Biodiversity Study Area

Figure: 3-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant guarantee or make representations regarding the currency and accuracy of information contained in this map.

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0 25 50km

Approx. Scale

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Figure 3-2 Approach to the Purari River Delta (June-July 2016)



Figure 3-3 Orokolo Bay Coastline (June-July 2016)



Figure 3-4 Caution Bay – View Northwest from the Shore, South of PNG LNG Project Jetty (June-July 2016)

3.1 Climate

The following provides an overview of the climatic setting of the study area. More detailed climatic and meteorological information is provided in the Upstream Hydrology and Meteorology Baseline Report (BMT WBM 2017a; Part 2 of ESBS Dossier) and the Physical Oceanography Baseline Report (BMT WBM, 2017d Part 10 of ESBS Dossier).

At a regional level, Papua New Guinea is affected by El Niño-Southern Oscillation (ENSO) leading to long-term cycles of periods of drought and of higher than average rainfall. Drought events are associated with cooler surface water temperature (occurring during El Niño) while higher rainfalls occur with higher surface water temperature (La Niña). Changes in rainfall levels impacts on the level of sediment and freshwater input from river catchments into the Gulf of Papua.

Climate change is expected to cause heightened extremes associated with ENSO, as well as warming of the ocean, ocean acidification, and more frequent and/or intense cyclone events, potentially entering more frequently into the Gulf of Papua.

3.1.1 Orokolo Bay, Purari Delta and Western Offshore Export Pipeline Corridor (Gulf Province)

Seasonal wind patterns in the Gulf Province are the occurrence of southeast trade winds from April to November and lighter northwest monsoon from December to March. In contrast to Caution Bay, rainfall at Kerema (to the east of the study area) is not as strongly seasonal, with mean monthly totals ranging from 209 to 437 mm. May to October represent the wetter months with mean monthly rainfall above 299 mm. The mean annual rainfall is 3,612 mm and mean evaporation rate 1,420 mm (Evesson, 1983).

The coolest month is August which has mean daily maximum and minimum temperatures of 27ºC and 22ºC respectively. The warmest months are December and January with a mean daily maximum temperature of 31ºC. There is little variation in the mean daily minimum (±1ºC) and maximum (±3.5ºC) temperatures throughout the year (Evesson, 1983).

The Gulf Province coast is north of the main cyclone belt.

3.1.2 Caution Bay and Eastern Offshore Export Pipeline Corridor (Central Province)

The main seasonal climate patterns of Caution Bay, within the Central Province, consist of:

- Dry season from May to October, with prevailing southeast trade winds.
- Wet season from December to March, when the lighter northwest monsoon winds prevail. Approximately 80% of the mean annual rainfall of 1,200 mm occurs during the wet season.
- Transition periods during April and November, when winds are generally calmer.

Monsoon surges with strong northwest winds have been observed in the region. These short-lived squalls of about one hour's duration with wind speeds of 55 to 65 km/hr are known as *gubas*.

The coolest months are July and August when the mean daily maximum and minimum temperatures are 28ºC and 23ºC respectively. The warmest months are December and January when the mean daily maximum and minimum temperatures are 32ºC and 24ºC respectively. There is little variation in the mean daily minimum (±1ºC) and maximum (±4ºC) temperatures throughout the year (CNS, 2009).

Caution Bay (i.e. the location of the LNG Plant and downstream supporting infrastructure) is north of the main cyclone belt and occurrence of such events in the Gulf of Papua is rare, with only five named cyclones in 15 years entering the gulf, all situated well south of Caution Bay. Cyclones generally occur from February to April.

3.2 Anthropogenic Setting

The following provides an overview of the anthropogenic setting of the study area, including population distribution and marine-based activities. More detailed information is provided in the Upstream Community and Demographics Baseline Report (Finlayson, 2017; Part 14 of ESBS Dossier), Marine Fisheries and Resources Baseline Report (ERIAS Group, 2017b; Part 13 of ESBS Dossier), and Marine and River Traffic and Transport Baseline Report (ERIAS Group, 2017c; Part 22 of ESBS Dossier).

3.2.1 Orokolo Bay and Purari River Delta (Gulf Province)

Population patterns across Orokolo Bay and the Purari River delta are marked by a generally low inland population scattered or concentrated in small villages along riverbanks, and a much denser population in large villages and hamlets across the coastal strip. The principal villages in the Purari River delta and Orokolo Bay area are:

- Purari River delta: Akoma, Aivei and Apiope.
- Orokolo Bay: Harevavo and Hororo.

All coastal communities engage in subsistence fishing activities in nearshore and offshore waters, with some limited commercial fishing also occurring. These activities tend to occur in the coastal zone out to three nautical miles, beyond which commercial trawling occurs as part of the Gulf of

Papua Prawn Fishery (see below). Fishing activities typically use small outrigger canoes and y-nets, with canoes primarily used to set gill nets but also to fish in deeper water with hook-and-line.

Subsistence and artisanal fishing activities are strongly seasonal, with fishing from outrigger canoes more restricted during the southeast trade winds due to the generation of dangerous sea conditions.

Limited shipping traffic occurs in Orokolo Bay and offshore of the Purari River delta as it is outside of existing commercial shipping channels, with the exception of boats from local villages (ERIAS Group, 2017c).

3.2.2 Offshore Export Pipeline Corridor

The offshore export pipeline corridor includes areas within the Gulf of Papua Prawn Fishery, regulated by the National Fisheries Authority (NFA). This fishery occurs at least three nautical miles offshore, following the 30 to 60 m depth contours, extend east as far as the village of Iokea (near the border of Gulf and Central provinces).

An artisanal dive fishery for rock lobsters occurs on the coastal reefs around Yule Island where lobster annually migrate from Torres Strait to spawn during November to April.

Various shipping traffic occurs within the Gulf of Papua, including a number of coastal vessels that cross the offshore export pipeline corridor. These include cargo, tanker and passenger vessels, as well as logging ships transiting between ports at Port Moresby, Baimuru, Kumul terminal, Kikori and Daru.

The offshore export pipeline corridor passes through a number of petroleum license blocks. These are Petroleum Prospecting Licenses (PPLs) 312 (Hillsborough), 381 (Chinampa) and 340 (Kina Petroleum).

3.2.3 Caution Bay (Central Province)

Along the coastal strip of Caution Bay there are four villages: Lea Lea, Papa, Boera and Porebada. Each of these villages are populated by mixed populations of people from the Koita and Motu people groups. The population density across the area is 10 persons/km^2.

In addition to these villages, the ExxonMobil PNG LNG Facilitiesoccupy part of the coastal strip between Papa and Boera. This facility includes an LNG jetty and wharf that extend out into Caution Bay. Brine from desalination is discharged into the bay from a pipeline attached to this jetty, while hydrotest water (produced during construction phase only) was discharged to nearshore waters north of the LNG jetty.

Artisanal fisheries in Caution Bay are considered important for subsistence and income purposes for Lea Lea, Papa, Boera and Porebada. Fishing is primarily undertaken on inshore fringing reefs and shallow shoals, but is also undertaken in mangrove communities and barrier reefs. There is a high dependence on local communities on coastal and marine resources. Subsequent to the development on the LNG plant, a 500 m exclusion zone is maintained around the LNG jetty, restricting fishing activities in this area.

Most boat traffic in Caution Bay is associated with the local villages or with operations of the LNG Plant. Commercial shipping traffic, including commercial fishing vessels, occur beyond the outer reef, outside of Caution Bay.

3.3 Protected Areas

There are no marine protected areas within the study area. The closest protected area is Paga Hill National Park Scenic Reserve, which covers part of Port Moresby harbor but is not considered relevant to the study area. This site is approximately 13 km southeast of Caution Bay.

4 Existing Information

The following section presents the details of previous studies that are considered relevant to the study area. The actual content of this literature has been integrated, as relevant, into the findings described in Section 6.

4.1 Prior Studies within the Study Area

4.1.1 Published Reports

Table 4-1 summarizes all the significant previous environmental impact assessment studies conducted within the study area (and neighboring regions). These represent a significant body of existing information relevant to the study area which has been used in the preparation of this report. NOTE: This section considers only published reports; unpublished reports are discussed in Section 4.1.2.

Table 4-1 Summary of Previous Relevant Environmental Assessment Studies

Project/study	Year	Author	Geographic overlap	Relevance to ESBS
PNG LNG Project EIS (prepared for Esso Highlands Limited)	2009	Coffey Natural Systems (CNS)	Offshore export pipeline corridor and Caution Bay	Detailed marine biodiversity information for offshore pipeline route and Caution Bay Regional and comparative marine biodiversity information
Purari River (Wabo) Hydroelectric Scheme Environmental Studies	1979	Papua New Guinea Government	Orokolo Bay and nearshore waters adjacent to Purari River	Detailed marine biodiversity information for mouth of Purari River and Orokolo Bay

Most of the studies undertaken as part of the 1979 Purari Hydroelectric Project EIS have been reported in Petr (1983), *The Purari: Tropical environment of a high rainfall river basin*. The most important chapters of this book in the context of the marine biodiversity baseline report are:

- Evesson, DT, 'The climate of the Purari River basin' (Part I, Chapter 2).
- Gwyther, D: 'The importance of the Purari River Delta to the prawn trawl fishery of the Gulf of Papua' (Part II Chapter 8).
- Haines, AK: 'Fish fauna and ecology' (Part II Chapter 9).

These existing studies have been utilized in the preparation of this baseline report where relevant.

The survey sites from these previous studies that overlap with the study area are shown in the following figures:

- Figure 4-1 – aquatic ecology in the lower Purari River and Orokolo Bay (Haines, 1979).
- Figure 4-2 – aquatic ecology and sediment quality for offshore export pipeline corridor (CNS, 2008a).
- Figure 4-3 – aquatic ecology, water and sediment quality for Caution Bay (CNS, 2008b).

4.1.2 Unpublished Reports

In addition to the published reports discussed in Section 4.1.1, the other studies known to have occurred in the study area, but which have not been published, consist of:

- Acoustic habitat/seafloor mapping conducted for a corridor between Kerema and Port Moresby.
- Marine biodiversity assessments in Kerema Bay.

The information from these studies has been used where relevant in the preparation of this baseline report.

4.2 Studies in Neighboring Regions

The PNG LNG Project EIS (CNS, 2009) and the Pasca A Development Project (ERIAS Group, 2016a) cover areas extending beyond the present study area. The EIS for the PNG LNG Project includes assessment undertaken in neighboring areas, i.e. the Kikori River delta and parts of the western Gulf of Papua, while the Pasca A Development Project EIS focuses marine biodiversity within deep-water (i.e. >90 m) as well as the Gulf of Papua on a regional basis. Both of these studies provide a contextual understanding of the marine biodiversity of the gulf.



Figure 4-1 Lower Purari River and Orokolo Bay aquatic ecology survey sites for the Purari River (Wabo) Hydroelectric Scheme Environmental Studies (Haines, 1979)

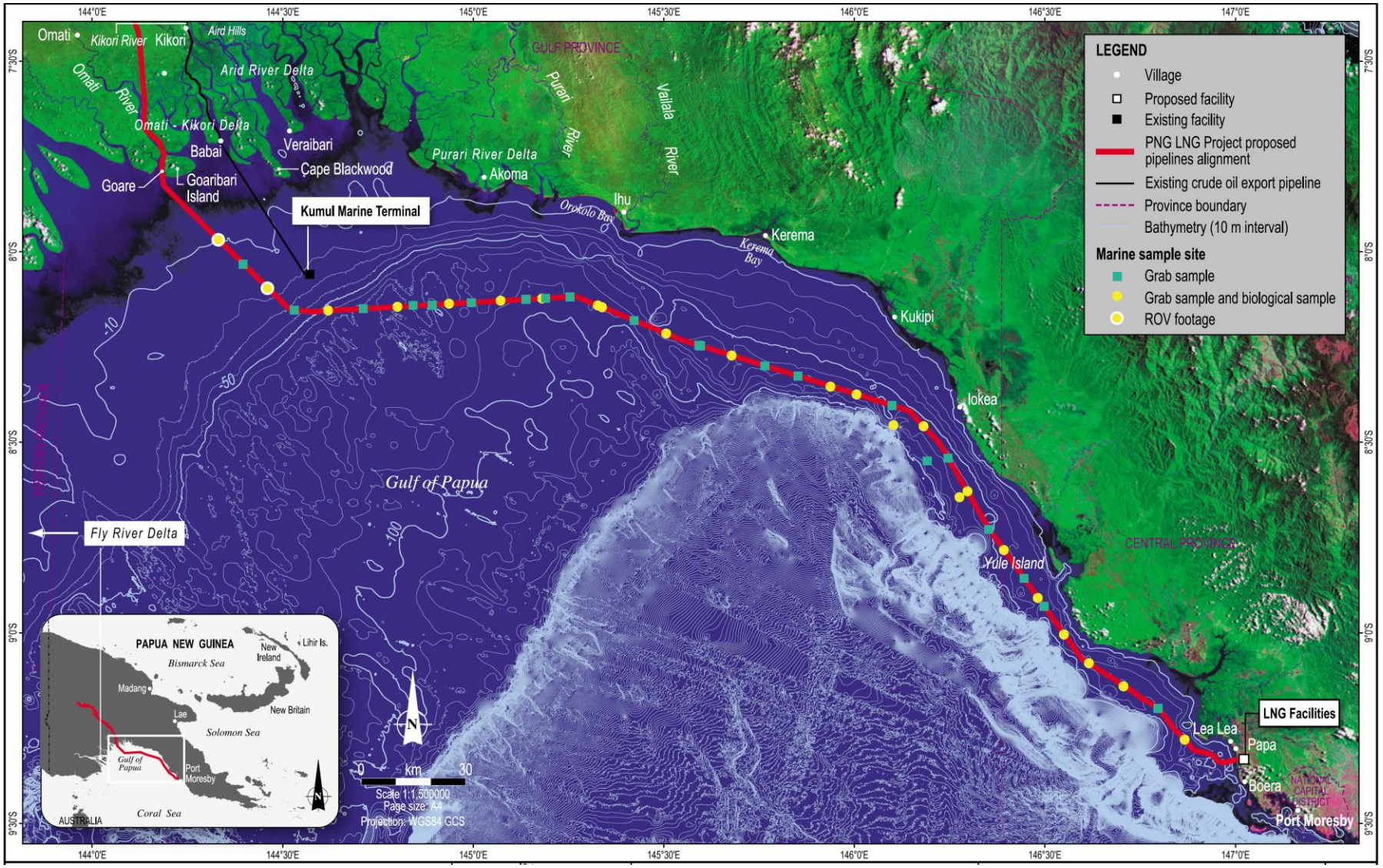


Figure 4-2 Offshore pipeline aquatic ecology and sediment quality survey sites – PNG LNG EIS (CNS, 2008a)

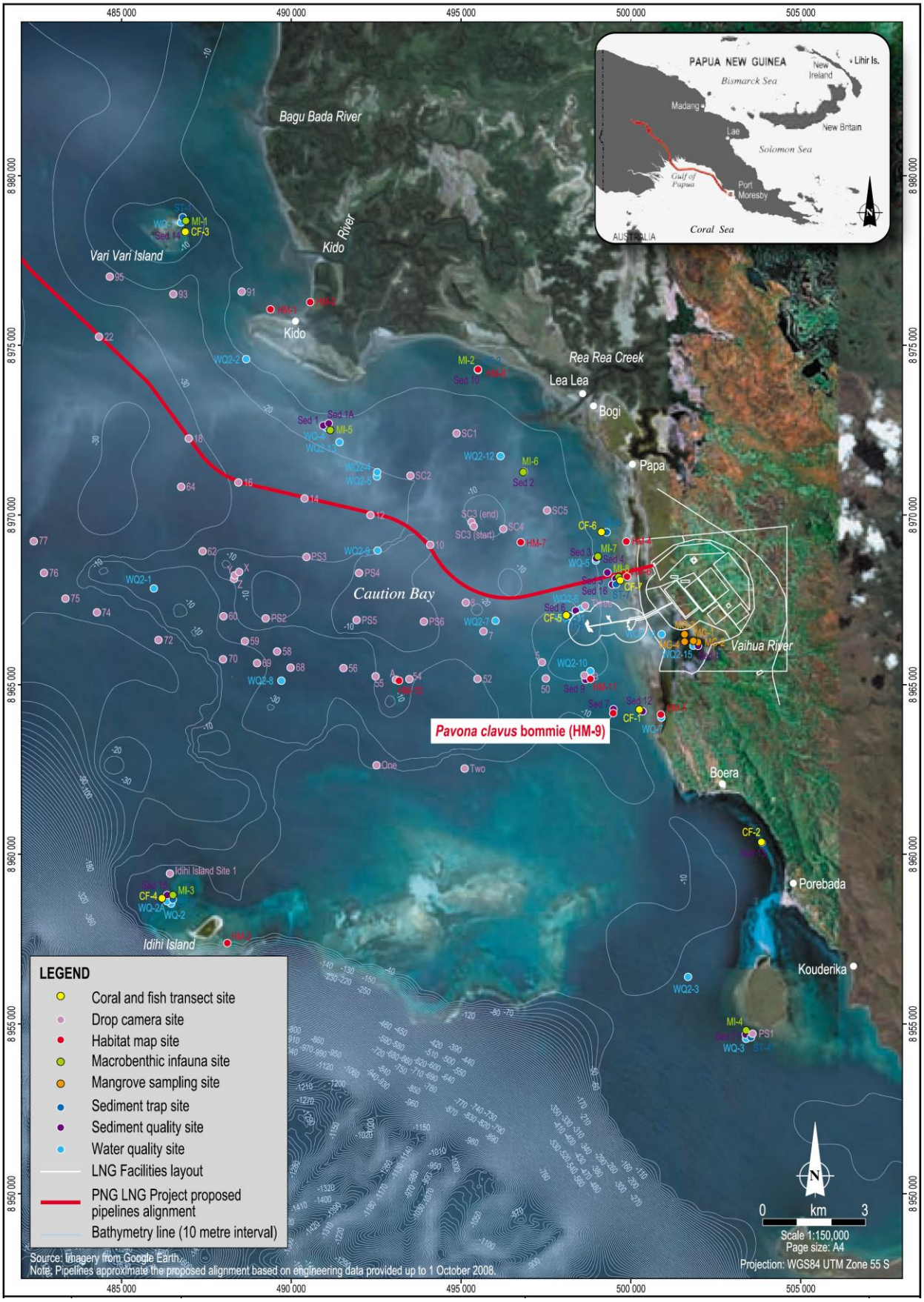


Figure 4-3 Caution Bay Water and Sediment Quality Survey Sites – PNG LNG Project EIS (CNS, 2008b)

4.3 Summary

Based on the studies cited above, the following information is known to be available for the study area:

- Benthic biotopes, coral assemblages, fish, macroinvertebrate communities, and species of conservation value within Caution Bay. Note however that this information was collected prior to the development of infrastructure for the PNG LNG Project and therefore may not be representative of *existing* baseline conditions.
- Limited benthic biotope data for the offshore export pipeline corridor.
- Limited aquatic ecology data for the Purari River and Orokolo Bay, focused on fish species and wetland assemblages. However, data on fish species is considerably dated (1979).

Regional/adjoining information is available from Kerema Bay and the Kikori River nearshore areas, as well as the Gulf of Papua more generally. This provides some relevant information that can be used to contextualize the study area and/or can be extrapolated to assist with predictions for the study area.

5 Approach and Methods

This section provides a summary of the methods adopted for the desktop studies and field survey data collection and analysis. A complete description is provided within the scope and methods ('rationale') report for marine studies (ERIAS Group, 2016b) and relevant addendum (ERIAS Group, 2016c).

5.1 General Approach

The study approach was based on a review and analysis of existing information, together with targeted field surveys to address identified data gaps. Both desktop review and field surveys focused on obtaining the following information within the study area:

- Mapping and assessment of benthic biotope types using acoustic survey methods and ground-truthing, with a focus on sensitive receptor sites (e.g. reefs, seagrass) – such biotopes may support a range of values and may be subject to both direct and indirect effects from Project infrastructure and activities.
- Quantification of benthic macroinvertebrate assemblage structure in the study area – benthic macroinvertebrates provide a rapid 'bioindicator' of ecosystem health within aquatic environments (cf. Pearson and Rosenberg, 1978, Kennedy and Jacoby, 1999; Borja et al. 2009; Hallock et al. 2003).
- Presence, or likely presence, of marine species listed as threatened or protected under the IUCN Red List and/or *Fauna (Protection and Control) Act 1996* or potentially relevant to a Critical Habitat assessment (cf. IFC Performance Standard 6) – these are high priority species for the purposes of impact assessment and management.

The study focused on each of the three areas described in Section 3, with particular focus on Orokolo Bay and Caution Bay. These areas represent the key sites where direct and indirect impacts from the Project may possibly occur.

The bibliographic review was undertaken considering the habitat assessments conducted for the environmental studies discussed in Section 4. These informed field survey activities and allowed for the understanding of both the marine habitats supported in the study area and the species likely to occur within these habitats. Further species occurrence information was derived from the databases described in Section 5.2.

5.2 Data Sources

Key data sources are referenced in Section 6, and include those outlined in Section 4. In addition, searches of the following public-access databases were conducted:

- IUCN Red List of Threatened Species on-line database: www.iucnredlist.org (IUCN, 2017).
- Reefbase on-line database: http://www.reefbase.org/ (Munday and Allen, 2000).
- FishBase: http://www.fishbase.org/ (Froese and Pauly, 2016).
- NFA website (including information on commercial fisheries by-catch): http://www.fisheries.gov.pg/.

Imagery used in mapping was taken from Bing Aerial.

5.3 Field Surveys

5.3.1 Overview

Two field surveys were undertaken in order to supplement existing information on marine biodiversity in the study area. These surveys were undertaken in June–July 2016 during the southeast trade wind season and January 2017 during the northeast monsoon season. The detailed methodology for these field activities is described in the marine studies scope and methods ('rationale') (ERIAS Group, 2016b) and addendum (ERIAS Group, 2016c).

Sampling activities consisted of the following activities:

- Mapping of benthic biotopes using acoustic survey techniques with validation by drop-camera and/or benthic grabs. Drop-camera activities were also undertaken to validate some of the findings of previous studies (i.e. PNG LNG marine ecology studies) and at locations where acoustic survey techniques were not used (i.e. offshore export pipeline corridor). Where appropriate, biotic cover estimates were made using standardized percent cover assessment charts.
- Collection of benthic macroinvertebrate samples using a Van Veen grab sampler for laboratory analysis and identification.
- Deployment of baited remote underwater video (BRUV) cameras to capture footage of reef fish assemblages.
- Opportunistic observation of threatened and/or important flora and fauna species during vessel movement.

Not all activities were conducted as part of both surveys or at all sites. This is shown in Table 5-1, with summaries of activities undertaken at each location per survey. A total of 80 sites were sampled across both surveys, with a summary of the rationale for site selection provided in Section 5.3.2. These sites are shown in Figure 5-1 to Figure 5-3 and coordinates and depths are listed in Table 5-2.

Sampling techniques are shown in Figure 5-4 to Figure 5-7 and more detail on acoustic survey mapping is provided in Section 5.3.3 and Appendix A. Field surveys were conducted from a live-aboard research vessel, the *Browse Enterprise*.

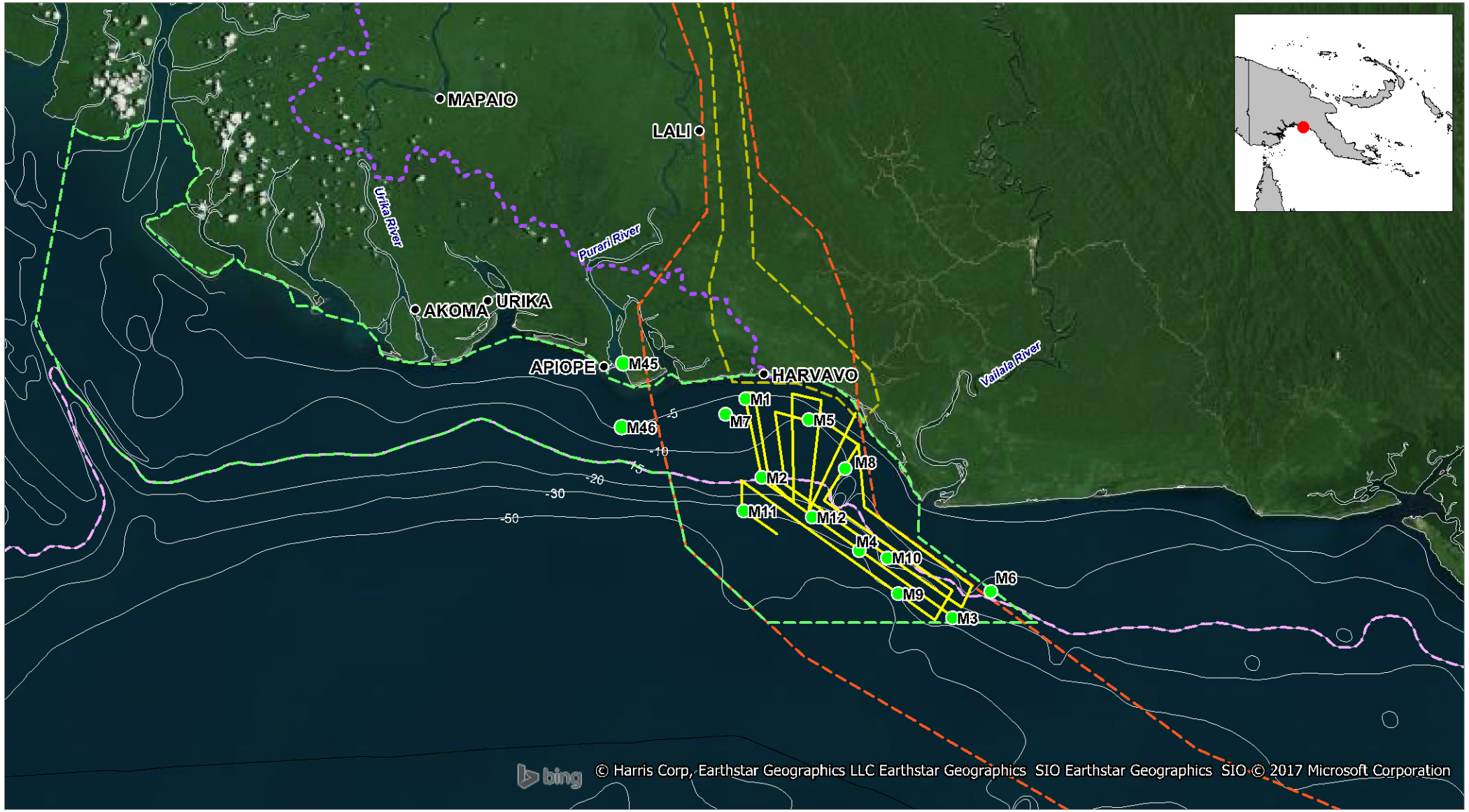
Table 5-1 Summary of Marine Biodiversity Sampling Activities

Sampling activity	Sites	Survey	Notes
Acoustic survey and validation	Orokolo Bay	June-July 2016	
	Caution Bay	January 2017	
	M1 to M12 (Orokolo Bay)	June-July 2016	Validation undertaken by both benthic grabs and drop-camera (where visibility permitted)
	M1 to M12 (Orokolo Bay)	January 2017	Validation undertaken by both benthic grabs and drop-camera (where visibility permitted)
	M13 to M24, BRUV1 to BRUV3, and 28 additional validation sites (Caution Bay)	January 2017	Validation undertaken by drop-camera only, due to risk of unexploded ordnances
Additional drop camera	M25 to M44	June-July 2016	Where visibility permitted
		January 2017	Where visibility permitted
Collection of benthic macroinvertebrate samples (3 replicates per site)	M25, M31, M37, M43 (offshore export pipeline corridor)	June-July 2016	No benthic macroinvertebrate sampling at Caution Bay due to risk of unexploded ordnances
	M1 to M12, M45 to M46 (Orokolo Bay)	January 2017	
Deployment of BRUVs	BRUV1, BRUV2, BRUV3 (Caution Bay)	January 2017	Undertaken only at Caution Bay as this was the only location in the study area with coral reefs
Opportunistic observations	Entire study area	June-July 2016 January 2017	

Table 5-2 Sampling Site Coordinates and Depths

No.	Coordinates*	Depth	No.	Coordinates*	Depth
Orokolo Bay (sampling)			*Caution Bay (BRUV Sites))*		
M1	-7.870057, 145.27448	6.3 m	BRUV1	-9.419432, 146.887181	12 m
M2	-7.927804, 145.286573	16.6 m	BRUV2	-9.345960, 146.942537	8 m
M3	-8.030354, 145.427321	27.4 m	BRUV3	-9.369279, 146.995478	10 m
M4	-7.981364, 145.358308	27.5 m	*Offshore export pipeline corridor*		
M5	-7.885546, 145.321091	8.9 m	M25	-8.084702, 145.501914	24.6 m
M6	-8.011039, 145.455618	12.3 m	M26	-8.147329, 145.592558	46.2 m
M7	-7.881584, 145.361872	7.5 m	M27	-8.195253, 145.701121	41.9 m
M8	-7.921208, 145.259665	10.9 m	M28	-8.240063, 145.803743	48.9 m
M9	-8.012703, 145.387214	26.4 m	M29	-8.269933, 145.906365	49.2 m
M10	-7.986407, 145.379265	21.1 m	M30	-8.314733, 145.99314	52.6 m
M11	-7.952096, 145.273035	26.7 m	M31	-8.368488, 146.084444	53.8 m
M12	-7.956869, 145.32362	24.8 m	M32	-8.435670, 146.165183	60.4 m
M45	-7.844326, 145.184641	7.2 m	M33	-8.501348, 146.230075	59.0 m
M46	-7.890951, 145.183274	6.8 m	M34	-8.581938, 146.27535	63.7 m
Caution Bay			M35	-8.659201, 146.316514	63.1 m
M13	-9.277466, 146.869846	22.8 m	M36	-8.732625, 146.36288	52.7 m
M14	-9.293712, 146.884815	22.2 m	M37	-8.805708, 146.412682	45.1 m
M15	-9.317768, 146.888878	30.7 m	M38	-8.875795, 146.467011	35.5 m
M16	-9.329183, 146.907774	31.2 m	M39	-8.959286, 146.528131	35.0 m
M17	-9.340335, 146.942079	28.7 m	M40	-9.033815, 146.581707	30.5 m
M18	-9.349162, 146.959855	22.3 m	M41	-9.105348, 146.660935	52.0 m
M19	-9.359326, 146.979414	19.1 m	M42	-9.150049, 146.729602	42.3 m
M20	-9.360864, 146.999434	7.4 m	M43	-9.198948, 146.804434	43.8 m
M21	-9.341529, 146.987706	8.2 m	M44	-9.244915, 146.842235	39.4 m
M22	-9.391556, 147.011961	10.5 m			
M23	-9.281133, 146.932183	5.0 m			
M24	-9.410869, 146.880965	15.9 m			

*Coordinates used are based on Papua New Guinea 1994 datum (PNG94) and projection Universal Trans Mercator (UTM) Zone 55 South



LEGEND

- Town/Village
- Macroinvertebrate and Validation Site
- ESBS Study Area
- -5 Contours (m)
- Acoustic Survey Lines
- Nearshore/Offshore Waters Boundary
- Indicative Estuarine/ Freshwater Boundary
- Pipeline Corridor
- Narrowed Onshore Pipeline Corridor

Title:

Survey Sites – Orokolo Bay

Figure: 5-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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Title:

Survey Sites – Offshore Pipeline Corridor

Figure: 5-2

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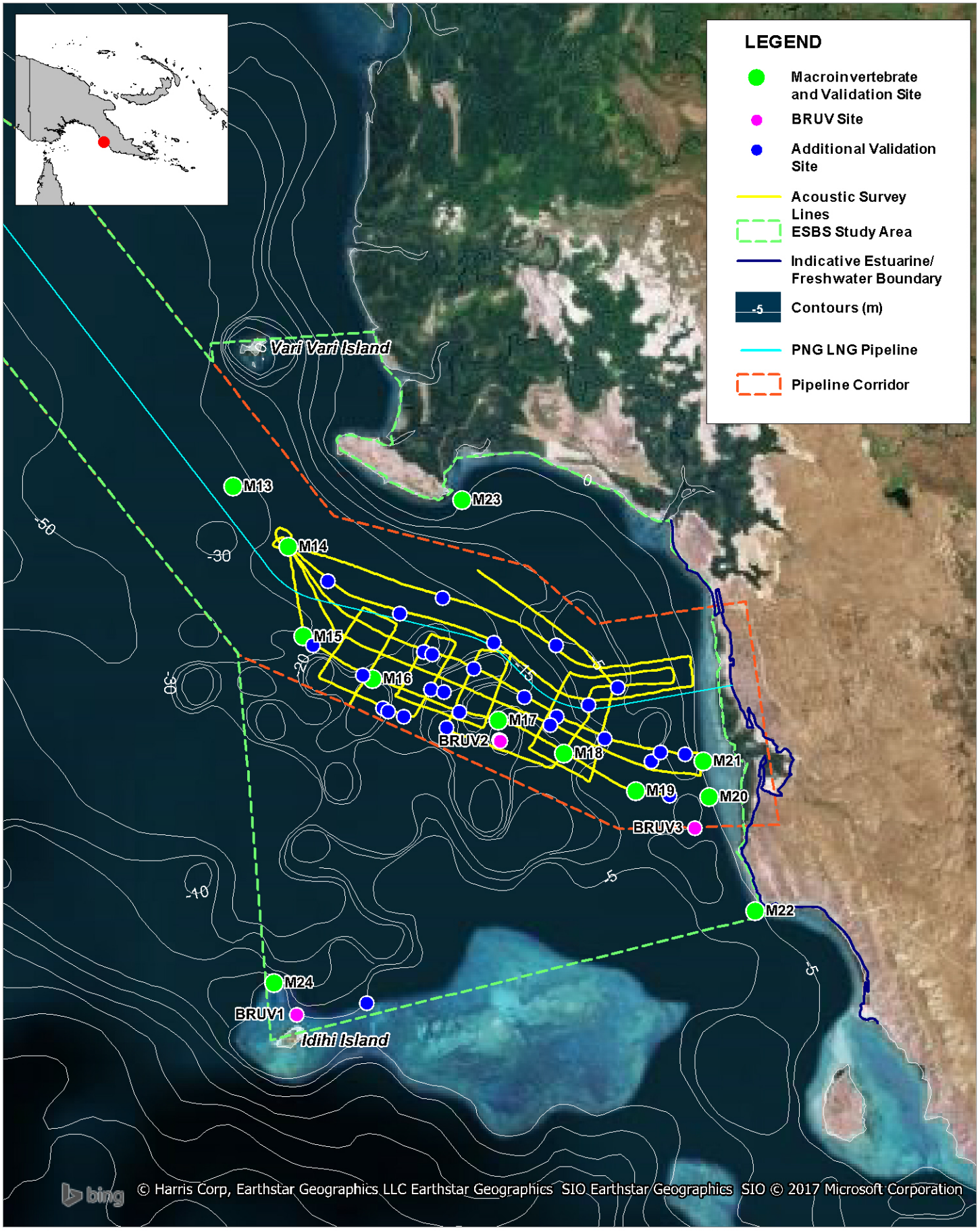
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Title:

Survey Sites – Caution Bay

Figure: 5-3

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Figure 5-4 Field Survey Techniques: benthic macroinvertebrate sampling using Van Veen grab (left) and deployment of drop camera for validation (right)



Figure 5-5 Drop Camera Used for Validation



Figure 5-6 Acoustic Survey Equipment: Single-beam Acoustic Capture Hardware (Top Left); Single-Beam Acoustic Downscan (Top Right); Sidescan Towfish, Bomb, and Tow-line (Lower Left); 200 kHz transducer (Lower Right)



Figure 5-7 *Browse Enterprise*, Vessel Used for Field Surveys

5.3.2 Site Selection

Sites selection was based on the following: (i) targeting known or potential features of biodiversity significance; and (ii) characterization of the range of biotopes represented in the study area. The location of marine infrastructure alignments had not yet been made at the time of surveys. Survey sites at Orokolo Bay and Caution Bay encompass a wide range of areas, such that once infrastructure alignments are finalized, *post hoc* classification of sites as background and 'test/impact' sites can be undertaken.

Orokolo Bay

Survey lines for acoustic-based sampling were chosen to provide broad coverage of the bay and potential different biotope features. Validation sampling of benthic biotopes and assemblages was conducted at 12 sites (M1 to M12) coincident with major sediment classes identified by acoustic surveys, and to describe spatial gradients in water depth and distance from the Purari and Vailala rivers.

Sampling sites M45 to M46 were included in the second surveys to allow for additional characterization of the benthic habitat and macroinvertebrate assemblages at the bar located at the mouth of the Purari River. Site M45 was located immediately upstream of the bar in the main channel of the river (Aievi Passage), while Site M46 was located offshore of the bar, at the 5 m depth contour.

Offshore Export Pipeline Corridor

Twenty sites were uniformly positioned along the offshore export pipeline corridor for water quality assessment, as discussed in the Marine Water and Sediment Quality Baseline Report (BMT WBM, 2017e; Part 11 of ESBS Dossier). Benthic biotopes and assemblages were systematically sampled at every sixth site to assess any longitudinal gradients in assemblages along the corridor.

Caution Bay

Acoustic survey lines within Caution Bay were chosen to provide coverage of features within the export pipeline corridor, including north and south of the existing PNG LNG gas pipeline. Sites M13 to M21 were then selected as sampling sites distributed across a variety of depths within the offshore export pipeline corridor and corresponding to the acoustic survey lines. Where possible, these sites were located at sites previously sampled for the PNG LNG Project EIS, allowing for comparison of results. Additional drop camera sites for validation were added after acoustic survey was completed in order to allow more detailed assessment of key features identified in the study area.

In addition to these sites, sites M22 to M23 were selected as likely 'reference' sites due to their distance from the likely location of the export pipeline. Each of these sites is located at similar depths to sites within the export pipeline corridor (most less than <15 m water depths) but at locations representing different environments, as follows:

- Site M23 – located north of the corridor, in the embayment formed by Redscar Head, characterized by nearshore seagrass meadows.
- Site M22 – located south of the corridor, immediately adjacent to mangrove-dominated coastline.
- Site M24 – located south of the corridor, adjacent to coral reef communities of Idihi Island.

These three locations characterize the different types of environment within Caution Bay for the purposes of understanding local marine habitat.

The three BRUV sites were located at important coral reef assemblages within the export pipeline corridor (BRUV2 and BRUV3), as identified from the acoustic survey, and at the Idihi Island fringing reef (near reference site M24). These sites are considered indicative of reef assemblages within and outside of the export pipeline corridor.

5.3.3 Single Beam Data Collection and Sidescan Sonar

As discussed above, data collection for acoustic habitat mapping was undertaken during field surveys of Orokolo Bay in June-July 2016 and Caution Bay in January 2017. This was based on the use of a single beam data collector and sidescan sonar.

The single beam data collector records the shape of the return or echo from a single pulse or beam, directed straight down to the seafloor. The shape of the echo is also known as its waveform. There are various parameters associated with the waveform that can be analyzed to distinguish between different bottom types and allows mapping of sediment grain sizes.

The sidescan sonar sends out a series of beams at a variety of frequencies known as compressed high-intensity radar pulse (CHIRP). This is a swath composed of multiple beams at multiple frequencies. The interpreted signal is simply a visualized acoustic reflection of the seabed, utilizing acoustic returns to create an image. The signal is affected by proximity to the target, meaning that the intensity of the return declines with distance from the sonar head. Sidescan mosaics are used to visualize details within the swath range (e.g. reefs) but have less ability than single beam to discriminate between various soft or hard sediment types.

The two acoustic techniques are used together to allow for identification of features in a wide area (sidescan sonar) that can then be targeted for more detailed mapping (single beam). Equipment used to collect the acoustic data is shown in Figure 5-6.

5.4 Laboratory Analysis

Dardanus Scientific (Stephen Cook) was used in the preparation of this report. Stephen provided identification of benthic macroinvertebrate samples to a morph-species level, in accordance with the AusRivAS methodology (e.g. DNRM, 2001). Stephen is a former curator of invertebrates at Queensland Museum and holds AusRivAS accreditation for Module 3 – Laboratory.

5.5 Permits Obtained

The following permits were obtained for the marine biodiversity surveys:

- Permit to Export – allows for the export of benthic macroinvertebrate samples from Papua New Guinea which are a scheduled species group under the *International Trade (Fauna and Flora) Act 1979*.
- Exemption to Permit to Import – a permit to import was not required to bring benthic macroinvertebrate samples into Australia as, once stored within formaldehyde, benthic macroinvertebrates are exempt from customs requirements.

The Permit to Export from Papua New Guinea is managed by the Wildlife Division of CEPA while Australian importation requirements are managed by the Australian Department of Agriculture and Fisheries.

Additional permits, which were not considered relevant, were 'taking' permits under the *Fauna (Protection and Control) Act 1966*. A 'Permit to Take' protected or restricted species applies in Papua New Guinea to species listed under Kula and George (1996). The only species 'taken' for the purposes of marine ecology investigations were benthic macroinvertebrates, which are not included in Kula and George's list.

5.6 Protocols Used

5.6.1 Taxonomy and Nomenclature

Taxonomic arrangements and nomenclature in this report follows the IUCN Red List where available. For fish species where nomenclature is not available from the Red List, the report follows the nomenclature of Allen (1991).

Where it is not possible to assign an established name to a species encountered during survey and subsequent analysis, the following system of tags and abbreviations has been adopted:

- sp. – used where single taxa can be identified to a genus level but not a species level
- spp., where multiple species are being referred to within a genus.
- sp. 1, sp. 2 etc. – used to distinguish between multiple taxa within the same genus that have not been identified to a genus level but are expected to be different species within the genus.
- cf. – used for species identification that are uncertain.

5.6.2 Occurrence

The occurrence of threatened/important species is described by one of the following categories:

- Known – species has been recorded in the study area as part of present surveys or similar surveys within the past 5 to 10 years and there is no evidence to suggest species would no longer occur in the study area.
- Likely – species was recorded in the study area more than 10 years ago but there is no evidence to suggest species would no longer occur in the study area, OR the study area supports suitable habitat for the species and is within its known or modeled distribution.
- Possible – the study area supports marginal habitat for the species but is within its known or modeled distribution.
- Unlikely – the study area does not support habitat likely to be utilized by the species, OR the study area is outside of the species known or modeled distribution.
- Does not occur – the species *cannot* occur within the study area due to habitat restrictions.

5.6.3 Threatened/Important Species

Within this report, the term ***threatened/important species*** is used to describe species in one of the five following categories:

(1) Species listed under the *Fauna (Protection and Control) Act 1966*.

(2) Trade-restricted under CITES and/or the *International Trade (Fauna and Flora) Act 1979.*

(3) Species with a 'threatened' status under the IUCN Red List of Threatened Species (IUCN, 2017).

(4) Endemic and/or restricted-range species.

(5) Migratory and congregatory species.

Further detail on these categories and the process of classifying species is provided below.

5.6.3.1 Nationally Listed Species

Under the *Fauna (Protection and Control) Act 1966* species can be listed as Protected or Restricted based on a gazetted list. The current list is published in Kula and George's *Protected Fauna of Papua New Guinea* (1996).

5.6.3.2 Trade-restricted Species

Trade-restricted species consist of those listed in Appendix I or Appendix II of CITES. This convention has been adopted in Papua New Guinea through the *International Trade (Fauna and Flora) Act 1979* which replicates the CITES appendices in schedules 1 and 2.

Appendix I/Schedule 1 species are those where trade is permitted only in exceptional circumstances, principally due to the threat of extinction of the species as a result of trade. Appendix II/Schedule 2 species are not necessarily threatened with extinction but trade must be controlled in order to avoid utilization which is incompatible with their survival.

5.6.3.3 IUCN Threatened Species

The IUCN Red List places all species (regardless of risk) into one of the following categories:

- Extinct.
- Extinct in the Wild.
- Critically Endangered.*
- Endangered.*
- Vulnerable.*
- Near Threatened.*
- Least Concern.
- Data Deficient.
- Not Evaluated.

Of these categories, those marked with an asterisk (*) are considered to be threatened for the purposes of this report. This does not include species already identified as extinct (Extinct and Extinct in the Wild) and those where insufficient data or existing assessments are available to evaluate threatened status (Data Deficient and Not Evaluated).

5.6.3.4 Endemic and Restricted-range Species

Endemic and restricted-range are categories for species provided under IFC PS 6 in the context of critical habitat assessments.

Endemic species are those that have greater than of equal to 95% of its global range inside the country or region of analysis. For the purposes of this assessment, the 'region of analysis' is defined as the combined Gulf of Papua and Southeast Papua New Guinea ecoregions, defined by

Spalding *et al.* 2007 (see Section 6.1). Whether or not species are restricted to the Gulf of Papua is based on available scientific literature, including species profiles on the IUCN Red List.

IFC PS 6 recommends restricted-range marine species as those considered to have an extent of occurrence of 100,000 km^2 (based on Edgar *et al.* 2009). This has been determined for individual species based on the profiles on the IUCN Red List and/or any other available scientific literature.

5.6.3.5 *Migratory and Congregatory Species*

Migratory and congregatory are categories for species provided under IFC PS 6 in the context of critical habitat assessments.

Migratory species have been defined as species of which a significant proportion of its members cyclically and predictably move from one geographical area to another. Congregatory species are those whose individuals gather in large groups on a cyclical or otherwise regular and/or predictable basis, such as the following:

- Species that form colonies, including for breeding and non-breeding purposes.
- Species that move through bottleneck sites where a significant number of individuals of a species pass over a concentrated period of time.
- Species with large but clumped distributions leading to a large number of individuals being concentrated in a single or few sites.
- Source populations where certain sites hold populations of species that make an inordinate contribution to recruitment of the species elsewhere.

Whether or not species are migratory or congregatory for the purposes of these definitions has been based on an assessment of their lifecycle, as described in scientific literature. As a large number of congregatory species are also migratory species (and vice versa) a distinction is not always possible between these two definitions. Species will also be considered migratory where they are recognized as such under an international convention, e.g. Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention).

Many fish and other marine species migrate as part of their life-cycle. This does not necessarily imply that these species are more sensitive than a non-migratory species. However, migratory species may be more difficult to protect when they move between national boundaries. For this reason, a legal definition (adapted from the Bonn Convention) rather than a purely biological definition has been adopted here to define migratory species, i.e. any species or lower taxon of wild animals in which a significant proportion of the members of the entire population or any geographically separate part of the population cyclically and predictably crosses one or more national jurisdictional boundaries.

5.6.4 Threatened/Important Ecosystems

Threatened/important ecosystems have been defined as those with a threatened status on the IUCN Red List of Ecosystems. This includes all with a status of Collapsed, Critically Endangered, Endangered, Vulnerable or Near Threatened. As no ecosystem relevant to the study area has currently been assessed under the Red List, this status has been determined based on provisional assessments using the guidelines published for the Red List (Rodriguez et al. 2011).

This guideline uses the following criteria for categorizing ecosystems:

- Short-term decline in distribution or ecological function.
- Historical decline in distribution or ecological function.
- Small current distribution and decline in distribution or ecological function.
- Very small current distribution.

5.7 Prioritization of Biodiversity Values

Within this report, biodiversity values have been prioritized for the purposes of understanding the sensitivity and/or significance of particular biotopes, ecosystems and species. This informs environmental assessment and management approaches as part of the EIS/ESHIA. Prioritization is based on the following:

- Potential critical habitat.
- Irreplaceability and vulnerability.

5.7.1 Critical Habitat

'Critical habitat' relates to a category of habitat under IFC PS 6 considered important for the purposes of assessment and management. Critical habitat is defined as follows:

> *Critical habitats are areas with high biodiversity value, including (i) habitat of significant importance to Critically Endangered and/or Endangered species, (ii) habitat of significant importance to endemic and/or restricted-range species, (iii) habitat supporting globally significant concentrations of migratory species and/or congregatory species, (iv) threatened and/or unique ecosystems, and/or (v) areas associated with key evolutionary processes.*

It is not the intention of this report to identify critical habitat within the study area; however, where relevant, elements that are expected to contribute to a critical habitat designation have been highlighted, such as the occurrence of threatened/important species.

5.7.2 Irreplaceability and Vulnerability

Irreplaceability relates to the spatial limitation of a particular biodiversity value. For example, a value may be considered irreplaceable where it only occurs within a limited location and therefore, once lost, cannot be substituted with an identical value elsewhere. Vulnerability relates to the likelihood of a value being lost due to its threatened status and/or sensitivity to particular kinds of impacts.

In order to determine sensitivity for a biodiversity value based on irreplaceability and vulnerability, the following steps have been taken:

For species

- Identification of the 'vulnerability rating' of the species, based on Table 5-3 (using categories for threatened/important species from Section 5.6.3); and
- Identification of a 'sensitivity rating' of habitat for the species based on the criteria in Table 5-4 which include consideration of irreplaceability.

For habitat features

- Identification of the 'sensitivity rating' of the habitat feature, based on Table 5-3 (based on the IUCN Red List of Threatened Ecosystems methodology in Section 5.6.4), which is based on vulnerability and irreplaceability; or
- Identification of the 'sensitivity rating' for the habitat feature based on the criteria in Table 5-4, which is based on irreplaceability.

This allows for a sensitivity rating that is linked to a spatially distributed habitat value.

NOTE: The following tables have been developed based on a combination of guidelines to the IFC Performance Standards and IUCN Red List, previous practice for other EISs/ESHIAs, and expert judgement of the authors of this report.

Table 5-3 Vulnerability Rating for Species and Habitat Features

Category	Vulnerability rating			
	Low	Moderate	High	Extreme
Nationally listed species	n/a – the threatened status under national legislation is considered superseded by the status provided under IUCN Red List			
Trade-restricted species	Unlisted species	Appendix II	Appendix I	-
IUCN threatened species	Least Concern Data Deficient Not Evaluated	Near Threatened Least Concern species with global trend of decreasing population	Vulnerable	Critically Endangered Endangered
Endemic and restricted-range species	Species that are not endemic or restricted-range	Endemic and/or restricted to study area ecoregion	Endemic and/or restricted to local marine features across multiple areas	Endemic and/or restricted to local marine features in a single area

Table 5-4 Sensitivity of Biodiversity Values in the Study Area

Category		Sensitivity rating			
		Low	Moderate	High	Extreme
IUCN threatened ecosystems		Least Concern	Near Threatened	Vulnerable	Collapsed Critically Endangered Endangered
Areas used by species of *low* or *moderate vulnerability*	Low	Area that provides 'suitable'[2] habitat for species of *low vulnerability* that is widespread and abundant through the subject and adjoining ecoregions	Area that provides 'suitable'[2] habitat for species of *low vulnerability* that only occurs within the subject ecoregion	Area that provides 'suitable'[2] habitat for a species of *low vulnerability* that is considered critical to the survival of the global population of the species.	-
	Moderate	Area that provides habitat of 'marginal'[1] value for species of *moderate vulnerability*	Area that provides 'suitable'[2] habitat for species of *moderate vulnerability* that is widespread and abundant through the subject and adjoining ecoregions	Area that provides 'suitable'[2] habitat for species of *moderate vulnerability* that only occurs within the subject ecoregion	Area that provides 'suitable'[2] habitat for a species of *moderate vulnerability* that is considered critical to the survival of the global population of the species.
	Migratory/congregatory	-	Areas within a defined migration route for migratory and/or congregatory species that is widespread and abundant through the subject and adjoining ecoregions	Area within a defined migration route for migratory and/or congregatory species that only occurs within the subject ecoregion OR Habitat that is used by a migratory and/or congregatory species for functions critical to the lifecycle of the species but which is widespread and abundant through the subject and adjoining ecoregions	Habitat that is used by a migratory and/or congregatory species for functions critical to the lifecycle of the species which is has a highly restricted distribution, and therefore highly sensitive to disturbance even at a highly localized scale
Areas used by species with *high* or *extreme vulnerability*		-	Area that provides habitat of 'marginal'[1] value for species of *high* or *extreme vulnerability*	Area that provides 'suitable'[2] habitat for species of *high* or *extreme vulnerability* that is widespread and abundant through the subject and adjoining	Area that provides 'suitable'[2] habitat for a species of *high* or *extreme vulnerability* that is considered critical to the survival of a regional or global population of the species

Category	Sensitivity rating			
			ecoregions	OR Area that provides 'suitable'[2] habitat for species of *high* or *extreme vulnerability* that occurs only in the subject ecoregion.
Areas with intrinsic value*	Habitat, landform or ecosystem that is not restricted to New Guinea	Habitat, landform or ecosystem that only occurs within Papua New Guinea but is well represented nationally	Habitat, landform or ecosystem feature that occurs only within the local and adjoining catchments	Habitat, landform or ecosystem feature that occurs only within the local catchment
			Area within a protected area declared under national legislation	Area expected to support a unique assemblage of species and/or be important to evolutionary processes.

*This refers to areas that have biodiversity values that are not necessarily linked to the occurrence of a single sensitive species

[1]Marginal habitat, as defined by the IUCN Habitat Classification Scheme (IUCN, 2017b), is habitat where a species occurs only irregularly or infrequently or where only a small proportion of species individuals are found in the habitat

[2]Suitable habitat, as defined by the IUCN Critical Habitat Classification Scheme (IUCN, 2017b), is habitat where a species occurs regularly or frequently

5.8 Limitations

The following limitations are noted:

- Seabed mapping was based on single beam sonar. The sonar samples a narrow swathe of the seabed, and the unsurveyed seabed between soundings was mapped based on interpolations between known classifications. Therefore, small patches of habitat that differ to the interpolated maps may exist between survey lines. Depth estimates may also be subject to error as a result of sea surface anomalies (modeled in the Gulf of Papua by Saint-Cast and Condie, 2006) where trade winds either raise or lower the sea level, depending on whether they are from the southeast or northwest, respectively. Vertical estimates were made against mean sea level as defined by deployed tide gauges over the survey period, which are subject to these trade wind anomalies.

  Depth estimates and habitat classifications can also be affected by survey conditions (e.g. wave height, pitch and yaw of survey vessel), and the sonar manufacturer recommends collecting data in conditions with less than 10° of vessel movement. Acoustic data were collected under very calm conditions conforming to manufacturer recommendations, hence the risk of mis-classification is considered very low.

- Due to the risk of unexploded ordnances (UXOs) at Caution Bay, sediment sampling was not undertaken in this area. This limited the ability to undertake verification of acoustic habitat mapping (e.g. comparison of actual sediment grabs to acoustically-collected data). This is not considered to be a significant limitation as high visibility allowed seabed class validation using a drop camera.

These limitations are not expected to impact on the ability to characterize the baseline marine ecological environment suitable for preparation of an EIS/ESHIA. However, dependent on the outcome of the impact assessment, pre-construction surveys may be necessary in order to supplement any gaps prior to actual works commencing.

6 Baseline Characterization

This section provides a description of the existing marine biodiversity of the study area, including an overview of regional context, focusing on the following technical areas:

- Marine biogeographic context.
- Marine and benthic biotopes (i.e. habitat), including marine vegetation.
- Fish and macrocrustacean species.
- Marine mammals and reptile species.
- Marine pests.

It draws on information available from previous studies in the area, scientific literature and databases and targeted field studies undertaken during June-July 2016 and January 2017 to fill information gaps, as well as information collected as part of other baseline studies for the ESBS. A summary of the field survey data is provided in the baseline description below, with the more detailed data provided in Appendix B.

6.1 Biogeographic Overview

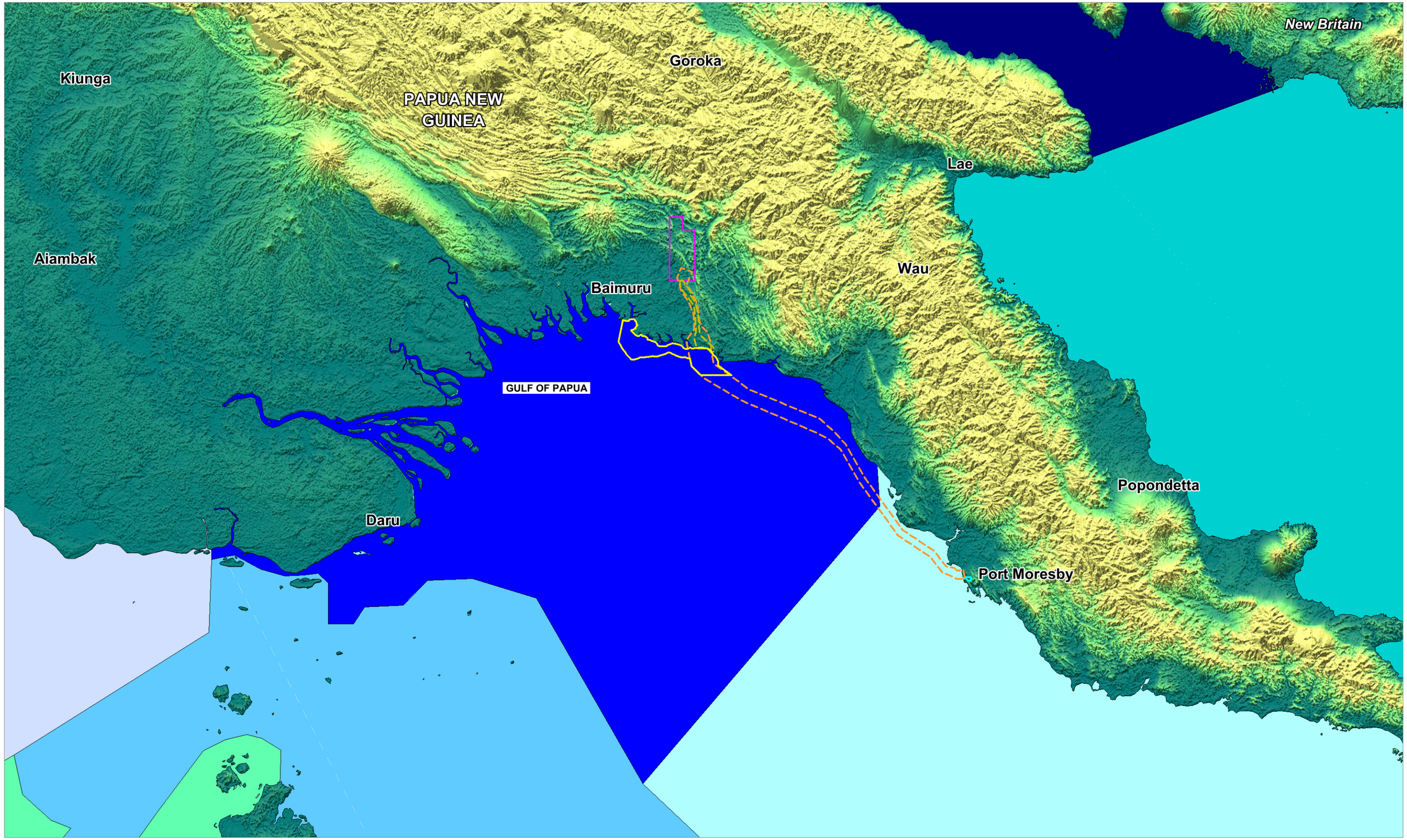
Spalding *et al*. (2007) classified the marine (coastal and shelf) ecoregions of the world, based on defining areas of relatively homogeneous species composition that were clearly distinct from adjacent systems. Two ecoregions are of relevance to the study area (Figure 6-1):

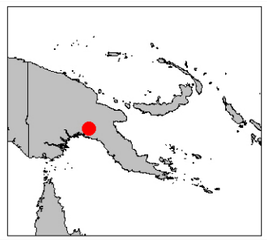
- Ecoregion 20138 – Gulf of Papua. This ecoregion is part of the Sahul Shelf. It encompasses the eastern and central section of the Gulf of Papua, from Boigu Island in the west to north of Yule Island in the east. The western section of the export pipeline corridor fall within this ecoregion.
- Ecoregion 20137 – Southeast Papua New Guinea. This ecoregion is part of the Eastern Coral Triangle (Marine Province). The eastern boundary of this ecoregion abuts the Gulf of Papua ecoregion, and extends east to the south-eastern tip of Papua New Guinea. The eastern section of the export pipeline corridor fall within this ecoregion.

The island of New Guinea rests on five lithospheric plates and has great geological and marine biogeographic complexity (Pandolfi, 1992). New Guinea is also located in the Indo-Pacific triangle, a globally recognized hotspot of marine biodiversity.

Southern New Guinea (including the study area) is located on the Indo-Australian Plate, and therefore, shares a strong biogeographic affinity with northern Australia, to which it was land-bridged during the last Pleistocene glacial period. The northern part of New Guinea is a composite of terranes built up over much more recent geological times and has stronger affinities with Indonesia and Southeast Asia (Pandolfi, 1992). The differences between northern and southern Papua New Guinea also reflects dispersal restrictions by the New Guinea landmass, glaciation and unfavorable hydrological conditions including the formation of tropical cyclones in the Arafura Sea.

Due to the close proximity and recent geographic affinity of northern Australia and southern New Guinea, there are few endemic marine flora and fauna species in southern Papua New Guinea (Sekhran and Miller, 1996).





LEGEND

- Gas/Condensate Field Area
- Purari/Orokolo Study Area
- Caution Bay Study Area
- Offshore Export Pipeline Corridor
- Narrowed Onshore Pipeline Corridor

Ecoregions

- Gulf of Papua
- Arafura Sea
- Bismarck Sea
- Solomon Sea
- Torres Strait Northern Great Barrier Reef
- Southeast Papua New Guinea
- Arnhem Coast to Gulf of Carpenteria

Marine Ecosystems of the World - WWF

Title:
Ecoregions of Southern New Guinea (Spalding et al. 2007)

Figure: 6-1

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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6.2 Marine and Benthic Biotopes of Study Area

The coastline and offshore waters of southern Papua New Guinea, including the study area, contain a wide diversity of marine and benthic biotopes, including:

- Marine wetland vegetation.
- Reefs benthic biotope and communities.
- Soft sediment habitats and benthic macroinvertebrate assemblage.
- Pelagic environments.

Examples of these biotopes are shown in Figure 6-2.



Figure 6-2 Example Images of Marine Biotopes: marine wetlands (mangroves) top left; reefs, top right; soft sediment habitats (lower left); pelagic environments, (lower left).

NOTE: As noted in Section 5, acoustic habitat mapping was used to assist in identifying and characterizing some of these biotope types at Orokolo Bay (June-July 2016 survey) and Caution Bay (January 2017) survey. Details of the mapping methodology is provided in Appendix A. The results of this mapping have been split for Orokolo Bay and Caution Bay based on the dominant habitat type identified during the surveys; Orokolo Bay results are presented in the context of soft sediment habitats (Section 6.2.3) and Caution Bay as part of reefs (Section 6.2.2).

6.2.1 Marine Wetland Vegetation

Marine wetland vegetation consists of mangrove forests (mangals) and seagrass meadows. Seagrass meadows are discussed below while mangrove communities are described in the Upstream Terrestrial Biodiversity Baseline Report (ERIAS, 2017; Part 6 of ESBS Dossier) and the Upstream Freshwater and Estuarine Biodiversity Baseline Report (BMT WBM, 2017b).

6.2.1.1 Regional Overview

Environmental conditions prevent the development of significant seagrass meadows in the Gulf of Papua. McKenzie *et al.* (2006) identify the key limiting factors to seagrass growth in the Gulf of Papua as bottom type, and light availability (depth and turbidity), as well as temperature, exposure to drying, and tide and water movement.

In accordance with bottom type and light availability factors, seagrass meadows are extensive within Torres Strait, where waters are shallow (15 to 20 m deep) and clear, but more restricted in the Gulf of Papua due to the influence of large, turbid rivers (e.g. Purari, Fly, Kikori, Bamu and Turama rivers) (McKenzie *et al.* 2006).

No seagrass meadows occur within Orokolo Bay, as determined during field surveys (June-July 2016 and January 2017). This is presumed to be the result of:

- Bed mobilization by wave disturbance and fluvial discharges.
- High sediment loads (and associated low light and high sediment deposition) associated with fluvial discharges and bed remobilization.
- Low salinity in nearshore waters due to fluvial discharges.

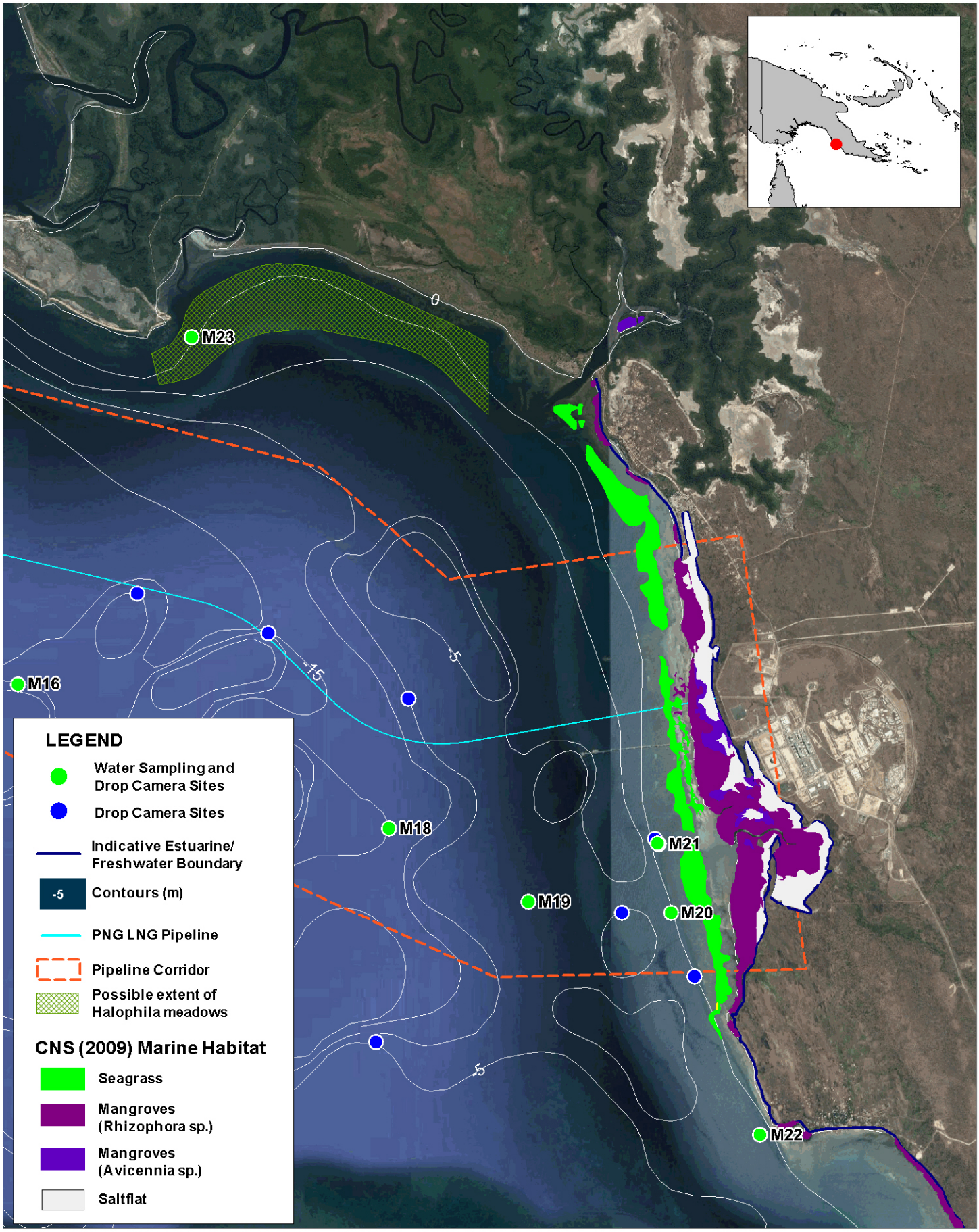
Similarly, no seagrass was recorded during field surveys along the offshore export pipeline corridor. This is consistent with the findings of the marine pipeline survey carried out by EGS Survey Pty Ltd in March and April 2008 for the PNG LNG Project (CNS, 2009). It is expected that the water depths here are too deep (i.e. insufficient light) to support seagrass meadows.

The only seagrass identified in the study area occurs at Caution Bay, which is not subject to large turbid plumes that occur in the north of the gulf.

6.2.1.2 Caution Bay

Seagrass meadows occur in the shallow, clear waters of Caution Bay. In 2009, CNS mapped locally dense meadows that were generally located on the flat, sandy seafloor between the mangrove lined shore and the fringing reef (CNS, 2009). The dense seagrass meadows were comprised of *Enhalus acoroides*, *Syringodium isoetifolium*, and *Cymodocea* spp. These meadows are considered to have high ecological significance by stabilizing the substrate and through the provision of nursery or feeding habitats for a range of marine organisms including prawns, lobsters, fish and turtles (CNS, 2009).

Additional seagrass meadows were identified in the northern area of Caution Bay at Site M23 in the present study (June-July 2016 and January 2017 field surveys). Figure 6-3 depicts the potential extent of seagrass in this northern area based on bathymetric and sediment characteristics. Seagrass meadows in the northern part of Caution Bay were sparse and composed of species from the genus *Halophila*, potentially including *H. ovalis, H. capricorni,* and/or *H. decipiens* (Figure 6-4). The percent cover of seagrass at Site M23 was less than 5% during both the June-July 2016 and January 2017 surveys. Observations from the recent surveys also indicate that seagrass meadows mapped by CNS (2009) in eastern Caution Bay remain intact.



Title:

Caution Bay marine wetland vegetation map

Figure: 6-3

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Figure 6-3 provides a composite map of potential seagrass occurrence, based on mapping undertaken by CNS (2009) and the inferred distribution of *Halophila* meadows based on water depths and the distributions seen during the present study. This map also shows distribution of mangroves which are discussed further in the Upstream Freshwater and Estuarine Biodiversity Baseline Report (BMT WBM, 2017b).

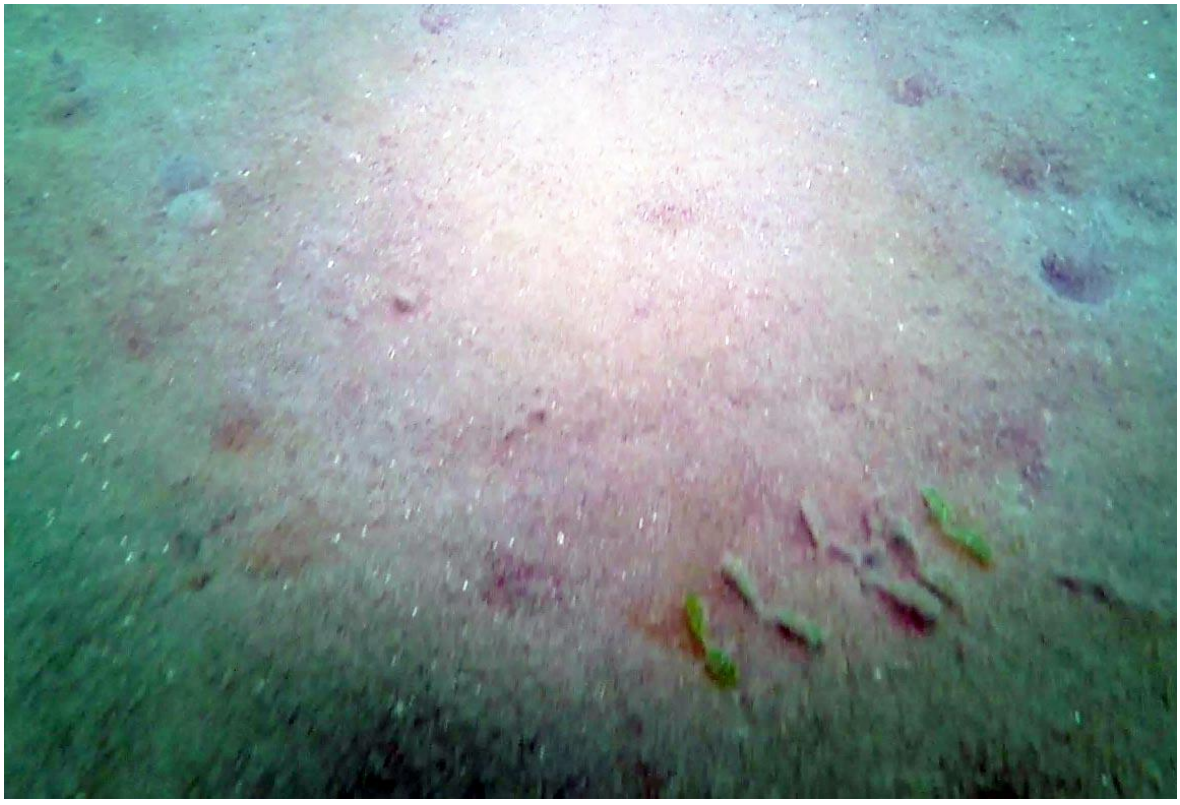


Figure 6-4 Sparse Cover of *Halophila* sp. (lower right hand side of image) at Site M23

There is little historical data available regarding trends in seagrass health at Caution Bay. Future trends in health are expected to be strongly linked to catchment management and land use, with seagrass highly susceptible to sediment and other runoff from the land.

6.2.1.3 Sensitive Species and Ecosystems

All seagrass species known or likely to occur in the study area are currently listed as Least Concern on the IUCN Red List. In addition, none of these species are trade-restricted, locally endemic or have a restricted-range and are therefore not considered to be threatened/important species and are of *low vulnerability*. The exception is *E. acoroides* which is discussed below.

Seagrass meadows as an ecosystem may constitute a threatened ecosystem based on the criteria developed by Rodriguez *et al.* (2011). This is also considered below.

The importance of seagrass meadows as a habitat feature for other threatened/important species is considered in Sections 6.4.2 and 0.

Enhalus acoroides

Nationally-listed	×	Not listed
Trade-restricted	×	Not listed
IUCN threatened	✓	Least Concern (decreasing)
Endemic and/or restricted-range	×	Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	×	n/a
Overall sensitivity	***Moderate vulnerability***	

Enhalus acoroides was identified at Caution Bay during surveys conducted in 2008 for the PNG LNG Project EIS (CNS, 2009). While not identified during present surveys, habitat utilized by this species is considered to occur at Caution Bay. The species is currently listed as Least Concern but has a trend of decrease in global population (Short and Waycott, 2010). On this basis, it is considered to be of *moderate vulnerability*.

This species is restricted to intertidal and shallow subtidal areas (Short and Waycott, 2010). It is a large leafed species that is slow to produce new shoots and has poor resistance to disturbance (Green and Short, 2003).

The main threats to this species are activities that impact on water quality within seagrass meadows, including development of maritime infrastructure, dredging, shipping and coastal runoff (Short and Waycott, 2010). Due to the narrow depth range at which the species is found, it is considered sensitive to disturbance.

Based on habitat and distribution, the following occurrence is noted for this species:

- Orokolo Bay and offshore Purari River delta – ***Does not occur***, due to unsuitable substrate and water quality (low benthic light) conditions.
- Offshore export pipeline corridor – ***Does not occur***, due to unsuitable water quality (low benthic light) conditions.
- Caution Bay – ***Known***, based on PNG LNG Project EIS surveys in 2008 (CNS, 2009).

Seagrass Meadow Ecosystems

The 11th International Seagrass Biology Workshop, held in Sanya China in 2014, recognized that seagrass meadows globally are in decline, with losses up to 7% of known surface area per year (IUCN, 2014). While the ecosystem has not been assessed under the criteria for the IUCN Red List of Ecosystems and while sufficient data for conducting such an assessment is not currently available, it is considered possible that seagrass meadows may be threatened as an ecosystem and meet the criteria for Vulnerable ecosystems (cf. Rodriguez *et al.* 2011). On this basis, all seagrass meadows in the study area should be considered to have *moderate sensitivity*. See Section 6.6.

6.2.2 Reef Benthic Biotopes and Communities

6.2.2.1 Regional Overview

Coral reef within the Gulf of Papua are associated with islands within the eastern and western parts of the gulf or near the edge of the continental shelf. These include reefs associated with Parama, Daru and Bobo islands (near Fly River delta) on the western side of the gulf, and reefs associated

with Yule, Vari Vari and Idihi islands, or occurring between Kapripata Point and Ou Ou Point (south of Yule Island) and Redscar Head and Konebada Point, on the eastern side of the gulf (CEPA, 2015; Spalding *et al.* 2001). There are also extensive reef assemblages in Torres Strait, south of the western side of the gulf.

The regional distribution of reef communities is shown in Figure 6-5.

6.2.2.2 Orokolo Bay and Offshore Export Pipeline Corridor

No coral reefs or intertidal rocky shores were recorded in nearshore coastal environments at Orokolo Bay or near the Purari River mouth in the present study or previous surveys.

A subtidal rocky reef was recorded at Site M6 further offshore in the southeast quadrant of the Orokolo Bay study area (Figure 6-6 and discussed further in Section 6.2.3.1). This rocky reef was situated in approximately 12 to 15 meters of water and supported an assemblage of soft corals (*Dendronephthya* sp., sea pens), crinoids, colonial ascidians, hydroids, sponges and other encrusting organisms (Figure 6-7 and Figure 6-8). Waves were seen breaking on the reef in more shallow areas, although actual depth at these locations is unknown. No hermatypic corals ('reef-building' species that require light) or macroalgae species were recorded. The species that occur on this reef tolerate large fluctuations in salinity and turbidity associated with river discharges and/or bed sediment remobilization.

None of the seabed rises on the Australian Hydrographic Chart shown on Figure 6-6 within the acoustic survey area represent actual features (reefs or shoals). The Australian Hydrographic Chart indicates that there were shallow rises with water depths of -3.8 m and -1.3 m (lowest astronomical tide) to the west of Auma Point where waves occasionally break. However, the seabed at these locations was observed to be flat and featureless (i.e. no rises). Waves were not observed to break at these locations under calm conditions (seas were less than 0.5 m during the survey), whereas waves were observed to break on the reef near Site M6.

Based on the results of site based sampling undertaken for the PNG LNG Project EIS (CNS, 2009; 2008a) and acoustic surveys conducted for a corridor between Kerema and Port Moresby (unpublished report), no reefs or rocky habitats are known to occur along the offshore export pipeline corridor. Reefs are present outside of the study area between the pipeline corridor and the Gulf of Papua coastline, especially near Kerema and Yule Island. No reefs were observed at sampling points along the offshore export pipeline corridor during the present surveys.



LEGEND

- Coral Reefs
- Purari/Orokolo Study Area
- Caution Bay Study Area
- Pipeline Corridor
- Narrowed Onshore Pipeline Corridor (for reference purposes)

Title:

Coral Reefs in Gulf of Papua

Figure: 6-5

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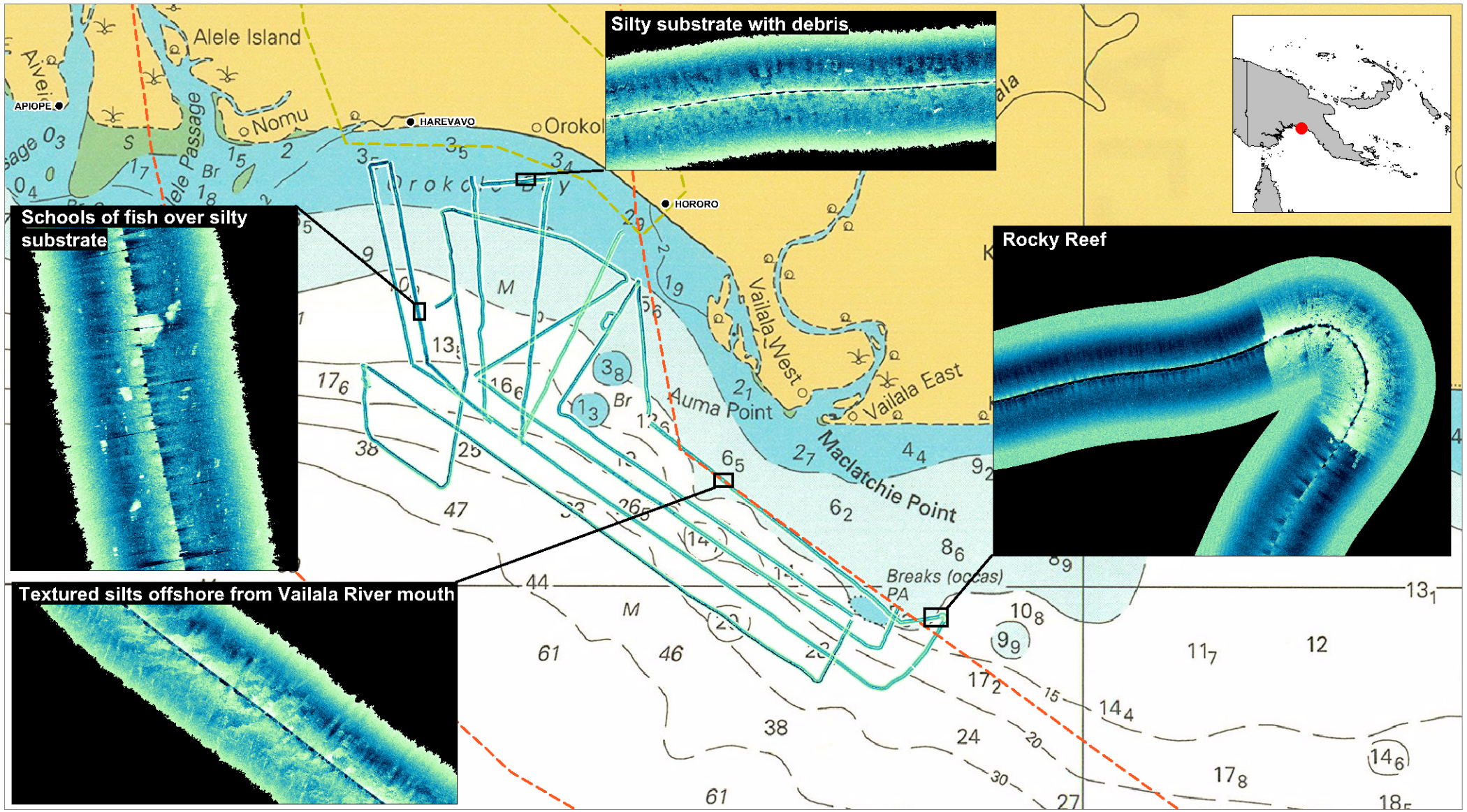
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LEGEND

- Town/Village
- Pipeline Corridor
- Narrowed Onshore Pipeline Corridor
- SSS survey lines

Title:

Sidescan Sonar mosaic of Orokolo Bay

Figure: 6-6

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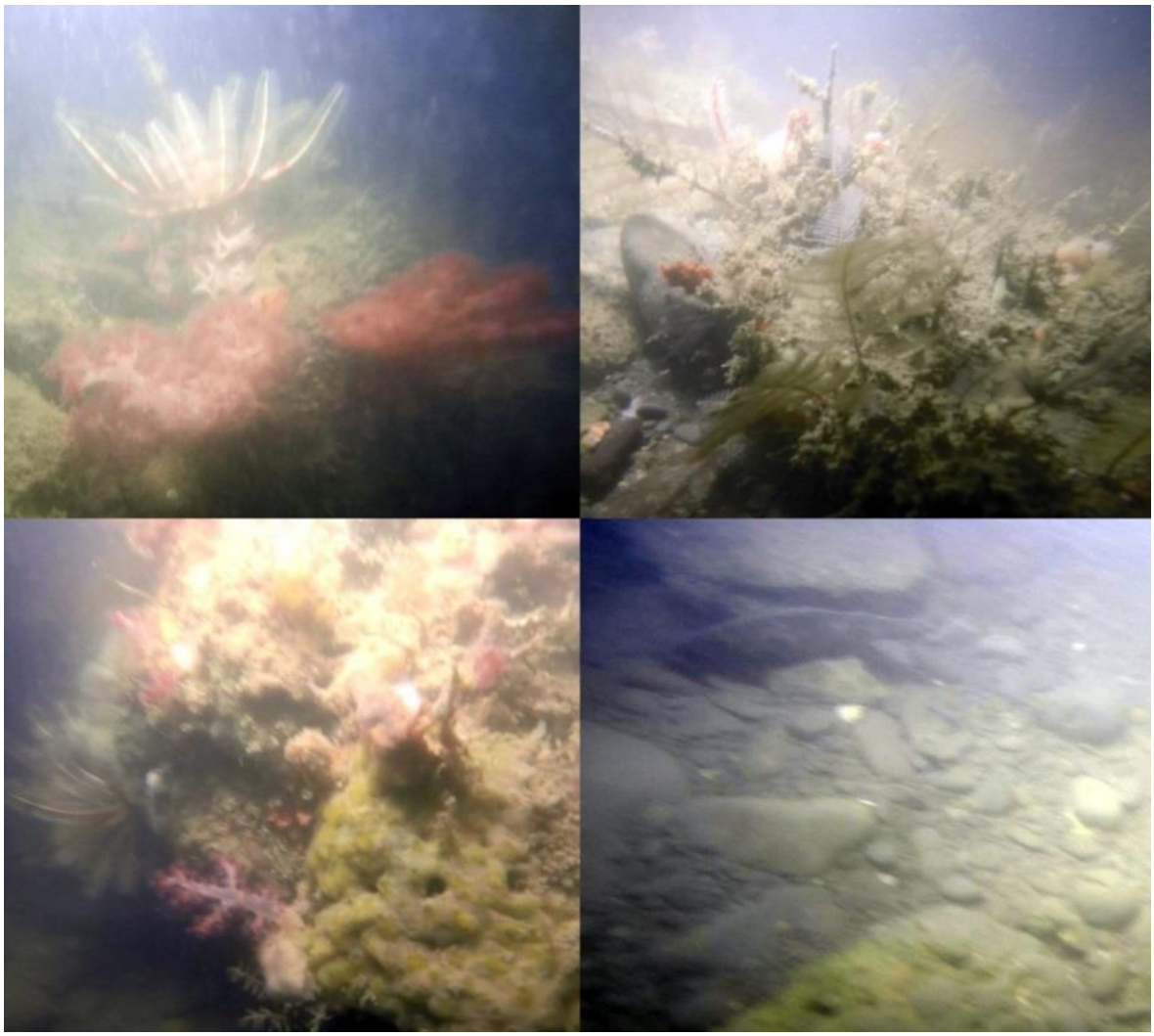


Figure 6-7 Rocky Reef Benthos at Site M6 During the June-July 2016 Field Survey: crinoid and *Dendronephthya* sp. (top left); hydroids (top right); mixed community with crinoid, *Dendronephthya* sp. and colonial ascidian (lower left); and bare rubble (lower right)



Figure 6-8 Rocky Reef Benthos at Site M6 During the January 2017 Field Survey: crinoids (top left); polychaete tube worms, crinoids and *Dendronephthya* sp. (top right); snapper *Lutjanus* sp. (lower left); high relief rocky outcrop (lower right)

6.2.2.3 Caution Bay

Reef Distribution

Coral reef systems in Caution Bay are comprised of the following:

- An extensive nearshore fringing reef, located approximately 200 to 500 m offshore, parallel to the eastern shoreline in Caution Bay. Live coral was present between the 10 m depth contour and the intertidal zone (CNS, 2009; see Figure 6-9).
- An outer barrier reef located along the southwest offshore boundary of Caution Bay, which provides protection from ocean swells.
- Offshore reef environments at Vari Vari Island (situated to the north) and Idihi Island (near the outer barrier reef). Idihi Island is a coral cay, located on the northwest limit of the barrier reef. Live coral was observable from between the -15 to -20 m depth contours to the intertidal zone.
- A large number of coral outcrops and reefs extending from the seafloor up to 5 m below the water surface; these are found mostly in the southern and central regions of Caution Bay (Figure 6-9) including several throughout the acoustic survey area. Low densities of live coral

were occurred from the -15 m to 10 m depth contours, with much higher densities between the -10 m and -5 m depth contours.

Mapping was undertaken of fringing and nearshore reef habitat present on the eastern shore of Caution Bay for the PNG LNG Project EIS (CNS, 2009). Figure 6-9 depicts these areas of fringing reef as well as interpolated reef habitat based on data collected during the June-July 2016 and January 2017 field surveys. In the present study, reefs and other subtidal benthic habitat classes were differentiated based on processing of backscatter characteristics from 200 kHz single beam acoustic survey data and validated by examination of bathymetric profile characteristics, sidescan sonar mosaic imagery which was collected in conjunction with the single beam acoustic survey (Figure 6-10) and drop camera video footage. Reef structures identified through this mapping at Caution Bay are discussed here however acoustic habitat mapping outputs for Orokolo Bay are discussed in Section 6.2.3 as benthic biotopes in the Orokolo Bay region were dominated by soft sediment substrates.

Five habitat categories were identified from the single beam acoustic survey as shown in Figure 6-9. These habitats consisted of:

(1) Silty mud with a low prevalence of bioturbation (burrows).

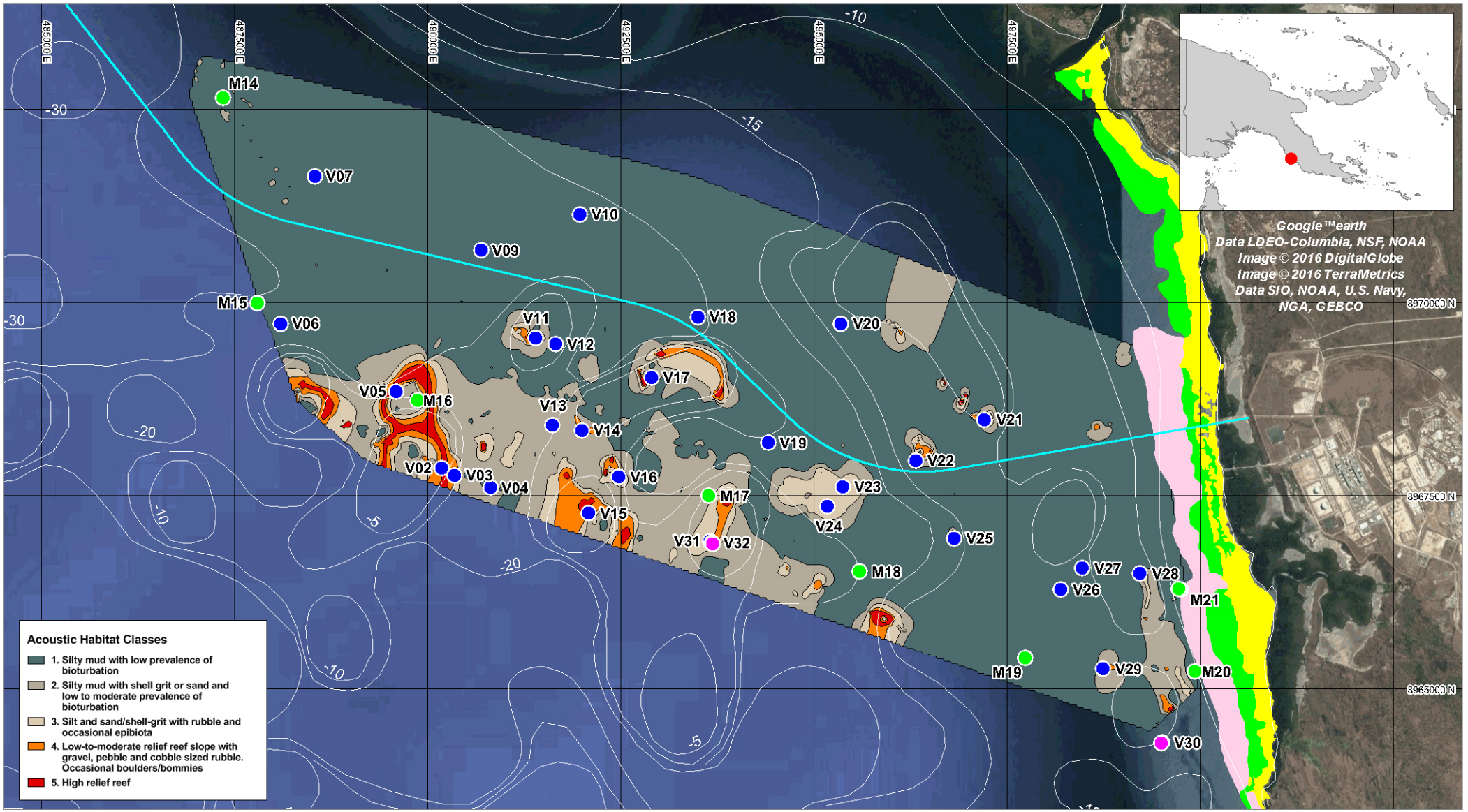
(2) Silty mud with shell grit or sand and low to moderate levels of bioturbation.

(3) Silt and sand/shell grit with rubble and occasional epibiota.

(4) Low to moderate relief reef slope with gravel, pebble, and cobble-sized boulders. Occasional boulders/ bomboras and corals.

(5) High relief reef with coral.

Habitat classes 1 to 3 included substrates dominated by silts but were mainly differentiated based on content of other grain sizes (i.e. sand, shell-grit and/or rubble) and surface textures. Video surveys indicate that class 5 (red) had moderate to high (30 to 70%) cover of living coral. Sparse coverage (≤5%) of living corals was seen within class 4 (orange) habitats and living coral was absent or very low on class 3 (beige) habitats.



LEGEND

- Water Sampling Site
- Acoustic Validation Site
- BRUV Site
- Pipeline Corridor
- PNG LNG Pipeline

CNS (2009) Marine Habitat

- Coral Reef (Fringing Reef)
- Seagrass
- Submerged sand patches

Projection UTM (WGS 84) Zone 55 South

Title:

Interpolated Benthic Biotope Types in the Caution Bay Acoustic Survey Area

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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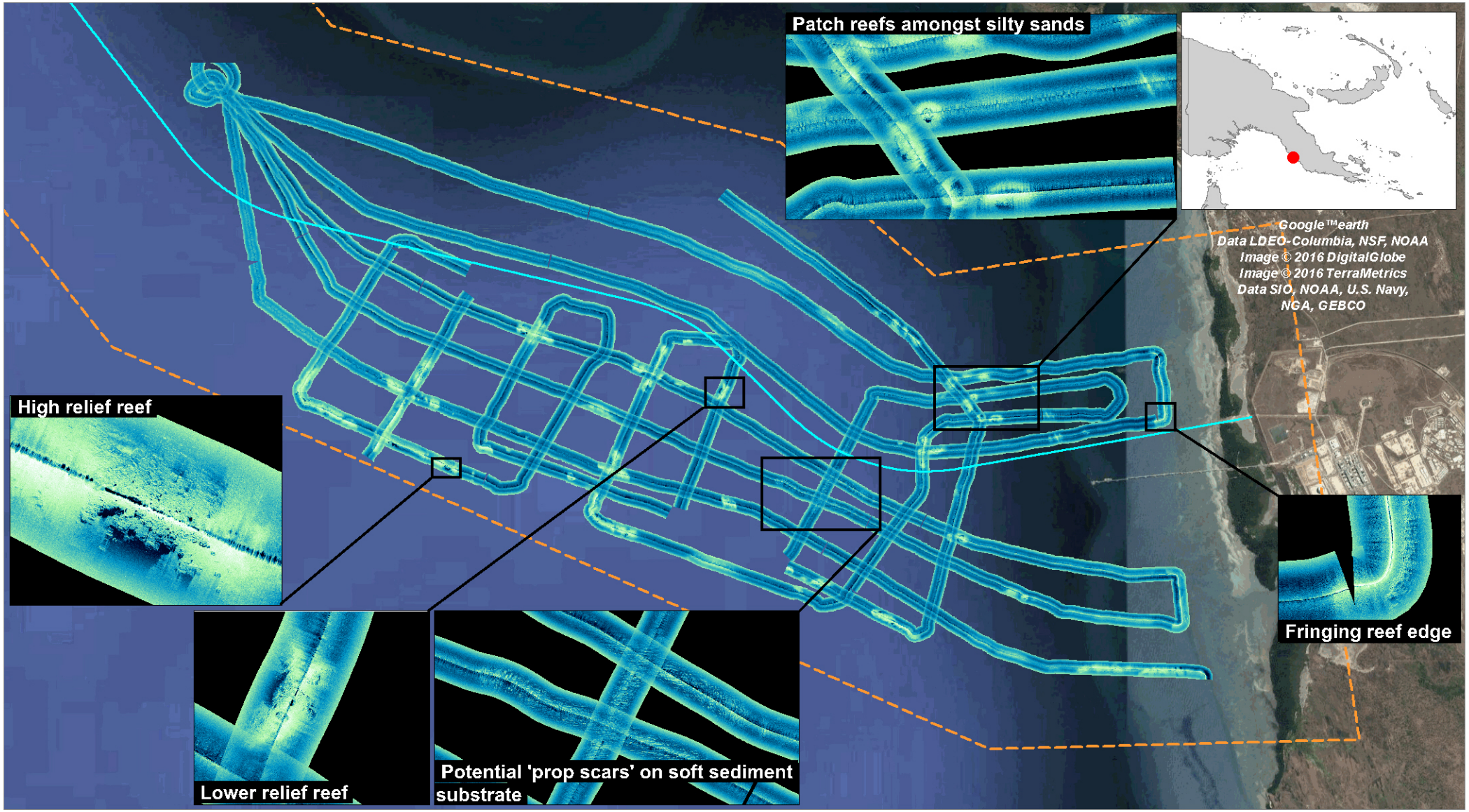
Approx. Scale

Figure: 6-9

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LEGEND

- PNG LNG Pipeline
- Pipeline Corridor

Title:

Sidescan Sonar mosaic of Caution Bay showing reefs (light colour) and soft sediment substrates (darker colour)

Figure: 6-10

Rev: B

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Nearshore and Fringing Reef Habitats

The PNG LNG Project EIS found that the nearshore coral reef community within Caution Bay were in poor condition, with low fish and coral abundance (CNS, 2009). The main identified cause of degradation was high intensity fishing activities, including dynamite fishing (CNS, 2009). Resuspension of sediment during periods of strong winds and waves was also identified as a key control on community structure.

A number of survey sites in eastern Caution Bay originally surveyed for the PNG LNG Project EIS (CNS, 2009) were re-surveyed in the present study. These included three sites (V26, V29 and V30, shown in Figure 6-7) where coral was observed by CNS (2009) and during the present survey. CNS (2009) observed that coral assemblages at these sites were in poor condition overall. The present survey found that these sites had low overall coverage of live corals (<5%), but there were patches of high coral cover that indicates that assemblages were in a state of recovery.

It is likely that the prevalence of dynamite fishing has reduced in parts of the Caution Bay region after the development of the PNG LNG facilities. Reductions in destructive fishing practices may have resulted in some improvement in reef condition between the two surveys. However, this cannot be reliably ascertained without quantitative cover data between the two periods, which are lacking.

In summary, observations at these three sites during the present survey were that:[3]

- Assemblages at Site V26 consisted of a small raised coral bombora (high structural complexity) surrounded by rubble and silty sand (low structural complexity). Coral cover on the outcrop at V26 was dominated by *Acropora* sp*.,* which had up to 100% cover in patches and approximately 30% overall on the bombora. *Acropora* at this site had long apical growing tips suggesting rapid growth rates had occurred recently, further suggesting that coral was in a recovery state (Figure 6-11).
- Site V29 had low cover of live corals (approximately 2%). The site was comprised of isolated rocky outcrops surrounded by sandy substrates.
- Site V30 consisted of a large *Pavona clavus* bombora, consistent with observations reported in CNS (2009). This large, isolated outcrop was surrounded by sandy substrate with occasional patches of low relief epifauna, including beds of the calcareous algae *Halimeda sp*., hydroids, soft corals and some isolated hard coral plates. The *P. clavus* bombora at V30 was in good condition with up to 100% coral cover in patches and 80% cover overall on the bombora. Abundant fish assemblages were also observed.

Fringing rubble reef was recorded to the west of Boera at Site M22. This site consisted of a rubble slope habitat with sparse cover of soft corals, zoanthids, hydroids, sponges, ascidians, brittle stars and a variety of marine algae species (Figure 6-12). Solitary, free-living *Heteropsammia* sp*.* corals were also abundant at this site in June 2016 and January 2017.

[3] Note that due to the scale of interpolation some items described here may not have been captured in detail in the acoustic habitat mapping. This is particularly the case for small features of a particular class that are distinct to the dominant class of surrounding areas.

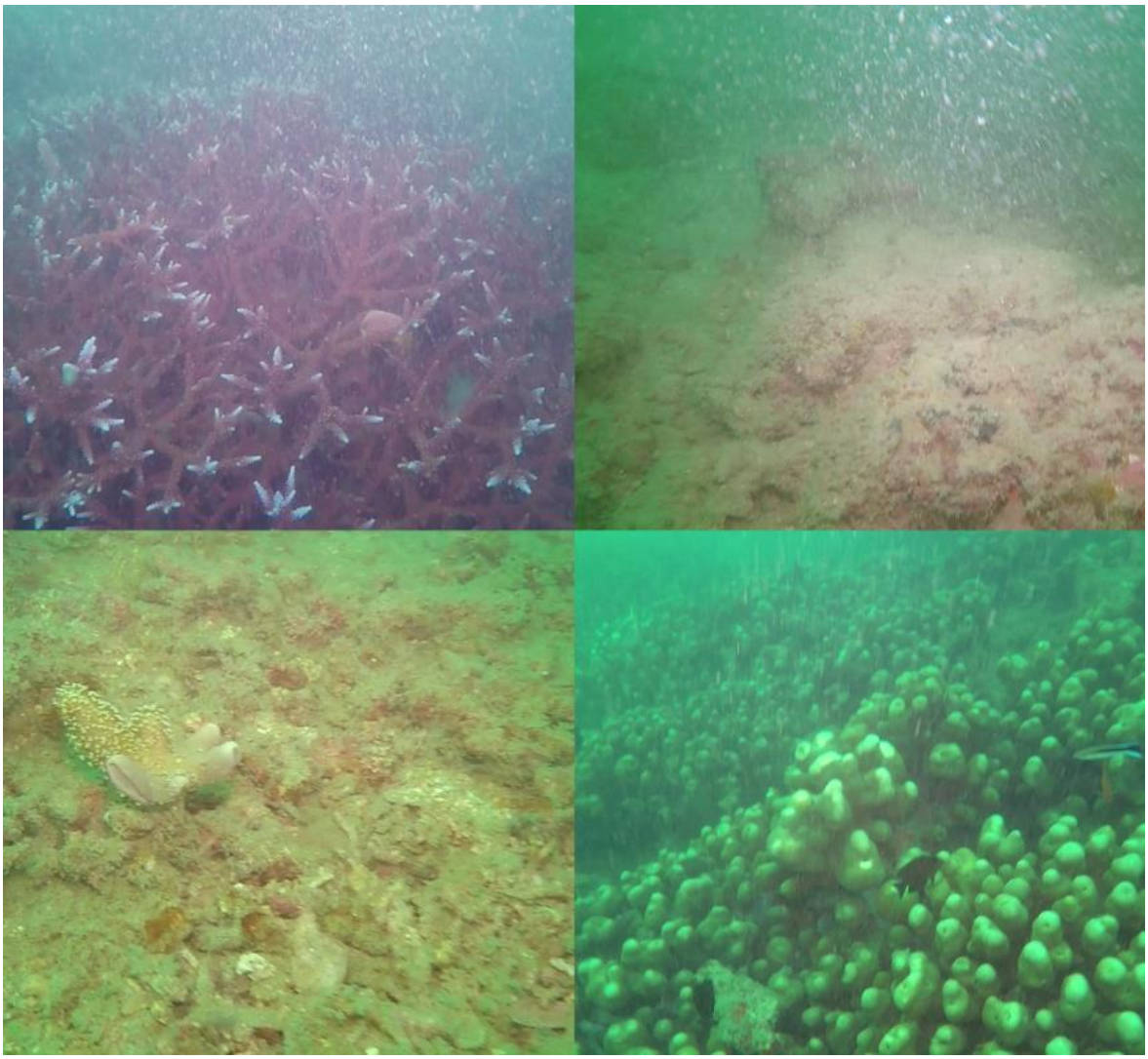


Figure 6-11 Coral at Validation Sites: Site V26 with *Acropora* bombora (upper left) adjacent to silt-covered boulders and rubble (upper right); coral rubble and *Sarcophyton* soft coral at Site V29 (lower left); *Pavona clavus* bommie at Site V30 (lower right)

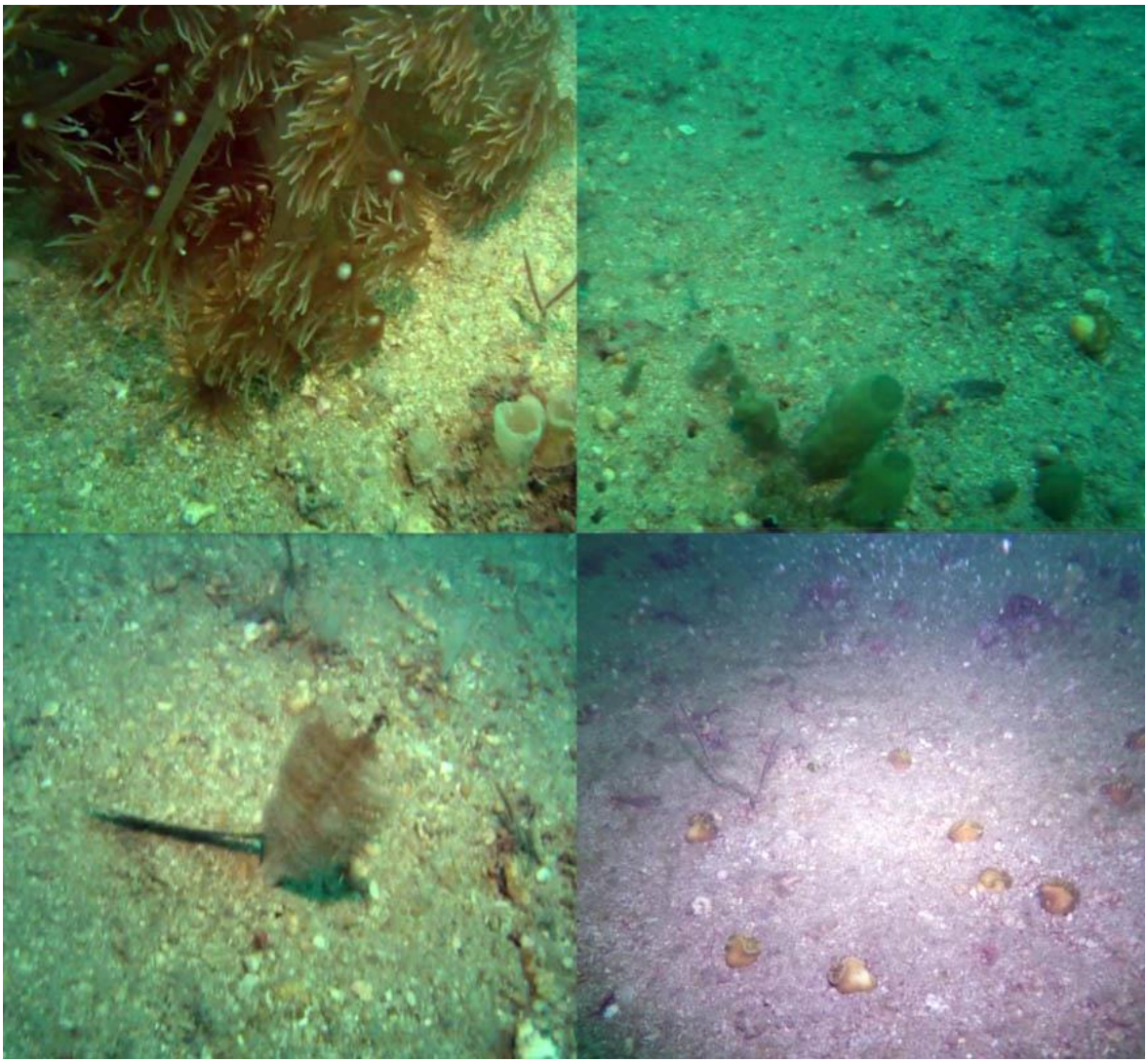


Figure 6-12 Rubble Reef Community at Site M22: *Alveopora* sp. (upper left); sponge (upper right); sea pen (lower left); free-living *Heteropsammia* sp. coral polyps (lower right).

Offshore Reef Habitats

Offshore islands and outer barrier reefs at Caution Bay supported more extensive reefs with higher overall coral cover than the nearshore/fringing reefs. The two main island locations for Caution Bay are Vari Vari and Idihi Islands. The following observations have been made for these locations:

- Vari Vari Island was surveyed as part of the PNG LNG Project EIS (CNS, 2009). Coral was in 'good condition with high coral cover' and a range of species observed to be present with few signs of disturbance.
- Idihi Island, surveyed as part of both the present surveys and the PNG LNG Project EIS had high coral cover (up to 70% during both CNS and BMT WBM surveys), a wide range of species, no to low sediment cover on colonies, and few signs of anthropogenic or natural disturbance. The coral assemblages forming the northern slope and reef flat of the coral cay for Idihi Island contain a wide variety of soft corals, sea whips, other gorgonians, and hard corals in a number of morphological forms (Figure 6-13). This area forms a reef back-slope environment, which typically display lush coral assemblages with high species richness (Veron, 1986). The most abundant hard coral genera recorded in the present study at this site were *Acropora*, *Montipora* and *Porites* spp.



Figure 6-13 Reef Slope at Site M24 (Idihi Island): mixed coral and soft coral community including *Acropora* sp. (upper left); coral colonies with massive growth form including *Porites* sp. *Stylophora* sp. and *Pavona* sp. (upper right); branching *Millepora* sp. soft corals, mushroom corals and sea whips (lower left); reef edge (lower right).

Patch Reefs and Atolls

Subtidal patch reefs and atolls were recorded in the lagoon between fringing reefs to the east and the barrier reef at Idihi Island to the south-west. These reefs occur at water depths between 5 m and 25 m, and vary in physical habitat and community structure.

An extensive reef was recorded at the western extent of the acoustic survey area (Site V02). The reef forms an atoll with a steep reef slope which transitions into a shallow reef crest (5 m water depth). The reef had moderate (30%) cover of living corals on the reef crest (Figure 6-14) including branching and digitate forms (particularly *Acropora* spp.) that can be sensitive to physical disturbance and changes to light regimes.

Shallow patch reefs or atolls supporting autotrophic (light dependent) corals and algae were also identified at the following locations:

- East of the reef atoll at Site V2, near the south-western extent of the acoustic survey area.
- Adjacent to Site M17.
- At Site V32.
- At and adjacent to Site V17.
- In the north-eastern quadrant of the acoustic survey area near sites V20 and V21.

Deep-water (>25 m) reef assemblages were identified at Site V15 (Figure 6-15), Site V16 and adjacent to Site M16. These reefs featured high cover and high diversity of octocorals (soft corals, gorgonians and sea whips) including *Sarcophyton, Sinularia, Ellisella, Viminella* and *Ctenocella* and representatives from the families Xeniidae and Nephtheidae. Hard corals were also abundant including species with sub-massive growth forms and daytime expanded polyps (*Goniopora* and *Alveopora* spp.), solitary *Fungia* colonies, and delicate growth forms (vases, fronds and plates) from the genera *Leptoseris*, *Pavona,* and *Acropora.* Other reef associated organisms observed including crinoids and sponges, including several large basket sponges.

Rubble Slopes

Rubble slopes were recorded at a number of locations in the acoustic survey area. Rubble slopes were most commonly observed at the transition between high relief reefs and adjacent unconsolidated substrates, but also occurred as stand-alone patches. There was variation in the structure of rubble slope habitats as follows:

- Rubble reefs with a high cover of pebble to cobble sized rubble and occasional living coral colonies were observed at Site V14 (Figure 6-16) and adjacent to high relief reefs at Site V17. It is likely that these rubble slopes were formed by historic dynamite fishing. Discussions with local fisherman suggest that some local communities still practice dynamite fishing but that this mostly occurs at reefs located further to the south towards Port Moresby. Due to bans put in place in association with the PNG LNG Project (Esso Highlands Limited, 2012), it is understood that dynamite fishing has not been practiced in Caution Bay for some time.
- Site V11, and sites V22 and V25 adjacent to reefs, contained isolated patches of rubble reef with scattered boulders/corals. This structure is more likely to reflect the natural form of rubble slopes and transitional habitat in Caution Bay.



Figure 6-14 Shallow-Water Coral Assemblages at Site V2



Figure 6-15 Deep-water Reef Community at Site V15

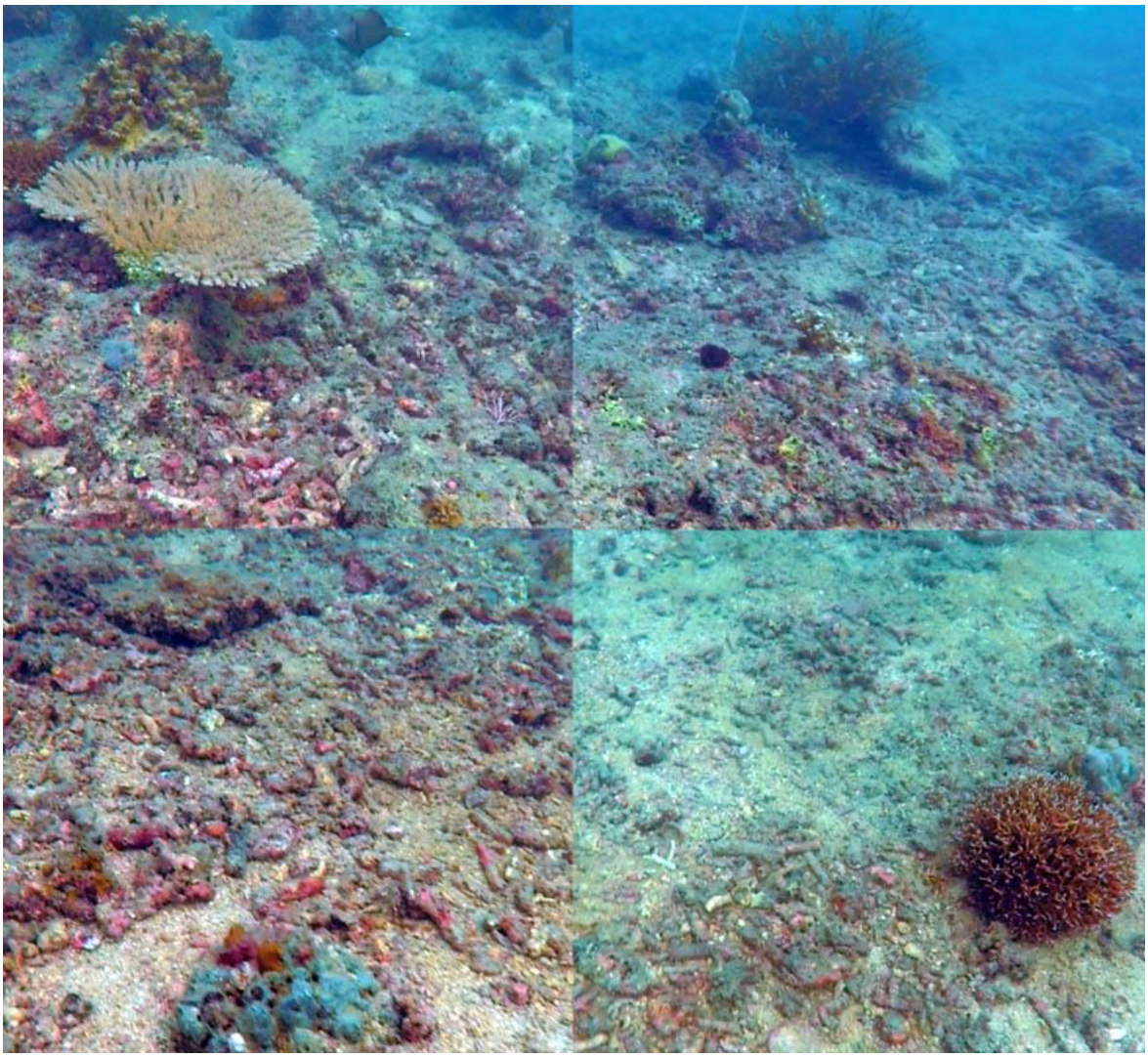


Figure 6-16 Rubble Reef at Site V14

6.2.2.4 Sensitive Species and Ecosystems

Some coral species are considered threatened/important species, as set out below. In addition, coral reef ecosystems may qualify as a threatened ecosystem based on the criteria of Rodriguez *et al.* (2011), but no formal assessment has been carried out for Papua New Guinea reefs to date.

The importance of coral reef as a habitat feature for other threatened/important species is considered in sections 6.4.2 and 0.

Threatened/Important Species

There are numerous hard coral species listed as threatened or near threatened under the IUCN Red List that have a geographic distribution that overlaps with the ecoregion. This includes members of the following genera: *Acropora* (table, elkhorn and staghorn corals), *Pavona*, *Montipora*, *Porites*, *Goniopora* (flowerpot corals), *Alveopora*, *Fungia* (mushroom corals), *Leptoseris and Millepora* (fire corals). No species within the above genera are considered endemic or restricted-range, and are not included in the appendices to CITES/schedules to the *International Trade (Fauna and Flora) Act 1979*.

No detailed taxonomic survey of coral species has been carried out in Caution Bay and adjacent areas to date. The identification of most hard corals to species level requires close visual

inspection of the coral skeleton and/or polyps, either by divers or typically in the laboratory using a microscope. The present study did not involve sampling of corals by divers, and therefore taxa could only be identified to genera.

It has been conservatively assumed that records of any of the above genera indicate the potential presence of threatened or near threatened coral species listed under the IUCN Red List. On this basis, the presence of any of the above genera is considered to represent a feature of *high vulnerability*.

The main threats to coral reef species are marine and coastal developments that impact on water quality, such as dredging, maritime infrastructure and coastal runoff. In particular, coral reefs globally are significantly impacted by nutrient and sediment runoff from the development of adjoining catchments. Coral reefs are also vulnerable to destructive reef fishing activities, such as dynamite fishing. The crown-of-thorns starfish (*Acanthaster planci*) is capable of causing significant impacts to coral reef species and is known to have impacted the reefs near Port Moresby (see Section 6.7). In addition to these impacts, global climate change has the potential to cause coral mortality through increases in water temperature (resulting in bleaching) and sea level rise (decreasing light penetration to corals).

Coral reef species occur at Caution Bay and at Yule Island adjacent to the offshore export pipeline corridor. On this basis, the occurrence of these species is as follows:

- Orokolo Bay – ***Does not occur***, due to unsuitable water quality and habitat conditions.
- Offshore export pipeline corridor – ***Does not occur***, due to lack of suitable reef habitat.
- Caution Bay – ***Known***, based on present surveys and surveys conducted in 2008 for the PNG LNG Project EIS.

Coral Reef Ecosystems

A study by Pandolfi *et al.* (2003) indicates a long-term global trajectory of decline in coral reef ecosystems. This is potentially accelerated by risks associated with climate change (e.g. sea level rise and sea temperature increases). Based on this trajectory, it is possible that coral reef ecosystems could be considered to be Vulnerable or Endangered ecosystems, using the criteria developed by Rodriguez *et al.* (2011). On this basis, coral reefs should be considered to be of *high sensitivity*.

It is also noted that, as part of the Coral Triangle Initiative on Coral Reefs Fisheries and Food Security (CTI-CFF), Papua New Guinea is committed to the recognition and protection of coral reef ecosystems. If this is seen as a surrogate for a 'protected area', coral reefs should be considered to be of *high sensitivity*, regardless of global declines.

Threat mapping conducted by CTI-CFF in the Caution Bay region (Figure 6-17) describes existing and potential threats to coral reefs (Reefbase, 2017). The area is considered to be at relatively low risk to impacts from coastal development and marine pollution and catchment runoff. Areas surrounding existing settlements are most at risk to the impacts of coastal development and catchment impacts. The biggest threat to the region is considered to be overfishing and destructive fishing practices, which are currently rated as being high across most of the area (Figure 6-17D). The integrated present threat, which considers all processes, suggests that most inshore areas are under high to very high levels of threat, with only the most offshore reefs experiencing moderate threat. Projected threat levels for 2030 and 2050 are shown in Figure 6-17F to Figure 6-17H. These maps include warming and sea-level rise scenarios and suggest that the region is under extreme

threat. The Coral Triangle does not contain any reefs mapped as low-threat in the 2050 scenario. The Caution Bay area sits within the very high to critical threat range.

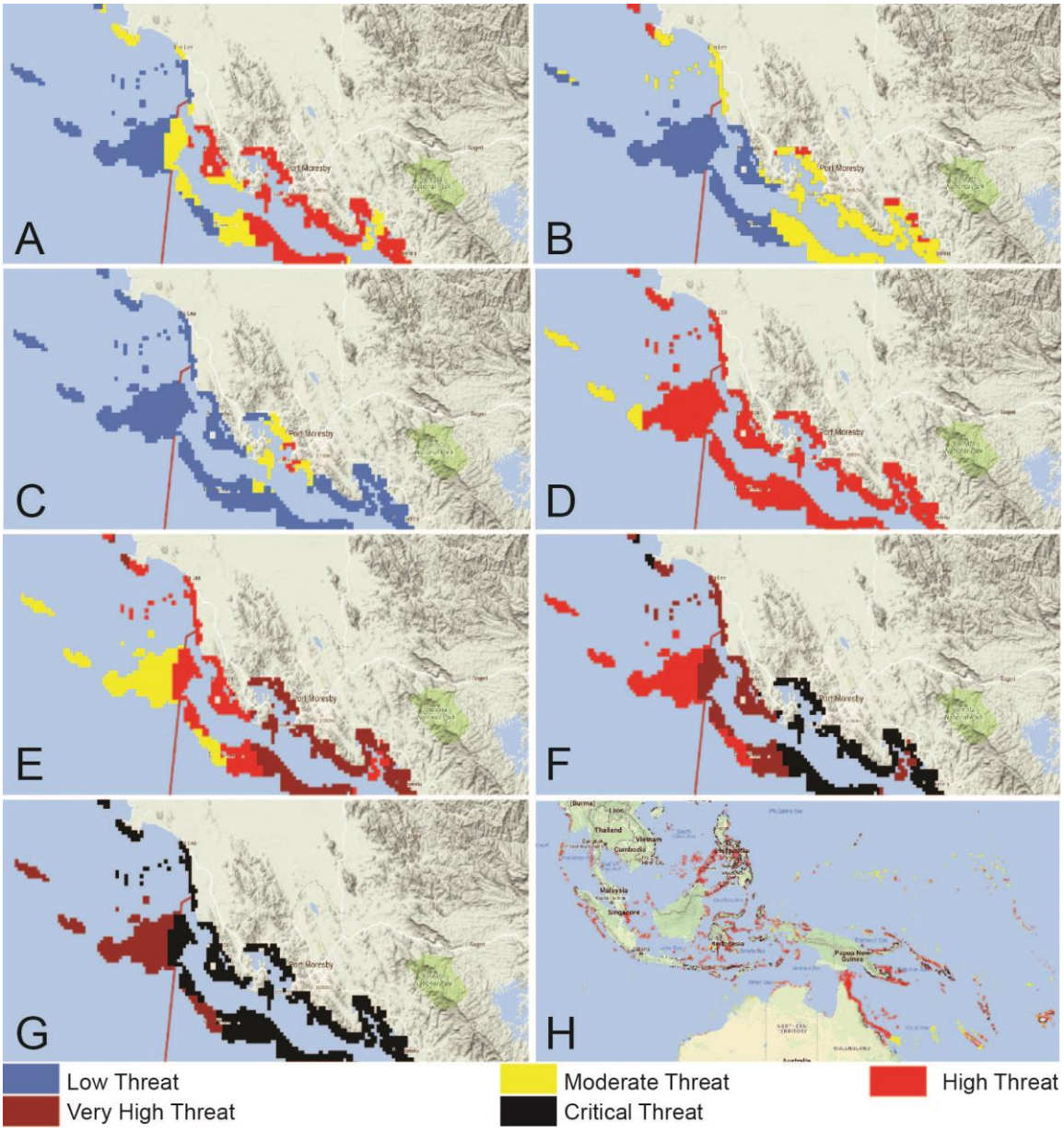


Figure 6-17 Present and Potential Future Threats for Caution Bay Reefs: Coastal Development (A); Watershed-based Pollution (B); Marine Pollution (C); Overfishing and Destructive Fishing (D); Integrated Present Local Threat (E); Integrated Local and Global Threat 2030 (F); Integrated Local and Global Threat 2050 (G); Integrated Local and Global Threat 2050 across the Coral Triangle (H)

6.2.3 Soft Sediment Habitats

6.2.3.1 Orokolo Bay

While mangrove wetlands dominate the coastline along much of the Gulf of Papua and Purari River delta, sandy beaches occur intermittently between tidal inlets and river mouths. Further east of the Purari delta within Orokolo Bay, sandy beaches are more continuous, due to westward longshore drift generated by predominant southeasterly waves (Bird, 2010). The beaches here are comprised of dark sandy material (Figure 6-18). The substrate composition of beaches is spatially variable,

consisting of fine sands on the beaches of Orokolo Bay near the Purari River, grading to coarser material (sand and gravels) towards the Vailala River.



Figure 6-18 Black Sand Beaches at Harevavo Village

Substrates in inshore (<15 m depths) and offshore (>15 m depths) subtidal areas of Orokolo Bay are mostly comprised of clay and silt-sized fractions, with minor (<10%) proportions of sand-sized fractions (Figure 6-19 and Figure 6-20). Fluvial sediment inputs from the Purari and Vailala rivers represent a major source of fine material to these nearshore environments, as described in the Seabed and Coastal Geomorphology Baseline Report (BMT WBM, 2017c; Part 9 of ESBS Dossier; see also Robertson *et. al.* 1998). Overlying waters were highly turbid throughout Orokolo Bay, and a suspended fluid mud layer was observed above the seabed at sites M2 and M5 during the June-July 2016 survey.[4] Improved water clarity was observed in January 2017 during the northeast monsoon season when lighter winds and calmer sea conditions are more prevalent. Despite this, turbid pulses were still evident around the mouth of the Purari River and other major rivers in the region during the January 2017 survey, especially following flow events associated with heavy rainfall in the upper catchment.

[4] This survey was conducted during the local dry season at a time of high winds and significant wave resuspension of sediments.

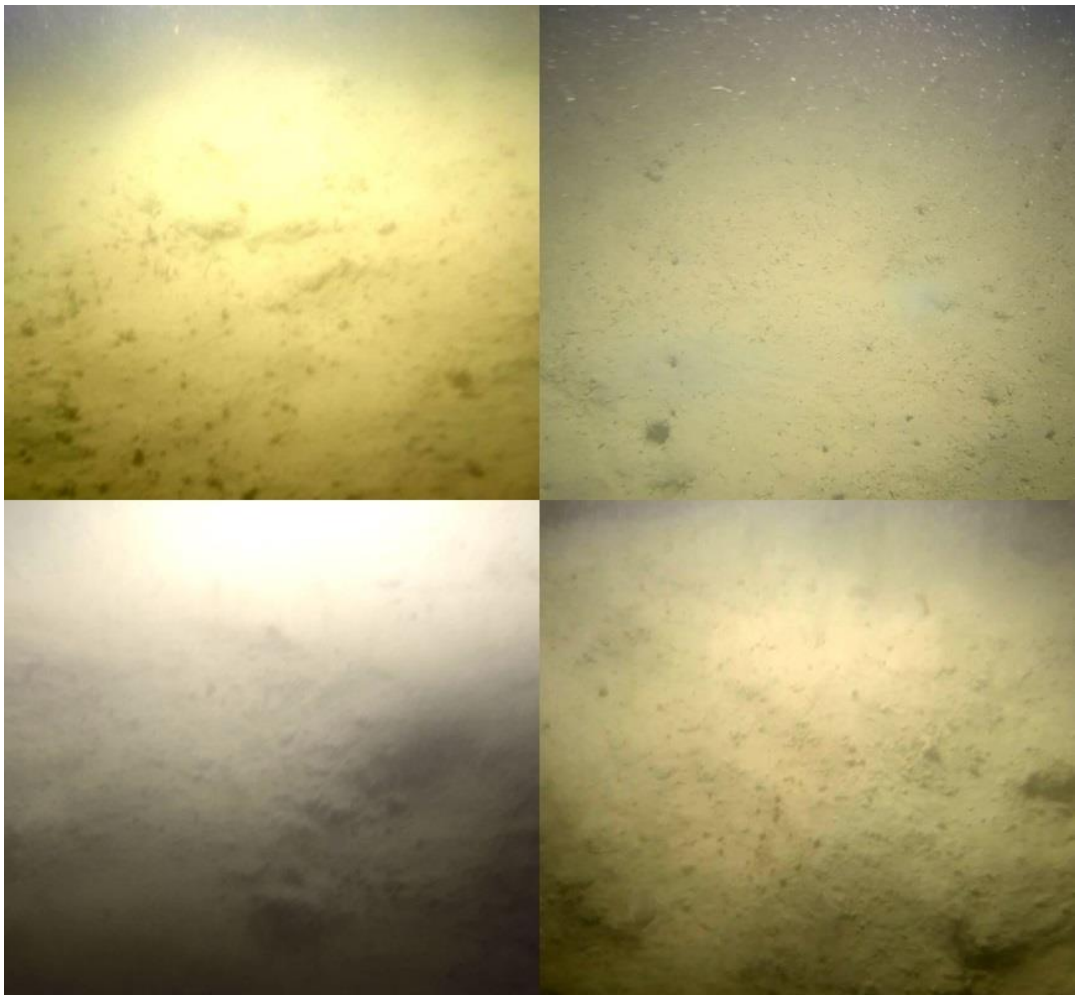


Figure 6-19 Muddy Substrate Dominated by Silts and Clays in Orokolo Bay: sites M4 (upper left), M9 (upper right), M11 (lower left) and M12 (lower right); bioturbation (burrowing) of the seabed is evident

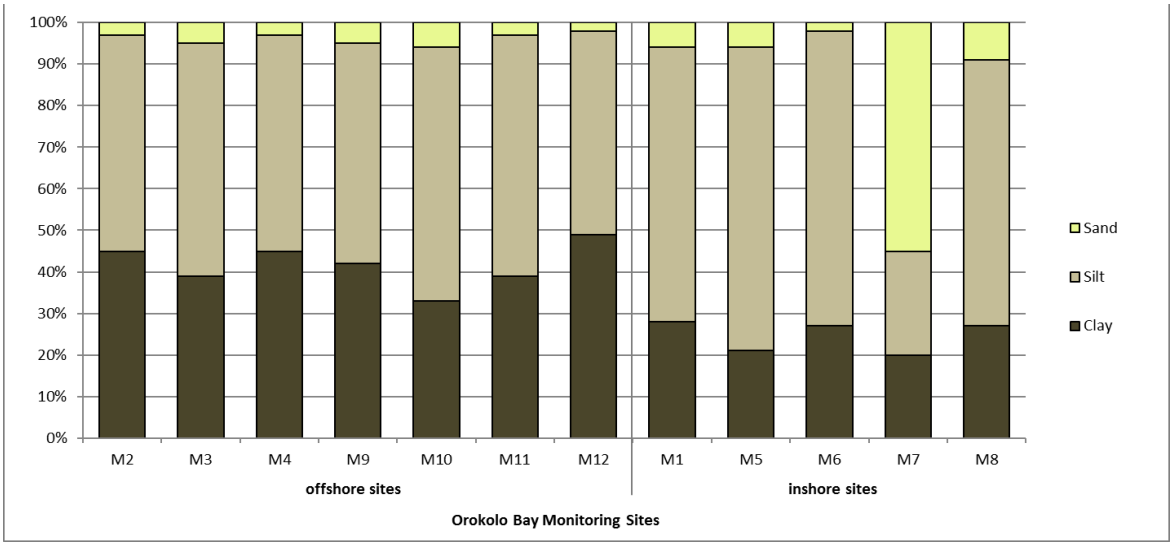


Figure 6-20 Particle Size Distribution Results for Orokolo Bay

There is a longitudinal gradient in sediment types, with higher proportions of silt and sand and less clay closer inshore. The results of acoustic habitat mapping of Orokolo Bay are shown in Figure 6-24 which suggests a general trend for more textured benthos (i.e. greater variability in grain size,

assemblage etc.) in shallower, nearshore environments than in deeper offshore areas. The mapping shows that Orokolo Bay is dominated by soft sediment substrates. The observed variation between offshore and nearshore areas is most likely due to differences in coastal processes (particularly wave resuspension) operating in the region. This is discussed further in the Seabed and Coastal Geomorphology Baseline Report (BMT WBM, 2017c).

6.2.3.2 Offshore Export Pipeline Corridor

The entire length of the corridor consists of fine sediments with moderate to high levels of bioturbation (i.e. burrows formed by infauna and demersal fish). The corridor also had a sparse cover of epibenthic macrofaunal (i.e. animals living on top of the seabed). Video transect data collected at sites M27, M39 and M40 recorded burrowing gobies, crinoids, sponges, sea pens, cerianthid anemones and polychaete worms.

Particle size distribution (PSD) data collected in surface sediments in June-July 2016 (southeast trade winds season) are provided in Figure 6-22. Sediments were generally clayey silts with a small proportion of sand. Site M37 was different to other sites, being dominated by sand and shell grit with lesser amounts of silt and clay. Some examples of substrate along the offshore export pipeline corridor are shown in Figure 6-21. The western segment of the offshore export pipeline corridor passes adjacent to Kerema, where previous unpublished investigations have been undertaken. They documented that in this area the seafloor was composed of a layer of very soft, slightly silty clay and that the area also had rock outcrops surrounded by slightly clayey, slightly sandy gravel, and areas of shallow seafloor depressions. In the present study, sediments at Site M25 at the western end of the offshore export pipeline corridor were clayey silts with a small proportion (<5%) of sand. No rock outcrops were identified along the offshore export pipeline corridor where it passes offshore from the Kerema region.

Near Caution Bay, as water depth becomes more shallow, the seafloor is composed of a slightly silty clay substrate (CNS, 2009). Some areas of rock outcrops may also occur. This substrate type extends to the outer edge of Caution Bay.



Figure 6-21 Benthic Substrates Along the Offshore Export Pipeline Corridor: silt with bioturbation at M28 (upper left); silt and shell grit with bioturbation and feeding polychaetes at M27 (upper right); silt with bioturbation and seapen at M39 (lower left); silt with bioturbation at M41 (lower right)

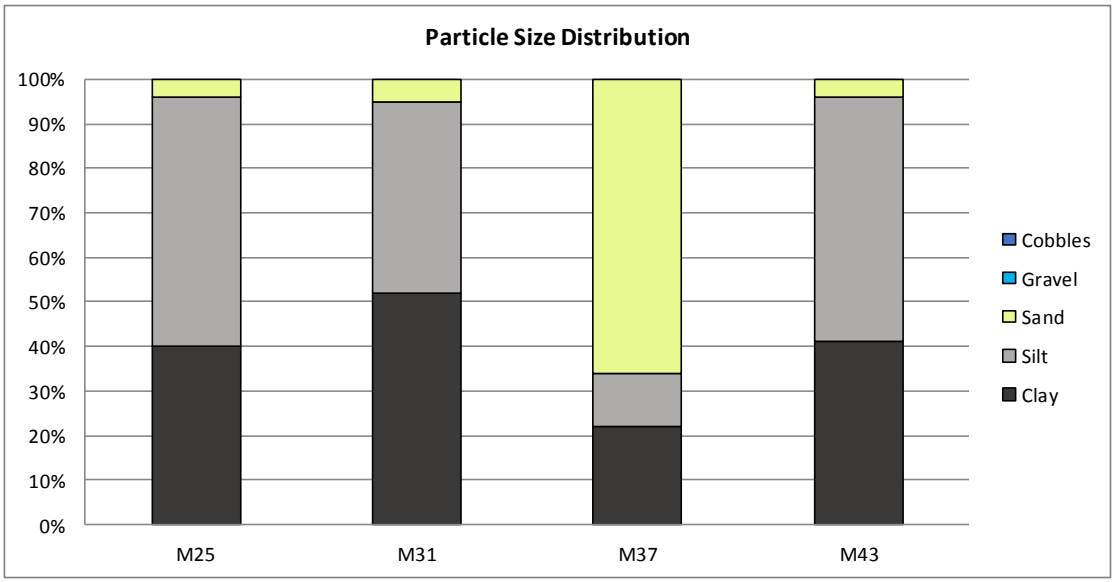


Figure 6-22 Particle Size Distribution Data for Offshore Pipeline Corridor Sites

6.2.3.3 Caution Bay

Intertidal environments in Caution Bay are largely comprised of sandy beaches and small pockets of mud associated with mangrove forests near the Vaihua River estuary. The supratidal zone (above the level of high tide) adjoining this mangrove forest is mostly saltpan mudflats.

The dominant subtidal (below the level of low tide) soft substrate types within Caution Bay are muds and sands, as described in CNS (2009) and verified during the June-July 2016 and January 2017 surveys. These soft sediments occur seaward of the fringing reef and between coral outcrops and shoals. Based on validated acoustic habitat mapping undertaken in January 2017, two main types of substrate are present:

- Substrate mostly composed of fine muds.
- Substrate between reef structures and in shallower environments in the eastern section of Caution Bay – mostly composed of muds with variable quantities of coarse sands, shell grit and/or coral rubble.

Habitat mapping in Caution Bay (described in Section 6.2.2.2 and shown in Figure 6-7) revealed the dominant substrate type to be fine silty muds (Class 1). Other soft sediment areas adjacent to fringing reefs in the east of Caution Bay and between reef structures (Class 2) are also present but tend to be more textured (i.e. greater levels of bioturbation) and to also contain some coarser grains (predominantly sands and/or shell grit) within the sediments. More details on acoustic habitat mapping techniques are provided in Appendix A.

Acoustic survey also indicated sediment distribution consistent with propeller scars west of the LNG facility (Figure 6-10). This may be the result of shipping-related sediment resuspension although this has not been confirmed.

6.2.3.4 Sensitive Ecosystems

Soft sediment habitats within the study area are not considered to be important habitat for any species of *moderate*, *high* or *extreme vulnerability* due to the high level of representativeness of this habitat, noting that many marine species forage in the waters over soft sediment habitats. Certain distinct areas over soft sediment habitat can be more closely linked to particular species, however, as discussed in Sections 6.4.2 and 0.

These areas do not meet the criteria for threatened ecosystems set out by Rodriguez *et al.* (2011) and are not considered to have important intrinsic values.

6.2.4 Pelagic Environments

The pelagic environments of the Gulf of Papua vary in depth, from 5 m along the coast to greater than 100 m offshore in the study area (with even greater depths near the edge of and beyond the continental shelf). They play a crucial role in primary production and nutrient recycling from the photic zone (upper layer of the water column) to the benthos (fauna and flora on the seafloor).

Primary production in pelagic environments of the Gulf of Papua is generated from a combination of autotrophic (photosynthetic, i.e. phytoplankton) and heterotrophic (non-photosynthetic, i.e., microbial) sources. While the relative contributions from autotrophic and heterotrophic producers are thought to shift with seasonal changes and other variables, both groups form important base levels of food webs in the gulf (Robertson *et al.,* 1998; McKinnon *et al.,* 2007). Autotrophic production and chlorophyll-*a* (a surrogate for phytoplankton biomass) levels are typically greater in

waters more heavily influenced by fluvial discharges, primarily due to nutrient inputs from the rivers (Davies, 2004; McKinnon *et al.,* 2007).

There is strong benthic-pelagic coupling in the Gulf of Papua, with detrital input from rivers driving nearshore primary productivity (Robertson *et al.,* 1998). The present study also recorded high numbers of empty planktonic pteropod[5] skeletons in benthic samples along the offshore export pipeline corridor (especially at sites M31, M37 and M45). This detrital material represents a source of food for benthic suspension-feeders and detritivores that dominate the benthos in the study area (see Section 6.2.3), which in turn support demersal fish and shellfish (prawns) of fisheries significance.

Pelagic environments provide habitat to a range of pelagic fish, marine turtles and marine mammals of conservation significance. Furthermore, many fish of direct economic significance are pelagic, as further described in Section 6.4.

Pelagic environments are controlled by fluvial runoff and coastal processes, which are described in relation to the study area in the Upstream Hydrology and Meteorology Baseline Report (BMT WBM, 2017a) and Physical Oceanography Baseline Report (BMT WBM, 2017d). Fluvial influences are also reflected in the water quality conditions, which are discussed further in the Marine Water and Sediment Quality Baseline Report (BMT WBM, 2017e).

6.2.4.1 Sensitive Ecosystems

Due to the continuous nature of pelagic habitats, they are not considered to be relevant habitats in the context of any species with *moderate*, *high* or *extreme vulnerability*. Certain distinct areas within the pelagic environment are utilized by such species, however, as discussed in Sections 6.4.2 and 0, these areas are also not considered to have intrinsic value and are therefore not considered to be sensitive habitats.

6.3 Benthic Macroinvertebrates

Depending on a variety of factors, soft sediment substrate is typically occupied by benthic macroinvertebrates (i.e. invertebrates large enough to be seen with the naked eye that live within sediment). Macroinvertebrates are typically detrivores or suspension feeders. Examples of some of the common macroinvertebrate taxa are shown in Figure 6-23.

[5] Free-swimming pelagic gastropods.

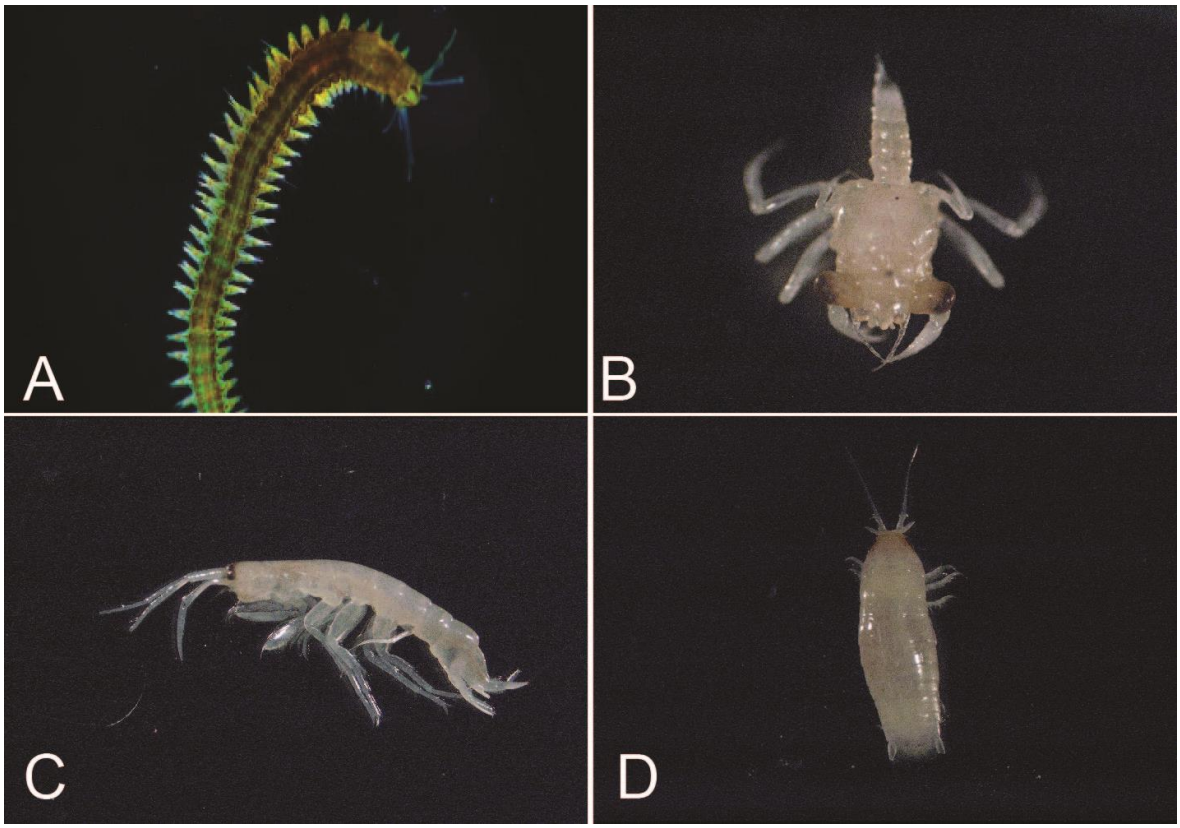


Figure 6-23 Examples of Macroinvertebrate Taxa: polychaete (A); zoea (larval crustacean B); amphipod (C); and cirolanid isopod (D)

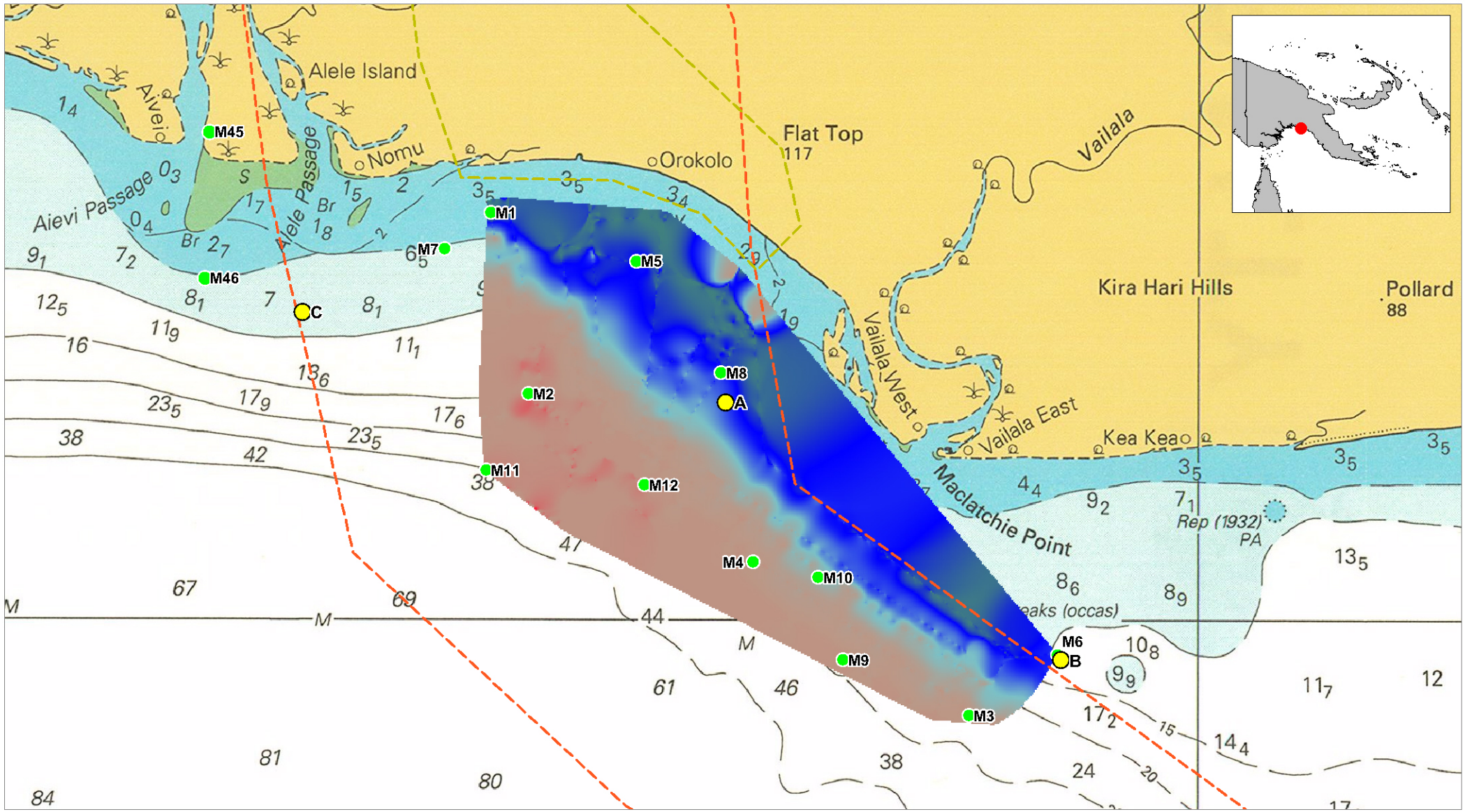
6.3.1 Orokolo Bay

A total of 3,742 individuals from 216 morpho-species were identified in benthic macroinvertebrate samples collected from Orokolo Bay. Benthic assemblages were numerically dominated by three groups of taxa that were abundant in most samples:

- Polychaete worms (82 taxa, 1,295 individuals).
- Decapod crustaceans (24 taxa, 1,390 individuals).
- Amphipod crustaceans (13 taxa, 255 individuals).

The following taxa comprised the remaining individuals: phoronid worms (three taxa 234 individuals); sipunculan worms (five taxa, 99 individuals); gastropod mollusks (20 taxa, 80 individuals), bivalve mollusks (22 taxa, 112 individuals); echinoderms (nine taxa, 21 individuals); tanaicean crustaceans (three taxa, 29 individuals); stomatopod crustacean (four taxa, 13 individuals); isopod crustaceans (four taxa, 10 individuals), cumacean crustaceans (four taxa, five individuals), anthozoans (anemones and soft corals) (seven taxa, 10 individuals); 23 chaetognaths; 24 copepod crustaceans; three hemichordates; ostracods (two taxa, two individuals); one brachiopod; one mysid crustacean; one leptostracan crustacean; one flatworm and one scaphopod mollusk.

Several groups were common and widespread throughout the study area, including decapod crustaceans (the yabby *Callianassa* sp. and crab *Xenophthalmus* sp.), polychaete worms from the genera *Sternaspis, Terebellides, Paraprionospio and Prionospio ehlersi*, and Ampeliscidae amphipods.



LEGEND

- Town/Village
- Sampling and validation sites
- Instrument deployment site
- Pipeline Corridor
- Narrowed Onshore Pipeline Corridor

Benthic Habitat Classes

1. Silty substrate with debris
2. Textured silty mud with 25-30% clay
3. Uniform silty mud
4. Uniform silty clay
5. Higher relief bed structures

Title:

Acoustic habitat mapping results and validation sites

Figure: 6-24

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 4 8

Approx. Scale

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Benthic communities within the study area were characterized as having the following attributes:

- A suite of numerically dominant taxa that was typically common throughout the study area. Figure 6-25 shows that taxa that were abundant also tended to be recorded in the most samples (i.e. were widespread).
- A small number of taxa that were highly abundant. Of the 216 infauna taxa recorded in grab samples in the present study, only a few of these can be considered to be abundant. One species of crab (*Xenophthalmus* sp.) represented 31% of the catch, two other taxa each represented approximately 6% of the catch (a phorid horseshoe worm and the polychaete worm *Sternaspis* sp.), and collectively these three taxa comprised 43% of the catch. High overall taxonomic richness but dominance of a few taxa is also a common feature recorded by others in other sub-tropical and tropical systems in northern Australia (Alongi, 1989; Skilleter, 1998; Currie and Small, 2005).
- A large proportion of uncommon taxa. Sixty seven of the 216 taxa (31%) were singletons, and a further 35 taxa were represented by 70 individuals. Remaining taxa were represented by five or fewer individuals per taxa. The high proportion of uncommon taxa is also a typical feature of benthic communities in other tropical and sub-tropical soft sediment habitats in northern Australia (Alongi, 1989; Currie and Small, 2005).

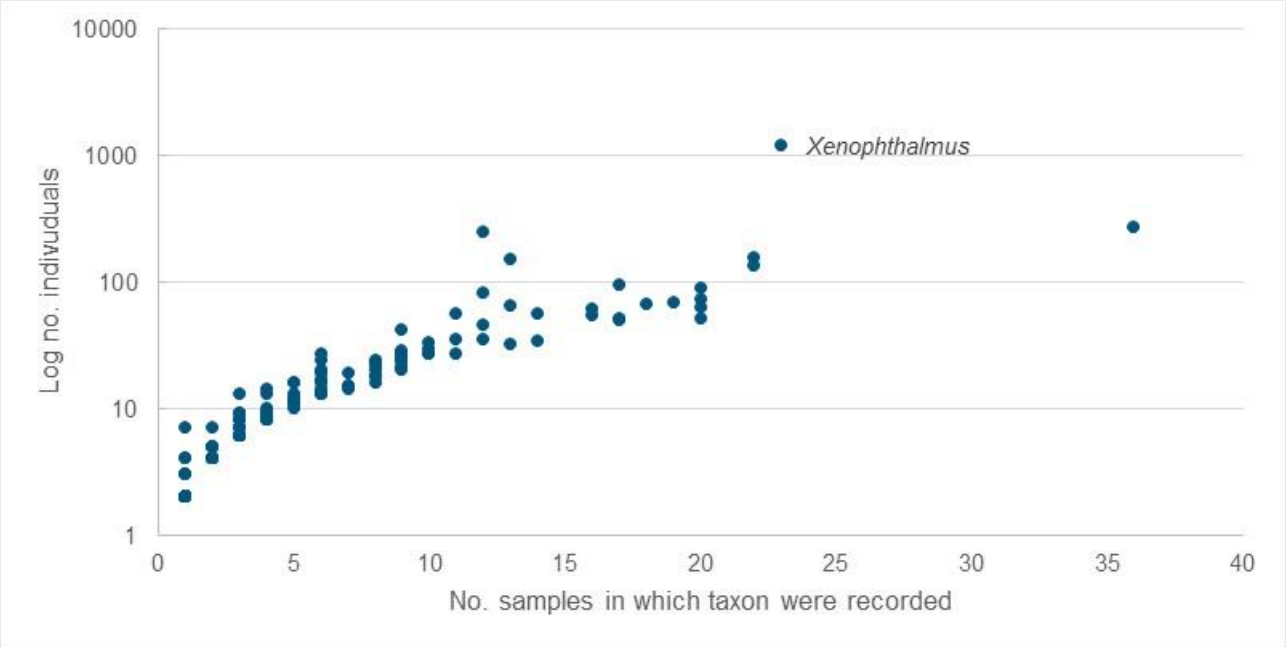


Figure 6-25 Relationship Between Number of Samples in Which Taxon were Recorded and their Total Abundance

Figure 6-26 provides a non-metric multidimensional scaling (nMDS) ordination based on site-averaged data showing patterns in similarity of macroinvertebrate assemblages by locations: 1) offshore (sites with >15 m depth), 2) inshore (sites with <15 m depths) and, 3) nearshore – near mouth (sites within 5 km of the Purari or Vailala river mouths). Sites M45 and M46 nearshore tended to group to the left side of the ordination while offshore sites grouped more to the right. Furthermore, the inshore and nearshore sites (excluding sites M45 and M46) are grouped into clusters, showing a 20% similarity in macroinvertebrate assemblages. Offshore sites M3, M4, M9

and M10 are also grouped into a cluster, with a similarity of 30% in assemblages. These patterns suggest a gradient in assemblage structure with distance from the shore.

Figure 6-27 shows the average taxonomic species richness, abundance, and Shannon's diversity index for each site. Taxonomic richness, abundance and Shannon's diversity index were lowest at nearshore sites M45 and M46 (closest to the Purari River mouth). Overall (Shannon's) diversity was lowest at sites M2, M45 and M46 (see Figure 6-27). The low diversity at Site M2, which was an offshore site located approximately 10 km from the Purari River mouth, was due to the high abundance of *Xenophthalmus* crabs at this site.

Overall, these results show a spatial change in assemblage structure with distance offshore and proximity to river mouth. The depauperate benthic assemblages at the Purari River mouth area is likely due to multiple natural stressors including low and temporally variable salinity, and the physical disturbance and remobilization of bed sediments by waves and fluvial discharges.

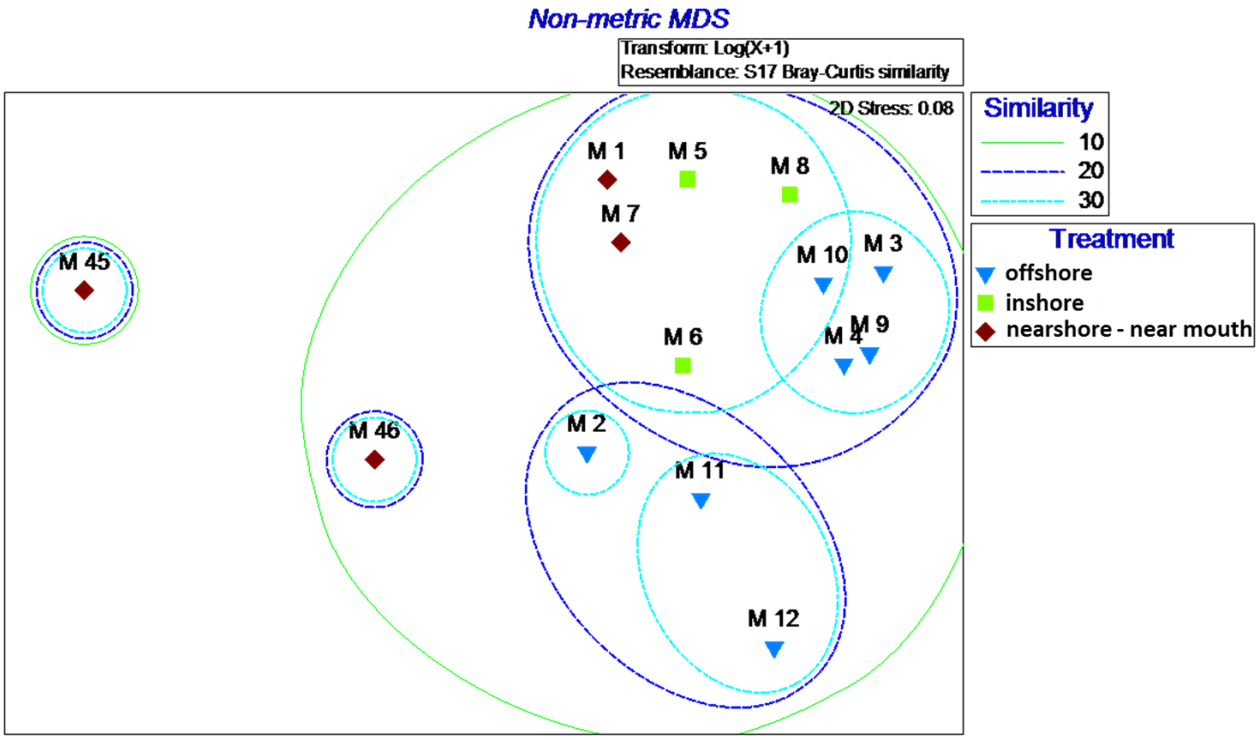


Figure 6-26 nMDS Ordination on Site-averaged Macroinvertebrates Data - Orokolo Bay

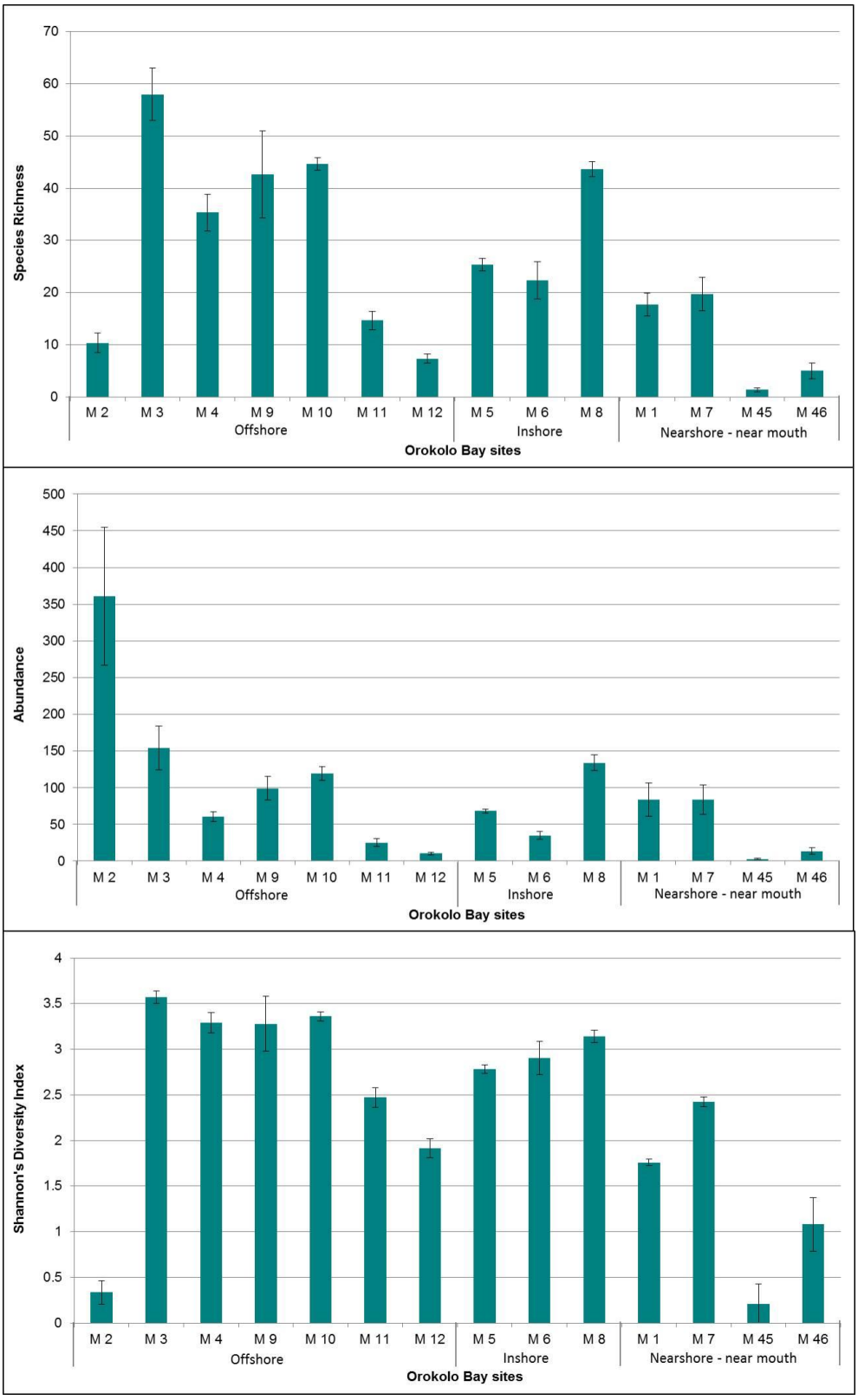


Figure 6-27 Community Metrics for Orokolo Bay Benthic Macroinvertebrates: mean species richness (upper plot), mean abundance (middle plot) and Shannon's diversity index (lower plot). Error bars show standard errors

6.3.2 Offshore Export Pipeline Corridor

Sampling of benthic macroinvertebrates was undertaken as part of the present survey, and previously for the PNG LNG Project EIS (CNS, 2009) and as part of unpublished studies of a corridor between Kerema and Port Moresby. Both the present survey and CNS (2009) identified over 100 morpho-species in the area (181 for June-July 2016 survey, 137 for PNG LNG Project EIS surveys), with polychaete worms and crustaceans (isopods, amphipods, shrimps and crabs) being the most abundant. The Kerema-to-Port Moresby study identified over 170 macroinvertebrate individuals (21 morpho-species) across two locations which were dominated by polychaete worms, crustaceans (tanaids, amphipod), gastropods and thalassinidean shrimps. No species new to science were observed, but many taxa were not able to be identified to species level.

Benthic assemblage metrics generated from the June-July 2016 survey data indicate that taxonomic richness, abundance and Shannon's diversity index were all higher at Site M37 (located due west of Yule Island) than the other three sites sampled along the offshore export pipeline corridor (Figure 6-28). These three sites had similar taxonomic richness, abundance and Shannon's diversity index values. Unlike other sites, sediments at Sites M37 had a higher content of coarse particles (see Figure 6-22), which may in part explain differences in assemblages among sites. It is possible that some of these coarse sediments are derived from nearby reefs at Yule Island, providing greater diversity in sediment grain size and infauna.

Consistent with patterns in nearshore benthic infauna assemblages observed in Orokolo Bay, assemblages had a high proportion of uncommon taxa. Singletons comprised 34 of the 181 taxa (19%), and a further 86 taxa (48%) were represented by five or fewer individuals.

A small number of taxa were also widespread and abundant. The most abundant taxa were heart urchins (7.7% of the catch), the amphipod *Cheiriphotis* sp 1 (5% of the catch), and the polychaete worm *Paraprionospio sp* (3% of the catch).

6.3.3 Caution Bay

Benthic macroinvertebrate sampling undertaken for the PNG LNG Project EIS identified a total of 68 morpho-species in Caution Bay. The majority of these were crustaceans and polychaetes, with lesser numbers of gastropods, bivalves and echinoderms (CNS, 2008b). While the taxa numbers differed across sites, polychaete worms and crustaceans were numerically dominant across all sites (CNS, 2008b).

6.3.4 Sensitive Species

There are no marine benthic macroinvertebrates in Papua New Guinea listed as threatened or trade-restricted, and there is insufficient information on the taxonomy and ecology of PNG marine macroinvertebrates to determine whether locally endemic or restricted-range species occur. Other than ornate rock lobster *Panulirus ornatus* (discussed in Section 6.4.2), no other migratory/congregatory marine benthic invertebrates are known to occur in Papua New Guinea.

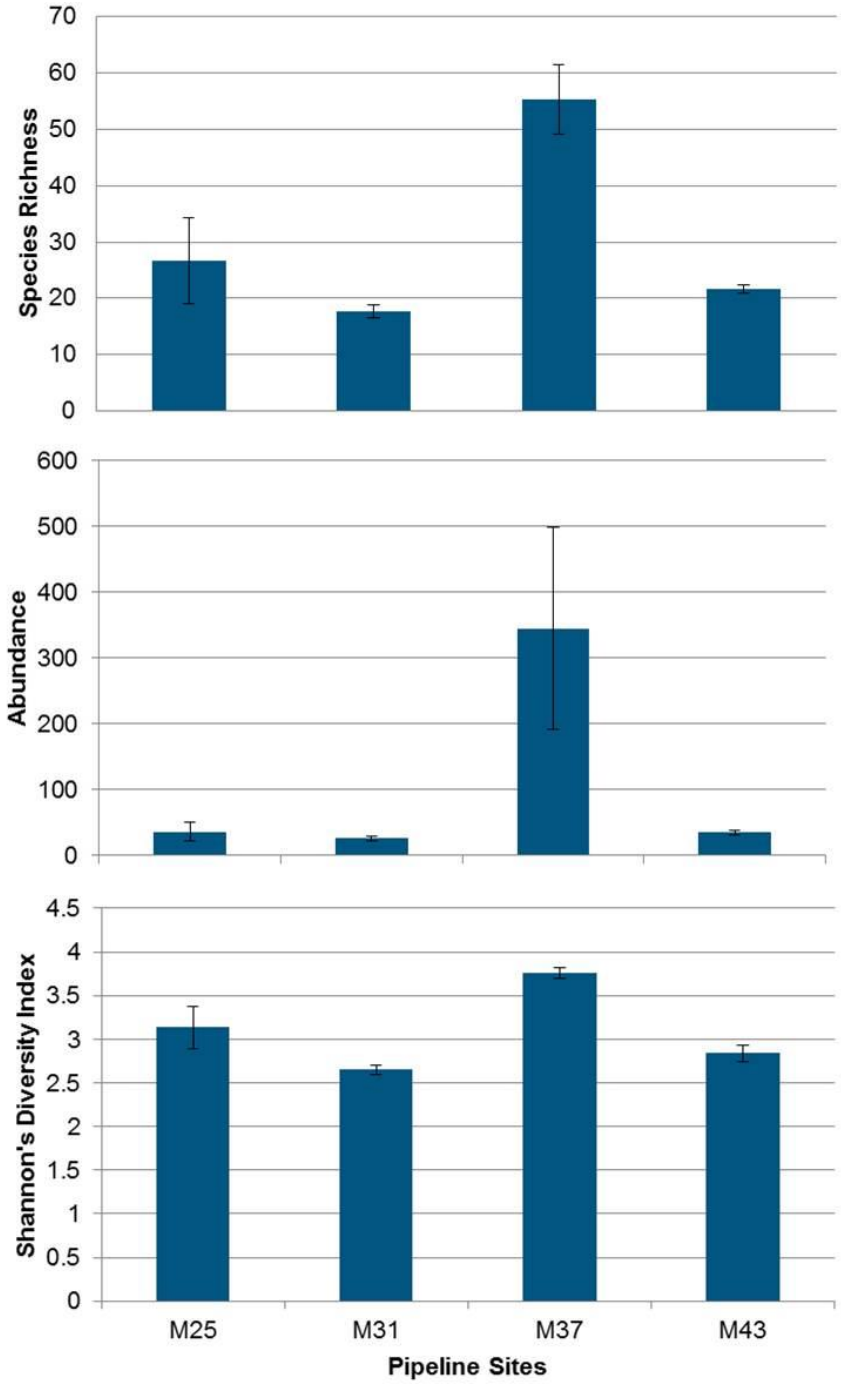


Figure 6-28 Community Metrics for Offshore Export Pipeline Corridor Benthic Macroinvertebrates: mean species richness (upper plot), total abundance (middle plot) and Shannon's diversity index (lower plot). Error bars show standard error.

6.4 Fish and Macrocrustaceans

This section considers the occurrence of fish (bony fish and cartilaginous fish such as sharks and rays) and commercially important prawns in the study area. This is based primarily on scientific literature, databases, bycatch data from commercial fisheries, incidental observations during surveys undertaken by BMT WBM (June-July 2016 and January 2017) and as part of social surveys for the Project, and baited remote underwater video (BRUV) data collected at Caution Bay during the January 2017 field study. Further consideration of significant species for commercial and artisanal fisheries purposes is provided in the Marine Fisheries and Resources Baseline Report (ERIAS Group, 2017b).

6.4.1 Regional Perspective

Most fish (including shellfish such as prawns, crabs, lobsters etc.) use different biotope types throughout their lifecycle. Most demersal fish and shellfish have a two phase or bipartite lifecycle comprised of a pelagic larval stage and a demersal post-larval stage. Following settlement, post-larval stages may also move between biotopes; many fish, prawns and crab species settle in estuarine and nearshore coastal 'nursery habitats', moving into marine waters as adults. Other species can complete their entire lifecycle in offshore demersal or pelagic habitats. For this reason, the following sections describe the key fish assemblages occurring within the Gulf of Papua, before providing specific discussion for coastal areas.

6.4.1.1 All of Study Area

Much of the information on the structure and characteristics of fish (and shellfish) assemblages of the study area is based on commercial fishing data, including bycatch. A national report of bycatch management in Papua New Guinea (REBYC-II CTI, 2013) assessed the bycatch of prawn trawl fisheries in the Gulf of Papua (Gulf Province), Orangerie Bay (Milne Bay Province) and Torres Strait (Western Province). The report identified that the following finfish families numerically dominated by quantity:

- Clupeidae sardines/herrings (20% of total fish catch).
- Leiognathidae ponyfish (15% of total fish catch).
- Engraulidae anchovies (10% of total fish catch).
- Lutjanidae seaperches, snappers, sweetlips and red emperors (8% of total fish catch).
- Mullidae goatfish (4% of total fish catch).

Some of the same families dominate demersal trawl catches in northern Australia (e.g. Tonks *et al.* 2008).

Gulf fish assemblages can vary greatly both spatially and temporally. Kailola and Wilson (1978; in Watson, 1984) found differences in nearshore fish assemblages in areas west and east of Orokolo Bay. The west of Orokolo Bay had a higher percentage of ariids, sciaenids, polynemids, engraulids and harpodontids, while the east was dominated by leiognathids, theraponids, carangids, synodontids, priacanthids and mullids (Kailola and Wilson, 1978). They attributed these differences mostly to habitat conditions; areas to the west had a muddier substrate and were more strongly influenced by fluvial inputs then areas to the east. Watson (1984) found that nearshore fish assemblages around Kerema were generally similar to those described by Kailola and Wilson

(1978), and that differences were likely due to temporal (seasonal) changes in the distribution of key species, and environmental conditions (particularly depth).

The fish assemblage sampled by Watson (1984) encompassed a variety of trophic classes (Table 6-1). Most families (10) captured feed primarily on benthic invertebrates; planktivores and piscivores were also well represented in the catch. The most abundant (by weight) family (Sciaenidae) are demersal species that feed on benthic invertebrates. The second and third most abundant families (Engraulidae, Leiognathidae) have many representatives that are planktivorous, however many Leiognathidae feed predominantly on small benthic invertebrates. Few of the families recorded rely on reefs to complete their lifecycle.

The national report (REBYC-II CTI, 2013) found that approximately 90% of the trawl catch in the Gulf of Papua was bycatch. Of this bycatch, 20% is retained and comprises larger finfish including Mullidae (goatfish), Lutjanidae (seaperch, snapper, sweetlips, red emperor), Serranidae (groupers), Scombridae (mackerel), Carangidae (black pomfret) and Polynemidae (threadfin salmon). Approximately 45% of the discarded marine bycatch includes finfish Clupeidae (sardine/herring), Leiognathidae (ponyfish), and Engraulididae (anchovy).

In addition to these finfish species, a number of shellfish and macrocrustaceans comprise a significant part of the fish biomass within the Gulf of Papua. These consist of the following:

- Banana prawn (*Fenneropenaeus merguiensis)* and Indian banana prawn (*F. indicus*) – inhabit tropical and subtropical coastal and estuarine waters with muddy and sandy bottoms. Banana prawn larvae rely on estuarine nurseries, including mangrove habitats, until they reach maturity and migrate to the ocean.
- Black-tiger prawn (*Penaeus monodon* and *P. semisulcatus*) – inhabit coastal waters to depths of 200 m in muddy and sandy bottoms. Similar to banana prawn larvae, juvenile tiger prawns are found in shallow brackish estuarine waters until they reach maturity and migrate to the ocean.
- Endeavor prawn (*Metapenaeus ensis, M. endeavouri*, and *M. demani*) – inhabit tropical coastal water over sandy and muddy substrates to depths up to 95 m. Juvenile blue endeavor prawn (*M. endeavouri*) rely on seagrass beds in shallow estuaries as nurseries while juvenile red endeavor prawn (*M. ensis*) are widely distributed across seagrass beds, mangrove banks, mud flats and open channels.
- Ornate rock lobster (*Panulirus ornatus*) – migrate annually from northern Torres Strait to the Gulf of Papua to spawning grounds offshore from Yule Island.

These species are considered important commercial fisheries and are discussed in further detail in the Marine Fisheries and Resources Baseline Report (ERIAS Group, 2017b).

Marine fish species (including sharks and rays) that have been identified from previous studies (e.g. Haines (1979), during the June-July 2016 and January 2017 marine biodiversity surveys, or during the upstream social study community surveys for the Project (described in Finlayson, 2017)) are listed in Appendix C. This also includes marine species expected (based on scientific literature, historical observations and habitat suitability) but not confirmed (by surveys) to occur in the area.

Estuarine fish (many of which also occur in the marine biodiversity study area) are also described in the Upstream Freshwater and Estuarine Biodiversity Baseline Report (BMT WBM, 2017b).

Table 6-1 Catch per Unit Effort (CPUE; kg/trawl hr) and Percentage Occurrence in All Samples from East Gulf of Papua Prawn Fishery Bycatch (Watson 1984)

Family	CPUE total	% occur. in samples	Habitat*	Feeding ecology*
Sciaenidae croakers	48.2	100	Demersal – mud or sand bed in coastal and estuarine environments (juveniles)	Mostly small benthic fauna
Engraulidae anchovies	33.7	98	Pelagic – coastal, estuarine	Mostly planktonic feeders
Leiognathidae ponyfish	33.0	91	Demersal – mud or sand bed in coastal and estuarine environments (juveniles)	Mostly small benthic fauna and plankton
Trichiuridae cutlassfish	17.1	98	Bentho-pelagic – coastal and shelf waters	Piscivore (adults), pelagic crustaceans (juveniles)
Synodontidae (Harpodontinae) lizardfish	13.6	71	Demersal – mud or sand, typically in coastal environments	Piscivores
Haemulidae grunts	12.4	42	Demersal – coastal reefs, inshore bays, estuaries	Benthic invertebrates and fish
Mullidae goatfish	11.1	75	Demersal – sand and mud substrates in coastal waters to shelf	Benthic invertebrates
Clupeidae herrings	8.6	75	Pelagic – marine, coastal, estuaries, freshwater	Many are planktivores, some are predators
Theraponidae grunters	6.7	71	Typically demersal – highly variable habitats (coastal, estuarine freshwater)	Typically benthic invertebrates and small fish
Ariidae catfish	6.6	50	Demersal – highly variable habitats (coastal, estuarine freshwater)	Highly variable – omnivores to carnivores
Polynemidae threadfin	4.4	50	Demersal – sand and mud flats, occasionally rivers and estuaries	Typically prawns
Ephippidae spadefish	2.6	38	Pelagic – offshore, coastal, estuarine	Typically invertebrates (pelagic and benthic)
Carangidae jacks	1.8	29	Pelagic to demersal – offshore, coastal and estuarine waters, often around reefs	Typically piscivores
Cynoglossidae tonguefish	1.6	46	Demersal – mud to sand bottoms, estuaries, coastal, offshore	Typically benthic invertebrates
Synodontidae (Synodontinae) lizardfish	1.3	12	Demersal – mud or sand, typically coastal	Piscivores
Priacanthidae bigeyes	<1	8	Epibenthic, typically around reefs	Zooplankton, benthic invertebrates, fish larvae
Other fish	11.6	57	-	-
Non-fish	10.7	96	-	-
Total (Fish)	**225**[6]	-	-	-

*Habitat and feeding ecology data is derived from the FishBase database (https://www.fishbase.org)

[6] Watson (1984) lists the total as 209 kg/trawl hr but it is uncertain what this total is based on.

6.4.1.2 Orokolo Bay and Caution Bay

Marine habitats located at Orokolo Bay, the Purari River mouth and/or Caution Bay, including reefs and seagrass meadows, support finfish species, including species of economic significance. Studies near or in the Purari River delta undertaken by Haines (1979) identified 143 species of fish from 58 different families. All of these families are listed in Appendix C.

The most important area for fish and macrocrustaceans near Orokolo Bay is within the Purari River delta. Many of the fish occurring at Orokolo Bay use the mangroves within the delta for nursery and/or refuge habitat (Haines, 1983). For this reason, a more detailed description of the fish species for Orokolo Bay is provided within the Upstream Freshwater and Estuarine Ecology Baseline Report (BMT WBM, 2017b)

At Caution Bay, studies have been conducted by both CNS in 2008 (CNS, 2009) for the PNG LNG Project EIS and by BMT WBM in June-July 2016 and January 2017.

Studies undertaken for the PNG LNG Project EIS at Caution Bay identified fish from a number of families, predominantly consisting of reef fish (CNS, 2009). Pomacentrid damselfish comprised more than half of all fish observations. Notably absent were larger fish, such as snappers, emperors and sharks. This was suggested by CNS (2009) to be the result of heavy fishing pressures at Caution Bay. Most observations were of small-sized fish (<10 cm in length) with smaller numbers of medium (10 to 20 cm) and larger (>20 cm) fish (CNS, 2009).

Community consultation conducted for the PNG LNG Project EIS indicated potential spawning grounds for coral trout (*Plectropomus leopardus*), hammerhead sharks (Sphyrnidae species) and fingermark bream (*Lutjanus johnii*) along coastal reefs within Caution Bay (CNS, 2009). This was based on reporting of catches of juveniles within the area. However, these three species have not been identified in either the surveys undertaken for the PNG LNG Project or the June-July 2016 and January 2017 surveys.

Baited remote underwater video stations (BRUVS) were deployed to conduct fish surveys during the January 2017 field survey at Caution Bay. A total of 42 fish species (Table 6-2 and Figure 6-29) were identified across three BRUVS located on reefs throughout Caution Bay (see Figure 5-3). Reef fish assemblages were dominated by damselfish (Pomacentridae) and wrasses (Labridae), especially at station BRUV3 (Figure 6-30). Butterflyfish (Chaetodontidae) were also well represented. Representatives from several other families were also identified including squirrelfish (Holocentridae), goatfish (Mullidae), monocle bream (Nemipteridae), triggerfish (Balistidae) and pufferfish (Tetraodontidae).

Reef fish assemblages reported in CNS (2009) were numerically dominated by small to medium bodied species. In the present survey, several larger bodied species were observed including two unidentified trevallies (Carangidae), several snappers (Lutjanidae), groupers/rockcods (Serranidae) and surgeonfish (Acanthuridae). Large schools of fusiliers (Caesionidae) were also observed at station BRUV2 (Figure 6-31).

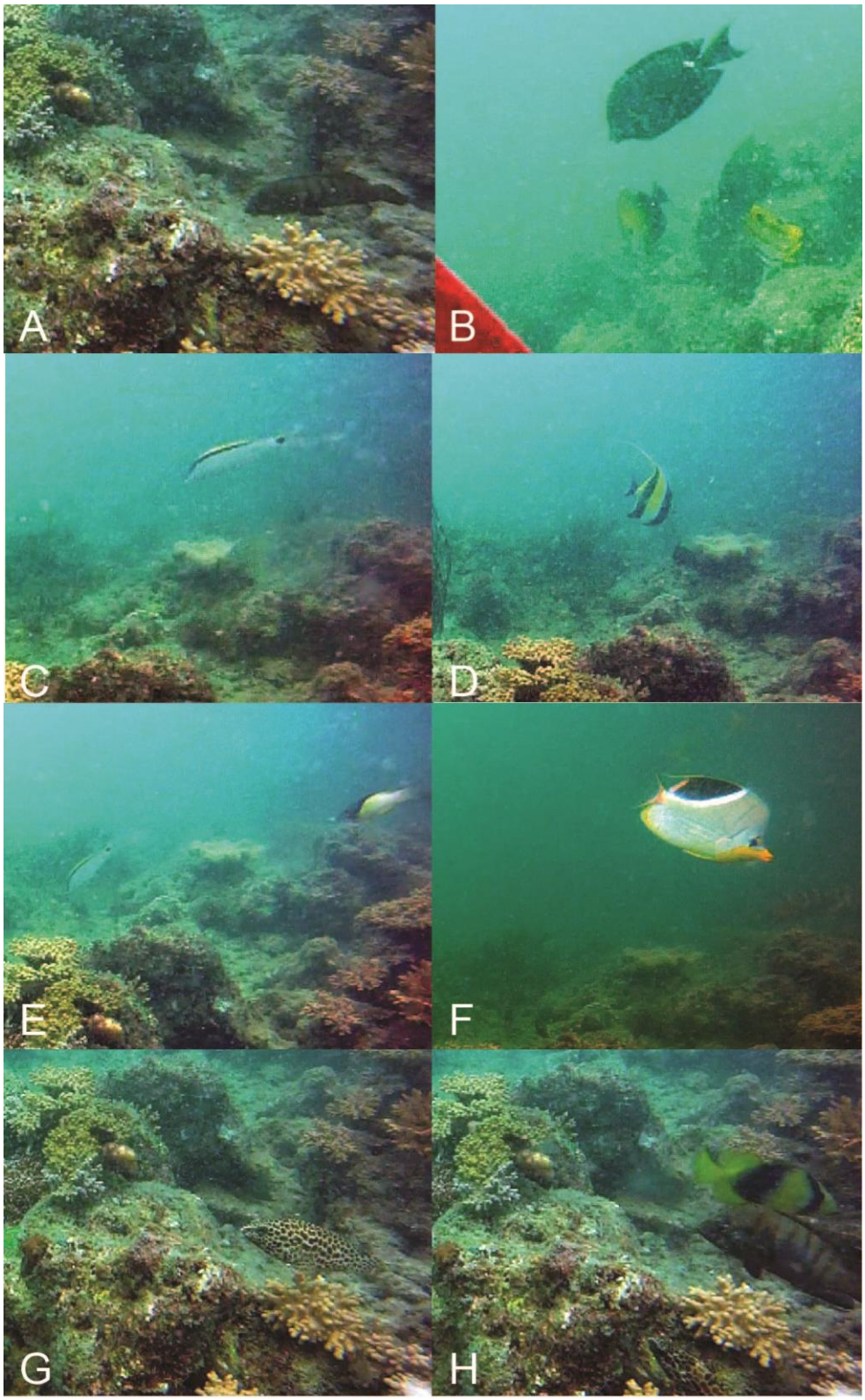


Figure 6-29 Examples of Reef Fish: brown-barred rock cod (*Cephalopholis boenak*) (A); surgeonfishes (Acanthuridae) and beaked coralfish (*Chelmon rostratus*)(B); dot-dash goatfish (*Purapeneus barberinus*) (C); Moorish idol (*Zanculs cornutus*) (D); dot-dash goatfish and hogfish (*Bodianus mesothorax*) (E); saddled butterflyfish (*Chaetodon ephippium*) (F); bird-wire cod (*Epinephelus merra*) (G); brown-barred rock cod and yellow soapfish (*Diploprion bifasciatum*) (H).

Table 6-2 Fish Taxa Observed from BRUVS Deployed at Caution Bay

Family	Species name	Common name	BRUV1	BRUV2	BRUV3
Acanthuridae	Acanthurus leucocheilus	palelipped surgeonfish		✓	
	Acanthuridae 2	surgeon 2		✓	
	Acanthuridae 3	surgeon 3		✓	✓
Balistidae	Balistidae 1	triggerfish 1	✓		
Caesionidae	*Caesio teres*	blue fusilier		✓	
	Pterocaesio marri	bigtail fusilier		✓	
Carangidae	Carangidae 1	unidentified carangid 1	✓		
	Carangidae 2	unidentified carangid 2		✓	
Chaetodontidae	*Chaetodon vagabundus*	vagabond butterflyfish	✓	✓	
	Chaetodon meyeri	saddle butterflyfish		✓	
	Chelmon rostratus	beaked coralfish		✓	
	Coradion sp.	coralfish			✓
	Heniochus acuminatus	longfin bannerfish		✓	✓
	Chaetodontidae 2	butterflyfish 2		✓	
	cf. Chaetodon lineolatus	butterflyfish 3		✓	
	Chaetodon sp.	butterflyfish 4			✓
	Cheatodontid 5	butterflyfish 5			✓
	Cheatodontid 6	butterflyfish 6			✓
Gobiidae	Gobiidae 1	goby 1	✓		
Grammistidae	*Diploprion bifasciatum*	yellow soapfish		✓	
Holocentridae	Holocentridae 1	squirrelfish 1			✓
Labridae	*Bodianus mesothorax*	eclipse pigfish		✓	
	Cheilinus chlorourus	redbreasted maori-wrasse		✓	
	Labroides dimidiatus	blue streak cleaner wrasse			✓
	Thalassoma sp.	wrasse 1		✓	✓
	Labridae 2	wrasse 2		✓	
Lutjanidae	Lutjanidae 1	snapper 1			✓
	Lutjanidae 2	snapper 2			✓
Mullidae	*Parupeneus barberinus*	dash-and-dot goatfish		✓	
Nemipteridae	*Scolopsis* sp.	monocle bream		✓	
Pomacanthidae	*Centropyge bicolor*	bicolour angelfish	✓		
Pomacentridae	*Abudefduf* sp.	sergeant damsel			✓
	Dischistodus chrysopoecilus	whitepatch damsel			✓
	Dischistodus perspicillatus	white damsel			✓
	Neopomacentrus violascens	violet damoiselle		✓	✓
	Pomacentrus nigromanus	goldback damsel		✓	
	Chromis sp.	puller 1		✓	✓

Family	Species name	Common name	BRUV1	BRUV2	BRUV3
	Pomacentridae 1	damsel 1			✓
	Pomacentridae 2	damsel 2		✓	✓
Serranidae	*Cephalopholis boenak*	brownbarred rockcod		✓	
	Epinephelus merra	birdwire rockcod	✓	✓	
	Serranidae 1	grouper 1			✓
Tetraodontidae	*Arothron* sp.	puffer 1		✓	
Zanclidae	*Zanclus cornutus*	Moorish idol		✓	

Species richness and abundance was quantified for each BRUV station data based on standardized unit effort (25 minutes of video). Station BRUV1 had the lowest richness and abundance overall while stations BRUV2 and BRUV3 had similar richness and maximum abundance (Figure 6-32). The time taken before the first observation was also greater at station BRUV1 than other sites (Figure 6-33), which is likely related to the lower abundance at this station compared with others. Stations BRUV2 and BRUV3 were both located on high relief reef structures which appear to have greater fish numbers and richness. Station BRUV1 was located on a rubble slope adjacent to the reef edge near Idihi Island, which represented more simplified structural habitat conditions than at stations BRUV2 and BRUV3.



Figure 6-30 Fish Assemblages at Station BRUV3



Figure 6-31 Large Schools of Bigtail Fusiliers (*Pterocaesio marri*) at Station BRUV2

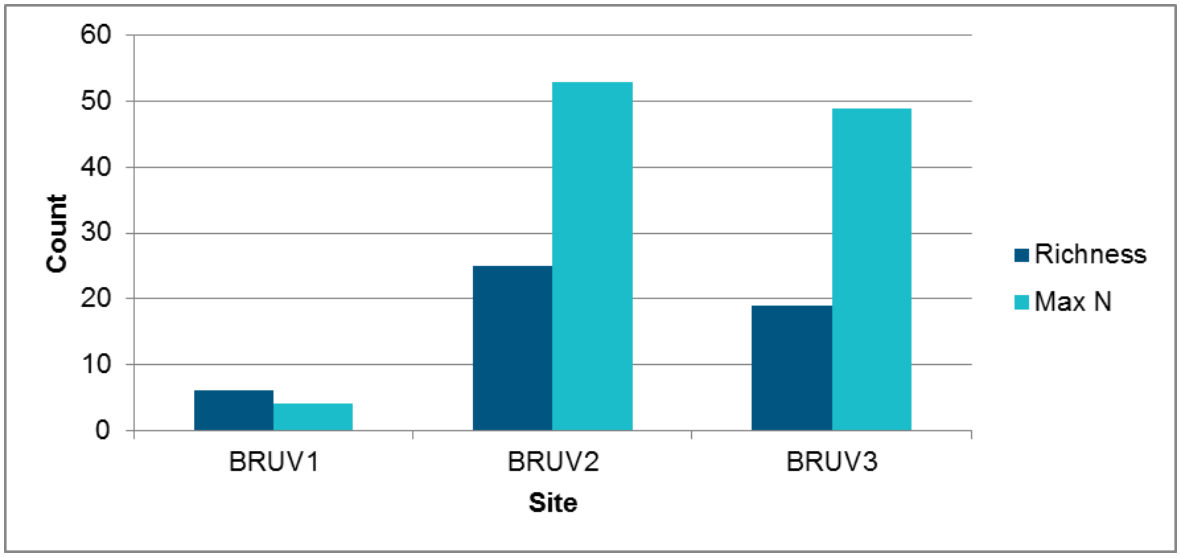


Figure 6-32 BRUVS Metrics Including Species Richness (S) and Maximum Abundance (Max N)

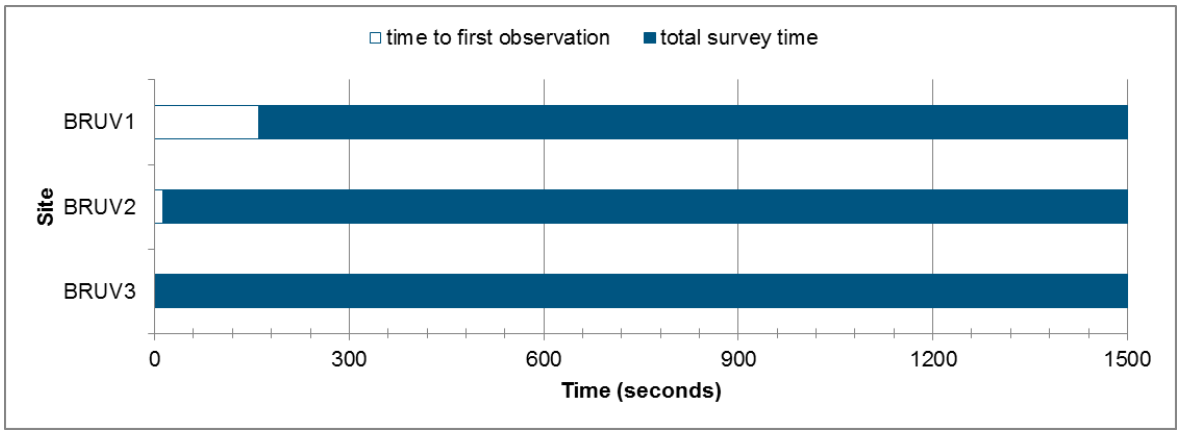


Figure 6-33 Time (seconds) Prior to First Observations Made at Each BRUVS

At Orokolo Bay, a single observation of a breaching mobula or manta ray (family Mobulidae) was made during the June-July 2016 survey (Site M1), and a hardnose shark was observed during drop camera validation at Site M9 (Figure 6-34). Several fish were also observed during drop camera at Site M6, including two snappers (Lutjanidae; see Figure 6-8) and several gobies (Gobiidae).



Figure 6-34 *cf*. Hardnose Shark (*Carcharhinus macloti*) at Site M9

6.4.2 Sensitive Species

The prioritization of values based on marine fish and macrocrustacean species includes an assessment and sensitivity rating of individual threatened/important species, based on the categories set out in Section 5.6.3, and the identification of sensitivity value of habitat features based on these species and other criteria in Section 5.7.2. A discussion of threatened/important species is provided below (summarized in Table 6-3) while the sensitivity of habitat features is discussed in Section 6.6.

The following fish and macrocrustacean species are likely to occur within parts of the study area and are considered to be threatened/important (grouped based on principle criteria):

IUCN Threatened

- Largetooth sawfish (*Pristis pristis*).
- Green sawfish (*Pristis zijsron*).
- Narrow sawfish (*Anoxypristis cuspidata*).
- Speartooth shark (*Glyphis glyphis*).
- Northern river shark (*Glyphis garricki*).
- Bull shark (*Carcharhinus leucas*).
- Hardnose shark *Carcharhinus macloti*).
- Papuan epaulette shark (*Hemiscyllium hallstromi*).
- Winghead shark (*Eusphyra blochii*).
- Giant shovelnose ray (*Glaucostegus typus*).
- Spotted eagle ray (*Aetobatus narinari*).
- Giant manta ray (*Manta birostris*).
- Reef manta ray (*Manta alfredi*).
- Pygmy devilray (*Mobula eregoodootenkee*).
- Narrow-barred Spanish mackerel (*Scomberomorus commerson*).
- Orange-spotted grouper (*Epinephelus coioides*).
- Brown-marbled grouper (*Epinephelus fuscoguttatus*).
- Deepwater redfish (*Actinopyga echinites*).
- Surf redfish (*Actinopyga mauritana*).
- Hairy blackfish (*Actinopyga miliaris*).
- White teatfish (*Holothuria fuscogilva*).
- Golden sandfish (*Holothuria lessoni*).
- Black teatfish (*Holothuria nobilis*).
- Sandfish (*Holothuria scabra*).
- Curryfish (*Stichopus hermannii*).
- Prickly redfish (*Thelenota ananas*).

Endemic/Restricted-Range

- Papuan seerfish (*Scomberomorus multiradiatus*).

Migratory/Congregatory

- Ornate rock lobster (*Panulirus ornatus*).

NOTE: The following species and/or species groups that may otherwise qualify against the threatened/important species categories have been excluded from further assessment based on the reasons provided:

- Dwarf sawfish (*Pristis clavata*). This species historically occurred within the study area but is now considered extinct within this area and restricted to northern Australia (Kyne *et al.* 2013b).
- Schooling species. Langhammer *et al.* (2007) defines congregatory species as "species that gather in globally significant numbers at a particular site and at a particular time in their life cycle for feeding, breeding or resting (during migration)." Many marine species aggregate in schools, but with the exception of ornate rock lobster *Panulirus ornatus* (discussed below), no other fish or invertebrate species are known to qualify as congregatory species in accordance with the above definition.

***Pristis pristis*[7] – largetooth sawfish**

Nationally-listed	× Not listed
Trade-restricted	✓ Appendix I
IUCN threatened	✓ Critically Endangered
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Juveniles expected to migrate from freshwater reaches of rivers to estuarine and marine waters at 4-5 years of age. Listed under Bonn Convention
Overall vulnerability	***Extreme vulnerability***

Haines (1979) recorded this species (as *P. microdon*) as 'common' at two nearshore sites: Orokolo Bay and offshore of western Purari River delta (near Port Romilly). This represents the occurrence of 5-10 individuals in each standard catch, suggesting a high level of abundance of the species at this time. Haines also found the species in the freshwater and estuarine areas of the Purari and Kikori rivers. Based on the known lifecycle of the species, species found within nearshore and offshore environments are expected to be adults while juveniles and sub-adults, up to 4-5 years of age, occur within freshwater and estuarine environments (Steven *et al.* 2005). The occurrence of the species in freshwater and estuarine environments is discussed further in the Upstream Freshwater and Estuarine Biodiversity Baseline Report (BMT WBM, 2017b).

In addition to historical sightings at Orokolo Bay and the Purari River delta, the Upstream Land and Natural Resources Baseline Report (Booyong Forest Science, 2017; Part 18 of ESBS Dossier) recorded the importance of sawfish to artisanal fishing activities at coastal and estuarine environment in this area. This may include *P. pristis*, indicating the ongoing occurrence of this species.

Within offshore waters, individuals occur to depths of up to 25 m (Stevens *et al.* 2005). Individuals are noted to have high fidelity to an area, generally occurring within small areas (a few square kilometers) that are close to the coastal fringe (Stevens *et al.* 2008). Movements are often linked to tidal influences: during high tide, in areas adjoining mangroves, individuals rest within inundated vegetation; on the moving tide, individuals are more active and feed on mud and sand flats (Stevens *et al.* 2008).

[7] Previously recorded as *Pristis microdon*

The principle threat to the largetooth sawfish is net fishing, particularly the use of gill nets (Kyne *et al.* 2013a; DoEE, 2017b). This is due to the long-toothed rostrums of sawfish. While gill-netting does occur within the study area, no high intensity fisheries based on gill-netting is known to occur – see Marine Fisheries and Resources Baseline Report (ERIAS Group, 2017b) and Upstream Land and Natural Resources Baseline Report (Booyong Forest Science, 2017). Artisanal fisheries along the Orokolo Bay coast and at Caution Bay may target this species within the marine and estuarine environments.

Historical fishing pressures at Caution Bay have been higher than those at Orokolo Bay due to a higher population intensity. Resource use surveys conducted in the area for the PNG LNG Project EIS did not note the use of sawfish as part of artisanal fishing in this area, and it was suggested that it no longer occurs or only in very limited numbers (CNS, 2008c).

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Likely***, based on historical observations by Haines (1979) and continued habitat suitability.
- Offshore export pipeline corridor – ***Possible***, but restricted to areas with a depth less than 25 m.
- Caution Bay – ***Unlikely***, due to historical fishing pressure.

***Pristis zijsron* – green sawfish**

Nationally-listed	× Not listed
Trade-restricted	✓ Appendix I
IUCN threatened	✓ Critically Endangered
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Listed under Bonn Convention
Overall vulnerability	***Extreme vulnerability***

The green sawfish commonly occurs in shallow coastal and estuarine waters over muddy bottom habitats but is also known to depths up to 70 m (Stevens *et al.* 2005). Tracking studies undertaken by Peverell and Pillans (2004) and Stevens *et al.* (2008) indicate that individuals tend to occur across a small strip of shallow water to depths of less than 2 m. While little is known about species lifecycle, pupping is known to occur in inshore waters (Stevens *et al.* 2005).

Green sawfish have not been confirmed within the study area but village surveys undertaken for the Upstream Land and Natural Resources Baseline Report (Booyong Forest Science, 2017) indicate the presence of sawfish species at Orokolo Bay and the Purari River delta. This may indicate individual green sawfish.

Green sawfish are long-lived but have low fecundity and late maturation, increasing the susceptibility of the species to anthropogenic mortality (Stevens *et al.* 2005). This also reduces ability of the species to recover from impacts. Similar to the largetooth sawfish, the green sawfish is highly threatened by fishing activities, particularly gill-netting and trawling. However, unlike the largetooth sawfish, the green sawfish does not utilize large river systems as adults and therefore are more likely to be impacted by the commercial fisheries operating within the Gulf of Papua – see Marine Fisheries and Resources Baseline Report (ERIAS Group, 2017c). In addition, monitoring of the species in Australia suggest a link between species decline and habitat degradation associated with anthropogenic settlements (DoEE, 2017c).

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Possible***, based on habitat availability.
- Offshore export pipeline corridor – ***Unlikely***, due to preference for shallow habitat.
- Caution Bay – ***Unlikely***, due to historical fishing pressure.

***Anoxypristis cuspidata* – narrow sawfish**[8]



Nationally-listed	×	Not listed
Trade-restricted	✓	Appendix I
IUCN threatened	✓	Endangered
Endemic and/or restricted-range	×	Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓	Juveniles utilize inshore and estuarine waters before moving into deeper waters offshore as adults. Listed under Bonn Convention
Overall vulnerability	***Extreme vulnerability***	

The narrow sawfish occurs within marine waters to a depth of 40 m, occurring predominantly near the bottom but also known to occur in the mid-water column (GBRMPA, 2012). Juveniles and pumping females utilize inshore and estuarine waters, although these areas may also be used occasionally by adults (D'Anastasi *et al.* 2013). The species is known to have a higher intrinsic rate of population increase compared to other sawfish species, allowing it to persist across most of its historical range (D'Anastasi *et al.* 2013).

Distribution mapping of the species indicates that it occurs across the coastal fringe of New Guinea, Indonesia and the Gulf of Carpentaria (Australia). Exchange of individuals between different areas does not seem to occur, suggesting that the population of New Guinea can be considered separate to those of other areas (Faria *et al.* 2013).

While the species has not been confirmed during fishing surveys as part of the current study or the Purari River (Wabo) Hydroelectric Scheme EIS, a specimen was identified based on photographs of fish catch taken during Orokolo Bay coastal village surveys in 2016. Surveys with villagers indicate that sawfish species are regularly caught in coastal and estuarine areas of Orokolo Bay, which may indicate the abundance of this species in this part of the study area. See further Upstream Land and Natural Resources Baseline Report (Booyong Forest Science, 2017).

As for other sawfish species, the toothed rostrum of the narrow sawfish makes them susceptible to net-based fishing activities (D'Anastasi *et al.* 2013). The species is known to be targeted by

[8] Photo taken during 2016 Orokolo Bay coastal village surveys

artisanal fishing in Orokolo Bay but may also be caught as by-catch in trawling activities further offshore. As juveniles of the species occur within estuarine waters, gill-netting within these areas also are a threat to the species, though as noted above, high-intensity gill-netting is not known to have occurred throughout estuarine waters of the study area. D'Anastasi (2010) suggest that localized depletions in populations may not be replenished by adjacent stocks due to the presence of distinct genetic stocks, increasing the susceptibility of localized 'collapses' of species population.

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Known***, based on recent sightings.
- Offshore export pipeline corridor – ***Possible***, but only in waters with depth less than 40 m.
- Caution Bay – ***Unlikely***, due to historical fishing pressure.

***Glyphis glyphis*[9] – speartooth shark**

Nationally-listed	× Not listed
Trade-restricted	× Not listed
IUCN threatened	✓ Endangered
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	× Species does not migrate or congregate
Overall vulnerability	***Extreme vulnerability***

During surveys for the Purari River (Wabo) Hydroelectric Scheme EIS, Haines (1979) identified *Carcharhinus glyphis* (now *Glyphis glyphis*) is the Kikori and Era rivers but not at Orokolo Bay. The occurrence of this species was noted at 'rare', consisting only of occasional individuals. Based on sightings by White *et al.* (2015) in 2014 in coastal waters of Daru, the species still occurs within the Gulf of Papua. This was the first confirmed sighting since Haines (1979).

This species was not identified during the marine surveys conducted in June-July 2016 and January 2017. However, based on habitat availability and previous sightings in the western gulf, this species is still considered likely to occur in the coastal waters near the Purari River.

With some exceptions, almost all sightings of the species have been within freshwater and estuarine environment, rather than in marine waters (Compagno *et al.* 2009). While the species is expected to be euryhaline (i.e. can occur in and travel between freshwater and marine environments) it is likely to be restricted to nearshore areas (Stevens *et al.* 2005). Investigations of the eyes of individual sharks indicate that it is likely to be a fish eater adapted to living in turbid waters with poor visibility (Compagno *et al.* 2009).

Similar to *Pristis* species, the speartooth shark is threatened by fishing activities, particularly as by-catch in gill-netting for species such as barramundi (*Lates calcarifer*) and as part of recreational line-fishing (DoEE, 2017a). Habitat degradation/modification from anthropogenic influences is also a threat to the species. Compagno *et al.* (2009) also note the tailings discharge from the Ok Tedi mine into the Fly River as a threat to the population occurring within this area.

On the basis of the above information, the following occurrence is noted for the study area:

[9] Previously recorded as *Carcharhinus glyphis*

- Orokolo Bay – ***Likely***, based on sightings in the western gulf (White *et al.* 2015) and habitat suitability in study area, especially immediately adjacent to Purari River delta.
- Offshore export pipeline corridor – ***Unlikely***, due to depth.
- Caution Bay – ***Unlikely***, due to water quality.

***Glyphis garricki/gangeticus*[10] – northern river shark**

Nationally-listed	×	Not listed
Trade-restricted	×	Not listed
IUCN threatened	✓	Critically Endangered
Endemic and/or restricted-range	×	Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	×	Species does not migrate or congregate
Overall vulnerability	***Extreme vulnerability***	

Haines (1979) recorded *Carcharhinus gangeticus* as occurring in the lower mangrove systems of the Kikori and Era rivers with a 'rare' abundance (i.e. occasional individuals only). *Carcharhinus gangeticus* is a synonym for *Glyphis gangeticus,* which is known only from the lower reaches of the Ganges-Hooghli river system, India (Compagno, 2007). Due to the uncertainty in Haines' identification, it is considered more likely that this record relates to the northern river shark (*G. garricki*) which is known from the Fly River (Compagno, 2002), and the coastal waters of Daru (White *et al.* 2015). Pogonoski and Pollard (2003) note that *G. garricki* is very difficult to distinguish from other *Glyphis* species, with accurate identifications requiring the use of x-rays of the vertebral column (see Taniuchi *et al.* 1991).

Little is known about the ecology of the northern river shark, except that it has been recorded in shallow marine, estuarine and freshwater environments over muddy substrate. It appears to have similar habitat requirements to *G. glyphis*.

Similar to *Pristis* species and *G. glyphis*, the northern river shark is threatened primarily by fishing activities, including recreational and commercial fishing using gill nets and long-lines (Pogonoski and Pollard, 2003).

Assuming a similar occurrence to *G. glyphis*, the following is noted for this species:

- Orokolo Bay – ***Possible***, based habitat suitability in study area, especially immediately adjacent to Purari River delta.
- Offshore export pipeline corridor – ***Unlikely***, due to depth.
- Caution Bay – ***Unlikely***, due to water quality.

Carcharhinus leucas* – bull shark and *C. macloti

Nationally-listed	×	Not listed
Trade-restricted	×	Not listed
IUCN threatened	✓	Near Threatened
Endemic and/or restricted-range	×	Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2

[10] Previously recorded as *Carcharhinus garricki/gangeticus*

Migratory and congregatory	× Species does not migrate or congregate
Overall vulnerability	***Moderate vulnerability***

Both the bull and hardnose sharks occur across the continental shelf (up to depths of 150 m), commonly within nearshore areas (Simpfendorfer and Burgess, 2009; Simpfendorfer and Stevens, 2003). The bull shark is capable of occurring within both freshwater and marine environments while the hardnose shark is more restricted to marine and estuarine waters. Typically, adults occur in offshore waters before moving into estuarine waters to give birth to their young (Simpfendorfer and Burgess, 2009; Simpfendorfer and Stevens, 2003). The bull shark commonly returns to estuarine areas. Juvenile sharks use estuarine habitats as nursery areas before travelling back out to sea.

Haines (1979) recorded bull sharks within the Purari, Vailala, Era and Kikori rivers, suggesting the presence of adult sharks within the coastal waters of the Gulf of Papua. The species is also expected to occur along the continental shelf within most of the gulf.

During the present field survey, a hardnose shark was observed at Caution Bay based on drop camera footage. On the basis of this presence, the species is also expected to occur across the Gulf of Papua.

The principle threats to both sharks are fishing and conversion of estuarine/freshwater nursery habitat (Simpfendorfer and Burgess, 2009). However, the species is known to proliferate in some artificial waterway environments, such as canals.

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Likely***, based on habitat suitability.
- Offshore export pipeline corridor – ***Likely***, based on habitat suitability.
- Caution Bay – ***Likely*** (bull shark), based on habitat suitability, and ***Known*** (hardnose shark) based on recent sightings.

***Hemiscyllium hallstromi* – Papuan epaulette shark**

Nationally-listed	× Not listed
Trade-restricted	× Not listed
IUCN threatened	✓ Vulnerable
Endemic and/or restricted-range	✓ Species expected to be endemic to Gulf of Papua and Southeast Papua New Guinea ecoregions
Migratory and congregatory	× Species does not migrate or congregate
Overall vulnerability	***High vulnerability***

The Papua epaulette shark is expected to have a geographic distribution restricted to the Gulf of Papua and the southeast coastline of Papua New Guinea (Dudgeon *et al.* 2016). Based on this distribution, it is considered to be an endemic species. Most records of the species appear to be from the Port Moresby region.

Epaulette sharks occur within shallow coastal waters, and are usually associated with seagrass beds and coral outcrops (Dudgeon *et al.* 2016). Little else is known about the occurrence or biology of the species. Based on congeners (i.e. species of the same genus) that occur elsewhere, individuals are likely to occur only in waters less than 30 m deep.

The principle threats to this species, as listed by Dudgeon *et al.* (2016) are commercial and artisanal fisheries, especially where targeting reef communities, runoff from coastal development

and urban areas causing the discharge of pollutants and sedimentation into coastal waters, dynamite fishing, and oil exploration and pipeline development. It is considered likely that this species is currently or historically exploited as part of artisanal fisheries at Caution Bay (cf. CNS, 2008c) and may also form part of the by-catch of the trawl fisheries in the Gulf of Papua.

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Unlikely***, based on lack of coral reefs and seagrass.
- Offshore export pipeline corridor – ***Unlikely***, based on lack of coral reefs and seagrass.
- Caution Bay – ***Likely***, based on habitat suitability.

***Eusphyra blochii* – winghead shark**[11]



Nationally-listed	× Not listed
Trade-restricted	× Not listed
IUCN threatened	✓ Endangered
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	× Species does not migrate or congregate
Overall vulnerability	***Extreme vulnerability***

Winghead sharks have been confirmed within the study area based on fish catches observed during 2016 Orokolo Bay coastal village surveys (see Booyong Forest Science, 2017). This species is mainly found in coastal nearshore waters, typically with a distribution of less than 50 km^2 (Smart and Simpfendorfer, 2016) but has been observed within deeper waters, up to the edge of the continental shelf (Lyle, 1989). There is little information about the habitat requirements of the species but it does not appear to require estuarine systems for reproductive activities.

The principle threat to winghead sharks is fishing pressures, especially associated with gill-netting and trawling (Smart and Simpfendorfer, 2016). This includes fisheries targeting the species as well as by-catch. Pressures appear to have caused significant declines in Asian waters. While there is no longer a shark fishery within the Gulf of Papua, sharks make up a significant component of trawl fishery bycatch (ERIAS Group, 2017c). This is expected to include *E. blochii*. As noted in village interviews at Orokolo Bay, this species is also subject to ongoing exploitation in artisanal fisheries (Booyong Forest Science, 2017).

[11] Photo taken during 2016 Orokolo Bay coastal village surveys

During resource use surveys at Caution Bay it was reported that hammerhead sharks were caught as part of artisanal fisheries (CNS, 2008c). This may include *E. blochii* and is consistent with the habitat availability in this area.

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Known***, based on recent sightings.
- Offshore export pipeline corridor – ***Likely***, due to habitat suitability.
- Caution Bay – ***Likely***, based on habitat suitability.

***Glaucostegus typus* – giant shovelnose ray**

Nationally-listed	× Not listed
Trade-restricted	× Not listed
IUCN threatened	✓ Vulnerable
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	× Species does not migrate or congregate
Overall vulnerability	***High vulnerability***

Haines (1979) identified giant shovelnose rays[12] at two marine sites during surveys for the Purari River (Wabo) Hydrolectric Scheme EIS: Orokolo Bay and offshore of the Purari River delta near Port Romilly. Rays were identified as normally present but not abundant, representing 1 to 4 individuals within each catch. Based on case studies elsewhere, juvenile *G. typus* are known to occur in inshore environments, such as mangrove systems and estuaries, and around atolls, whilst adults are found in the deeper waters of the continental shelf to about 100 m (Last and Stevens 1994).

White and McAuley (2016) note the following major threats to the species:

- Market for *G. typus* fins, leading to targeted fishing as well as removal of fins of individuals caught in by-catch.
- Fishing within mangrove estuaries using gill and seine nets.

White and McAuley (2016) note most of these impacts are occurring within eastern Indonesia (i.e. Papua) but not in areas with better regulation and no target fisheries. This may indicate a lesser level of threat in the study area, as there is no known target fishery for the species (see ERIAS Group, 2017c), although there is also only limited regulation of artisanal fisheries in this area.

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Likely***, based on historical sightings (Haines, 1979) and ongoing habitat suitability.
- Offshore export pipeline corridor – ***Possible***, based on available habitat.
- Caution Bay – ***Likely***, based on habitat suitability.

[12] Identified as *Rhinobatos batillum*, a synonym for *G. typus*

***Aetobatus narinari* – spotted eagle ray**

Nationally-listed	×	Not listed
Trade-restricted	×	Not listed
IUCN threatened	✓	Near Threatened
Endemic and/or restricted-range	×	Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	×	Species does not migrate or congregate
Overall vulnerability	***Moderate vulnerability***	

The spotted eagle ray is primarily a coastal species, occurring up to a depth of 60 m, and often occurs around coral reef ecosystems (Kyne *et al.* 2006). The species feeds on a range of benthic species commonly found within coral reef areas, including fish, mollusks, cephalopods and crustaceans (Kyne *et al.* 2006).

Rays can occur both as solitary individuals and in larger schools, up to several hundred individuals (McEachran and de Carvalho, 2002). However, the species is not known to form significant breeding aggregations (Kyne *et al.* 2006).

Haines (1979) identified this species within the coastal waters of Orokolo Bay and offshore of the Purari River. As these areas have not been subject to significant change, it is likely this species continues to occur. It was not found within the estuarine or freshwater environment and is expected to occur only in marine waters.

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Likely***, based on historical sightings (Haines, 1979) and ongoing habitat suitability.
- Offshore export pipeline corridor – ***Possible***, based on available habitat.
- Caution Bay – ***Likely***, based on habitat suitability.

***Manta birostris* – giant manta ray**

Nationally-listed	×	Not listed
Trade-restricted	✓	Appendix II
IUCN threatened	✓	Vulnerable
Endemic and/or restricted-range	×	Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓	Individuals are continually migrating throughout global waters. Listed under Bonn Convention
Overall vulnerability	***High vulnerability***	

M. birostris is distributed throughout the globe in tropical and temperate waters, including those of the study area, but populations are known to be highly fragmented and sparse throughout this range (Marshall *et al.* 2011b). The species is pelagic, feeding on plankton and fish, and is therefore more likely to occur on the boundaries of the study area in deeper waters, although individuals can also occur in nearshore waters. Individual rays are highly migratory and solitary, although groups are known to aggregate at various sites globally. There are no aggregation sites known to occur within the study area.

During the June-July 2016 a single manta or ray species was seen breaching at Caution Bay. This may have been an example of *M. birostris*.

The main threats to the species is fishing, including as part of targeted fisheries and bycatch (Marshall *et al.* 2011b). The species is not known to be targeted as part of any existing fishery in the Gulf of Papua or as part of artisanal fisheries (see Booyong Forest Science, 2017; ERIAS Group, 2017c), principally due to its occurrence within deeper waters.

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Unlikely***, due to depth.
- Offshore export pipeline corridor – ***Possible***, due to depth.
- Caution Bay – ***Unlikely***, due to depth.

***Manta alfredi* – reef manta ray**

Nationally-listed	×	Not listed
Trade-restricted	✓	Appendix II
IUCN threatened	✓	Vulnerable
Endemic and/or restricted-range	×	Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓	Individuals are continually migrating throughout waters in their range and also form schools. Listed under Bonn Convention.
Overall vulnerability	***High vulnerability***	

M. alfredi has a smaller range than *M. birostris* although both species have significant cross-over in their range. Unlike *M. birostris*, reef manta rays are known to school and have higher level of site fidelity, although these varies with sex and age class (Marshall *et al.* 2011a). Schools of rays are also thought to be often resident in productive nearshore environments (Marshall *et al.* 2011a).

Schools are known to migrate large distances between aggregation sites, however, there are no aggregation sites currently known in the study area.

During the June-July 2016 a single manta or ray species was seen breaching at Caution Bay, which was possibly *M. alfredi*.

Reef manta rays are also threatened by fishing activities (Marshall *et al.* 2011a) but are expected to be more highly exploited by artisanal fisheries than *M. birostris* due to their habit of schooling and occurrence within nearshore environments. Exploitation of this species is not currently known to occur in the study area (see Booyong Forest Science, 2017; ERIAS Group, 2017c).

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Possible***, based on available habitat.
- Offshore export pipeline corridor – ***Possible***, based on available habitat.
- Caution Bay – ***Likely***, based on habitat suitability.

***Mobula eregoodootenkee* – pygmy devilray**

Nationally-listed	× Not listed
Trade-restricted	✓ Appendix II
IUCN threatened	✓ Near Threatened
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Listed under Bonn Convention.
Overall vulnerability	***Moderate vulnerability***

The distribution of the pygmy devilray includes the waters of the study area. Pierce and Bennett (2003) note that the species is locally common within its distribution, which encompasses the tropical Indo-west Pacific and northern Indian Ocean. It is a filter-feeder that grazes on planktonic organisms and small fish and is restricted to surface waters within the epipelagic zone (Pierce and Bennett, 2003). Mating and birthing both occur in shallow waters where juveniles remain until fully-grown.

During the June-July 2016 a single manta or ray species was seen breaching at Caution Bay. This may have been an example of *M. eregoodootenkee*.

The species is noted as being caught in bycatch in commercial fisheries (Pierce and Bennet, 2003) and is expected to be targeted by artisanal fisheries. However, there is little information available on the exploitation of this species internationally or in the study area.

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Possible***, based on available habitat.
- Offshore export pipeline corridor – ***Possible***, based on available habitat.
- Caution Bay – ***Possible***, based on available habitat.

Scomberomorus commerson – narrow-banded Spanish mackerel

Nationally-listed	× Not listed
Trade-restricted	× Not listed
IUCN threatened	✓ Near Threatened
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Species is known to be fully migratory and often crosses jurisdictional boundaries for spawning and other activities
Overall vulnerability	***Moderate vulnerability***

The Spanish mackerel is a commercially important species across a number of global fisheries (Collette *et al.* 2011b). The species was noted to form up to 8% of the incidental catch associated with the Gulf of Papua shark fishery between the early 1980s and 1990s (ERIAS Group, 2017c). While this fishery is no longer active, the species is still expected to form part of the ongoing finfish fishery within the gulf.

As with *S. multiradiatus*, the Spanish mackerel is a pelagic and oceanodromous species, undertaking long-shore migrations and continually moving within the marine environment (Collette *et al.* 2011b). It can tolerate areas of low salinity and high turbidity and is therefore likely to occur near the mouths of major rivers.

Spawning occurs off reef slopes and edges, with species forming spawning aggregations at specific sites. There are no known spawning sites for the species in the study area, although it is possible that spawning activities occur near the coral reefs of Caution Bay.

As the Spanish mackerel is a highly important commercial species, it is threatened by overfishing (Collete *et al.,* 2011b). It does not appear to be overexploited within the Gulf of Papua, with stock numbers in the Torres Strait expected to currently be stable.

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Likely***, based on habitat suitability.
- Offshore export pipeline corridor – ***Likely***, based on habitat suitability.
- Caution Bay – ***Likely***, based on habitat suitability.

***Epinephelus coioides* – orange-spotted grouper and *E. fuscoguttatus* – Brown-marbled grouper**

Nationally-listed	× Not listed
Trade-restricted	× Not listed
IUCN threatened	✓ Near Threatened
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	× Species does not migrate or congregate
Overall vulnerability	***Moderate vulnerability***

Both the orange-spotted grouper and the brown-marbled grouper are associated with reef communities (Cornish, 2004; Cornish and Harmelin-Vivien, 2004). In addition, *E. coioides* is known to occur within mangroves and brackish water over mud and rubble. This species undertakes

spawning activities within mangrove systems, with juveniles typically occurring within mangrove wetlands of estuaries (Cornish and Harmelin-Vivien, 2004). By contrast, *E. fuscoguttatus* forms spawning aggregations near coral reef communities (Cornish, 2004). Juvenile brown-marbled groupers then find refuge within a combination of coral reef and seagrass communities.

The orange-spotted grouper is known to occur in the study area based on observations made during the marine field survey. The brown-marbled grouper was recorded historically at Orokolo Bay by Haines (1979) although in very small numbers.

The main threats to both species are overfishing and habitat modification (Cornish, 2004; Cornish and Harmelin-Vivien, 2004). For *E. coioides* this includes the loss of mangrove habitats while for *E. fuscoguttatus* this relates to loss of seagrass (used by juveniles) and coral reefs.

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Known*** (orange-spotted grouper), based on recent sightings and ***Likely*** (brown marbled grouper), based on historical sightings (Haines, 1979) and ongoing habitat suitability.
- Offshore export pipeline corridor – ***Possible***, based on available habitat.
- Caution Bay – ***Likely***, based on habitat suitability.

***Actinopyga echinites* – deepwater redfish, *A. mauritana* – surf redfish, *A. miliaris* – hairy blackfish, *Holothuria fuscogilva* – white teatfish, *H. lessoni* – golden sandfish, *H. nobilis* – black teatfish, *H. scabra* – sandfish, Stichopus *hermannii* – curryfish and *Thelenota ananas* – prickly redfish**

Nationally-listed	×	Not listed
Trade-restricted	×	Not listed
IUCN threatened	✓	Vulnerable (*A. echinites*, *A. mauritana*, *A. miliaris*, *H. fuscogilva*, *S. hermannii*)
		Endangered (*H. lessoni*, *H. nobilis*, *H. scabra*, *T. ananas*)
Endemic and/or restricted-range	×	Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	×	Species does not migrate or congregate
Overall vulnerability	***High vulnerability (Vulnerable species)***	
	Extreme vulnerability (Endangered species)	

These sea cucumber species form part of the Papua New Guinea bêche-de-mer fishery within the Gulf of Papua, as described in the Marine Fisheries and Resources Baseline Report (ERIAS Group, 2017c). The habitat utilized by these species consists of:

- Outer reef flats and fringing reefs.
- Littoral zone
- Estuaries.
- Seagrass meadows.

H. lessoni is also known to occur over sandy substrate in shallow waters. The species tend not to occur in areas of coral reef substrate, preferring reef flat or seagrass.

Most species occur only in shallow waters, up to 20 m deep, though some can occur in much deeper waters, including *H. nobilis* (up to 60 m deep).

Fishing for these species is managed through the National Bêche-de-mer Fishery Management Plan (UTS, 2016). A moratorium was in effect for the fishery between 2009 and the end of 2016 in order to protect the fishery from overfishing. This is considered to be the main threat to each sea cucumber species, including fishing threats from illegal harvesting.

The National Bêche-de-mer Fishery Management Plan indicates that all of these species are present within the coastal waters of Papua New Guinea. On the basis of this information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Known***, based on presence of fishery.
- Offshore export pipeline corridor – ***Unlikely***, due to depth.
- Caution Bay – ***Known***, based on presence of fishery.

***Scomberomorus multiradiatus* – Papuan seerfish**[13]



Nationally-listed	×	Not listed
Trade-restricted	×	Not listed
IUCN threatened	×	Least Concern
Endemic and/or restricted-range	✓	Based on current records, the species is considered to be endemic to the Gulf of Papua and Southeast Papua New Guinea ecoregions. The species may also be restricted-range based on its known distribution. NOTE: There is the potential that this species also occurs in the Timor Sea. If this is the case, it would not be endemic or restricted-range.
Migratory and congregatory	×	Species does not migrate beyond national borders.
Overall vulnerability	***Moderate vulnerability***	

Papuan seerfish was identified in the study area from photographs taken of artisanal fish catches during the 2016 Orokolo Bay coastal villages survey (see Booyong Forest Science, 2017). This species is not currently threatened or targeted by commercial fisheries, although it is often caught as incidental bycatch (Collette *et al.* 2011a). As it is currently thought to be limited to the Gulf of Papua and Southeast Papua New Guinea ecoregions this species is considered to be endemic and restricted range. However, there is the potential that this species is distributed as far as the Timor Sea; if this is the case, it would not be endemic or restricted range.

[13] Photo taken during 2016 Orokolo Bay coastal village surveys

The Papuan seerfish is a pelagic, schooling species that continually migrates within marine waters (i.e. oceanodromous). It prefers shallow turbid waters, up to a depth of 50 m, and has traditionally been associated with the waters off the mouth of the Fly River (Collette *et al.* 2011a).

This species is not considered to be subject to any significant threats at present.

On the basis of the above information, the following occurrence is noted for the study area:

- Orokolo Bay – ***Known***, based on recent sightings.
- Offshore export pipeline corridor – ***Likely***, based on habitat suitability.
- Caution Bay – ***Likely***, based on habitat suitability.

***Panulirus ornatus* – ornate rock lobster**

Nationally-listed	×	Not listed
Trade-restricted	×	Not listed
IUCN threatened	×	Least Concern (stable)
Endemic and/or restricted-range	×	Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓	Species migrates from Torres Strait across Gulf of Papua to Yule Island for spawning.
Overall vulnerability	***Moderate vulnerability***	

The ornate rock lobster (*Panulirus ornatus*) is a migratory lobster species that occurs in four principal global populations. One of these populations is the Torres Strait-Gulf of Papua population whose individuals spend most of their life at the islands and reefs of Torres Strait (Cockcroft *et al.* 2011). On an annual basis, large aggregations of individuals migrate from the Torres Strait Warrior Reefs to the Gulf of Papua (Moore and Macfarlane, 1984; Macfarlane and Moore; 1986). This migratory path is shown in Figure 6-35. It passes from Torres Strait into the top of the Gulf of Papua offshore of the Purari River, and follows the coastline around to breeding grounds at Yule Island. These are the only breeding grounds utilized by this population of the species. While the individuals typically occur in nearshore coastal waters to a depth of 8 m, during migration the individuals travel within deeper waters, mostly to a depth of 40 to 80 m (Moore and Macfarlane, 1984).

Migration begins when lobsters reach three years of age and occurs between August-September (when individuals leave Torres Strait) and January-February (when spawning begins) (MacFarlane and Moore, 1986). Spawning results in almost total mortality of adults, with little evidence of a return migration to Torres Strait (Dennis *et al.* 1992).



LEGEND

- Ornate Rock Lobster Migration Path
- Ornate Rock Lobster Spawning Ground
- Purari/Orokolo Study Area
- Caution Bay Study Area
- Pipeline Corridor
- -40 Contours

Title:

Migration Path of the Ornate Rock Lobster Across the Gulf of Papua

Figure: 6-35

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 40 80km

Approx. Scale

BMT WBM
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Filepath: I:\B21414_I_GML_Elk_Antelope_EIA_JV\DRG\ECO_054_170712_LobsterMigration.wor

The offshore export pipeline corridor crosses the migration route in two places: immediately offshore (below the 40 m depth contour) of Orokolo Bay, and an area north of Berema through to Yule Island. The corridor also overlaps with parts of the Yule Island spawning ground. Notably, these areas (except at Orokolo Bay) are also overlapped by the route of the PNG LNG gas pipeline.

There are no major threats to this species, principally due to effective management of the lobster fishery. See Marine Fisheries and Resources Baseline Report for further description of this (ERIAS Group, 2017b).

On this basis of the above information, the occurrence of these species is as follows:

- Orokolo Bay – ***Possible***, but only as occasional individuals outside the key migration route.
- Offshore export pipeline corridor – ***Known***, within areas of overlap with migration route.
- Caution Bay – ***Likely***, as individuals associated with migration.

6.5 Marine Mammals and Reptiles

Marine megafauna (other than sharks and rays, which are described in Section 6.4) that are relevant to the study area include the following groups:

- Sirenians (i.e. dugongs).
- Cetaceans (i.e. dolphins and whales).
- Reptiles (sea turtles, crocodiles and sea snakes).

These are described below. As most megafauna species are threatened or otherwise important species, each section also includes a discussion of specific species that are included in the threatened/important categories in Section 5.6.3. This is then summarized in Table 6-3.

6.5.1 Sirenians

Sirenians, commonly known as sea cows, include dugongs and manatees. The only sirenian considered relevant to the study area is the dugong (*Dugong dugon*) which is discussed below.

***Dugong dugon* - dugong**.

Nationally-listed	✓ Protected
Trade-restricted	✓ Appendix I/Schedule 1
IUCN threatened	✓ Vulnerable
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Listed under Bonn Convention
Overall vulnerability	***High vulnerability***

Dugongs have a relatively broad geographic range that extends from east Africa to Vanuatu, between the latitudes of approximately 27° north and south of the equator (Marsh *et al.* 2002). Dugongs occur along the entire coast of Papua New Guinea, being most abundant on the northern coast in areas of seagrass coverage. They also occur at Manus Island, parts of West New Britain and west of the Fly River (CNS, 2008b). The species is also abundant in the Torres Strait region.

The specific distribution of dugongs is coincident with areas of seagrass, their primary foraging habitat. As discussed in Section 6.2.1, seagrass is not abundant within the Gulf of Papua. However, anecdotal evidence from unpublished studies, including of a dugong washing up on a beach at Kerema, indicates that dugongs may use some areas of the gulf as a migration route to known seagrass meadows in the southwest of Papua New Guinea. Pernetta and Hill (1981) also indicate that the species was historically hunted in Western Province.

The only seagrass meadows in the study area occur within Caution Bay. Surveys conducted for the PNG LNG Project EIS did not find evidence of dugong feeding trails in seagrass meadows (CNS, 2009). In addition, community consultation conducted as part of these surveys indicated that dugongs do not occur in Caution Bay. As a result, it is expected that any instances of dugongs in the study area would represent transient individuals only.

The potential occurrence of the species in the study area can be summarized as follows:

- Orokolo Bay – ***Unlikely***, due to lack of feeding habitat.
- Offshore export pipeline corridor – ***Unlikely***, due to lack of feeding habitat.
- Caution Bay – ***Possible***, due to available feeding habitat but noting no known occurrence in this area.

6.5.2 Cetaceans

The distribution and abundance of cetaceans in the Gulf of Papua is not well studied. However, a number of dolphin species are known or likely to occur in the study area, based on available scientific literature as well as observations and assessments from the June-July 2016 and January 2017 surveys, and those conducted for the PNG LNG Project EIS (CNS, 2009) and other unpublished studies of Kerema Bay and a corridor between Kerema and Port Moresby. These are:

- Common bottlenose dolphin (*Tursiops truncatus*) and Indo-Pacific bottlenose dolphin (*T. aduncus*).
- Spinner dolphin (*Stenella longirostris*) and pantropical spotted dolphin (*S. attenuata*).
- Short-beaked common-dolphin (*Delphinus delphis*).
- Australian snubfin dolphin (*Orcaella heinsohni*).
- Australian humpback dolphin (*Sousa sahulensis*).

All of these species are considered to be threatened/important and are discussed in more detail individually below.

NOTE: The study area is within the modeled distribution for the orca (*Orcinus orca*), humpback whale (*Megaptera novaeangliae*) and Bryde's whale (*Balaenoptera edeni*), all of which would qualify as threatened/important species. However, there has been no confirmed sighting of these species within the study area which, based on the highly conspicuous activities of these species, indicates that are unlikely to occur and have therefore not been considered further.

***Tursiops truncatus* – common bottlenose dolphin, *T. aduncus* – Indo-Pacific bottlenose dolphin, *Stenella longirostris* – spinner dolphin, *S. attenuata*- pantropical spotted dolphin and *Delphinus delphis* – short-beaked common dolphin**

Nationally-listed	× Not listed (all)
Trade-restricted	✓ Appendix II/Schedule 2 (all)
IUCN threatened	× Least Concern (*T. truncates*, *D. delphis* and *S. attenuata*) / Data Deficient (*T. aduncus* and *S. longirostris*)
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2 (all)
Migratory and congregatory	✓ Listed under Bonn Convention (all)
Overall vulnerability	***Moderate vulnerability***

These five species are all considered to be common and subject to a lower level of vulnerability, although their listing under CITES as cetaceans has elevated their status to *moderate vulnerability*. While the cetacean species of the Gulf of Papua have not been studied in detail, each of these species are expected to occur within the offshore environment, based on known distribution and habitat suitability.

A small pod of *T. truncatus* or *D. delphis* was identified during the June-July 2016 survey within Orokolo Bay, with an additional pod identified in the offshore export pipeline corridor (near Site M33) during the January 2017 survey. A pod of *T. aduncus* was also identified in the northern gulf during surveys for the PNG LNG Project EIS (CNS, 2008a).

All of these dolphin species principally inhabit offshore waters, although at varying depth ranges, but also occur occasionally within the nearshore environment. They feed on fish and prawn species occurring within the gulf. No parts of the study area are considered to support significant breeding locations or related activities for these species.

Based on the above, the following occurrence of these species is noted:

- Orokolo Bay – ***Likely***, based on habitat suitability.
- Offshore export pipeline corridor – ***Likely***, based on habitat suitability.
- Caution Bay – ***Likely***, based on habitat suitability.

***Orcaella heinsohni* – Australian snubfin dolphin**

Nationally-listed	× Not listed
Trade-restricted	✓ Appendix I
IUCN threatened	✓ Near Threatened
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Listed under Bonn Convention
Overall vulnerability	***High vulnerability***

O. heinsohni has a geographic distribution that is restricted to tropical and subtropical zones of Australia, and southern New Guinea (Beasley *et al.* 2005). It is an uncommon nearshore coastal species in most areas, and is often found in small groups (Parra, 2005; 2006). This species inhabits riverine, estuarine and nearshore coastal waters, with a preference for very shallow areas

(i.e. <2 m deep – Reeves *et al.* 2008). Where present in the marine environment, the species typically occurs near the mouth of rivers (Reeves *et al.* 2008).

A pod of five Australian snubfin dolphins were observed in the waters off Bluff Point, a coastal location 13 km west of Kerema as part of previous (unpublished) surveys. These surveys suggest that the pod travelled inshore to feed on resources available in association with the rocky reef areas, although this species is an opportunistic generalist and can feed in soft sediment, seagrass and reef habitats (Parra, 2006). The sighting was supported by the local community who claim that this species frequents the area on high tide. Beasley *et al*. (2016) found that *Orcaella* sp. (most likely *O. heinsohni)* was the most abundant marine mammal species recorded in boat-based surveys at the Kikori Delta between 2013 and 2015.

This species was recently separated from *O. brevirostris*, the Irrawaddy dolphin, and previous sightings of *O. brevirostris* in Papua New Guinean waters may actually be records of *O. heinsohni* as the currently recognized distribution of the former does not include Papua New Guinea. On this basis, records of the Irrawaddy dolphin in the western gulf during the PNG LNG Project EIS (CNS, 2008a) are considered to be records of the snubfin dolphin.

Based on previous counts of the species, discussed in Reeves *et al.* 2008, the total population of the species is expected to be less than 10,000 and may potentially be in decline. The key threats to the species are related to entanglement in netting set for anti-shark purposes or for fishing, including gill-nets in rivers (Reeves *et al.* 2008).

Based on the above, the following occurrence of this species is noted:

- Orokolo Bay – ***Likely***, based on habitat suitability and sightings in adjoining areas.
- Offshore export pipeline corridor – ***Unlikely***, due to depth.
- Caution Bay – ***Likely***, due to habitat suitability.

***Sousa sahulensis* – Australian humpback dolphin**

Nationally-listed	× Not listed
Trade-restricted	✓ Appendix I/Schedule 1 (as *S. chinensis*)
IUCN threatened	✓ Not recognized but expected to be Vulnerable (cf. Parra and Cagnazzi, 2016)
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Listed under Bonn Convention (as *S. chinensis*)
Overall vulnerability	***High vulnerability***

Until recently, *S. sahulensis* was not recognized as a separate species to *S. chinensis* (see below). While the species is now accepted as taxonomically separate, the IUCN Red List still lists only *S. chinensis*. Parra and Cagnazzi (2016) consider that this species meets the criteria of Vulnerable under IUCN criterion C2a(i).

Similar to *O. heinsohni*, the geographic distribution of *S. sahulensis* encompasses the tropical and subtropical east and west coasts of northern Australia and southern New Guinea. *S. sahulensis* occurs in a broad range of coastal habitats including coastal lagoons, enclosed bays, estuaries and open coastal waters (Jefferson and Karczmarski, 2001).

Beasley *et al.* (2016) found that *S. sahulensis* was the second-most abundant species recorded in boat-based marine mammal surveys of the Kikori Delta between 2013 and 2015. This species was recorded in water of low salinity and high turbidity at depths of 1.6 to 12 m. Surveys conducted in the far northern Great Barrier Reef region indicates that this species usually occurs close to the coast (within 5 km of land) in depths of less than 15 to 20 m, and usually within 20 km from the nearest river mouth (Parra *et al.* 2006). The species is an opportunistic generalist, feeding on fish and crustaceans from coastal, estuarine and nearshore reef habitats (Parra, 2006; Parra *et al.* 2006).

The principle threats to this species consist of the following (DoEE, 2017d):

- Habitat destruction and degradation, including noise pollution and harassment associated with boat use.
- Incidental capture in inshore gill-nets associated with riverine barramundi and threadfin fisheries.
- Incidental capture in shark nets.
- Competition with fisheries that target estuarine and nearshore fish species.

Based on the above, the following occurrence of this species is noted:

- Orokolo Bay – ***Likely***, based on habitat suitability and sightings in adjoining areas.
- Offshore export pipeline corridor – ***Unlikely***, due to depth.
- Caution Bay – ***Likely***, due to habitat suitability.

6.5.3 Marine Reptiles

6.5.3.1 Marine Turtles

Six marine turtles are known to occur within Papua New Guinea waters. These are:

- Green turtle (*Chelonia mydas*).
- Hawksbill turtle (*Eretmochelys imbricata*).
- Loggerhead turtle (*Caretta caretta*).
- Leatherback turtle (*Dermochelys coriacea*).
- Olive ridley turtle (*Lepidochelys olivacea*).
- Flatback turtle (*Natator depressus*).

Turtles have been recorded to nest along the northern beaches of Papua New Guinea, however no major sea turtle rookeries (nesting beaches) are known to occur within the Gulf of Papua (CNS, 2009). However, anecdotal information from unpublished studies suggest that suitable beaches within the gulf are used occasionally by nesting sea turtles. When this occurs, the eggs are often harvested.

All six species are considered to be threatened/important and discussed in more detail below.

***Chelonia mydas* – green turtle**

Nationally-listed	×	Not listed
Trade-restricted	✓	Appendix I/Schedule 1
IUCN threatened	✓	Endangered
Endemic and/or restricted-range	×	Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓	Listed under Bonn Convention
Overall vulnerability	***Extreme vulnerability***	

This species is known to occur in the gulf based on bycatch records (Gwyther, 1983; Spring and Gwyther, 1999) and historical subsistence fisheries (ERIAS Group, 2017c). The green turtle feeds directly on seagrasses and algae, and occasionally mangrove fruit and benthic fauna (Limpus, 2008b; Brand-Gardner *et al.* 1999) and is also known to occur in the vicinity of coral reef habitats. It is therefore expected to occur in association with seagrass and coral reefs. These areas also provide important habitat for juvenile development (Seminoff, 2004).

This species is known to nest on sandy beaches with low gradient, such as those found along the northern gulf. As discussed above, no known nesting sites occur in the study area but anecdotal evidence suggests that some nesting does occur in low density on the beaches of Kerema Bay (50 km east of Orokolo Bay).

Green turtles are mostly solitary species that only aggregate at feeding areas. A marine conservation assessment conducted by the Government of Papua New Guinea (CEPA, 2015) has identified Cape Suckling (north of Caution Bay) as an ‘aggregation’ site for this species (Figure 6-36; see also Section 6.6), based on data collected by the World Wildlife Fund of Indonesia. This site is expected to be associated with seagrass and reef environments near Yule Island. As these environments are also present in Caution Bay, it is possible that green turtle aggregations also occur there. However, the species was not observed during present surveys or those undertaken as part of the PNG LNG Project EIS (CNS, 2008b).

Based on tagging exercises, green turtles occurring at Cape Suckling are derived from one of three rookeries/stocks: northern Great Barrier Reef, Torres Strait and Coral Sea (Limpus, 2008b). This suggests significant nesting in the study area is unlikely. Nesting within these populations can occur year-round but is most concentrated in October to March, with hatchlings emerging from December to May (Limpus, 2008b).

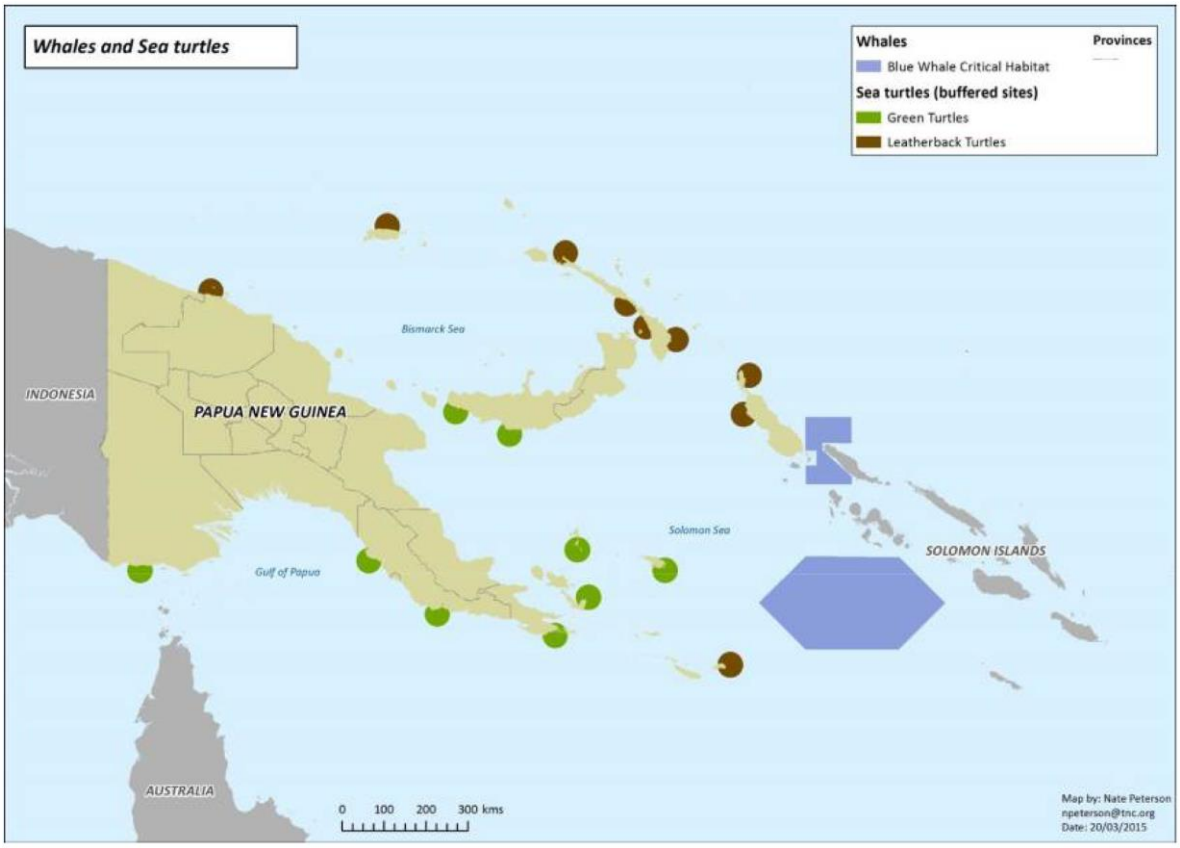


Figure 6-36 Whale and Turtle Aggregation Sites Identified in Marine Conservation Assessment, including Green Turtle Aggregation Site at Cape Suckling (CEPA, 2015)

Green turtles are considered susceptible to anthropogenic influences throughout their lifecycle, with major threats including harvesting of eggs, bycatch in marine fisheries, and degradation of nesting beaches and feeding areas (Seminoff, 2004). Artificial lighting at nesting beaches is also a significant threat as it disturbs hatchlings (DoEE, 2017e). Marine debris, such as discarded plastic, can cause injury to turtles through ingestion or entanglement. In particular, 'ghost nets' (i.e. discarded fishing nets) are responsible for the death of a significant number of turtles in Australia (DoEE, 2017e). Oil spills have the potential to choke and poison turtles and also inhibit swimming.

Based on the above, the following occurrence of the species is noted:

- Orokolo Bay – ***Possible***, based on beaches for nesting.
- Offshore export pipeline corridor – ***Likely***, in areas where the pipeline is close to the coast and important features such as nesting beaches, seagrass and coral reefs.
- Caution Bay – ***Likely***, based on seagrass and coral reef.

***Eretmochelys imbricata* – hawksbill turtle**

Nationally-listed	× Not listed
Trade-restricted	✓ Appendix I/Schedule 1
IUCN threatened	✓ Critically Endangered
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Listed under Bonn Convention
Overall vulnerability	***Extreme vulnerability***

Hawksbill turtles are omnivorous species, feeding on sponges, seagrasses, algae, soft corals, and benthic shellfish in a range of soft sediment and reef environments (Limpus, 2008c; Whiting, 2000; Mortimer and Donnelly, 2008). The species has not been recorded in the study area but is potentially supported by reef and seagrass habitat within Caution Bay.

Nesting by hawksbill turtles occurs on sandy beaches, although there is no evidence to suggest nesting occurs in any of the study area beaches. In the Great Barrier Reef the species nests year-round, with a peak in January-February (Limpus, 2008c). A rookery for this species occurs in the southwest of the Gulf of Papua, near Daru, from where species disperse into other areas of the eastern Pacific (Limpus, 2008c).

As with other marine turtles, the hawksbill is threatened by fishing and egg harvesting activities and marine debris (DoEE, 2017f), but is also subject to threats from illegal trade in turtle shells (Mortimer and Donnelly, 2008). This illegal trade is considered to be the principle threat to this species.

Based on the above, the following occurrence of the species is noted:

- Orokolo Bay – ***Unlikely***, based on lack of feeding habitat and no evidence of use of beaches for nesting.
- Offshore export pipeline corridor – ***Likely***, in areas where the pipeline is close to the coral reefs and seagrass.
- Caution Bay – ***Likely***, based on seagrass and coral reef.

***Caretta caretta* – loggerhead turtle**

Nationally-listed	× Not listed
Trade-restricted	✓ Appendix I/Schedule 1
IUCN threatened	✓ Vulnerable
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Listed under Bonn Convention
Overall vulnerability	***High vulnerability***

The loggerhead turtle is a carnivorous species which feeds in pelagic, seagrass, and reefal environments, with a diet comprised of jellyfish, crustaceans, echinoderms, and bivalve (Limpus, 2008a; Casale and Tucker, 2015; Limpus *et al.* 1994). All soft sediment within the study area represent potential foraging habitat for this species, as would also reefs and seagrass meadows in Caution Bay.

This species may also nest on sandy beaches within the study area, although there is no evidence of historical nesting in the Gulf of Papua, with principle nesting sites occurring within the Great Barrier Reef (DoEE, 2017g; Limpus, 2008a). Turtle breeding (based on observations in Australia) occurs from November to March, with a peak in late December/early January (DoEE, 2017g; Limpus, 2008a). Nesting occurs from October to March, with hatchlings emerging from December to May (Limpus, 2008a).

The loggerhead turtle is subject to similar threats to other marine turtles, including bycatch in fishing, marine pollution and debris, and disturbance of habitat (DoEE, 2017g; Casale and Tucker, 2015).

Based on the above, the following occurrence of the species is noted:

- Orokolo Bay – ***Unlikely***, based on lack of feeding habitat and no evidence of use of beaches for nesting.
- Offshore export pipeline corridor – ***Likely***, in areas where the pipeline is close to the coral reefs and seagrass.
- Caution Bay – ***Likely***, based on seagrass and coral reef.

***Dermochelys coriacea* – leatherback turtle**

Nationally-listed	✓ Protected
Trade-restricted	✓ Appendix I/Schedule 1
IUCN threatened	✓ Critically Endangered (West Pacific sub-population)
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Listed under Bonn Convention
Overall vulnerability	***High vulnerability***

Leatherback turtles are oceanic species that feed primarily on jellyfish and other soft-bodied invertebrates (Limpus, 2008f; DoEE, 2017h; Tiwari *et al.* 2013). As a pelagic species, leatherback turtles are less common in nearshore waters and are not associated with coral reefs or seagrass meadows.

There are no nesting sites for the species within the Gulf of Papua, with the closest sites occurring on the northern coast of Papua New Guinea (Tiwari *et al.* 2013). However, Ulaiwi (1997) indicates that historical nesting may have occurred in southern Papua New Guinea, although without an indication of location. There are also no known aggregation sites for the species in the Gulf of Papua (see Figure 6-36).

Leatherbacks suffer from high mortality associated with ingestion of plastic bags due to their resemblance to jellyfish (DoEE, 2017h). In addition, the species is subject to other major threatening processes common to marine turtles, including entanglement in nets (DoEE, 2017h; Tiwari *et al.* 2013).

Based on the above, the following occurrence of the species is noted:

- Orokolo Bay – ***Unlikely***, due to depth.
- Offshore export pipeline corridor – ***Possible***, based on available habitat.
- Caution Bay – ***Unlikely***, due to depth.

***Lepidochelys olivacea* – olive ridley turtle**

Nationally-listed	× Not listed
Trade-restricted	✓ Appendix I/Schedule 1
IUCN threatened	✓ Vulnerable
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Listed under Bonn Convention
Overall vulnerability	***High vulnerability***

Olive ridley turtles are known to occur in the Gulf of Papua based on historical bycatch (Gwyther, 1983; Spring and Gwyther, 1999). This species is mostly carnivorous, with a diet mostly comprised of urchins, small crabs, and mollusks (DoEE, 2017i) and is known to favor shallow seagrass meadows and coral reef habitats (Limpus, 2008d; Abreu-Grobois and Plotkin, 2008).

The species is known to nest in large congregations as well as at dispersed locations (Abreu-Grobois and Plotkin, 2008). However, Limpus (2008d) notes that no nesting for the species occurs within the Gulf of Papua, with most nesting concentrated in northern Australia, Indonesia, Malaysia and India.

The species is considered to be subject to the same threats as other marine turtles, including fishing and habitat degradation (Abreu-Grobois and Plotkin, 2008; DoEE, 2017i).

Based on the above, the following occurrence of the species is noted:

- Orokolo Bay – ***Unlikely***, based on lack of feeding habitat.
- Offshore export pipeline corridor – ***Likely***, in areas where the pipeline is close to the coral reefs and seagrass.
- Caution Bay – ***Likely***, based on seagrass and coral reef.

***Natator depressus* – flatback turtle**

Nationally-listed	× Not listed
Trade-restricted	✓ Appendix I/Schedule 1
IUCN threatened	× Data Deficient
Endemic and/or restricted-range	× Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓ Listed under Bonn Convention
Overall vulnerability	***Moderate vulnerability***

Flatback turtles feed on soft corals, sea cucumbers and jellyfish, and typically occur over a range of soft-sediment habitats (DoEE, 2017j). Turtle nesting occurs on sandy beaches.

Limpus (2008e) identifies nesting along the southern coast of Papua New Guinea, near the border with Indonesia, as well as within Torres Strait, but not within the Gulf of Papua. However, an unpublished report on marine ecology at Kerema Bay indicates a major turtle rookery occurs within this area. The location and nature of this rookery is uncertain but would suggest potential nesting activities in the northeast gulf. There is no other evidence suggesting use of this area for nesting so this suggestion should be treated with caution.

Nesting occurs all year around, although there is a peak in flatback nesting mid-year (Limpus, 2008e).

The species is considered to be subject to the same threats as other marine turtles, including egg harvesting, fishing and habitat degradation (DoEE, 2017j).

Based on the above, the following occurrence of the species is noted:

- Orokolo Bay – ***Possible***, based on potential rookery site near Kerema.
- Offshore export pipeline corridor – ***Likely***, in areas where the pipeline is close to the coral reefs and seagrass.
- Caution Bay – ***Likely***, based on seagrass and coral reef.

6.5.3.2 Sea Snakes

There are 23 species of sea snake that are known to occur within the waters of Papua New Guinea, including both nearshore and open ocean species (CNS, 2008a). No sea snake species were observed at Orokolo Bay or Caution Bay during the present survey or as part of the PNG LNG Project EIS, but a small banded sea krait (*Laticauda* sp.) was observed along the offshore export pipeline route during the June-July 2016 survey. This may be *L. guineai*, a Near Threatened and restricted-range species, which is considered in more detail below.

Another restricted-range species, the banded watersnake (*Cantoria annulata*) is also considered possibly occurring within the study area based on modeled distribution by the IUCN Red List (Murphy and Allison, 2010).

Most sea snakes are found between the surface and 50 m depth, with some species venturing to depths approaching 100 m to forage. They are most at risk from benthic trawling and are estimated to make up 2% of the bycatch from the Gulf of Papua trawl fishery.

***Laticauda guineai* – Guinea's sea krait**

Nationally-listed	× Not listed
Trade-restricted	× Not listed
IUCN threatened	✓ Near Threatened
Endemic and/or restricted-range	✓ Species is limited to the Southeast Papua New Guinea ecoregion.
Migratory and congregatory	× Species does not migrate or congregate
Overall vulnerability	***Moderate vulnerability***

Guinea's sea krait is endemic to southern Papua New Guinea, having been identified only from two areas along the southeastern coastline between Port Moresby and Orangerie bays, making an area less than 20,000 km^2 (Lane and Guinea, 2010). Individuals within the species are restricted to shallow areas, up to a depth of 10 m, and are noted to occur primarily around coral reefs (Lane and Guinea, 2010).

While *L. guineai* was not identified during field surveys, an unknown *Laticauda* spp. was identified during the June-July 2016 field survey and may represent an occurrence of the sea krait. This observation was made immediately adjacent to the known range of the species.

This species lays its eggs on land and relies on suitable cover within the intertidal area in order to access areas for nesting (Lane and Guinea, 2010). Major threats therefore include anthropogenic

disturbance and habitat conversion within the coastal zone, as well as destruction of coral reef habitat which is also utilized by the species.

Based on the above, the following occurrence of the species is noted:

- Orokolo Bay – ***Does not occur***, due to lack of coral reefs.
- Offshore export pipeline corridor – ***Possible***, in areas where the pipeline is close to the coral reefs and seagrass.
- Caution Bay – ***Likely***, based on seagrass and coral reef.

***Cantoria annulata* – banded watersnake**

Nationally-listed	×	Not listed
Trade-restricted	×	Not listed
IUCN threatened	×	Data Deficient
Endemic and/or restricted-range	✓	This species is expected to be restricted-range based on a distribution of less than 100,000 km^2
Migratory and congregatory	×	Species does not migrate or congregate
Overall vulnerability	***Moderate vulnerability***	

The banded watersnake is a sea snake species known only from seven records within the western gulf (Murphy and Allison, 2010). Based on its current distribution, it is considered to be restricted-range and endemic to the mangrove and nipa palm habitat of the southern coastline of New Guinea. The species has not been recorded to date near the Purari River delta but, due to the presence of mangrove wetlands, is considered as potentially occurring.

There is currently very little information available regarding *C. annulata*.

Based on the above, the following occurrence of the species is noted:

- Orokolo Bay – ***Possible***, based on available habitat within proximity to historical sightings.
- Offshore export pipeline corridor – ***Unlikely***, based on lack of suitable habitat.
- Caution Bay – ***Unlikely***, as area is beyond modelled distribution.

6.5.3.3 Crocodiles

There is only one crocodile known to occur within the marine waters of Papua New Guinea: saltwater crocodile (*Crocodylus porosus*). This is discussed below.

***Crocodylus porosus* – saltwater crocodile**[14]



Nationally-listed	×	Not listed
Trade-restricted	✓	Appendix II/Schedule 2
IUCN threatened	×	Least Concern
Endemic and/or restricted-range	×	Species is not restricted to the Gulf of Papua and Southeast Papua New Guinea ecoregions and has a range greater than 100,000 km^2
Migratory and congregatory	✓	Listed under Bonn Convention
Overall vulnerability	***Moderate vulnerability***	

Saltwater crocodiles are known to occur in the Purari River based on observations during the January 2017 survey and village interviews conducted at Orokolo Bay – see Upstream Land and Natural Resources Baseline Report (Booyong Forest Science, 2017). The species commonly uses marine waters (Crocodile Specialist Group, 1996; DoEE, 2017k) and is therefore expected to occur within Orokolo Bay. It is unlikely to occur in offshore waters as individuals tend to stay close to the coast (DoEE, 2017k).

The species was not, however, recorded in Caution Bay or the Vaihua River estuary as part of the PNG LNG Project EIS (CNS, 2009), despite there being suitable habitat in this area.

Nesting by saltwater crocodiles occurs within freshwater swamps (DoEE, 2017k) and estuarine areas and is therefore not expected within the marine environment. See further description in the Upstream Terrestrial Biodiversity Baseline Report (ERIAS, 2017a).

Key threats to this species are habitat conversion as well as illegal harvesting, although the species is not currently considered to be threatened.

Based on the above, the following occurrence of the species is noted:

- Orokolo Bay – ***Known***, based on recent sightings.
- Offshore export pipeline corridor – ***Unlikely***, due to depth.
- Caution Bay – ***Possible***, based on available habitat.

[14] Photo from January 2017 marine field survey

Table 6-3 Threatened/Important Marine Flora and Fauna Species with Likely or Possible Occurrence in the Study Area

Species name	Common name	Relevant threatened/ important status	Supporting habitat	Purari / Orokolo Bay	Offshore export pipeline corridor	Caution Bay
Hydrocharitaceae						
Enhalus acoroides	-	Least Concern (decreasing)	Shallow waters (<5 m depth) with high water clarity	Does not occur	Does not occur	Known
Sawfish (Pristidae)						
Pristis pristis	Largetooth sawfish	CITES Appendix I IUCN Critically Endangered Migratory	Coastal waters near large river mouths	Likely	Possible	Unlikely
Pristis zijsron	Green sawfish	CITES Appendix I IUCN Critically Endangered Migratory	Shallow coastal waters near large river mouths	Possible	Unlikely	Unlikely
Anoxypristis cuspidata	Narrow sawfish	CITES Appendix I IUCN Endangered Migratory	Coastal waters near large river mouths	Known	Possible	Unlikely
Requiem sharks (Carcharhinidae)						
Glyphis glyphis	Speartooth shark	IUCN Endangered	Coastal waters near large river mouths	Likely	Unlikely	Unlikely
Glyphis garricki	Northern river shark	IUCN Critically Endangered	Coastal waters near large river mouths	Possible	Unlikely	Unlikely
Carcharhinus leucas	Bull shark	IUCN Near Threatened	Coastal waters through to edge of continental shelf	Likely	Likely	Likely
Carcharhinus macloti	Hardnose shark	IUCN Near Threatened	Coastal waters through to edge of continental shelf	Likely	Likely	Known
Hammerhead sharks (Sphyrnidae)						
Eusphyra blochii	Winghead shark	IUCN Endangered	Coastal waters through to edge of continental shelf	Known	Likely	Likely
Bamboo sharks (Hemiscylliddae)						
Hemiscyllium hallstromi	Papuan epaulette shark	IUCN Vulnerable Endemic	Coastal waters near coral reefs and seagrass meadows	Unlikely	Unlikely	Likely

Species name	Common name	Relevant threatened/ important status	Supporting habitat	Purari / Orokolo Bay	Offshore export pipeline corridor	Caution Bay
Guitarfish (Rhinobatidae)						
Glaucostegus typus	Giant shovelnose ray	IUCN Vulnerable	Coastal waters through to edge of continental shelf	Likely	Unlikely	Likely
Aetobatus narinari	Spotted eagle ray	IUCN Near Threatened	Coastal waters, especially near coral reefs	Likely	Possible	Likely
Rays (mantas and mobulas)						
Manta birostris	Giant manta ray	CITES Appendix II IUCN Vulnerable Migratory	Pelagic waters	Unlikely	Possible	Unlikely
Manta alfredi	Reef manta ray	CITES Appendix II IUCN Vulnerable Migratory	Nearshore through to pelagic waters	Possible	Possible	Likely
Mobula eregoodootenkee	Pygmy devilray	CITES Appendix II IUCN Near Threatened Migratory	Nearshore through to pelagic waters	Possible	Possible	Possible
Mackerels (Scombridae)						
Scomberomorus multiradiatus	Papuan seerfish	Restricted-range	Coastal waters through to edge of continental shelf	Known	Likely	Likely
Scomberomorus commerson	Narrow-barred Spanish mackerel	IUCN Near Threatened Migratory	Coastal waters through to edge of continental shelf	Likely	Likely	Likely
Groupers (Serranidae)						
Epinephelus coioides	Orange spotted grouper	IUCN Near Threatened	Coastal waters near large river mouths	Known	Possible	Likely
Epinephelus fuscoguttatus	Brown marbled grouper	IUCN Near Threatened	Coastal waters near coral reefs and seagrass meadows	Likely	Possible	Likely
Sea cucumbers (Holothuridae)						
Actinopyga echinites	Deepwater redfish	IUCN Vulnerable	Coastal waters, estuaries, reef flats, seagrass meadows	Known	Unlikely	Known
Actinopyga mauritana	Surf redfish	IUCN Vulnerable				
Actinopyga miliaris	Hairy blackfish	IUCN Vulnerable				

Species name	Common name	Relevant threatened/ important status	Supporting habitat	Purari / Orokolo Bay	Offshore export pipeline corridor	Caution Bay
Holothuria fuscogilva	White teatfish	IUCN Vulnerable				
Holothuria lessoni	Golden sandfish	IUCN Endangered				
Holothuria nobilis	Black teatfish	IUCN Endangered				
Holothuria scabra	Sandfish	IUCN Endangered				
Stichopus hermannii	Curryfish	IUCN Vulnerable				
Thelenota ananas	Prickly redfish	IUCN Endangered				
Rock Lobsters (Paniluridae)						
Panulirus ornatus	Ornate lobster	Migratory and/or congregatory	Usually occurrence in shallow waters (<8 m depth) near coast Migration in waters 40-80 m deep through northern gulf to Yule Island Spawning near Yule Island	Possible	Known	Likely
Dugong (Dugongidae)						
Dugong dugon	Dugong	Protected CITES Appendix I IUCN Vulnerable Migratory	Coastal waters near seagrass meadows	Unlikely	Unlikely	Possible
Dolphins (Delphinidae)						
Tursiops aduncus	Indo-Pacific bottlenose dolphin	CITES Appendix II Migratory	Pelagic waters	Likely	Likely	Likely
Tursiops truncatus	Common bottlenose dolphin	CITES Appendix II Migratory	Pelagic waters	Likely	Likely	Likely
Delphinus delphis	Short-beaked common dolphin	CITES Appendix II Migratory	Pelagic waters	Likely	Likely	Likely
Stenella longirostris	Spinner dolphin	CITES Appendix II Migratory	Pelagic waters	Likely	Likely	Likely
Stenella attenuata	Pantropical spotted dolphin	CITES Appendix II Migratory	Pelagic waters	Likely	Likely	Likely
Orcaella heinsohni	Australian snubfin	CITES Appendix I	Coastal waters near large river mouths	Likely	Unlikely	Likely

Species name	Common name	Relevant threatened/ important status	Supporting habitat	Purari / Orokolo Bay	Offshore export pipeline corridor	Caution Bay
	dolphin	IUCN Near Threatened Migratory	Coastal waters near seagrass meadows			
Sousa sahulensis	Australian humpback dolphin	CITES Appendix I IUCN Vulnerable Migratory	Coastal waters near large river mouths	Likely	Unlikely	Likely
Sea Turtles (Cheloniidae and Demochelyidae)						
Chelonia mydas	Green turtle	CITES Appendix I IUCN Endangered Migratory	Coastal waters near seagrass meadows Low-gradient sandy beaches	Possible	Likely	Likely
Eretmochelys imbricata	Hawksbill turtle	CITES Appendix I IUCN Critically Endangered Migratory	Coastal waters near coral reefs and seagrass meadows	Unlikely	Likely	Likely
Caretta caretta	Loggerhead turtle	CITES Appendix I IUCN Vulnerable Migratory	Coastal waters near coral reefs and seagrass meadows	Unlikely	Likely	Likely
Dermochelys coriacea	Leatherback turtle	Protected CITES Appendix I IUCN Critically Endangered Migratory	Pelagic waters	Unlikely	Possible	Unlikely
Lepidochelys olivacea	Olive ridley turtle	CITES Appendix I IUCN Vulnerable Migratory	Coastal waters near coral reefs and seagrass meadows	Unlikely	Likely	Likely
Natator depressus	Flatback turtle	CITES Appendix I Migratory	Coastal waters near coral reefs and seagrass meadows	Possible	Likely	Likely
Elapid Snakes (Elapidae)						
Laticauda guineai	Guinea's sea krait	IUCN Near Threatened Endemic	Coastal waters near coral reefs	Does not occur	Possible	Likely
Water snakes (Homolopsidae)						

Species name	Common name	Relevant threatened/ important status	Supporting habitat	Purari / Orokolo Bay	Offshore export pipeline corridor	Caution Bay
Cantoria annulata	Banded water snake	Restricted-range	Coastal waters near mangroves and nipa palm wetlands	Possible	Unlikely	Unlikely
Crocodiles (Crocodylidae)						
Crocodylus porosus	Saltwater crocodile	CITES Appendix II Migratory	Coastal waters near large river mouths	Known	Unlikely	Possible

6.6 Sensitive Habitat Features

The preceding sections describe the threatened/important species and ecosystems of the study area and their vulnerability. The following identifies the overall sensitivity of discrete areas of the study area based on these species and other criteria discussed in Section 5.7.2.

Based on the information in preceding sections, the following sensitive marine habitat are identified for the study area:

- Soft sediment benthic substrate, including sand, silts and mud.
- Rocky reefs.
- Coral reefs.
- Seagrass meadows.
- Highly turbid waters adjacent to the Purari and Vailala rivers.
- Tropical rock lobster migratory path (northern Gulf between Purari River and Yule Island, between 40 and 80 m depth contours).
- Tropical rock lobster spawning ground (Yule Island).
- Green turtle aggregation site (Cape Suckling).
- Turtle nesting beaches.

Table 6-4 assesses each of these habitats against vulnerability and irreplaceability criteria from Section 5.7.2 and provides an overall rating of sensitivity.

Table 6-4 Sensitivity Rating of Marine Habitat Values and Areas

Marine habitat value/area	Sensitivity rating	Comments/applicable criteria
Soft sediment benthic substrate	***Low***	Habitat type does not provide suitable habitat for species of *moderate*, *high* or *extreme* vulnerability AND is not considered to be unique.
Rocky reefs	***Low***	
Coral reefs	***High***	Potentially supports coral species with *extreme* vulnerability. Provides habitat utilized by non-coral species with *moderate*, *high* and *extreme* vulnerability, although not considered to be critical to survival and/or lifecycle functions of these species. NOTE: Due to uncertainty regarding presence of coral species with *extreme* vulnerability, the overall sensitivity rating is *high* rather than *extreme*.
Seagrass meadows	***Moderate***	Supports seagrass species (*E. acoroides*) with *moderate* vulnerability. Provides habitat utilized by non-seagrass species with *moderate*, *high* and *extreme* vulnerability, although not considered critical to survival and/or lifecycle functions of these species.
Highly turbid waters adjacent to large rivers	***Moderate***	Provides primary feeding habitat for species with *high* (*O. heinsohni*, *S. sahulensis*) and *extreme* vulnerability (*G. glyphis*).
P. ornatus migratory path	***High***	Area within migration route for migratory species (*P. ornatus*) that occurs only within the Gulf of Papua and Southeast Papua New Guinea ecoregions.

Marine habitat value/area	Sensitivity rating	Comments/applicable criteria
P. ornatus spawning ground	***High***	Area within spawning ground for migratory species (*P. ornatus*) that occurs only within the Gulf of Papua and Southeast Papua New Guinea ecoregions.
C. mydas aggregation site	***High***	Area used by congregatory species (*c. mydas*) that is of *extreme* vulnerability but is representative within other parts of the ecoregions of the study area and surrounds.
Turtle nesting beaches	***Moderate***	Potentially provides habitat important to lifecycle functions of a species with *moderate*, *high* or *extreme* vulnerability (green turtle). NOTE: Due to the uncertainty regarding the use of specific locations for nesting, the overall rating for all possible nesting beaches is *moderate* rather than *high* or *extreme*.

6.7 Invasive Species

Information on invasive alien species in Port Moresby and throughout Papua New Guinea is not available. However, many of the reef-associated species of northern Australia and the Great Barrier Reef are common to Papua New Guinea and move between the Torres Strait, the northern Great Barrier Reef and fringing reefs of Papua New Guinea. Current marine pests of northern Australia include the Asian green mussel (*Perna viridis*) and Caribbean tubeworm (*Hyrdoides sanctaecrucis*). These species have not yet been recorded outside of port areas, but may be present in Port Moresby given close shipping movements between it and Cairns.

In addition to invasive alien species, some invasive native species can reach levels where they cause harm to the environment. The crown-of-thorns sea star (*Acanthaster planci*) is native to the reefs of the Indo-Pacific (including Papua New Guinea), mostly occurring at very low densities (typically less than one individual/hectare) (Birkeland and Lucas, 1990). However, population outbreaks are one of the most significant biological disturbances on tropical coral reefs.

The closest reported crown-of-thorns sea star outbreak site to the study area is Bootless Bay, a large, embayment, approximately 15 km southeast of Port Moresby. High levels (up to 85%) of recent coral mortality recorded throughout Bootless Bay in 2006 were associated with a severe outbreak (Pratchett *et al*. 2009). Mean densities of the sea star recorded in Bootless Bay averaged 162/ha, significantly exceeding the benchmark of 15/ha which has been used to characterize reef-wide outbreaks on the Great Barrier Reef (Moran and De'ath, 1992). This was the first reported outbreak of the sea star in this region.

The proximity of Bootless Bay to the Caution Bay, coupled with the known coral coverage within the area, indicates that this site may be prone to an outbreak of the starfish.

6.8 Summary

The marine biodiversity baseline for each of the three parts of the study area can be described as set out below.

6.8.1 Orokolo Bay

This area represents a marine delta and coastal embayment, heavily influenced by the outflows from the Purari River. As a result, benthic habitat within the marine environment consists predominantly of soft sediment, with a mixture of sandy substrate and areas of high silt content. The most significant benthic feature in this area is a rocky reef (at Site M6, offshore of Vailala River). This reef supports filter feeding soft corals, sponges, ascidians, and echinoderm species that tolerate episodes of high turbidity and low salinity associated with fluvial discharges and seasonal weather patterns.

Due to the proximity of this area and the Purari River, it is expected that a number of juvenile and sub-adult fish species, as well as estuarine fish and reptile species, occur within the area. This may include threatened sawfish and river sharks as well as nearshore dolphin species. Beaches in the area may also support nesting by green turtles.

There are no known invasive species within this area.

6.8.2 Offshore Export Pipeline Corridor

The benthic environment of the offshore export pipeline corridor is predominantly bare substrate and does not support a significant diversity of macrobenthic invertebrate or fish species.

The ornate rock lobster (*Panulirus ornatus*) migration route overlaps with some areas of the offshore export pipeline corridor. Near Yule Island, the spawning area for the lobster as well as part of the Cape Suckling green turtle aggregation area also overlap with the corridor. In addition, cetacean, fish and marine turtle species are expected to pass through the pelagic waters of this area.

6.8.3 Caution Bay

Caution Bay supports a number of different and important marine biotope types, including seagrass, coral reefs and soft sediment substrates. These habitats support assemblages of high fish diversity, although previous fish surveys found some impact from local fishing pressures. Some coral reef habitat within the bay shows signs of degradation due to fishing pressure, but many shallow and deep reefs within the bay and at Vari Vari and Idhihi islands are considered to be in excellent condition.

Any impacts from the PNG LNG Project at Caution Bay are not readily discernible, however restrictions on damaging fishing practices, such as use of dynamite, may have facilitated the recovery of living coral habitat in the area.

A number of threatened/important species are likely to occur within this area, including sea turtles, fish and dolphins.

Caution Bay may also be impacted by outbreaks of the crown-of-thorns sea star (*Acanthaster planci*) an invasive native species that can cause significant harm to coral reef ecosystems.

6.8.4 Sensitive Species, Ecosystems and Habitat Features

In total, the study area is expected to support 35 threatened/important species. This includes:

- Five species listed as Critically Endangered on the IUCN Red List, two of which are considered Likely to occur in part of the study area while three are considered Possible to occur. These species are elasmobranchs (cartilaginous fish), including sharks, rays and sawfish, as well as sea turtles.
- Eight species listed as Endangered, six of which are Known to occur in the study area and two which are considered Likely to occur. These species include elasmobranchs, sea turtles and sea cucumbers.
- Thirteen species listed as Vulnerable, five of which are Known to occur in the study area, six of which are considered Likely to occur, and two of which are considered Possible to occur.
- Nine listed as Near Threatened, two of which are Known to occur in the study area, six of which are considered Likely to occur, and one of which is considered Possible to occur.

The remainder of the threatened/important species are not considered as threatened on the IUCN Red List but are relevant due to endemism, restricted-range status, migratory and/or congregatory status, or restricted from trade under CITES or the *International Trade (Fauna and Flora) Act 1979*. Two of the species that could possibly occur in the study area, the dugong and the leatherback turtle, are Protected under the *Fauna (Protection and Control) Act 1966*.

In addition to these species, a number of habitats in the study area are considered to be of *moderate* or *high sensitivity* due to their intrinsic value and/or support of vulnerable species. These are coral reefs and seagrass meadows (Caution Bay), highly turbid waters adjacent to large rivers (Orokolo Bay), the *P. ornatus* migratory path and spawning ground (offshore export pipeline corridor), the Cape Suckling aggregation area for green turtles (offshore export pipeline corridor), and potential green turtle nesting beaches at Orokolo Bay.

7 Conclusions

The Papua LNG Project has the potential to affect the marine biodiversity values of habitats of the Gulf of Papua, between the Purari River and Caution Bay. While some previous studies of marine biodiversity in these areas have been conducted (most comprehensively and recently at Caution Bay for the PNG LNG Project EIS), further studies have been required in order to characterize the baseline environment for the purpose of an EIS/ESHIA.

These studies have focused on mapping and characterizing available marine habitat (e.g. seagrass, coral reefs and benthic substrate), identifying the occurrence of marine fauna populations, and identifying key species likely to occur in the study area that are threatened, protected under legislation or important for the purposes of impact assessment.

The key findings of the baseline characterization are as follows:

- Nearshore environments of Orokolo Bay (particularly those at and near river mouths) provide potential or known habitat for threatened sawfish and shark species, as well as nearshore dolphin species. Fauna inhabiting such an environment are less sensitive to periodic disturbance (e.g. changes in salinity and high turbidity) than reef systems in Caution Bay.
- The most significant marine habitat feature at Orokolo Bay is a rocky reef occurring offshore of the Vailala River. The remainder of the bay predominantly consists of soft sediment without seagrass meadows.
- Habitat values of the offshore export pipeline corridor are restricted to soft sediment substrate without seagrass meadows or reef assemblages.
- By contrast to Orokolo Bay and the offshore export pipeline corridor, Caution Bay provides a range of coral reef systems and seagrass meadows, together with soft sediment substrate. Coral reef and seagrass are features of high biodiversity significance and are sensitive to disturbance.
- Threatened/important species are known or likely to occur in the study area, including sawfish and river sharks, nearshore dolphins, sea turtles, reef, nearshore and pelagic fish, and rays. The most important habitat values associated with these species are seagrass meadows, coral reef, the mouths of large rivers and low gradient beaches. Other sensitive areas include the migratory path and spawning ground of the ornate rock lobster and the Cape Suckling green turtle aggregation site.
- There is little information available regarding invasive species in the study area, although Caution Bay is expected to be most at risk due to proximity to shipping channels and Port Moresby.

8 Study Team

The members of the study team responsible for the preparation of the Marine Biodiversity Baseline Report are listed in Table 8-1 below.

Table 8-1 Marine Biodiversity Study Team

Personnel	Position	Qualifications
Dr Darren Richardson	Study Director Technical Lead for Ecology	Bachelor of Applied Science (Honors) Doctor of Philosophy
Dr Conor Jones	Senior Marine Ecologist	Bachelor of Science (Honors) Doctor of Philosophy
Daniel Moran	Marine Ecologist	Bachelor of Science (Honors)
Brad Hiles	Senior Environmental Scientist	Bachelor of Applied Science, Bachelor of Education
Jeremy Visser	Study Coordinator	Bachelor of Laws, Bachelor of Environmental Management
Lyn Leger	Study Manager	Bachelor of Laws, Bachelor of Science (Honors) Master of Laws

9 Glossary and Abbreviations

Autotrophic	Autotrophic organisms (e.g., plants, algae) that can manufacture their own food from their surroundings, such as through photosynthesis
Benthic suspension-feeders	An aquatic organism pertaining to the seafloor (or bottom) of a river, coastal waterway, or ocean that feeds on particles of organic matter suspended in the water column
Biotope	An area that supports a specific set of environmental conditions. Often synonymous with 'habitat'.
Bonn Convention	Convention on the Conservation of Migratory Species of Wild Animals
BRUV	Baited Remote Underwater Video
Caution Bay	Subset of the Study Area, including all the waters of Caution Bay, as far seaward as the offshore export pipeline corridor
CEPA	Conservation and Environment Protection Authority of Papua New Guinea
CHIRP	Compressed High Intensity Radar Pulse
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CNS	Coffey Natural Systems
Congregatory	Referring to species whose individuals gather in large groups on a cyclical or otherwise regular and/or predictable basis
CPF	Central Processing Facility
CPUE	Catch per unit effort
Critical Habitat	Habitat feature identified under IFC Performance Standard 6. Described as 'areas with high biodiversity value, including: (i) habitat of importance to Critically Endangered and/or Endangered species (as listed under IUCN Red List); (ii) habitat of significant importance to endemic and/or restricted-range species; (iii) habitat supporting globally significant concentrations of migratory and/or congregatory species; (iv) highly threatened and/or unique ecosystems; and/or (v) areas associated with key evolutionary processes.
CTI-CFF	Coral Triangle Initiative on Coral Reefs Fisheries and Food Security
Demersal fish	Bottom foraging fish that normally live near or on the seabed
Detritivore	An organism that feeds on dead organic material, particularly plant detritus
DoEE	Australian Federal Department of the Environment and Energy
DNRM	Queensland (Australia) State Department of Natural Resources and Mines
EHS Guideline	Environment, Health and Safety Guidelines, developed by the IFC as representation of good international industry practice
EIS	Environmental Impact Statement
ENSO	El Niño-Southern Oscillation
ESBS	Environmental and Social Baseline Study
ESHIA	Environment, Social and Health Impact Assessment
GBRMPA	Australian Federal Great Barrier Reef Marine Park Authority
GL-ENV/02/2004	*Guideline for Conduct of Environmental Impact Assessment & Preparation of Environmental Impact Statement*, prepared by (former) Department of Environment and Conservation (2004)

GS EP ENV 120	*Environmental impact assessment of E&P activities*, General Specification prepared by TOTAL (2007)
GS EP ENV 111	*Environmental Baseline and Monitoring Studies: Onshore Sites*, General Specification prepared by TOTAL (2012)
GS EP ENV 112	*Environmental Baseline and Monitoring Studies: Offshore and Nearshore Sites*, General Specification prepared by TOTAL (2012)
Heterotroph	Rely on consuming organic material for nutrition
IFC	International Finance Corporation
IUCN	International Union for the Conservation of Nature
IPIECA	International Petroleum Industry Environmental Conservation Association
LNG	Liquid natural gas
MARPOL	International Convention for the Prevention of Pollution from Ships
Migratory	Any species of which a significant proportion of its members cyclically and predictably move from one geographical area to another
NFA	National Fisheries Authority of Papua New Guinea
NMSA	National Maritime Safety Authority of Papua New Guinea
OECD	Organization for Economic Cooperation and Development
Offshore export pipeline corridor	Subset of the study area based on the offshore export pipeline corridor defined for the Project
Papua LNG	Gas extraction, transport and processing project proposed by TEP PNG. Involves operation of Elk-Antelope gasfields in Gulf Province, and onshore and subsea pipeline via Orokolo Bay to LNG Plant at Caution Bay, Central Province
PDL	Petroleum Development License
Pelagic	Of or relating to open ocean
PL	Pipeline License
PNG LNG	Gas extraction, transport and processing project operated by ExxonMobil. Involves operation of gasfields in Hela and Western Provinces, and onshore and subsea pipeline to LNG Plant at Caution Bay, Central Province
PPFL	Petroleum Processing Facility License
PPL	Petroleum Prospecting License
Primary production	The rate in which biomass is produced by photosynthetic organisms
PRL	Petroleum Retention License
Project	The Papua LNG Project
PCA	Principal components analysis
PNG94	Papua New Guinea 1994 datum
PSD	Particle size distribution
Orokolo Bay	Subset of the study area, including the waters immediately adjacent to the Purari River mouth through to Orokolo Bay, as far seaward as the offshore export pipeline corridor
QTC	Quester Tangent Corporation
Red List of Threatened Ecosystems	List maintained by the IUCN that provides threatened status for a range of assessed ecosystems
Red List of Threatened Species	List maintained by the IUCN that provides threatened status for a range of assessed species

Restricted-range	A species that is known to be restricted to a limited geographic area. Within marine systems, this is all species with an extent of occurrence of 100,000 km^2 or less
SSS	Sidescan Sonar, a series of sonic beams used to display seafloor characteristics
Study Area	The area which is the focus of this ESBS report, consisting of the following three subsets: (i) Orokolo Bay. (ii) Offshore export pipeline corridor. (iii) Caution Bay.
Subtidal	Permanently below the level of low tide, an underwater environment
Supratidal	Above the level of high tide, a terrestrial environment
TEP PNG	Total E&P Papua New Guinea
Threatened/important species	Term used to describe species considered of key relevance to the ESBS based on listing or conservation status. Consists of the following: • species listed as Protected or Restricted under the *Fauna (Protection and Control) act 1966* as per the list in Kula and George (1996). • species listed in appendices I or II of CITES or in schedules 1 or 2 of the *International Trade (Flora and Fauna) Act 1979.* • species listed as Near Threatened, Vulnerable, Endangered or Critically Endangered on the IUCN Red List. • species that are endemic and/or restricted range based on IFC PS 6 principles. • species that are migratory or congregatory based on IFC PS 6 principles.
UTM	Universal Trans Mercator
UTS	University of Technology Sydney
UXO	Unexploded ordnance
WMA	Wildlife Management Area

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Appendix A Acoustic Habitat Mapping Methodology

Soft sediment habitats within and adjacent to the project areas at Orokolo Bay and Caution Bay were mapped using acoustic techniques including a single beam (200 kHz) Hondex Model 7300 echo sounder with a sonar beam width of 10° and a Tritech Starfish 450kHz Sidescan Sonar (SSS) system with a swath width of up to 200 meters. The echo sounder was interfaced to the Quester Tangent Corporation (QTC) View Series 5 (Version R2.10) system, which consists of hydrographic survey hardware and software components tailored to acoustic seabed discrimination based upon the shape of acoustic sonar returns from the seabed. Acoustic data from the SSS was captured and processed using the StarFish Scanline software. The use of SSS in conjunction with the single beam habitat mapping apparatus allowed both validation of the single beam results and coverage of a greater swath width during the survey. The raw acoustic data were stored in real-time on laptop computers running the QTC View Series 5 software and StarFish Scanline software and backup copies of the acoustic data were created each day during data acquisition.

The QTC system records the characteristics of the reflected acoustic waveforms to generate habitat classifications, based upon the diversity of scattering and penetration of the acoustic signal from varying types of seabed. The process involves collection of acoustic data which are time stamped and geo-referenced using dGPS. The 200 kHz frequency has consistently provided reliable seabed habitat descriptions in studies by BMT WBM and others. Previous studies comparing the results of the two frequencies with the results of video ground-truthing surveys found that the 200 kHz acoustic frequency provided the most reliable and consistent output (BMT WBM 2008). This approach has been utilized previously by Riegl et al. (2005), who also found a 200 kHz frequency to provide greater resolution and detail for mapping habitats when compared to the results from a 50 kHz frequency, when using the same QTC View dual frequency methodology.

The QTC suite of programs was used to process acoustic data (Locker and Wright, 2003; Riegl and Purkis 2005; Preston *et al.* 2006). During data acquisition, QTC Real-Time was used to show preliminary classifications which allowed sampling effort to be adjusted based on the heterogeneity of the seafloor. Raw data files were also post-processed using the QTC IMPACT software package and all data were checked for correct time stamps, correct depths and correct signal strengths. Acoustic records from all of the data acquisition at Orokolo Bay were combined for the backscatter analysis using the QTC Impact seabed classification software. This allowed comparison of sediments (and eventually habitat classes) between these areas. The same methods were used to process data from Caution Bay.

Using the QTC IMPACT software (version R3.40), the acoustic echoes were digitized and normalized to a range between 0 and 1, before being subjected to further analysis. The data were then reduced by generating Full Feature Vectors, referred to hereafter as acoustic records. Acoustic records were displayed on a bathymetry plot where the recorded depth was checked against the blanking (minimum recordable) depth and the maximum depths expected for the study area, based upon existing bathymetric information.

QTC IMPACT was used to classify acoustic signals (echograms) that returned from the seabed into statistically different acoustic classes. All acoustic records were subjected to principal components analysis (PCA) to eliminate redundancies and noise. The first three principal components of each echo (called Q values) were retained, according to the theory that these typically describe 95% of the information within each echo. Data points were then projected into three dimensional space along these three components (Figure A-1), where they were then subjected to cluster analysis to determine echoes of similar signature. QTC Impact's Auto Clustering Engine was used to determine the most probable number of habitat classes out of a maximum of 30 classes.

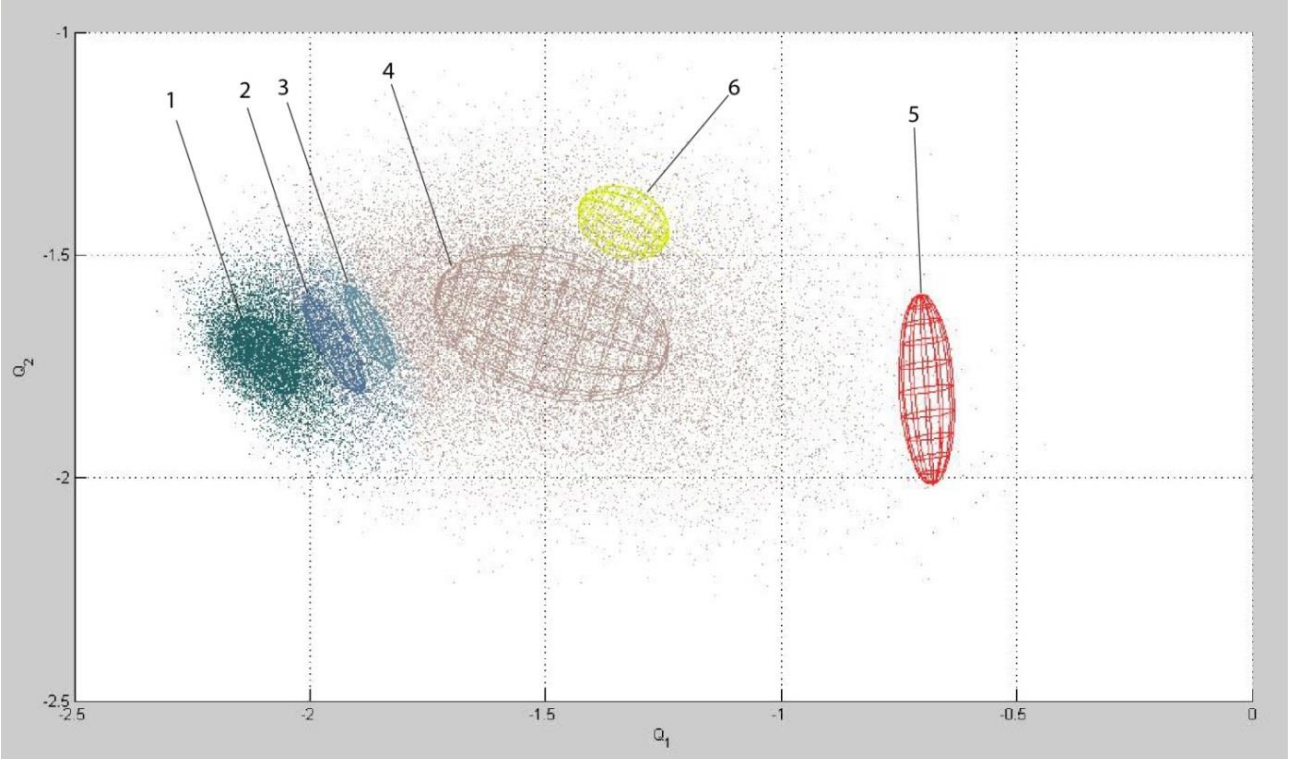
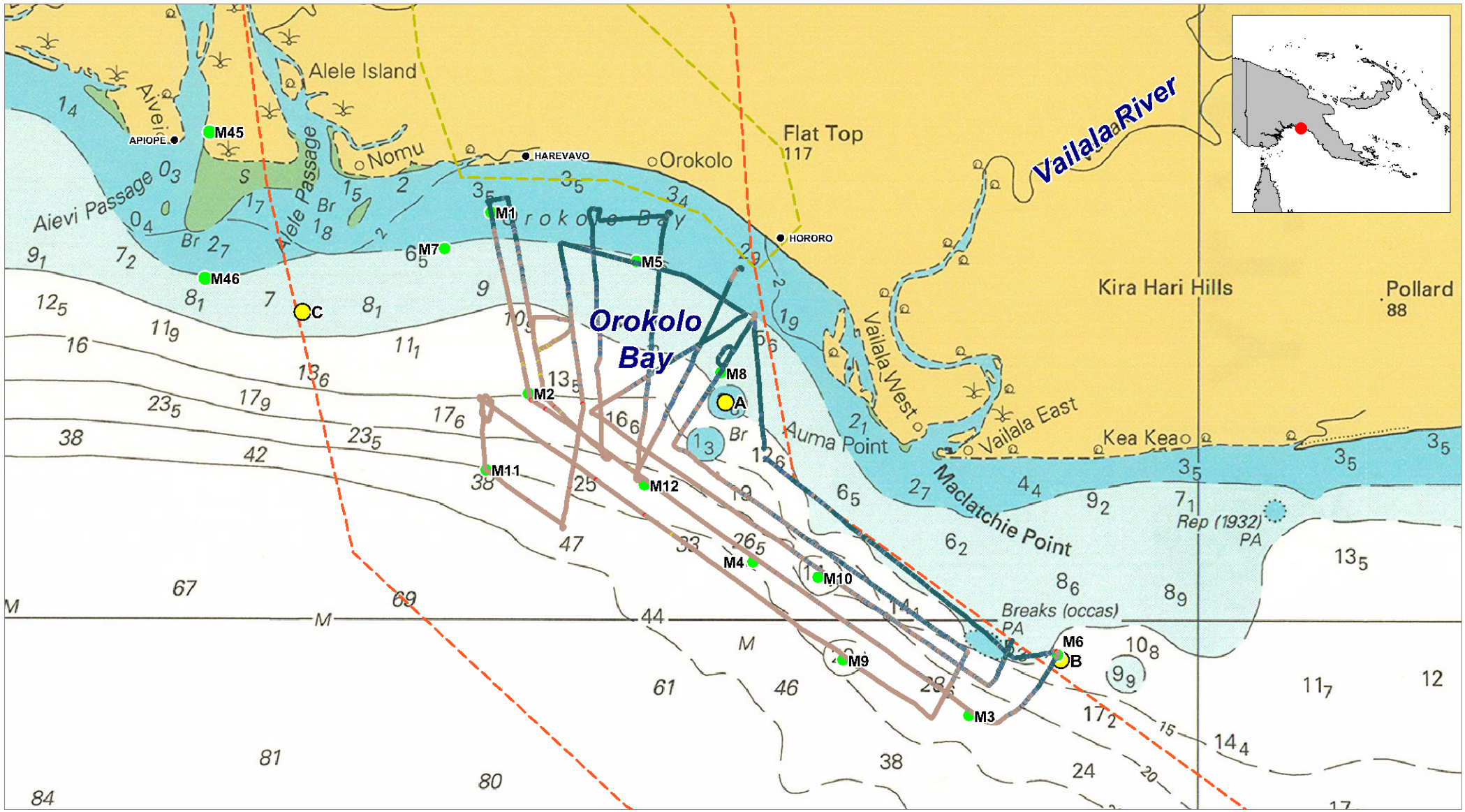


Figure A-1 PCA Ordination of Acoustic Returns

For each individual signal, the following data were exported from QTC IMPACT: latitude and longitude; depth (uncorrected for tidal or wave states); three PCA axes (called Q axes); a class category; a class assignment confidence value and a class probability value, which both range from 0 to 100%. These indices may be useful for further determining the overall 'quality' of individual data points and classes. Records with confidence less than 95% were removed from the analysis.

Six habitat classes were identified from the data collected at Orokolo Bay (Figure A-1). Five of these classes were real habitat classifications which included four grades of silty mud and one category of hard substrate. The sixth category was not a substrate type but was an anomalous category generated from the presence of large schools of fish which the survey vessel passed on a number of occasions in the north-western quadrant of the survey area. No other anomalous categories were recorded during the survey at Orokolo Bay. For the purposes of data presentation and interpolation, each dataset has been reduced to a three column matrix consisting of a single x, y and geo-referenced seabed class category. The locations and classification of 41,161 'cleaned' acoustic records used in this study are shown in Figure A-2. For Caution Bay, a total of 5 real habitat classes were identified from the raw data and the same processes were used to reduce the data to a useable geo-referenced form.



LEGEND

- Town/Village
- Sampling and validation sites
- Instrument deployment site
- Pipeline Corridor
- Narrowed Onshore Pipeline Corridor

Acoustic Habitat Categories

- 1
- 2
- 3
- 4
- 5
- 6

Title:

Acoustic Data Collection Locations and Classifications

Figure: A-2

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 5 10

Approx. Scale

BMT WBM

www.bmtwbm.com.au

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A natural neighbor interpolation with mean values was used to create benthic habitat maps using Vertical Mapper v3.1 through the MapInfo 10.5 platform.

Natural-neighbor interpolations use a Voronoi tessellation, which is a grid-mesh drawn between existing 'real' data points used to fill in data between 'missing' data points (Figure A-3). In the example shown below, the central black data point (cell) is interpolated by calculating the relative input from surrounding points. The relative contributions of neighboring points are shown as green circles, and relate to how much of their respective areas fall within the search radius. The search radius is shown as a blue polygon surrounding the cell (Figure A-3).

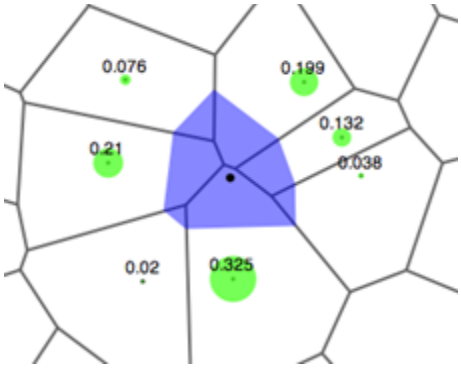


Figure A-3 Example Natural-neighbor Interpolation: the Voronoi tessellation is shown as a black grid, relative weighting is shown in green, the cell size (pixel width) is shown as a central black dot, and the radial aggregation distance is shown in blue

Mean values were interpolated because acoustic classes agreed well with reference sediment types from the broad-scale mapping, and classes showed serial ordination (Figure A-1). For example, class 2 and 4 habitats were separated by class 3 habitats existing between them.

Additional ground-truthing of the acoustic mapping study area was also carried out to further assess the sediment and biotope types within the acoustic habitat classes, and to characterize epibenthic communities within each habitat class. Sediment types were sampled through grab-based sampling and subsequently subject to sieve analysis to determine particle grain size distribution. Epibenthic communities were sampled using an underwater video camera.

Appendix B June-July 2016 and January 2017 Survey Results

Table B-1 summarizes the field survey results that have been analyzed for the purposes of the Marine Biodiversity Baseline Report. Some of these results are provided within Section 6 of this report while the others are shown below.

Table B-1 Data Sources

Type of result	Description	Location
Macroinvertebrate data	Results of macroinvertebrate identification	Appendix B
Particle size distribution data	Results of PSD testing on sediment samples – provides indication of benthic habitat types	Marine Water and Sediment Quality Baseline Report (BMT WBM, 2017e)
Acoustic habitat mapping	Results of processing of acoustic imaging data – provides indication of benthic habitat types	Section 6-2
Representative stills at validation points	Stills of video footage representing the habitat identified at individual ground-truthing/validation points	Section 6-2
Summary data from validations points	Summary information extracted from drop camera footage	Appendix B
Representative stills or BRUV footage	Stills of BRUVS footage representing key species and/or aggregations	Section 6-3
Summary data from BRUV footage	Summary information extracted from BRUV footage	Section 6-3

B.1 Macroinvertebrate Results

Table B-2 Macroinvertebrate Results: June-July 2016 Survey (Offshore Export Pipeline Corridor). Numbers represent abundance in each replicate (A, B, and C) for each site

Species						Site 25			Site 31			Site 37			Site 43		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C
18	Adamnestia sp	Cylichnidae	Cephalaspidea	Gastropoda	Mollusca	1		1	1	1							1
12	Agalophamus sp	Nephtyidae	Phyllodocida	Polychaeta	Annelida	1						3					
7	alpheid	Alpheidae	Decapoda	Malacostraca	Crustacea	1	1				1		1	2			
111	Amaeana trilobata (Sars:1863)	Terebellidae	Terebellida	Polychaeta	Annelida							1	1				
174	Amoria sp	Volutidae	Neogastropoda	Gastropoda	Mollusca			1									
98	Ampelisca sp 1	Ampeliscidae	Amphipoda	Malacostraca	Crustacea			1				1	3	3			
139	ampharetid 1	Ampharetidae	Terebellida	Polychaeta	Annelida			1					1				
137	amphinomid 1	Amphinomidae	Amphinomida	Polychaeta	Annelida								1				
163	Amphioplus sp	Amphiuridae	Ophiurida	Ophiuroidea	Echinodermata			2						1			
164	amphipod 1	.	Amphipoda	Malacostraca	Crustacea									2			
165	amphipod 2	.	Amphipoda	Malacostraca	Crustacea			1						3			
176	Ancistrosyllis sp	.	Amphipoda	Malacostraca	Crustacea			2									
85	anemone 1	.	Actinaria	Anthozoa	Cnidaria												1
43	anthurid 1	Anthuridae	Isopoda	Malacostraca	Crustacea				1		1					1	
95	anthurid 2	Anthuridae	Isopoda	Malacostraca	Crustacea							1					
127	anthurid 3	Anthuridae	Isopoda	Malacostraca	Crustacea							1					
140	anthurid 4	Anthuridae	Isopoda	Malacostraca	Crustacea								1				
141	anthurid 5	Anthuridae	Isopoda	Malacostraca	Crustacea								1	1			
156	anthurid 6	Anthuridae	Isopoda	Malacostraca	Crustacea									1			
180	anthurid 7	Anthuridae	Isopoda	Malacostraca	Crustacea												
54	Apseudes sp 1	Apseudidae	Tanaidacea	Malacostraca	Crustacea						1			2	1	2	

Species						Site 25			Site 31			Site 37			Site 43		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C
78	Apseudes sp 2	Apseudidae	Tanaidacea	Malacostraca	Crustacea			2				1				1	1
87	Apseudes sp 3	Apseudidae	Tanaidacea	Malacostraca	Crustacea							6	1				3
130	Apseudes sp 4	Apseudidae	Tanaidacea	Malacostraca	Crustacea							1					
145	Apseudes sp 5	Apseudidae	Tanaidacea	Malacostraca	Crustacea			1					1	1			
179	Apseudes sp 6	Apseudidae	Tanaidacea	Malacostraca	Crustacea			3									
100	Arca sp	Arcidae	Arcida	Bivalvia	Mollusca							3					
110	ascidian 1	.	Stolidobranchia	Ascidiacea	Chordata							2					
75	Aspidosiphon sp	Aspidosiphonidae	Aspidosiphonida	Phascolosomatidea	Sipuncula			3								1	
73	Birubius sp 1	Phoxocephalidae	Amphipoda	Malacostraca	Crustacea									3		2	2
27	bivalve 1	.	.	Bivalvia	Mollusca		1										
103	bivalve 2	.	.	Bivalvia	Mollusca							1	1				
184	bivalve 3	.	.	Bivalvia	Mollusca			1									
190	bivalve 4	.	.	Bivalvia	Mollusca												
198	bivalve 5	.	.	Bivalvia	Mollusca												
	bivalves unident																
70	Bregmaceros sp	Bregmacerotidae	Gadiformes	Actinopterygii	Chordata									1	1		
8	brittlestar 1	.	.	Ophiuroidea	Echinodermata	1	1										
41	brittlestar 2	.	.	Ophiuroidea	Echinodermata			1	3	4	1				1	1	
49	brittlestar 3	.	.	Ophiuroidea	Echinodermata			1	1						1		
59	brittlestar 4	.	.	Ophiuroidea	Echinodermata			1		1							
162	brittlestar 5	.	.	Ophiuroidea	Echinodermata			1						2			
25	Byblis sp	Ampeliscidae	Amphipoda	Malacostraca	Crustacea		1	2				2	2	2			
81	Cadulus sp	Gadilidae	Gladiola	Scaphopoda	Mollusca							1					2

Species						Site 25			Site 31			Site 37			Site 43		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C
22	Callianassa sp	Callianassidae	Decapoda	Malacostraca	Crustacea		1	2			6	2		1	2		
126	Capitella sp	Capitellidae	Scolecida	Polychaeta	Annelida							3	1				
36	capitellid 1	Capitellidae	Scolecida	Polychaeta	Annelida			2	1	1	1	1					1
106	capitellid 2	Capitellidae	Scolecida	Polychaeta	Annelida							1					
160	capitellid 3	Capitellidae	Scolecida	Polychaeta	Annelida									2			
192	capitellid 4	Capitellidae	Scolecida	Polychaeta	Annelida												
204	capitellid 5	Capitellidae	Scolecida	Polychaeta	Annelida												
134	caprellid	Caprellidae	Amphipoda	Malacostraca	Crustacea								1				
64	Caragobius sp	Gobiidae	Perciformes	Actinopterygii	Chordata										1		
79	cardiidae juv	Cardiidae	Veneroida	Bivalvia	Mollusca								1			1	
101	chaetopterid 1	Chaetopteridae	Spionida	Polychaeta	Annelida			2				3	1	4			
44	Cheiriphotis sp 1	Corophiidae	Amphipoda	Malacostraca	Crustacea			1	7	1	2	5	2	3	1	8	8
129	Cheiriphotis sp 2	Corophiidae	Amphipoda	Malacostraca	Crustacea							1					
51	Chloea sp	Amphinomidae	Amphinomida	Polychaeta	Annelida						1			1		3	1
9	cirolanid 1	Cirolanidae	Isopoda	Malacostraca	Crustacea	1											
29	cirratulid 1	Cirratulidae	Terebellida	Polychaeta	Annelida		1										
125	cirratulid 2	Cirratulidae	Terebellida	Polychaeta	Annelida							3	1				
203	cirratulid 3	Cirratulidae	Terebellida	Polychaeta	Annelida												
205	cirratulid 4	Cirratulidae	Terebellida	Polychaeta	Annelida												
182	copepod	.	Cyclopoida	Copepoda	Crustacea			1									
10	Corbula sp	Corbulidae	Myoida	Bivalvia	Mollusca	2								2			
30	crab 1	.	Decapoda	Malacostraca	Crustacea		1										
183	crab juv	.	Decapoda	Malacostraca	Crustacea			1									

Species						Site 25			Site 31			Site 37			Site 43		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C
76	cumacean 1	.	Cumacea	Malacostraca	Crustacea											1	
90	cumacean 2	.	Cumacea	Malacostraca	Crustacea							2		1			
132	cumacean 3	.	Cumacea	Malacostraca	Crustacea								1				
133	cumacean 4	.	Cumacea	Malacostraca	Crustacea								1				
150	cumacean 5	.	Cumacea	Malacostraca	Crustacea												
155	cumacean 6	.	Cumacea	Malacostraca	Crustacea									1			
178	Cumacean 7	.	Cumacea	Malacostraca	Crustacea												
112	Cyclaspis sp 1	Bodotriidae	Cumacea	Malacostraca	Crustacea							1		1			
173	Cyclaspis sp 2	Bodotriidae	Cumacea	Malacostraca	Crustacea			1									
74	Dendrophyllum sp	Dendrophylliidae	Scleractina	Anthozoa	Cnidaria											1	
153	didemnid	Didemnidae	Aplousobranchia	Ascidiacea	Chordata									1			
109	Dimorphyostylis sp	Diastylidae	Cumacea	Malacostraca	Crustacea							2					
20	Diogenes sp 1	Diogenidae	Decapoda	Malacostraca	Crustacea	1											
53	Diplocirrus sp	Flabelligeridae	Terebellida	Polychaeta	Annelida						1						1
122	Dispio sp	Spionidae	Spionida	Polychaeta	Annelida							1					
92	echinoid juv	.	.	Echinoidea	Echinodermata							1		1			
57	Edwardsia sp	Edwardsiidae	Actinaria	Anthozoa	Cnidaria					1			1		1		
55	Ennucula sp	Nuculidae	Nuculoida	Bivalvia	Mollusca			2		1	1			1		1	1
167	Ericthonius sp	Ischyroceridae	Amphipoda	Malacostraca	Crustacea			2						2			
177	Eupanthalis sp	Acteonidae	Phyllodocida	Polychaeta	Annelida			1									
143	Eunice sp 1	Eunicidae	Eunicida	Polychaeta	Annelida								1	1			
161	Eunice sp 2	Eunicidae	Eunicida	Polychaeta	Annelida									3			
63	Felaniella sp 1	Ungulinidae	Veneroida	Bivalvia	Mollusca							2		3	1		

Species						Site 25			Site 31			Site 37			Site 43		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C
115	Felaniella sp 2	Ungulinidae	Veneroida	Bivalvia	Mollusca							2	1				
52	foram 1	.	.	.	Foraminifera					1	2						
206	gastropod 1	.	.	Gastropoda	Mollusca												
34	Glycera sp 1	Glyceridae	Phyllodocida	Polychaeta	Annelida				1		1	1			1		
189	goby 1	Gobiidae	Perciformes	Actinopterygii	Chordata												
23	Golfingia sp	Golfingiidae	Golfingiida	Sipunculidea	Sipuncula		2	1		3							
13	goneplacid 1	Goneplacidae	Decapoda	Malacostraca	Crustacea	1	1			1						1	
14	goneplacid 2	Goneplacidae	Decapoda	Malacostraca	Crustacea	1			1						1	1	
42	goneplacid 3	Goneplacidae	Decapoda	Malacostraca	Crustacea				1						1		
47	goneplacid 4	Goneplacidae	Decapoda	Malacostraca	Crustacea			1	1								1
28	heart urchin 1 (juv)	.	Spatangoida	Echinoidea	Echinodermata		1				1	8	4	19	1	3	6
158	hesionid	Hesionidae	Phyllodocida	Polychaeta	Annelida									1			
45	holothurian 1	.	.	Holothurioidea	Echinodermata				1					2			
68	holothurian 2	.	.	Holothurioidea	Echinodermata									1	1		
154	hydroid 1	.	Hydroida	Hydrozoa	Cnidaria									1			
24	Leptochela sp	Pasiphaeidae	Decapoda	Malacostraca	Crustacea		1		1								1
159	leucosid 2	Leucosiidae	Decapoda	Malacostraca	Crustacea									1			
171	leucosid 3	Leucosiidae	Decapoda	Malacostraca	Crustacea			1									
84	leucosid juv	Leucosiidae	Decapoda	Malacostraca	Crustacea												1
50	lumbrinerid 1	Lumbrineridae	Eunicida	Polychaeta	Annelida						1						2
56	lumbrinerid 2	Lumbrineridae	Eunicida	Polychaeta	Annelida					1							
72	lumbrinerid 3	Lumbrineridae	Eunicida	Polychaeta	Annelida											1	
151	Magelona cf. cincta Ehlers:1908	Magelonidae	Spionida	Polychaeta	Annelida									1			

Species						Site 25			Site 31			Site 37			Site 43		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C
157	Maldane sp 1	Maldanidae	Scolecida	Polychaeta	Annelida									2			
96	maldanid 1	Maldanidae	Scolecida	Polychaeta	Annelida			1				1	1				
77	Marphysa sp	Eunicidae	Eunicida	Polychaeta	Annelida							4	1	1		1	
185	Mitra sp	Mitridae	Neogastropoda	Gastropoda	Mollusca			1									
170	Molgula sp	Molgulidae	Pleurogona	Ascidiacea	Chordata									3			
1	Nassarius distortus (A.Adams:1852))	Nassariidae	Caenogastropoda	Gastropoda	Mollusca	2							1				
19	Nassarius sp 1	Nassariidae	Caenogastropoda	Gastropoda	Mollusca	1											
32	Nassarius sp 2	Nassariidae	Caenogastropoda	Gastropoda	Mollusca		1										
62	Naticarius alapapilionis (Roding:1798)	Naticidae	Littorinimorpha	Gastropoda	Mollusca			1							1		
80	Nebalia sp	Nebaliidae	Leptostraca	Malacostraca	Crustacea												1
131	Nematonereis sp	Eunicidae	Eunicida	Polychaeta	Annelida								1				
46	nemertean 1	.	.	.	Nemertea			1	1			2	1	1			2
93	nemertean 2	.	.	.	Nemertea							1	1	1			
186	Nephtys sp	Nephtyidae	Phyllodocida	Polychaeta	Annelida												
120	nereid 1	Nereididae	Phyllodocida	Polychaeta	Annelida							3	1				
187	nereid 2	Nereididae	Phyllodocida	Polychaeta	Annelida												
114	Nuculana darwini (Smith:1884))	Nuculidae	Nuculoida	Bivalvia	Mollusca							2	1	1			
86	Oceanapia sp	Phloeodictyidae	Haplosclerida	Demospongiae	Porifera							1					
147	oedicerotid 1	Oedicerotidae	Amphipoda	Malacostraca	Crustacea									1			
202	oedicerotid 2	Oedicerotidae	Amphipoda	Malacostraca	Crustacea												
21	Ogyrides sp	Ogyrididae	Decapoda	Malacostraca	Crustacea		2		1								
2	Oliva caldania (Declos:1835)	Olividae	Caenogastropoda	Gastropoda	Mollusca	2	1										
11	Olphelina sp	Opheliidae	Scolecida	Polychaeta	Annelida	1											

Species						Site 25			Site 31			Site 37			Site 43		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C
148	onuphid 1	Onuphidae	Eunicida	Polychaeta	Annelida									2			
149	onuphid 2	Onuphidae	Eunicida	Polychaeta	Annelida									1			
99	Onuphis sp	Onuphidae	Eunicida	Polychaeta	Annelida							2		2			
193	Orthoprionospio sp	Spionidae	Spionida	Polychaeta	Annelida												
4	ostracod 1	.	.	Ostracoda	Crustacea	2											
5	ostracod 2	.	.	Ostracoda	Crustacea	1											
38	ostracod 3	.	.	Ostracoda	Crustacea			2	1						1		
91	ostracod 4	.	.	Ostracoda	Crustacea							1					
102	ostracod 5	.	.	Ostracoda	Crustacea			3				1		1			
144	ostracod 6	.	.	Ostracoda	Crustacea								1				
35	Paralacydonia paradoxa Fauvel:1913	Lacydoniidae	Phyllodocida	Polychaeta	Annelida			2	1								
124	Paraonides sp	Paraonidae	Scolecida	Polychaeta	Annelida							1					
119	Paraprionospio sp	Spionidae	Spionida	Polychaeta	Annelida							6	4	3			
196	penaeid juv	Penaeidae	Decapoda	Malacostraca	Crustacea												
33	Peronella sp	Laganidae	Clypeasteroida	Echinoidea	Echinodermata		1					1					
69	Phascolion sp	Phascolionidae	Golfingiida	Sipunculidea	Sipuncula										2		
88	phyllodocid 1	Phyllodocidae	Phyllodocida	Polychaeta	Annelida							1					
108	Pista sp	Terebellidae	Terebellida	Polychaeta	Annelida							2		2			
175	Poecilochaetus sp	Poecilochaetidae	Spionida	Polychaeta	Annelida			1									
121	polychaete 121	.	.	Polychaeta	Annelida							8	1	1			
200	Polydora sp	Spionidae	Spionida	Polychaeta	Annelida												
128	polynoid	Polynoidae	Phyllodocida	Polychaeta	Annelida							1					
3	Portunus sp juv	Portunidae	Decapoda	Malacostraca	Crustacea	1											

Species						Site 25			Site 31			Site 37			Site 43		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C
191	potamid	Potamididae	Caenogastropoda	Gastropoda	Mollusca												
105	Prionospio ehlersi Fauvel:1928	Spionidae	Spionida	Polychaeta	Annelida							1					
118	Prionospio sp 1	Spionidae	Spionida	Polychaeta	Annelida							6					
166	psammobiidae	Psammobiidae	Veneroida	Bivalvia	Mollusca									1			
195	Pseudopolydora sp	Spionidae	Spionida	Polychaeta	Annelida												
136	sabellariid	Sabellariidae	Sabellida	Polychaeta	Annelida								1				
194	sabellid 1	Sabellidae	Sabellida	Polychaeta	Annelida												
201	sabellid 2	Sabellidae	Sabellida	Polychaeta	Annelida												
107	Scalibregma sp	Scalibregmatidae	Scolecida	Polychaeta	Annelida							2					
17	Scalptia sp	Cancellariidae	Neogastropoda	Gastropoda	Mollusca	1											
82	sea pen	.	Pennatulacea	Anthozoa	Cnidaria									1			1
58	shrimp 1	.	Decapoda	Malacostraca	Crustacea					1							
83	shrimp 2	.	Decapoda	Malacostraca	Crustacea							1					
113	shrimp 3	.	Decapoda	Malacostraca	Crustacea							7					
138	shrimp 4	.	Decapoda	Malacostraca	Crustacea								1	1			
66	shrimp damaged unident	.	Decapoda	Malacostraca	Crustacea										1	1	
61	sigalionid	Sigalionidae	Phyllodocida	Polychaeta	Annelida					1							1
65	spionid 1	Spionidae	Spionida	Polychaeta	Annelida									1	1		
123	spionid 2	Spionidae	Spionida	Polychaeta	Annelida							1	1				
152	spionid 3	Spionidae	Spionida	Polychaeta	Annelida									1			
181	spionid 4	Spionidae	Spionida	Polychaeta	Annelida			2									
37	Sternaspis sp	Sternaspidae	Terebellida	Polychaeta	Annelida			5	1	1	1	1		1			
67	stomatopod 1	.	Stomatopoda	Malacostraca	Crustacea									1	1		

Species						Site 25			Site 31			Site 37			Site 43		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C
116	Streblosoma sp	Terebellidae	Terebellida	Polychaeta	Annelida							1	1				
97	syllid 1	Syllidae	Phyllodocida	Polychaeta	Annelida							2	1	1			
117	syllid 2	Syllidae	Phyllodocida	Polychaeta	Annelida							1					
135	syllid 3	Syllidae	Phyllodocida	Polychaeta	Annelida								1				
142	syllid 4	Syllidae	Phyllodocida	Polychaeta	Annelida								1				
6	tanaid 1	.	Tanaidacea	Malacostraca	Crustacea	1					1	1		1	4	1	
39	tanaid 2	.	Tanaidacea	Malacostraca	Crustacea				4						1	5	1
89	tanaid 3	.	Tanaidacea	Malacostraca	Crustacea							2	2				
94	tanaid 4	.	Tanaidacea	Malacostraca	Crustacea							1					
168	tanaid 5	.	Tanaidacea	Malacostraca	Crustacea			1						2			
146	Tellina sp 1	Tellinidae	Veneroida	Bivalvia	Mollusca								1				
197	Tellina sp 2	Tellinidae	Veneroida	Bivalvia	Mollusca												
104	Terebellides sp	Trichobranchidae	Terebellida	Polychaeta	Annelida							1					
26	Terebra sp 1	Terebridae	Neogastropoda	Gastropoda	Mollusca		1										
172	Theora lata (hinds:1843)	Semelidae	Cardiida	Bivalvia	Mollusca			1									
40	Theora nasuta Hedley:1909	Semelidae	Cardiida	Bivalvia	Mollusca				2	2							
60	Thracia sp	Thraciidae	Anomalodesmata	Bivalvia	Mollusca					1							
15	Timoclea sp	Veneridae	Veneroida	Bivalvia	Mollusca	1											
48	tongelsole	Cyonglossidae	Pleuronectiformes	Actinopterygi	Chordata				1								
31	trochidae	Trochidae	Archaeogastropoda	Gastropoda	Mollusca		2										
16	turrid 1	Turridae	Caenogastropoda	Gastropoda	Mollusca	1	1			1		1					
71	turrid 2	Turridae	Caenogastropoda	Gastropoda	Mollusca									1	1	1	
					Total Abundance:	**109**			**78**			**296**			**105**		

Table B-3 Macroinvertebrate Results – January 2017 Survey (Orokolo Bay) – Sites M1 to M7; numbers represent abundance in each replicate (A, B, and C) for each site

Species						M1			M2			M3			M4			M5			M6			M7		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
c	Adamnestia sp	Cylichnidae	Cephalaspidea	Gastropoda	Mollusca	1	1	3											3							
12	Agalophamus sp	Nephtyidae	Phyllodocida	Polychaeta	Annelida							1	4	6		2	2				1	1				
7	alpheid	Alpheidae	Decapoda	Malacostraca	Crustacea	1			1		2		1	7	4		1				1		3	3		1
111	Amaeana trilobata (Sars:1863)	Terebellidae	Terebellida	Polychaeta	Annelida							1	5		1	1	2									
98	Ampelisca sp 1	Ampeliscidae	Amphipoda	Malacostraca	Crustacea	1	1					1	6	1			1	13	13	18	5	5	3	3		6
231	Ampharetid 2	Ampharetidae	Terebellida	Polychaeta	Annelida							1									1					3
216	Amphicteis sp	Ampharetidae	Terebellida	Polychaeta	Annelida					1		1	1	1												
232	Amphipod 4	.	Amphipoda	Malacostraca	Crustacea																	1				
262	Amphipod 5	.	Amphipoda	Malacostraca	Crustacea								2	4								1				
288	Amphipod 6	.	Amphipoda	Malacostraca	Crustacea								1	1												
309	Amphipod 7	.	Amphipoda	Malacostraca	Crustacea																					
176	Ancistrosyllis sp	Pilargidae	Phyllodocida	Polychaeta	Annelida	2	2		1			1	1	4	1	1	1	1		2					1	5
257	Anemone 4	.	Actinaria	Anthozoa	Cnidaria													1								
327	Anemone 5	.	Actinaria	Anthozoa	Cnidaria																					
127	anthurid 3	Anthuridae	Isopoda	Malacostraca	Crustacea								1													
54	Apseudes sp 1	Apseudidae	Tanaidacea	Malacostraca	Crustacea							5	2	2	1											
87	Apseudes sp 3	Apseudidae	Tanaidacea	Malacostraca	Crustacea							1					1						1			
179	Apseudes sp 6	Apseudidae	Tanaidacea	Malacostraca	Crustacea								6													
247	Arca sp 2	Arcidae	Arcida	Bivalvia	Mollusca									1							1		1			
214	Arcania sp 1	Leucosidae	Decapoda	Malacostraca	Crustacea																					
290	Arcania sp 2	Leucosidae	Decapoda	Malacostraca	Crustacea									2												
310	Ascidian 2	.	Stolidobranchia	Ascidiacea	Chordata																					
75	Aspidosiphon sp	Aspidosiphonidae	Aspidosiphonida	Phascolosomatidea	Sipuncula	2		1	1	1		1	2	1	2	4	1									
249	Birubius sp 2	Phoxocephalidae	Amphipoda	Malacostraca	Crustacea							1	2								1					
268	Bivalve 6	.	.	Bivalvia	Mollusca																		2			
	bivalves unident (shells dissolved)	.	.	Bivalvia	Mollusca		3								1				1	1			2	3		2
294	Brada sp 1	Flabelligeridae	Phyllodocida	Polychaeta	Annelida							1														
312	Brada sp 2	Flabelligeridae	Phyllodocida	Polychaeta	Annelida																					
70	Bregmaceros sp	Bregmacerotidae	Gadiformes	Actinopterygii	Chordata								1		5	8	4				1					
284	Brittlestar 6	.	.	Ophiuroidea	Echinodermata							1		1												
306	Brittlestar 7	.	.	Ophiuroidea	Echinodermata											1										
	brittlestar unident	.	.	Ophiuroidea	Echinodermata																	1				
219	bubble shell	Haminoeidae	Cephalaspidea	Gastropoda	Mollusca																					
25	Byblis sp	Ampeliscidae	Amphipoda	Malacostraca	Crustacea								1													
22	Callianassa sp	Callianassidae	Decapoda	Malacostraca	Crustacea	1		1				14	11	19	8	4	9	2	4	3			1			
126	Capitella sp	Capitellidae	Scolecida	Polychaeta	Annelida							2	2	3												
36	capitellid 1	Capitellidae	Scolecida	Polychaeta	Annelida																					1
106	capitellid 2	Capitellidae	Scolecida	Polychaeta	Annelida																					
160	capitellid 3	Capitellidae	Scolecida	Polychaeta	Annelida													1								
192	capitellid 4	Capitellidae	Scolecida	Polychaeta	Annelida							3	22	33	3		1							1		

Species						M1			M2			M3			M4			M5			M6			M7		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
319	Capitellid 6	Capitellidae	Scolecida	Polychaeta	Annelida											1	1									
64	Caragobius sp	Gobiidae	Perciformes	Actinopterygii	Chordata																		2			
252	cardiidae juv 2	Cardiidae	Veneroida	Bivalvia	Mollusca														1							1
240	chaetognath	Chaetognatha	Chaetognatha	Chaetognatha	Chaetognatha			3					1		1	1	1	1	4	3					4	
101	chaetopterid 1	Chaetopteridae	Spionida	Polychaeta	Annelida	1									1			1	1			1				1
44	Cheiriphotis sp 1	Corophiidae	Amphipoda	Malacostraca	Crustacea								7	3				4		4	1		1			
129	Cheiriphotis sp 2	Corophiidae	Amphipoda	Malacostraca	Crustacea									3												
51	Chloea sp	Amphinomidae	Amphinomida	Polychaeta	Annelida								2	1	2	1	1									
212	Cirolanid 2	Cirolanidae	Isopoda	Malacostraca	Crustacea									1												
29	cirratulid 1	Cirratulidae	Terebellida	Polychaeta	Annelida							3	1	2	1	1			2							
203	cirratulid 3	Cirratulidae	Terebellida	Polychaeta	Annelida																					1
303	Cirratulid 5	Cirratulidae	Terebellida	Polychaeta	Annelida											1	1									
182	copepod	.	Cyclopoida	Copepoda	Crustacea								1	4	1	1	7									
258	Coppingeria sp	Flabelligeridae	Terebellida	Polychaeta	Annelida															1						
10	Corbula sp 1	Corbulidae	Myoida	Bivalvia	Mollusca							2	2	1		1	1									
210	Corbula sp 2	Corbulidae	Myoida	Bivalvia	Mollusca																					
239	Corophid 1	Corophiidae	Amphipoda	Malacostraca	Crustacea	8									2			1								
229	Cossura sp	Creediidae	Perciformes	Actinopterygii	Chordata		1								1			1	1							
297	Crab 2	.	Decapoda	Malacostraca	Crustacea						1															
183	crab juv 1	.	Decapoda	Malacostraca	Crustacea									2												
215	crab juv 2	.	Decapoda	Malacostraca	Crustacea																					
76	cumacean 1	.	Cumacea	Malacostraca	Crustacea									1												
178	Cumacean 7	.	Cumacea	Malacostraca	Crustacea																					
313	Cumacean 8	.	Cumacea	Malacostraca	Crustacea																					
300	Cuspidaria sp	Cuspidariidae	Pholadomyoida	Bivalvia	Mollusca										1											
74	Dendrophyllum sp	Dendrophylliidae	Scleractina	Anthozoa	Cnidaria								1				1									
20	Diogenes sp 1	Diogenidae	Decapoda	Malacostraca	Crustacea							1	1	1												
53	Diplocirrus sp	Flabelligeridae	Terebellida	Polychaeta	Annelida				1														1			2
122	Dispio sp	Spionidae	Spionida	Polychaeta	Annelida							1														
285	Dosinia sp	Veneridae	Veneroida	Bivalvia	Mollusca								1													
57	Edwardsia sp	Edwardsiidae	Actinaria	Anthozoa	Cnidaria																					
298	eel	.	Anguilliformes	Actinopterygi	Chordata										1											
55	Ennucula sp	Nuculidae	Nuculoida	Bivalvia	Mollusca																		1			
286	Eocuma sp	Bodotriidae	Cumacea	Malacostraca	Crustacea								1													
167	Ericthonius sp	Ischyroceridae	Amphipoda	Malacostraca	Crustacea																					
291	Fasciolarid 1	Fasciolariidae	Caenogastropoda	Gastropoda	Mollusca									1												
241	Fish 1	.	.	Actinopterygi	Chordata																				1	
311	flatworm	Polycladida	Polycladida	Turbellaria	Platyhelminthes																					
282	Gari sp	Psammobiidae	Veneroida	Bivalvia	Mollusca							1	1													
259	Glossobalanus sp	Ptychoderidae	Ptychoderidae	Enteropneusta	Hemichordata								1							1			1			
34	Glycera sp 1	Glyceridae	Phyllodocida	Polychaeta	Annelida	2	1							1				1	3					1	2	

Species						M1			M2			M3			M4			M5			M6			M7		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
299	gnathid	Gnathidae	Isopoda	Malacostraca	Crustacea										2											
189	goby 1	Gobiidae	Perciformes	Actinopterygii	Chordata	1																				
23	Golfingia sp	Golfingiidae	Golfingiida	Sipunculidea	Sipuncula	1						1	1		1		1							6	7	10
13	goneplacid 1	Goneplacidae	Decapoda	Malacostraca	Crustacea					1		3	3	2	3		2									
14	goneplacid 2	Goneplacidae	Decapoda	Malacostraca	Crustacea																					
230	Haploscoloplos sp	Orbiniidae	Scolecida	Polychaeta	Mollusca							1														
158	Hesionid 1	Hesionidae	Phyllodocida	Polychaeta	Annelida																					
264	Hesionid 2	Hesionidae	Phyllodocida	Polychaeta	Annelida								2	1									1			
68	holothurian 2	.	.	Holothurioidea	Echinodermata							1														
224	Holothurian 3	.	.	Holothurioidea	Echinodermata			1				1						2	1	1				1		
322	laevidentaliidae	Laevidentaliidae	Dentaliida	Scaphopoda	Mollusca																					
283	Laonice sp	Spionidae	Spionida	Polychaeta	Annelida							1	2	5												
24	Leptochela sp	Pasiphaeidae	Decapoda	Malacostraca	Crustacea							2	2	1			1						2			
251	Leptomya sp	Semelidae	Veneroida	Bivalvia	Mollusca	1																1				1
171	leucosid 3	Leucosiidae	Decapoda	Malacostraca	Crustacea												1									
279	Leucothoe sp	Leucothoidae	Amphipoda	Malacostraca	Crustacea							1														
227	liljeborgiid	Liljeborgiidae	Amphipoda	Malacostraca	Crustacea							3	2	1	1	1	3									
269	Lingula sp	Lingulidae	Lingulida	Lingulata	Brachiopoda																					
260	Listrolobus sp	Echiuridae	Echiurida	Echiuroidea	Echiura								1	2						1						
273	Lophiotoma sp 1	Turridae	Neogastropoda	Gastropoda	Mollusca								1													
278	Lophiotoma sp 2	Turridae	Neogastropoda	Gastropoda	Mollusca	2								1												
255	Lucifer sp	Luciferidae	Decapoda	Malacostraca	Crustacea								1		1			3		1						
50	lumbrinerid 1	Lumbrineridae	Eunicida	Polychaeta	Annelida														1					1		
56	lumbrinerid 2	Lumbrineridae	Eunicida	Polychaeta	Annelida				1								1									
226	Lumbrinerid 4	Lumbrineridae	Eunicida	Polychaeta	Annelida		1																			2
316	Lumbrinerid 5	Lumbrineridae	Eunicida	Polychaeta	Annelida																					
151	Magelona cf. cincta Ehlers:1908	Magelonidae	Spionida	Polychaeta	Annelida																					
207	Magelona sp 1	Magelonidae	Spionida	Polychaeta	Annelida	2	2	1					2											4	3	5
157	Maldane sp 1	Maldanidae	Scolecida	Polychaeta	Annelida							1														
96	maldanid 1	Maldanidae	Scolecida	Polychaeta	Annelida			1				1						2	2		1		3		2	3
228	Maldanid 2	Maldanidae	Scolecida	Polychaeta	Annelida																1	3	2			
280	Maldanid 3	Maldanidae	Scolecida	Polychaeta	Annelida							1														
	megalopa	.	Decapoda	Malacostraca	Crustacea					1																
208	mysid	Mysidae	Mysidacea	Malacostraca	Crustacea																					
1	Nassarius distortus (A.Adams:1852))	Nassariidae	Caenogastropoda	Gastropoda	Mollusca					1					1	1							1			
32	Nassarius sp 2	Nassariidae	Caenogastropoda	Gastropoda	Mollusca							2	2	1												
209	Natica sp 1	Naticidae	Littorinimorpha	Gastropoda	Mollusca																					
320	Natica sp 2	Naticidae	Littorinimorpha	Gastropoda	Mollusca																					
62	Naticarius alapapilionis (Roding:1798)	Naticidae	Littorinimorpha	Gastropoda	Mollusca					1												1		1		
80	Nebalia sp	Nebaliidae	Leptostraca	Malacostraca	Crustacea												1									
46	nemertean 1	.	.	.	Nemertea		1	1				1	3	5	2	1				2				1	1	1

Species						M1			M2			M3			M4			M5			M6			M7		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
93	nemertean 2	.	.	.	Nemertea		2						4	8	1	1	2		1							
243	Nereid 3	Nereididae	Phyllodocida	Polychaeta	Annelida	1							1	1	1			1							1	
244	Nereid 4	Nereididae	Phyllodocida	Polychaeta	Annelida																				1	
256	Nereid 5	Nereididae	Phyllodocida	Polychaeta	Annelida													1								
114	Nuculana darwini (Smith:1884))	Nuculidae	Nuculoida	Bivalvia	Mollusca								2	4			2			1						
302	octopus	Octopoda	Octopoda	Cephalopoda	Mollusca				1																	
21	Ogyrides sp	Ogyrididae	Decapoda	Malacostraca	Crustacea								2				1			1				2		
2	Oliva caldania (Declos:1835)	Olividae	Caenogastropoda	Gastropoda	Mollusca								4	1	1		1				1		1			
222	Onuphid 3	Onuphidae	Eunicida	Polychaeta	Annelida									1										1		
317	Onuphid 4	Onuphidae	Eunicida	Polychaeta	Annelida																					
99	Onuphis sp	Onuphidae	Eunicida	Polychaeta	Annelida					1									1	1						
11	Ophelina sp	Opheliidae	Scolecida	Polychaeta	Annelida		1											2	1	2						
326	Ophiocentrus sp	Amphiuridae	Ophiurida	Ophiuroidea	Echinodermata																					
193	Orthoprionospio sp	Spionidae	Spionida	Polychaeta	Annelida									2												3
38	ostracod 3	.	.	Ostracoda	Crustacea								1													
318	Ostracod 7	.	.	Ostracoda	Crustacea																					
296	Owenia sp	Oweniidae	Canalipalpata	Polychaeta	Annelida								1													
263	Pandora elongatus (Carpenter:1846)	Pandoridae	Pholadomyoida	Bivalvia	Mollusca																		1			
35	Paralacydonia paradoxa Fauvel:1913	Lacydoniidae	Phyllodocida	Polychaeta	Annelida							2	3	1		2										
124	Paraonides sp 1	Paraonidae	Scolecida	Polychaeta	Annelida	1						1		1					1							
271	Paraonides sp 2	Paraonidae	Scolecida	Polychaeta	Annelida									1												
119	Paraprionospio sp	Spionidae	Spionida	Polychaeta	Annelida					2		1	6	9	1		1				3	1			3	2
287	Pectinaria sp	Pectinariidae	Terebellida	Polychaeta	Annelida									1												
220	Penaeid juv 2	Penaeidae	Decapoda	Malacostraca	Crustacea																					
33	Peronella sp	Laganidae	Clypeasteroida	Echinoidea	Echinodermata																					
69	Phascolion sp	Phascolionidae	Golfingiida	Sipunculidea	Sipuncula											1										
238	Pherusa sp	Flabelligeridae	Terebellida	Polychaeta	Annelida																					
217	Philine sp	Philinidae	Cephalaspidea	Gastropoda	Mollusca											1										
221	phoronid	.	.	.	Phoronida	76	39	29										4	3	4		1		15	15	43
88	phyllodocid 1	Phyllodocidae	Phyllodocida	Polychaeta	Annelida																					
233	Phyllodocid 2	Phyllodocidae	Phyllodocida	Polychaeta	Annelida													1								
275	Phyllodocid 3	Phyllodocidae	Phyllodocida	Polychaeta	Annelida																					
323	Phyllodocid 5	Phyllodocidae	Phyllodocida	Polychaeta	Annelida																					
108	Pista sp 1	Terebellidae	Terebellida	Polychaeta	Annelida							1	1	1												
248	Pista sp 2	Terebellidae	Terebellida	Polychaeta	Annelida								1	1							1					
175	Poecilochaetus sp	Poecilochaetidae	Spionida	Polychaeta	Annelida								2	1	1		1									
211	polychaete *cf.* family 2	.	.	Polychaeta	Annelida																					
234	Polynoid 2	Polynoidae	Phyllodocida	Polychaeta	Annelida																		1			
254	Polynoid 3 (poly specific unident past family)	Polynoidae	Phyllodocida	Polychaeta	Annelida									3	1	1	2		1							
265	Polynoid 4	Polynoidae	Phyllodocida	Polychaeta	Annelida																		1			
272	Polynoid 5	Polynoidae	Phyllodocida	Polychaeta	Annelida																					

Species						M1			M2			M3			M4			M5			M6			M7		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
105	Prionospio ehlersi Fauvel:1928	Spionidae	Spionida	Polychaeta	Annelida							7	5	9	3	1	2		1	1	1					1
118	Prionospio sp 1	Spionidae	Spionida	Polychaeta	Annelida																					
328	Prionospio sp 2	Spionidae	Spionida	Polychaeta	Annelida																					
225	Pseudeurythoe sp	Amphinomidae	Amphinomida	Polychaeta	Annelida				17	1		1		3	1		1	1	1	2	2	2	3			
304	Pyramidella sp	Pyramidellidae	Heterobranchia	Gastropoda	Mollusca											1										
107	Scalibregma sp	Scalibregmatidae	Scolecida	Polychaeta	Annelida										1											
305	scaphandrid	Scaphandridae	Cephalaspidea	Gastropoda	Mollusca											1										
321	Schistomeringos	Dorvilleidae	Eunicida	Polychaeta	Annelida																					
307	sea pen 2	.	Pennatulacea	Anthozoa	Cnidaria					1																
325	sea star	.	.	Asteroidea	Echinodermata																					
83	shrimp 2	.	Decapoda	Malacostraca	Crustacea			1				2			1								1			
246	Shrimp 5	.	Decapoda	Malacostraca	Crustacea													1			1					
261	Shrimp 6	.	Decapoda	Malacostraca	Crustacea									2								1				
276	Shrimp 7	.	Decapoda	Malacostraca	Crustacea										1											
293	Shrimp 8	.	Decapoda	Malacostraca	Crustacea							1														
242	shrimp juv	.	Decapoda	Malacostraca	Crustacea								1													1
266	Sigalion sp 1	Sigalionidae	Phyllodocida	Polychaeta	Annelida																		1			
274	Sigalion sp 2	Sigalionidae	Phyllodocida	Polychaeta	Annelida										1	2										
289	Sigalion sp 3	Sigalionidae	Phyllodocida	Polychaeta	Annelida									1												
61	sigalionid	Sigalionidae	Phyllodocida	Polychaeta	Annelida										1						1					
223	Siliqua sp	Pharidae	Adapedonta	Bivalvia	Mollusca																			3	3	4
245	Sipunculus sp	Sipunculidae	Sipunculiformes	Sipunculidea	Sipuncula	2													1		1					
314	soft coral	.	Alcyonacea	Anthozoa	Cnidaria																					
123	spionid 2	Spionidae	Spionida	Polychaeta	Annelida								9	1	3	1	1			1		2				4
152	spionid 3	Spionidae	Spionida	Polychaeta	Annelida							1		1												
181	spionid 4	Spionidae	Spionida	Polychaeta	Annelida																					
315	Spionid 5	Spionidae	Spionida	Polychaeta	Annelida																					
37	Sternaspis sp	Sternaspidae	Terebellida	Polychaeta	Annelida	9	10	5	3	4	3	4	3	2	3	1	1	7	11	6	3	5	4	7	5	13
67	stomatopod 1	.	Stomatopoda	Malacostraca	Crustacea		1																			
236	Stomatopod 2	.	Stomatopoda	Malacostraca	Crustacea			1					1													
250	Stomatopod 3	.	Stomatopoda	Malacostraca	Crustacea															1	1		1			1
	stomatopod larvae	.	Stomatopoda	Malacostraca	Crustacea											1										
97	syllid 1	Syllidae	Phyllodocida	Polychaeta	Annelida																					
253	Syllid 5	Syllidae	Phyllodocida	Polychaeta	Annelida							1							1							
292	Syllid 6	Syllidae	Phyllodocida	Polychaeta	Annelida									1												
146	Tellina sp 1	Tellinidae	Veneroida	Bivalvia	Mollusca					1		1		1												
237	Tellina sp 3	Tellinidae	Veneroida	Bivalvia	Mollusca																1					
324	Tellina sp 4	Tellinidae	Veneroida	Bivalvia	Mollusca																					
267	Terebellid 1	Terebellidae	Terebellida	Polychaeta	Annelida							1		3									1			
104	Terebellides sp	Trichobranchidae	Terebellida	Polychaeta	Annelida					2		9	8	7	1	3	2									
26	Terebra sp 1	Terebridae	Neogastropoda	Gastropoda	Mollusca					1	1											1	1	2		

Species						M1			M2			M3			M4			M5			M6			M7		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
308	Terebra sp 2	Terebridae	Neogastropoda	Gastropoda	Mollusca					1																
329	Teredinidae	Teredinidae	Myida	Bivalvia	Mollusca																					
235	Themiste sp	Themistidae	Golfingiida	Sipunculidea	Sipuncula	7	1	3										7	6	6						
172	Theora lata (Hinds:1843)	Semelidae	Cardiida	Bivalvia	Mollusca	1													2							
40	Theora nasuta Hedley:1909	Semelidae	Cardiida	Bivalvia	Mollusca								1													
15	Timoclea sp	Veneridae	Veneroida	Bivalvia	Mollusca	1												1		1						
31	trochidae	Trochidae	Archaeogastropoda	Gastropoda	Mollusca								2	1												
218	turritellidae	Turritellidae	Caenogastropoda	Gastropoda	Mollusca																					
277	Xenophthalmus sp	Xenophthlamidae	Decapoda	Malacostraca	Crustacea	6	1	2	158	488	381			1				8		3		1	1	16	9	5
213	Yoldia sp 1	Nuculanidae	Nuculoida	Bivalvia	Mollusca						2															
	zoea	.	Decapoda	Malacostraca	Crustacea												1									
270	zooanthid	Zooanthidae	Zoanthidea	Anthozoa	Cnidaria																					
					Total Abundance:	**251**			**1082**			**462**			**182**			**204**			**104**			**251**		

Table B-4 Macroinvertebrate Results – January 2017 Survey (Orokolo Bay) – Sites M8 to M12 and M45 to M46; numbers represent abundance in each replicate (A, B, and C) for each site

Species						M8			M9			M10			M11			M12			M45			M46		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
c	Adamnestia sp	Cylichnidae	Cephalaspidea	Gastropoda	Mollusca	2											1									
12	Agalophamus sp	Nephtyidae	Phyllodocida	Polychaeta	Annelida	2		1	2		3	3	2	1		1				1					1	
7	alpheid	Alpheidae	Decapoda	Malacostraca	Crustacea		1		1	1			2	1					1							
111	Amaeana trilobata (Sars:1863)	Terebellidae	Terebellida	Polychaeta	Annelida	1			4	1	2	2		1			2									
98	Ampelisca sp 1	Ampeliscidae	Amphipoda	Malacostraca	Crustacea	10	21	9			1	4	5	3												1
231	Ampharetid 2	Ampharetidae	Terebellida	Polychaeta	Annelida	6	3	7																		
216	Amphicteis sp	Ampharetidae	Terebellida	Polychaeta	Annelida				2	2	1	2	5				1									
232	Amphipod 4	.	Amphipoda	Malacostraca	Crustacea	2		2																		
262	Amphipod 5	.	Amphipoda	Malacostraca	Crustacea		1		1	1		3	1	1												
288	Amphipod 6	.	Amphipoda	Malacostraca	Crustacea									1												
309	Amphipod 7	.	Amphipoda	Malacostraca	Crustacea							1														
176	Ancistrosyllis sp	Pilargidae	Phyllodocida	Polychaeta	Annelida	3	2	1	2		2	5	4													
257	Anemone 4	.	Actinaria	Anthozoa	Cnidaria																					
327	Anemone 5	.	Actinaria	Anthozoa	Cnidaria				1																	
127	anthurid 3	Anthuridae	Isopoda	Malacostraca	Crustacea		1					1		2												
54	Apseudes sp 1	Apseudidae	Tanaidacea	Malacostraca	Crustacea				2		1	1	1													
87	Apseudes sp 3	Apseudidae	Tanaidacea	Malacostraca	Crustacea	1		3			1															
179	Apseudes sp 6	Apseudidae	Tanaidacea	Malacostraca	Crustacea																					
247	Arca sp 2	Arcidae	Arcida	Bivalvia	Mollusca								2													
214	Arcania sp 1	Leucosidae	Decapoda	Malacostraca	Crustacea											1										
290	Arcania sp 2	Leucosidae	Decapoda	Malacostraca	Crustacea				1																	
310	Ascidian 2	.	Stolidobranchia	Ascidiacea	Chordata									1												
75	Aspidosiphon sp	Aspidosiphonidae	Aspidosiphonida	Phascolosomatidea	Sipuncula				1			1					1									
249	Birubius sp 2	Phoxocephalidae	Amphipoda	Malacostraca	Crustacea				1			1														
268	Bivalve 6	.	.	Bivalvia	Mollusca																					
	bivalves unident (shells dissolved)	.	.	Bivalvia	Mollusca				1		1															
294	Brada sp 1	Flabelligeridae	Phyllodocida	Polychaeta	Annelida							4	3	2												
312	Brada sp 2	Flabelligeridae	Phyllodocida	Polychaeta	Annelida									2												
70	Bregmaceros sp	Bregmacerotidae	Gadiformes	Actinopterygii	Chordata						4		1	3			1	1	2	2						
284	Brittlestar 6	.	.	Ophiuroidea	Echinodermata																					
306	Brittlestar 7	.	.	Ophiuroidea	Echinodermata																					
	brittlestar unident	.	.	Ophiuroidea	Echinodermata						1		1													
219	bubble shell	Haminoeidae	Cephalaspidea	Gastropoda	Mollusca										1											
25	Byblis sp	Ampeliscidae	Amphipoda	Malacostraca	Crustacea	1																				
22	Callianassa sp	Callianassidae	Decapoda	Malacostraca	Crustacea	2	1	2	8	2	5	3	4	2			4									
126	Capitella sp	Capitellidae	Scolecida	Polychaeta	Annelida			2		2																
36	capitellid 1	Capitellidae	Scolecida	Polychaeta	Annelida																					
106	capitellid 2	Capitellidae	Scolecida	Polychaeta	Annelida	1			1								2									

Species						M8			M9			M10			M11			M12			M45			M46		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
160	capitellid 3	Capitellidae	Scolecida	Polychaeta	Annelida		1																4			
192	capitellid 4	Capitellidae	Scolecida	Polychaeta	Annelida		1		18	22	11	9	9	2												
319	Capitellid 6	Capitellidae	Scolecida	Polychaeta	Annelida						1		1													
64	Caragobius sp	Gobiidae	Perciformes	Actinopterygii	Chordata						1				1	1		1								
252	cardiidae juv 2	Cardiidae	Veneroida	Bivalvia	Mollusca																					
240	chaetognath	Chaetognatha	Chaetognatha	Chaetognatha	Chaetognatha		4																			
101	chaetopterid 1	Chaetopteridae	Spionida	Polychaeta	Annelida	1																				
44	Cheiriphotis sp 1	Corophiidae	Amphipoda	Malacostraca	Crustacea	18	2	7			2	1	1	1												
129	Cheiriphotis sp 2	Corophiidae	Amphipoda	Malacostraca	Crustacea	1	1		1			2														
51	Chloea sp	Amphinomidae	Amphinomida	Polychaeta	Annelida								1	1	1											
212	Cirolanid 2	Cirolanidae	Isopoda	Malacostraca	Crustacea						1								1							
29	cirratulid 1	Cirratulidae	Terebellida	Polychaeta	Annelida	4	3	4	2		1	7	2	2	1	2										
203	cirratulid 3	Cirratulidae	Terebellida	Polychaeta	Annelida																					
303	Cirratulid 5	Cirratulidae	Terebellida	Polychaeta	Annelida																					
182	copepod	.	Cyclopoida	Copepoda	Crustacea			1	1			5	1	1			1									
258	Coppingeria sp	Flabelligeridae	Terebellida	Polychaeta	Annelida																					
10	Corbula sp 1	Corbulidae	Myoida	Bivalvia	Mollusca																					
210	Corbula sp 2	Corbulidae	Myoida	Bivalvia	Mollusca													1								
239	Corophid 1	Corophiidae	Amphipoda	Malacostraca	Crustacea	1		1						1												
229	Cossura sp	Creediidae	Perciformes	Actinopterygii	Chordata	1	1				1		2	2												
297	Crab 2	.	Decapoda	Malacostraca	Crustacea																					
183	crab juv 1	.	Decapoda	Malacostraca	Crustacea										1											
215	crab juv 2	.	Decapoda	Malacostraca	Crustacea											1										
76	cumacean 1	.	Cumacea	Malacostraca	Crustacea							1														
178	Cumacean 7	.	Cumacea	Malacostraca	Crustacea									1												
313	Cumacean 8	.	Cumacea	Malacostraca	Crustacea							1														
300	Cuspidaria sp	Cuspidariidae	Pholadomyoida	Bivalvia	Mollusca																					
74	Dendrophyllum sp	Dendrophylliidae	Scleractina	Anthozoa	Cnidaria			1																		
20	Diogenes sp 1	Diogenidae	Decapoda	Malacostraca	Crustacea			1																		
53	Diplocirrus sp	Flabelligeridae	Terebellida	Polychaeta	Annelida	3	1	2	2																	
122	Dispio sp	Spionidae	Spionida	Polychaeta	Annelida				1																	
285	Dosinia sp	Veneridae	Veneroida	Bivalvia	Mollusca																					
57	Edwardsia sp	Edwardsiidae	Actinaria	Anthozoa	Cnidaria								1	1												
298	eel	.	Anguilliformes	Actinopterygi	Chordata																					
55	Ennucula sp	Nuculidae	Nuculoida	Bivalvia	Mollusca																					
286	Eocuma sp	Bodotriidae	Cumacea	Malacostraca	Crustacea																					
167	Ericthonius sp	Ischyroceridae	Amphipoda	Malacostraca	Crustacea																1					
291	Fasciolarid 1	Fasciolariidae	Caenogastropoda	Gastropoda	Mollusca																					
241	Fish 1	.	.	Actinopterygi	Chordata																					

Species						M8			M9			M10			M11			M12			M45			M46		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
311	flatworm	Polycladida	Polycladida	Turbellaria	Platyhelminthes									1												
282	Gari sp	Psammobiidae	Veneroida	Bivalvia	Mollusca																					
259	Glossobalanus sp	Ptychoderidae	Ptychoderidae	Enteropneusta	Hemichordata																					
34	Glycera sp 1	Glyceridae	Phyllodocida	Polychaeta	Annelida	2	1	1				1														
299	gnathid	Gnathidae	Isopoda	Malacostraca	Crustacea																					
189	goby 1	Gobiidae	Perciformes	Actinopterygii	Chordata																				1	1
23	Golfingia sp	Golfingiidae	Golfingiida	Sipunculidea	Sipuncula				2	3	3		3	1											2	
13	goneplacid 1	Goneplacidae	Decapoda	Malacostraca	Crustacea				1		3			1												
14	goneplacid 2	Goneplacidae	Decapoda	Malacostraca	Crustacea										1		2									
230	Haploscoloplos sp	Orbiniidae	Scolecida	Polychaeta	Mollusca	1							2	1												
158	Hesionid 1	Hesionidae	Phyllodocida	Polychaeta	Annelida						1															
264	Hesionid 2	Hesionidae	Phyllodocida	Polychaeta	Annelida			1			1	1														
68	holothurian 2	.	.	Holothurioidea	Echinodermata																					
224	Holothurian 3	.	.	Holothurioidea	Echinodermata																					
322	laevidentaliidae	Laevidentaliidae	Dentaliida	Scaphopoda	Mollusca								1													
283	Laonice sp	Spionidae	Spionida	Polychaeta	Annelida				2	1																
24	Leptochela sp	Pasiphaeidae	Decapoda	Malacostraca	Crustacea		1		1		1			1												
251	Leptomya sp	Semelidae	Veneroida	Bivalvia	Mollusca			2																		
171	leucosid 3	Leucosiidae	Decapoda	Malacostraca	Crustacea																					
279	Leucothoe sp	Leucothoidae	Amphipoda	Malacostraca	Crustacea				1																	
227	liljeborgiid	Liljeborgiidae	Amphipoda	Malacostraca	Crustacea	2			1		1															
269	Lingula sp	Lingulidae	Lingulida	Lingulata	Brachiopoda			1																		
260	Listrolobus sp	Echiuridae	Echiurida	Echiuroidea	Echiura																					
273	Lophiotoma sp 1	Turridae	Neogastropoda	Gastropoda	Mollusca			1																		
278	Lophiotoma sp 2	Turridae	Neogastropoda	Gastropoda	Mollusca																					
255	Lucifer sp	Luciferidae	Decapoda	Malacostraca	Crustacea		1																			
50	lumbrinerid 1	Lumbrineridae	Eunicida	Polychaeta	Annelida	4	3	1	1	1	1	1		3												
56	lumbrinerid 2	Lumbrineridae	Eunicida	Polychaeta	Annelida																					
226	Lumbrinerid 4	Lumbrineridae	Eunicida	Polychaeta	Annelida	5	1																			
316	Lumbrinerid 5	Lumbrineridae	Eunicida	Polychaeta	Annelida						1															
151	Magelona cf. cincta Ehlers:1908	Magelonidae	Spionida	Polychaeta	Annelida			1	1			1														
207	Magelona sp 1	Magelonidae	Spionida	Polychaeta	Annelida							1												4	11	9
157	Maldane sp 1	Maldanidae	Scolecida	Polychaeta	Annelida		1																			
96	maldanid 1	Maldanidae	Scolecida	Polychaeta	Annelida	17	12	24													1					
228	Maldanid 2	Maldanidae	Scolecida	Polychaeta	Annelida	1	2	2				1		2												
280	Maldanid 3	Maldanidae	Scolecida	Polychaeta	Annelida																					
	megalopa	.	Decapoda	Malacostraca	Crustacea																					
208	mysid	Mysidae	Mysidacea	Malacostraca	Crustacea																				1	
1	Nassarius distortus (A.Adams:1852))	Nassariidae	Caenogastropoda	Gastropoda	Mollusca	1			1						2											

Species						M8			M9			M10			M11			M12			M45			M46		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
32	Nassarius sp 2	Nassariidae	Caenogastropoda	Gastropoda	Mollusca																					
209	Natica sp 1	Naticidae	Littorinimorpha	Gastropoda	Mollusca																					1
320	Natica sp 2	Naticidae	Littorinimorpha	Gastropoda	Mollusca					1																
62	Naticarius alapapilionis (Roding:1798)	Naticidae	Littorinimorpha	Gastropoda	Mollusca													1								
80	Nebalia sp	Nebaliidae	Leptostraca	Malacostraca	Crustacea																					
46	nemertean 1	.	.	.	Nemertea	1	2	1	1	1	3	1							1	1						
93	nemertean 2	.	.	.	Nemertea	1	4	5	1	2	1	5	4	3												
243	Nereid 3	Nereididae	Phyllodocida	Polychaeta	Annelida			1						1												
244	Nereid 4	Nereididae	Phyllodocida	Polychaeta	Annelida																					
256	Nereid 5	Nereididae	Phyllodocida	Polychaeta	Annelida																					
114	Nuculana darwini (Smith:1884))	Nuculidae	Nuculoida	Bivalvia	Mollusca		1	1		1	5					1										
302	octopus	Octopoda	Octopoda	Cephalopoda	Mollusca																					
21	Ogyrides sp	Ogyrididae	Decapoda	Malacostraca	Crustacea		1		3		5					1	1									
2	Oliva caldania (Declos:1835)	Olividae	Caenogastropoda	Gastropoda	Mollusca						1	1	1	3	1	1			2	1						
222	Onuphid 3	Onuphidae	Eunicida	Polychaeta	Annelida																					
317	Onuphid 4	Onuphidae	Eunicida	Polychaeta	Annelida						1															
99	Onuphis sp	Onuphidae	Eunicida	Polychaeta	Annelida	1	2	4					4	1												
11	Ophelina sp	Opheliidae	Scolecida	Polychaeta	Annelida																					
326	Ophiocentrus sp	Amphiuridae	Ophiurida	Ophiuroidea	Echinodermata				1																	
193	Orthoprionospio sp	Spionidae	Spionida	Polychaeta	Annelida																					
38	ostracod 3	.	.	Ostracoda	Crustacea																					
318	Ostracod 7	.	.	Ostracoda	Crustacea						1															
296	Owenia sp	Oweniidae	Canalipalpata	Polychaeta	Annelida							2														
263	Pandora elongatus (Carpenter:1846)	Pandoridae	Pholadomyoida	Bivalvia	Mollusca		1						1	1												
35	Paralacydonia paradoxa Fauvel:1913	Lacydoniidae	Phyllodocida	Polychaeta	Annelida	1		1	1	5	2	1														
124	Paraonides sp 1	Paraonidae	Scolecida	Polychaeta	Annelida	1		2																		
271	Paraonides sp 2	Paraonidae	Scolecida	Polychaeta	Annelida			1		1																
119	Paraprionospio sp	Spionidae	Spionida	Polychaeta	Annelida				2	1	3	4	5	3			3							1	1	1
287	Pectinaria sp	Pectinariidae	Terebellida	Polychaeta	Annelida							1	1	1												
220	Penaeid juv 2	Penaeidae	Decapoda	Malacostraca	Crustacea										1											
33	Peronella sp	Laganidae	Clypeasteroida	Echinoidea	Echinodermata														1							
69	Phascolion sp	Phascolionidae	Golfingiida	Sipunculidea	Sipuncula																					
238	Pherusa sp	Flabelligeridae	Terebellida	Polychaeta	Annelida	3																				
217	Philine sp	Philinidae	Cephalaspidea	Gastropoda	Mollusca							1					1									
221	phoronid	.	.	.	Phoronida	3		2																		
88	phyllodocid 1	Phyllodocidae	Phyllodocida	Polychaeta	Annelida	1	1																			
233	Phyllodocid 2	Phyllodocidae	Phyllodocida	Polychaeta	Annelida	1																				
275	Phyllodocid 3	Phyllodocidae	Phyllodocida	Polychaeta	Annelida		1					1														
323	Phyllodocid 5	Phyllodocidae	Phyllodocida	Polychaeta	Annelida								1													

Species						M8			M9			M10			M11			M12			M45			M46		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
108	Pista sp 1	Terebellidae	Terebellida	Polychaeta	Annelida				2				1	1												
248	Pista sp 2	Terebellidae	Terebellida	Polychaeta	Annelida																					
175	Poecilochaetus sp	Poecilochaetidae	Spionida	Polychaeta	Annelida	1			3	2	1															
211	polychaete *cf.* family 2	.	.	Polychaeta	Annelida							1	1					1								
234	Polynoid 2	Polynoidae	Phyllodocida	Polychaeta	Annelida	1																				
254	Polynoid 3 (poly specific unident past family)	Polynoidae	Phyllodocida	Polychaeta	Annelida								2													
265	Polynoid 4	Polynoidae	Phyllodocida	Polychaeta	Annelida																					
272	Polynoid 5	Polynoidae	Phyllodocida	Polychaeta	Annelida			1																		
105	Prionospio ehlersi Fauvel:1928	Spionidae	Spionida	Polychaeta	Annelida	6	3	7	6	1	4	2	3	5						1						
118	Prionospio sp 1	Spionidae	Spionida	Polychaeta	Annelida				1		1															
328	Prionospio sp 2	Spionidae	Spionida	Polychaeta	Annelida				1																	
225	Pseudeurythoe sp	Amphinomidae	Amphinomida	Polychaeta	Annelida	3	1	2	1	1			5	1												
304	Pyramidella sp	Pyramidellidae	Heterobranchia	Gastropoda	Mollusca																					
107	Scalibregma sp	Scalibregmatidae	Scolecida	Polychaeta	Annelida				2	1																
305	scaphandrid	Scaphandridae	Cephalaspidea	Gastropoda	Mollusca																					
321	Schistomeringos	Dorvilleidae	Eunicida	Polychaeta	Annelida								1													
307	sea pen 2	.	Pennatulacea	Anthozoa	Cnidaria																					
325	sea star	.	.	Asteroidea	Echinodermata				1																	
83	shrimp 2	.	Decapoda	Malacostraca	Crustacea		1		2		1			1												
246	Shrimp 5	.	Decapoda	Malacostraca	Crustacea								1													
261	Shrimp 6	.	Decapoda	Malacostraca	Crustacea									1												
276	Shrimp 7	.	Decapoda	Malacostraca	Crustacea		1																			
293	Shrimp 8	.	Decapoda	Malacostraca	Crustacea																					
242	shrimp juv	.	Decapoda	Malacostraca	Crustacea																					
266	Sigalion sp 1	Sigalionidae	Phyllodocida	Polychaeta	Annelida																					
274	Sigalion sp 2	Sigalionidae	Phyllodocida	Polychaeta	Annelida		1		1		1	5	3	2												
289	Sigalion sp 3	Sigalionidae	Phyllodocida	Polychaeta	Annelida																					
61	sigalionid	Sigalionidae	Phyllodocida	Polychaeta	Annelida	1									1	1	1			2						
223	Siliqua sp	Pharidae	Adapedonta	Bivalvia	Mollusca																					
245	Sipunculus sp	Sipunculidae	Sipunculiformes	Sipunculidea	Sipuncula																					
314	soft coral	.	Alcyonacea	Anthozoa	Cnidaria						1															
123	spionid 2	Spionidae	Spionida	Polychaeta	Annelida	1	3	1	8	6	4		1	1		1			1							
152	spionid 3	Spionidae	Spionida	Polychaeta	Annelida						3															
181	spionid 4	Spionidae	Spionida	Polychaeta	Annelida							1														
315	Spionid 5	Spionidae	Spionida	Polychaeta	Annelida				2	3	1															
37	Sternaspis sp	Sternaspidae	Terebellida	Polychaeta	Annelida	17	21	23	4	4	3	8	11	17	2	2	7	2		1					2	
67	stomatopod 1	.	Stomatopoda	Malacostraca	Crustacea																					
236	Stomatopod 2	.	Stomatopoda	Malacostraca	Crustacea	1						1		2												
250	Stomatopod 3	.	Stomatopoda	Malacostraca	Crustacea																					

Species						M8			M9			M10			M11			M12			M45			M46		
#	Genus species	Family	Order	Class	Phylum	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	stomatopod larvae	.	Stomatopoda	Malacostraca	Crustacea																	1				
97	syllid 1	Syllidae	Phyllodocida	Polychaeta	Annelida						1															
253	Syllid 5	Syllidae	Phyllodocida	Polychaeta	Annelida						1															
292	Syllid 6	Syllidae	Phyllodocida	Polychaeta	Annelida					1				1												
146	Tellina sp 1	Tellinidae	Veneroida	Bivalvia	Mollusca			1			1															
237	Tellina sp 3	Tellinidae	Veneroida	Bivalvia	Mollusca	1	1																			
324	Tellina sp 4	Tellinidae	Veneroida	Bivalvia	Mollusca								1													
267	Terebellid 1	Terebellidae	Terebellida	Polychaeta	Annelida				4		2	2														
104	Terebellides sp	Trichobranchidae	Terebellida	Polychaeta	Annelida			1	10	2	4	13	2	4	2		3			3						
26	Terebra sp 1	Terebridae	Neogastropoda	Gastropoda	Mollusca			1																		
308	Terebra sp 2	Terebridae	Neogastropoda	Gastropoda	Mollusca																					
329	Teredinidae	Teredinidae	Myida	Bivalvia	Mollusca				3																	
235	Themiste sp	Themistidae	Golfingiida	Sipunculidea	Sipuncula	1	1	1																		
172	Theora lata (Hinds:1843)	Semelidae	Cardiida	Bivalvia	Mollusca																					
40	Theora nasuta Hedley:1909	Semelidae	Cardiida	Bivalvia	Mollusca																					
15	Timoclea sp	Veneridae	Veneroida	Bivalvia	Mollusca		1																			
31	trochidae	Trochidae	Archaeogastropoda	Gastropoda	Mollusca																					
218	turritellidae	Turritellidae	Caenogastropoda	Gastropoda	Mollusca												1									
277	Xenophthalmus sp	Xenophthlamidae	Decapoda	Malacostraca	Crustacea	10		4				24	10	15	1		1					2				3
213	Yoldia sp 1	Nuculanidae	Nuculoida	Bivalvia	Mollusca						1				5	5	3			2						
	zoea	.	Decapoda	Malacostraca	Crustacea							1														
270	zooanthid	Zooanthidae	Zoanthidea	Anthozoa	Cnidaria			1																		
					Total Abundance:	**401**			**297**			**358**			**75**			**30**			**5**			**40**		

B.2 Drop Camera Information Summaries

Table B-5 Drop Camera Information Summaries – Orokolo Bay (24-25th June 2016)

Site	Silt	Sand	Gravel	Rubble	Boulders/reef	Notes
M1	✓					Tried without lights 1st but too dark. Second video is very turbid
M2	✓					No bottom – just intense turbidity layer 'liquid bottom' approx 0.5m from bottom. No fauna observed.
M3	✓					Some bioturbation. Good visibility on the bottom but sediments easily disturbed. No fauna observed
M4	✓					Fine silty mud. Some bioturbation
M5	✓					Very turbid in 1m above substrate. No fauna observed
M6	✓		✓	✓	✓	Rocky reef interspersed with silty areas. soft corals (Dendronephthya sp., sea pens), crinoids, colonial ascidians, hydroids, sponges and other encrusting organisms observed. No hard corals observed
M7	✓					Silty. No fauna observed
M8	✓					Poor visibility, Muddy bottom
M9	✓					Some jellies on the way down, potentially cubozonas. Shark halfway down. Fine sediment on bottom, no epibenthos observed
M10	✓					Video poor visibility Muddy bottom easily disturbed
M11	✓					Very fine silty bottom, no fauna observed. Benthic muds easily mobilised
M12	✓					Fine sediments – muddy silts easily mobilised. No fauna observed

Table B-6 Drop Camera Information Summaries – Offshore Export Pipeline Corridor (2-3rd June 2016)

Site	Silt	Sand	Gravel	Rubble	Boulders/reef	Notes
M25	✓					Fine silty mud.
M26	✓					Observed demersal fish. Bioturbation present, some shell debris and shell grit were observed, otherwise substrate dominated by mud. No other epifauna were observed
M27	✓					Muddy substrate with fine rippled texture and bioturbation. No epifauna were observed
M28	✓					Muddy substrate with bioturbation observed. Substrate appeared quite smooth. No epifauna were observed
M29	✓					Fine silts, moderate bioturbation. No epifauna were observed
M30	✓					Silt. No fauna were observed
M31	✓					Silty mud with bioturbation. No epifauna were observed
M32	✓					Silty mud with bioturbation. No epifauna were observed
M33	✓					Moderate turbidity at bottom. Low biotourbation. Demersal fish (Goby or gudgeon) but no other were epifauna observed.
M34	✓					Silty mud with bioturbation. No epifauna were observed
M35	✓					Silty mud with bioturbation. No epifauna were observed
M36	✓					Silty mud with bioturbation. 2 Demersal fish (Goby or gudgeon) but no other epifauna observed
M37	✓	✓				Appears to be some shell grit amongst silty mud. moderate bioturbation. Some fauna were observed including crinoids (90% sure), seapen and cerianthid anenome
M38	✓	✓				Appears to be some shell grit amongst silty mud. Low bioturbation. No epifauna were observed
M39	✓	✓				Fine silts. Shell grit visible at surface. Bioturbation present. Some fauna were observed including demersal fish, seapen and unidentified - possibly sponge or seapen.
M40	✓					Fine silt. Moderate bioturbation. Fauna were observed - cerianthid
M41	✓					Fine silt. Moderate bioturbation. No epifauna were observed
M42	✓					Silty mud with bioturbation. No epifauna observed
M43	✓					Footage is of marginal quality, but silty mud with bioturbation. No epifauna were observed
M44	✓					Footage is of marginal quality but silty mud with bioturbation likely. No epifauna were observed

Table B-7 Drop Camera Information Summaries – Caution Bay (January 24th to February 2nd, 2017)

Site	Silt	Silt with sand/grit	Sand	Gravel	Rubble	Boulders/reef	Some bioturbation	Heavy bioturbation	Epifauna low relief	Epifauna high relief	Rubble slope low relief	Rubble slope moderate relief	Reef high relief with soft corals/octocorals	Reef high relief with hard corals	Reef high relief with sensitive hard corals	Live coral % cover	Grass % cover	Possible dynamite	Notes
M14	✓						✓									0	0		
M15	✓						✓		✓							0	0		Couple of crinoids
M16	✓						✓									0	0		
M17	✓						✓									0	0		
M18	✓						✓									0	0		
M19								✓								0	0		
M20											✓	✓		✓		2	1		Starts as rubble slope with very sparse Halophila. Then changes to high relief reef, with low cover of live coral and lots of dead corals. Small reef. Transitions back to sand at end of video
M21		✓						✓	✓							0	0		Sandy/gritty silt with some halimeda at start
M22			✓	✓	✓				✓		✓					2	0		Gravel/rubble slope with solitary coral polyps - see previous survey for identification
M23		✓					✓									0	2		Low to moderate bioturb. Some Halophila seagrass and a few sea pens
M24			✓	✓		✓							✓	✓	✓	70	0		Great cover and diversity of live corals. Edge of reef gives way to sand with low cover of epifauna
V01			✓	✓	✓	✓					✓		✓	✓	✓	15	0	yes	Rubble slope (start of video) transitions to small patch of high relief reef (middle of video) and then back to low relief rubble (end of video).
V02			✓		✓	✓						✓	✓	✓	✓	30	0	yes	Coral reef with some very healthy sections and some heavily disturbed sections
V03	✓							✓								0	0		Silty
V04	✓						✓									0	0		Silty
V05		✓					✓			✓						0	0		Silt with high shell grit content. Occasional clumps of high relief sea whips, gorgonians and sponges
V06		✓					✓									0	0		
V07	✓						✓									0	0		
V09	✓						✓									0	0		
V10	✓						✓									0	0		Low to moderate bioturbation
V11	✓		✓	✓	✓		✓		✓							0	0		Low relief sand and rubble transitions into sandy silt. Some occasional soft corals/sea whips but sparse
V12	✓						✓									0	0		
V13	✓						✓									0	0		
V14			✓	✓	✓	✓						✓		✓		3	0	yes	Rubble reef with some very occasional boulders/bommies but moslty dominated by coral rubble. Sparse cover of live coral - most as small isolated colonies. Bommies become more dominant/common at end of video
V15			✓		✓	✓				✓			✓	✓		40	0		Deep reef. Large vase sponges (Montipora), lots of thin crusts (cf. povona) and day corals (Gonipora)
V16					✓	✓						✓	✓	✓		5	0		Deep reef with lots of sea whips, sorft corals and gorgonians. Some encrusting corals and a few plates. Plenty of turfing algae and other marine plants
V17			✓		✓	✓						✓	✓	✓		5	0	yes	Dominated by rubble - moderate relief with some bommies (mostly dead corals) and occasional live colonies. Probable that video start is on the edge of large high relief coral reef - see sss outputs
V18	✓						✓									0	0		Silt
V19	✓						✓									0	0		Silt
V20			✓		✓	✓						✓		✓	✓	25	0		High relief reef. Slopes away at start and end of video moderate size reef only.
V21	✓	✓					✓									0	0		Silt with a bit of shell grit evident
V22		✓	✓		✓	✓				✓		✓	✓	✓		15	0		Rubble/silt slope transitions to high relief reef with lots of sea whips, etc and low but healthy % cover of hard corals
V23	✓						✓									0	0		Silt. Some patches which had a bit of shell grit/more bioturb but dominated by silt with low bioturb still
V24	✓						✓									0	0		
V25		✓	✓		✓	✓	✓			✓	✓		✓			1	0		Rubble slope transitions to sandy silt with scattered bommies. Bommies mostly dominated by sea whips and gorgonians, some are quite large but tending to be fairly isolated/spread apart

Site	Silt	Silt with sand/grit	Sand	Gravel	Rubble	Boulders/reef	Some bioturbation	Heavy bioturbation	Epifauna low relief	Epifauna high relief	Rubble slope low relief	Rubble slope moderate relief	Reef high relief with soft corals/octocorals	Reef high relief with hard corals	Reef high relief with sensitive hard corals	Live coral % cover	Grass % cover	Possible dynamite	Notes
V26		✓	✓		✓	✓					✓	✓	✓	✓	✓	30	0		Rubble slope transitions to high relief reef with some very large stands of Acropora.
V27	✓						✓									0	0		Silt. Some areas with moderate to heavy bioturbation but mostly just silt with low bioturbation
V28		✓	✓					✓								0	0		Silt and sand. steep slope with moderate to heavy bioturbations
V29			✓		✓	✓					✓			✓		2	0		Low relief rubble and sand with patches of boulders/bommies. Low cover of live corals only.
V30-1		✓	✓					✓	✓	✓						3	0		Missed the P. clavus bombora. Sandy with bioturbation and grit. Patches of low relief epifauna (halimeda, stinging hydroids) and some moderate coral plates and boulders occasionally.
V30-2						✓								✓		100	0		P. clavus bommie. Totally surrounded by sand but 100% cover of P. clavus on the bommie and lots of fish
V30-3			✓	✓		✓	✓				✓			✓		2	0		Sand with shell grit and occasional boulders and corals
V31											✓					0	0		Start of BRUV 2 drop camera. Rubble slope
V32													✓	✓	✓	5	0		End of BRUV 2 drop camera. High relief reef

Appendix C Marine Fauna Species

The following provides a list of all of the fauna families identified within the study area, including individual species where identified. Species have been identified as either ***Known*** or ***Possible/Likely*** to occur. The sources used for identifying 'known' occurrence are:

(1) Marine field surveys in June-July 2016 or January 2017, including surveys in the estuarine areas (where species identified occur in both estuarine and marine waters).

(2) Orokolo Bay coastal village interviews conducted as part of the Upstream Land and Natural Resources Baseline Report (Booyong Forest Science, 2017).

(3) By-catch and other fisheries records discussed in the Marine Fisheries and Resources Baseline Report (ERIAS Group, 2017c).

(4) Surveys conducted for the PNG LNG Project EIS.

The 'possible/likely' occurrence is based on the literature and data sources discussed within the main body of this report.

For each species, information has also been provided regarding status against the following:

A. *Fauna (Protection and Control) Act 1966*, i.e. Protected or Restricted.

B. Trade-restricted status under CITES Appendices (I or II) and/or *International Trade (Fauna and Flora) Act 1979* schedules (1 or 2).

C. IUCN Red List of Threatened Species, i.e. Not Evaluated, Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered.

D. Endemism or restricted-range status.

E. Migratory or congregatory status.

F. Invasive species, including invasive alien and invasive native species.

NOTE: Table C-1 does not include flora, coral or benthic macroinvertebrate families or species.

Table C-1 List of Marine and Coastal Fauna Species Likely to Occur in Study Area

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
Aspiodochirotida													
Holothuriidae	*Actinopyga echinites*	Deepwater redfish					✓	-	-	VU	×	×	×
	Actinopyga lecanora	Stonefish					✓	-	-	DD	×	×	×
	Actinopyga mauritana	Surf redfish					✓	-	-	VU	×	×	×
	Actinopyga miliaris	Hairy blackfish					✓	-	-	VU	×	×	×
	Bohadschia argus	Tigerfish					✓	-	-	LC	×	×	×
	Bohadschia similis	Chalkfish					✓	-	-	DD	×	×	×
	Bohadschia vitiensis	Brown sandfish					✓	-	-	DD	×	×	×
	Holothuria atra	Lollyfish					✓	-	-	LC	×	×	×
	Holothuria coluber	Snakefish					✓	-	-	LC	×	×	×
	Holothuria edulis	Pinkfish					✓	-	-	LC	×	×	×
	Holothuria flavomaculata	Red snakehead					✓	-	-	LC	×	×	×
	Holothuria fuscinaraea	Labuyo					✓	-	-	LC	×	×	×
	Holothuria fuscogilva	White teatfish					✓	-	-	VU	×	×	×
	Holothuria fuscopunctata	Elephant trunkfish					✓	-	-	LC	×	×	×
	Holothuria hilla	-					✓	-	-	LC	×	×	×
	Holothuria lessoni	Golden sandfish					✓	-	-	EN	×	×	×
	Holothuria leucospilota	White threadfish					✓	-	-	LC	×	×	×
	Holothuria nobilis	Black teatfish					✓	-	-	EN	×	×	×
	Holothuria scabra	Sandfish					✓	-	-	EN	×	×	×
	Pearsonothuria graeffei	Flower fish					✓	-	-	LC	×	×	×
Sticopodidae	*Stichopus chloronotus*	Greenfish					✓	-	-	LC	×	×	×

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
	Stichopus hermannii	Curryfish					✓	-	-	VU	×	×	×
	Stichopys horrens	Dragonfish					✓	-	-	DD	×	×	×
	Stichopus naso	Pink curryfish					✓	-	-	LC	×	×	×
	Stichopus ocellatus	Ocellated curryfish					✓	-	-	DD	×	×	×
	Stichopus vastus	Brown curryfish					✓	-	-	LC	×	×	×
	Thelenota ananas	Prickly redfish					✓	-	-	EN	×	×	×
	Thelenota anax	Amberfish					✓	-	-	DD	×	×	×
	Thelenota rubralineata	Candy cane					✓	-	-	DD	×	×	×
Aulopiformes													
Synogontidae	Various unreported species					✓		-	-	-	-	-	-
Carcharhiniformes													
Carcharhinidae	*Carcharhinus leucas*	Bull shark					✓	-	-	NT	×	×	×
	Carcharhinus macloti	Hardnose shark	✓					-	-	NT	×	×	×
	Glyphis garricki	Northern river shark					✓	-	-	CE	×	×	×
	Glyphis glyphis	Speartooth Shark					✓	-	-	EN	×	×	×
	Rhizoprionodon acutus	Milk shark		✓				-	-	LC	×	×	×
Sphymidae	*Eusphyra blochii*	Winghead shark		✓				-	-	EN	×	×	×
Cetartiodactyla													
Delphinidae	Unidentified dolphin species (likely *D. delphis* or *T. trunacatus*)		✓					-	-	-	-	-	-
	Delphinus delphis	Short-beaked common dolphin					✓	-	II	LC	×	✓	×
	Orcaella heinsohni	Australian snubfin dolphin					✓	-	I	NT	×	✓	×
	Sousa sahulensis	Humpback dolphin					✓	-	I	VU	×	✓	×
	Stenella attenuata	Pantropical spotted dolphin					✓	-	II	DD	×	✓	×

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
	Stenella longirostris	Spinner dolphin					✓	-	II	LC	×	✓	×
	Tursiops aduncus	Indo-Pacific bottlenose dolphin					✓	-	II	DD	×	✓	×
	Tursiops truncatus	Common bottlenose dolphin					✓	-	II	LC	×	✓	×
Clupeiformes													
Chirocentridae	*Chirocentrus dorab*	Dorab wolf herring		✓				-	-	NE	×	×	×
Clupeidae	*Escualosa thoracata*	Deep-bodied herring					✓	-	-	NE	×	×	×
	Hilsa kelee	Kelee shad					✓	-	-	NE	×	×	×
	Sardinella gibbosa	Goldstripe sardinella		✓				-	-	NE	×	×	×
Engraulidae	Various unreported species					✓		-	-	-	-	-	-
	Thryssa hamiltonii	Hamilton's thryssa					✓	-	-	NE	×	×	×
	Stolephorus commersonnii	Commerson's anchovy					✓	-	-	NE	×	×	×
	Stolephorus waitei	Spotty-face anchovy					✓	-	-	NE	×	×	×
	Stolephorus indicus	Indian anchovy					✓	-	-	NE	×	×	×
Crocodylia													
Crocodylidae	*Crocodylus porosus*	Saltwater crocodile					✓	-	-	LC	×	✓	×
Decapoda													
Palinuridae	*Panulirus ornatus*	Ornate rock lobster			✓			-	-	LC	×	✓	×
Portunidae	*Scylla serrata*	Mud crab	✓		✓			-	-	NE	×	×	×
Penaeidae	*Fenneropenaeus merguiensis*	White banana prawn			✓			-	-	NE	×	×	×
	Fenneropenaeus indicus	Indian prawn					✓	-	-	NE	×	×	×
	Penaeus monodon	Black tiger prawn			✓			-	-	NE	×	×	×
	Penaeus semisulcatus	Green tiger prawn					✓	-	-	NE	×	×	×
	Metapenaeus ensis	Greasyback prawn			✓			-	-	NE	×	×	×

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
	Metapenaeus demani	Demon prawn			✓			-	-	NE	×	×	×
	Metapenaeus eboracensis	York prawn					✓	-	-	NE	×	×	×
	Metapenaeus endeavouri	Endeavour prawn			✓			-	-	NE	×	×	×
Diadematoida													
Diadematidae	*Diadema spp.*	Sea urchin				✓		-	-	-	-	-	-
Mugiliformes													
Mugilidae	*Cestraeus goldiei*	Goldie River mullet			✓		✓	-	-	DD	×	×	×
	Chelon macrolepis	Largescale mullet					✓	-	-	LC	×	×	×
	Chelon planiceps	Tade grey mullet					✓	-	-	NE	×	×	×
	Chelon subviridis	Greenback mullet	✓					-	-	NE	×	×	×
	Ellochelon vaigiensis	Squaretail mullet					✓	-	-	NE	×	×	×
	Moolgarda engeli	Kanda					✓	-	-	NE	×	×	×
	Moolgarda seheli	Bluespot mullet					✓	-	-	NE	×	×	×
	cf. Mugil cephalus	Flathead grey mullet		✓				-	-	LC	×	×	×
	Oedalechilus labiosus	Hornlip mullet					✓	-	-	NE	×	×	×
	Paramugil parmatus	Broad-mouthed mullet					✓	-	-	NE	×	×	×
	Rhinomugil nasutus	Shark mullet					✓	-	-	NE	×	×	×
	Valamugil buchanani	Bluetail mullet		✓				-	-	NE	×	×	×
Orectolobiformes													
Hemiscyllidae	*Hemiscyllium hallstromi*	Papuan epaulette shark					✓	-	-	VU	✓	×	×
Perciformes													
Acanthuridae	Various unreported species					✓		-	-	-	-	-	-
	Acanthurus leucocheilus	Palelipped surgeonfish	✓			✓		-	-	LC	×	×	×

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
	Acanthurus nigricans	Whitecheek surgeonfish				✓		-	-	LC	×	×	×
	Acanthuridae 2		✓					-	-	-	-	-	-
	Acanthuridae 3		✓					-	-	-	-	-	-
	Paracanthurus hepatus	Indo-Pacific blue tang				✓		-	-	LC	×	×	×
Apogonidae	Various unreported species					✓		-	-	-	-	-	-
	Yarica hyalosoma	Mangrove cardinalfish					✓	-	-	NE	×	×	×
Blenniidae	Various unreported species					✓		-	-	-	-	-	-
Callionymidae	*Callionymus sagitta*	Arrow dragonet					✓	-	-	LC	×	×	×
Caesionidae	Various unreported species					✓		-	-	-	-	-	-
	Caesio teres	Blue fusilier	✓					-	-	LC	×	×	×
	Pterocaesio marri	Bigtail fusilier	✓					-	-	NE	×	×	×
Carangidae	*Caranx sp juv.*						✓	-	-	-	-	-	-
	Caranx ignobilis	Giant trevally					✓	-	-	LC	×	×	×
	cf. Caranx heberi	Blacktip trevally		✓				-	-	LC	×	×	×
	Carangidae 1		✓					-	-	-	-	-	-
	Carangidae 2		✓					-	-	-	-	-	-
Callionymidae	*Eleutherochir opercularis*	Flap-gilled dragonet					✓	-	-	NE	×	×	×
Carangidae	*Pantolabus radiatus*	Fringefin trevally		✓				-	-	LC	×	×	×
	Scomberoides lysan	Doublespotted queenfish		✓				-	-	LC	×	×	×
	Scomberoides sp. juv	Queenfish sp.					✓	-	-	-	-	-	-
Chaetodontidae	Various unreported species					✓		-	-	-	-	-	-
	Chelmon rostratus	Beaked coral fish				✓		-	-	LC	×	×	×
	Chaetodon meyeri	Saddle butterflyfish	✓					-	-	LC	×	×	×

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
	cf. Chaetodon lineolatus	Lined butterflyfish	✓					-	-	LC	×	×	×
	Chaetodon vagabundus	Vagabond butterflyfish	✓					-	-	LC	×	×	×
	Chaetodon sp.		✓					-	-	-	-	-	-
	Chaetodontidae 2		✓					-	-	-	-	-	-
	Chaetodontidae 5		✓					-	-	-	-	-	-
	Chaetodontidae 6		✓					-	-	-	-	-	-
	Coradion sp.	Coralfish	✓					-	-	-	-	-	-
	Heniochus acuminatus	Longfin bannerfish	✓					-	-	LC	×	×	×
Drepaneidae	*Drepane punctata*	Spotted sicklefish					✓	-	-	NE	×	×	×
Eleotridae	*Prionobutis microps*	Small-eyed loter					✓	-	-	NE	×	×	×
Epinephelidae	*Epinephelus coioides*	Orange-spotted grouper	✓					-	-	NT	×	×	×
	Epinephelus merra	Birdwire rockcod	✓					-	-	LC	×	×	×
	Epinephelus fuscoguttatus	Brown-marbled grouper					✓	-	-	NT	×	×	×
	Epinephelus tauvina	Greasy grouper					✓	-	-	DD	×	×	×
Ephippidae	*Rhinoprenes pentanemus*	Threadfin scat		✓				-	-	NE	×	×	×
Gobiidae	*Glossogobius celebius*	Celebes goby					✓	-	-	DD	×	×	×
	Glossogobius concavifrons	Concave goby	✓					-	-	NE	×	×	×
	Glossogobius giuris	Tank goby					✓	-	-	NE	×	×	×
	Oligolepis jaarmani						✓	-	-	NE	×	×	×
	Oxyurichthys tentacularis	Redspot arrowfin goby					✓	-	-	DD	×	×	×
	Periophthalmodon schlosseri	Giant mudskipper					✓	-	-	NE	×	×	×
	Periophthalmus argentilineatus	Barred mudskipper					✓	-	-	NE	×	×	×
	Periophthalmus barbarus	Atlantic mudskipper					✓	-	-	LC	×	×	×

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
	Periophthalmus weberi	Weber's mudskipper					✓	-	-	NE	×	×	×
	Scartelaos histophorus	Walking goby					✓	-	-	NE	×	×	×
	Stenogobius gymnopomus						✓	-	-	LC	×	×	×
	Strenogobius psilosinous	Barcheek goby	✓					-	-	DD	×	×	×
	Gobiidae 1		✓					-	-	-	-	-	-
Haemulidae	*Pomadasys argenteus*	Silver grunt					✓	-	-	LC	×	×	×
	Pomadasys kaakan	Spotted javelinfish	✓					-	-	NE	×	×	×
Holocentridae	Holocentridae 1		✓					-	-	-	-	-	-
Kuhliidae	*Kuhlia marginata*	Dark-margined flagtail					✓	-	-	LC	×	×	×
	Kurtus gulliveri	Nurseryfish	✓					-	-	NE	×	×	×
Labridae	Various unreported species					✓		-	-	-	-	-	-
	Bodianus mesothorax	Eclipse pigfish	✓					-	-	LC	×	×	×
	Cheilinus chlorourus	Red-breasted maori-wrasse	✓					-	-	LC	×	×	×
	Labroides dimidiatus	Bluestreak cleaner wrasse	✓			✓		-	-	LC	×	×	×
	Thalassoma lunare	Moon wrasse	✓			✓		-	-	LC	×	×	×
	Thalassoma sp.	Wrasse sp.	✓					-	-	-	-	-	-
	Labridae 2		✓					-	-	-	-	-	-
Latidae	*Lates calcarifer*	Barramundi	✓					-	-	NE	×	×	×
Leiognathidae	Various unreported species					✓		-	-	-	-	-	-
	Gazza achlamys	Smalltoothed ponyfish					✓	-	-	LC	×	×	×
	Leiognathus berbis	Berber ponyfish					✓	-	-	NE	×	×	×
	Leiognathus equula	Common ponyfish		✓				-	-	LC	×	×	×
	Secutor sp	Ponyfish sp.					✓	-	-	-	-	-	-

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
Leptobramidae	*Leptobrama muelleri*	Beach salmon		✓	✓			-	-	NE	×	×	×
	Leptobrama pectoralis	Longfin beach salmon		✓				-	-	NE	×	×	×
Lethrinidae	*Lethrinus nebulosus*	Spangled emperor			✓			-	-	LC	×	×	×
Lobotidae	*Lobotes surinamensis*	Tripletail	✓					-	-	LC	×	×	×
Lutjanidae	Various unreported species					✓		-	-	-	-	-	-
	Lutjanus sp.	Snapper sp.					✓	-	-	-	-	-	-
	Lutjanidae 1		✓					-	-	-	-	-	-
	Lutjanidae 2		✓					-	-	-	-	-	-
	Lutjanus argentimaculatus	Mangrove red snapper					✓	-	-	LC	×	×	×
	Lutjanus goldiei				✓			-	-	NE	×	×	×
	Lutjanus johnii	Golden snapper	✓					-	-	LC	×	×	×
	Lutjanus sebae	Red emperor snapper					✓	-	-	LC	×	×	×
Malacanthidae	*Malacanthidae juv.*	Tilefish sp.					✓	-	-	-	-	-	-
Mullidae	Various unreported species					✓		-	-	-	-	-	-
	Parupeneus barberinus	Dash-and-dot goatfish	✓					-	-	LC	×	×	×
	Upeneus sulphureus	Sulphur goatfish					✓	-	-	LC	×	×	×
Nemipteridae	Various unreported species					✓		-	-	-	-	-	-
	Scolopsis sp.	Monocle bream	✓					-	-	-	-	-	-
Pholidichthyidae	*Pholidichthys* sp.						✓	-	-	-	-	-	-
Polynemidae	*Eleutheronema tetradactylum*	Fourfinger threadfin		✓	✓			-	-	NE	×	×	×
	Polydactylus macrochir	King threadfin			✓			-	-	NE	×	×	×
	Polydactylus plebeius	Striped threadfin	✓					-	-	NE	×	×	×
Pomacanthidae	Various unreported species					✓		-	-	-	-	-	-

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
	Centropyge bicolor	Bicolour angelfish	✓					-	-	LC	×	×	×
Pomacentridae	Various unreported species				✓			-	-	-	-	-	-
	Abudefduf sp.	Sergeant damsel	✓					-	-	-	-	-	-
	Dascyllus aruanus	Whitetail dascyllus				✓		-	-	NE	×	×	×
	Dischistodus chrysopoecilus	Whitepatch damsel	✓					-	-	NE	×	×	×
	Dischistodus perspicillatus	White damsel	✓					-	-	NE	×	×	×
	Neopomacentrus violascens	Violet damoiselle	✓					-	-	NE	×	×	×
	Pomacentrus nigromanus	Goldback damsel	✓					-	-	NE	×	×	×
	Chromis sp.	Puller sp.	✓					-	-	-	-	-	-
	Pomancentridae 1		✓					-	-	-	-	-	-
	Pomancentridae 2		✓					-	-	-	-	-	-
Scaridae	Various unreported species					✓		-	-	-	-	-	-
Scatophagidae	*Scatophagus argus*	Spotted scat					✓	-	-	LC	×	×	×
	Selenotoca multifasciata	Spotbanded scat					✓	-	-	NE	×	×	×
Sciaenidae	Various unreported species					✓		-	-	-	-	-	-
	Atrobucca brevis	Orange jewfish	✓					-	-	NE	×	×	×
	cf. Atrobucca nibe	Black mouth croaker		✓				-	-	NE	×	×	×
	Johnius coitor	Coitor croaker		✓				-	-	LC	×	×	×
	Johnius novaeguineae	Paperhead croaker					✓	-	-	LC	×	×	×
	Johnius macrorhynus	Big-snout croaker					✓	-	-	NE	×	×	×
	Nibea semifasciata	Sharpnose croaker					✓	-	-	NE	×	×	×
	Nibea soldado	Soldier croaker					✓	-	-	NE	×	×	×
	Nibea squamosa	Scaly jewfish		✓				-	-	NE	×	×	×

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
Scombridae	*cf. Scomberomorus multiradiatus*	Papuan seerfish		✓				-	-	LC	✓	×	×
	Scomberomorus commerson	Narrow-barred Spanish mackerel			✓			-	-	NT	×	×	×
Serranidae	Various unreported species					✓		-	-	-	-	-	-
	Cephalopholis boenak	Brownbarred rockcod	✓					-	-	LC	×	×	×
	Serranidae 1		✓					-	-	-	-	-	-
Sillaginidae	*Sillago* sp. *juv.*	Smelt-whitings sp.					✓	-	-	-	-	-	-
	Sillago sihama	Silver sillago					✓	-	-	LC	×	×	×
Sparidae	*Acanthopagrus berda*	Goldsilk seabream					✓	-	-	LC	×	×	×
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	✓					-	-	LC	×	×	×
Terapontidae	*Hephaestus fuliginosus*	Black bream					✓	-	-	NE	×	×	×
	Hephaestus lineatus	Lined grunter	✓					-	-	NE	×	×	×
	Hephaestus raymondi	Raymond's grunter					✓	-	-	NE	×	×	×
	Hephaestus trimaculatus	Threespot grunter					✓	-	-	DD	×	×	×
	Terapon jarbua	Tiger perch					✓	-	-	LC	×	×	×
Toxotidae	*Toxotes chatareus*	Spotted archerfish					✓	-	-	NE	×	×	×
	Toxotes jaculatrix	Banded archerfish					✓	-	-	LC	×	×	×
Trichiuridae	Various unreported species					✓		-	-	-	-	-	-
Pleuronectiformes													
Cynoglossidae	*Cynoglossus punticeps*	Speckled tonguesole					✓	-	-	NE	×	×	×
	Paraplagusia bilineata	Doublelined tonguesole					✓	-	-	NE	×	×	×
Paralichthyidae	*Pseudorhombus elevatus*	Deep flounder					✓	-	-	NE	×	×	×
Soleidae	*Leptachirus klunzingeri*	Tailed sole					✓	-	-	NE	×	×	×
	Leptachirus sp.	Sole					✓	-	-	-	-	-	-

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
Rajiformes													
Myliobatidae	*Aetobatus narinari*	Spotted eagle ray					✓	-	-	NT	×	×	×
Dasyatidae	*Dasyatis sephen*	Cowtail stingray					✓	-	-	NE	×	×	×
	Glaucostegus typus	Giant shovelnose ray					✓	-	-	VU	×	×	×
	Himantura uarnak	Reticulate whipray					✓	-	-	VU	×	×	×
Pristidae	*Anoxypristis cuspidata*	Narrow sawfish		✓				-	I	EN	×	✓	×
	Pristis pristis	Largetooth sawfish					✓	-	I	CE	×	✓	×
	Pristis zijsron	Green sawfish					✓	-	I	EN	×	✓	×
Scorpaeniformes													
Platycephalidae	*Platycephalus indicus*	Bartail flathead					✓	-	-	DD	×	×	×
Sirenia													
Dugongidae	*Dugong dugon*	Dugong					✓	P	I	VU	×	✓	×
Squamata													
Elapidae	*Laticauda guineai*	Guinea's sea krait					✓	×	×	NT	×	×	×
Homalopsidae	*Cantoria annulata*	Banded watersnake					✓	-	-	DD	✓	×	×
Syngnathiformes													
Syngnathidae	*Hippichthys heptagonus*	Belly pipefish					✓	-	-	NE	×	×	×
	Hippichthys spicifer	Bellybarred pipefish					✓	-	-	LC	×	×	×
	Microphis brachyurus brachyurus	Opossum pipefish					✓	-	-	LC	×	×	×
Testudines													
Cheloniidae	*Caretta caretta*	Loggerhead turtle					✓	-	I	VU	×	✓	×
	Chelonia mydas	Green turtle					✓	-	I	CE	×	✓	×
	Eretmochelys imbricata	Hawksbill turtle					✓	-	I	EN	×	✓	×

Family	Relevant species*		Occurrence[1]					Status[2]					
	Scientific name	Common name	Known to occur (source)				Possible/Likely						
			(1)	(2)	(3)	(4)		A	B	C	D	E	F
	Lepidochelys olivacea	Olive ridley turtle					✓	-	I	VU	×	✓	×
	Natator depressus	Flatback turtle					✓	-	I	DD	×	✓	×
Dermochelyidae	*Dermochelys coriacea*	Leatherback turtle					✓	P	I	CE	×	✓	×
Tetraodontiformes													
Balistidae	Various unreported species					✓		-	-	-	-	-	-
	Balistidae 1		✓					-	-	-	-	-	-
Tetraodontidae	*Arothron reticularis*	Reticulated pufferfish					✓	-	-	LC	×	×	×
	Arothron sp.	Puffer sp.	✓					-	-	-	-	-	-
	Chelonodon patoca	Milkspotted puffer					✓	-	-	LC	×	×	×
	Marilyna meraukensis	Merauke toadfish					✓	-	-	NE	×	×	×
	Marilyna pleurosticta	Banded toadfish					✓	-	-	LC	×	×	×
Triacanthidae	*Triacanthus biaculeatus*	Short-nosed tripodfish					✓	-	-	NE	×	×	×
Triacanthodidae	*Triacanthodes indicus*	Spikefish					✓	-	-	NE	×	×	×
Valvatida													
Acanthasteridae	*Acanthaster planci*	Crown-of-thorns starfish					✓	-	-	NE	×	×	N

[1]Occurrence is based on Known to Occur and Possible/Likely to Occur (P/L). For species Known to Occur, the following sources are used: (1) marine field surveys, (2) Orokolo Bay coastal villages surveys, (3) by-catch and fisheries records, and (4) PNG LNG Project EIS field surveys. A tick (✓) is placed in the occurrence category most relevant to the species.

[2]Status is based on the following categories: A. Protected (P) or Restricted (R) under *Fauna (Protection and Control) Act 1966*; B. trade-restricted status under CITES (I or II) or *International Trade (Fauna and Flora) Act 1979* (1 or 2); C. Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN) or Critically Endangered (CE) under IUCN Red List of Threatened Species; D. endemism or restricted-range; and E. migratory or congregatory. Status also includes F. invasive species, including native (N) and alien (A) invasives. A tick (✓) indicates the species meets the criteria and a cross (×) or a dash (-) indicates a species does not meet the criteria (- used where critera relates to a list, × used where criteria requires interpretation based on species' lifecycle) and/or ecological requirement.

*Identification of the species marked with a cf. should be treated with caution; these have been based on identification from photographs and have a degree of uncertainty
**Cells that are highlighted are threatened/important species, discussed in body of this report.



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