# Gorgon Gas Development and Jansz Feed Gas Pipeline

## Coastal and Marine Baseline State and Environmental Impact Report: Domestic Gas Pipeline

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|---|---|---|---|
| Document No: | G1-NT-REPX0002750 | Revision: | 1 |
| Revision Date: | 29 January 2015 | Copy No: | |
| IP Security: | Public | | |

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# Terms, Definitions and Abbreviations

Terms, definitions and abbreviations used in this document are listed below. These align with the terms, definitions and abbreviations defined in Schedule 2 of the Western Australian Gorgon Gas Development Ministerial Implementation Statement No. 800 (Statement No. 800) and the Commonwealth Gorgon Gas Development Ministerial Approvals (EPBC Reference: 2003/1294 and 2008/4178).

| | |
|---|---|
| $\mu E/m^2/s$ | Microeinsteins per square metre per second |
| µm | Micrometre. 1 µm = $10^{-6}$ metre = 0.000001 metre or one millionth of a metre. |
| $\mu mol/m^2/s$ | Micromoles per square metre per second |
| 2π quantum sensor | A light sensor that records down-welling irradiance, or light from one hemisphere |
| 3CCD | A three-CCD camera is a camera whose imaging system uses three separate charge-coupled-devices (CCDs), each one taking a separate measurement of the primary colours, red, green, or blue light. |
| ABU | Australasia Business Unit |
| ADCP | Acoustic Doppler Current Profiler. A sonar that produces a record of water current velocities for a range of depths. |
| ALS | Australian Laboratory Services Environmental |
| ANOVA | Analysis of Variance, which is a collection of statistical models, and their associated procedures, in which the observed variance is partitioned into components due to different explanatory variables. In its simplest form, ANOVA gives a statistical test of whether the means of several groups are all equal. |
| APASA | Asia Pacific Applied Science Associates |
| ARI | Assessment on Referral Information (for the proposed Jansz Feed Gas Pipeline dated September 2007) as amended or supplemented from time to time. |
| ASSD | Accumulated Sediment Surface Density |
| Asymptote | A straight line approached by a curve as one of the variables in the equation of the curve approaches affinity. |
| At risk | Being at risk of Material Environmental Harm or Serious Environmental Harm and/or, for the purposes of the EPBC Act relevant listed threatened species, threatened ecological communities and listed migratory species, at risk of Material Environmental Harm or Serious Environmental Harm. |

| | |
|---|---|
| Autocorrelation | The relationship between the values of a variable taken at certain times in the series and values of a variable taken at other times. Alternatively, more simply, it is the similarity between observations as a function of the time separation between them. |
| Bathymetric | Relating to measurements of the depths of oceans or lakes. |
| Bathyscope | Underwater viewer. |
| Bellmouth | An area comprised of 16 single rock bolts either side of the Domestic Gas pipeline, installed in an outward curving configuration to limit pipeline stresses caused by displacement. |
| Benthic | Living upon or in the seabed. |
| Benthic Habitats | Areas of the seabed that support living organisms. Examples include, limestone pavement, reefs, sand and soft sediments. |
| Benthic Primary Producer | Photosynthesising organisms (mangroves, seagrasses, algae) or organisms that harbour photosynthetic symbionts (corals, giant clams). |
| Biofouling | Unwanted marine growth on vessels or marine infrastructure. |
| Biomass | The total mass or amount of living organisms in a particular area or volume. |
| Biota | All the plant and animal life of a particular region. |
| Biotic | Of or relating to living organisms. |
| BOM | Australian Bureau of Meteorology |
| Bombora | Raised, dome-shaped, limestone feature, >1 m high, often formed by coral of the genus *Porites*. |
| Bombora | Raised, dome-shaped, limestone feature, >1 m high, often formed by coral of the genus Porites. |
| BPPH | Benthic Primary Producer Habitat; benthic habitats that support primary producers. |
| BRUV | Baited Remote Underwater Video system |
| Calcarenite | Rock formed by the percolation of water through a mixture of calcareous shell fragments and quartz sand causing the dissolved lime to cement the mass together. |
| CALM | Former Western Australian Department of Conservation and Land Management (now DPaW) |
| CALM Act | Western Australian *Conservation and Land Management Act 1984* |
| Carbon Dioxide ($CO_2$) Injection System | The mechanical components required to be constructed to enable the injection of reservoir carbon dioxide, including but not limited to compressors, pipelines and wells. |

| | |
|---|---|
| CDEEP | Construction Dredging Environmental Expert Panel |
| Chevron ETC | Chevron Energy Technology Company |
| Clade | A group of biological taxa or species that share features inherited from a common ancestor. |
| Commonality | The degree to which a species is observed universally across all samples or areas, measured as the percentage of stereo-BRUVs deployments where a species was observed. Distinct from relative abundance. |
| cm | Centimetre |
| $cm^2$ | Square centimetre |
| $CO_2$ | Carbon Dioxide |
| Construction | Construction includes any Proposal-related (or action-related) construction and commissioning activities within the Terrestrial and Marine Disturbance Footprints, excluding investigatory works such as, but not limited to, geotechnical, geophysical, biological and cultural heritage surveys, baseline monitoring surveys and technology trials. |
| Coral | Marine organisms from the class Anthozoa that exist as small sea-anemone-like polyps, typically in colonies of many identical individuals. Includes 'hard corals' within the order Scleractinia which secrete calcium carbonate to form a hard skeleton and form reefs; and 'Soft corals' within the order Alcyonacea which have no hard skeleton and are not considered reef-building organisms. |
| Coral Definitions | *Coral Assemblages* are benthic areas (minimum 10 $m^2$) or raised seabed features over which the average live coral cover is equal to or greater than 10%.<br>*The Change in coral mortality* is determined by subtracting the baseline extent of Gross coral mortality from the extent of Gross coral mortality measured on a sampling occasion.<br>*Detectable Net Mortality* is the result of subtracting the Change in coral mortality at the Reference Site(s) from the Change in coral mortality at the Monitoring Site.<br>*Average Net Detectable Mortality* is the result of averaging the net detectable mortality of all monitoring sites within the Zone i.e. the mean of net detectable mortality of any Zone.<br>*Gross coral mortality* at a site is expressed as a percentage of total coral cover at the time of sampling at that monitoring location.<br>In determining the coral loss, measurement uncertainty is to be taken into consideration. |
| CoV | Coefficient of Variation |
| CPCe | Coral Point Count with Excel extensions (software for the determination of coral cover from photographs) |

| | |
|---|---|
| Crustose | Forming a crust that is firmly attached to the substrate over its entire area. |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| CTD | Conductivity-Temperature-Depth |
| Cth | Commonwealth of Australia |
| DEC | Former Western Australian Department of Environment and Conservation (now DPaW) |
| Demersal | Living on the seabed or just above it. |
| DEWHA | Former Commonwealth Department of the Environment, Water, Heritage and the Arts (now DotE) |
| Diurnal | Daily |
| DO | Dissolved Oxygen |
| DoF | Western Australian Department of Fisheries |
| DomGas | Domestic Gas |
| Dominant | Most common (relating to the following ecological elements: macroalgae, seagrass, mangroves, non-coral benthic invertebrates and demersal fish). |
| Dominant Coral Species | Species with the highest relative percentage cover. Percentage cover is expressed as the proportion of total coral cover. |
| DoT | Western Australian Department of Transport |
| DotE | Commonwealth Department of the Environment |
| DPaW | Western Australian Department of Parks and Wildlife |
| DPI | Former Western Australian Department for Planning and Infrastructure |
| Dry season | Period of low rainfall in the Pilbara region of Western Australia between April and November. |
| Ebb Tide | The period between high tide and the next low tide in which the sea is receding. |
| Ecological Element | Element listed in listed in Condition 14.2 of Statement No. 800 and Condition 11.2 of EPBC Reference: 2003/1294 and 2008/4178. |
| EIS/ERMP | Environmental Impact Statement/Environmental Review and Management Programme (for the Proposed Gorgon Gas Development dated September 2005) as amended or supplemented from time to time. |

| | |
|---|---|
| Environmental Harm | Has the meaning given by Part 3A of the *Environmental Protection Act 1986* (WA). |
| EP Act | Western Australian *Environmental Protection Act 1986* |
| EPA | Western Australian Environmental Protection Authority |
| EPBC Act | Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* |
| EPBC Reference: 2003/1294 | Commonwealth Ministerial Approval (for the Gorgon Gas Development) as amended or replaced from time to time. |
| EPBC Reference: 2005/2184 | Commonwealth Ministerial Approval (for the Jansz Feed Gas Pipeline) as amended or replaced from time to time. |
| EPBC Reference: 2008/4178 | Commonwealth Ministerial Approval (for the Revised Gorgon Gas Development) as amended or replaced from time to time. |
| EPCM | Engineering, Procurement and Construction Management |
| Epiphyte | A plant that naturally grows upon another plant but does not derive any nourishment from it. |
| ESRI | Environmental Systems Research Institute |
| Feed Gas Pipeline | Pipeline from the wells to the Gas Treatment Plant |
| Fines | Fine particles |
| Finfish | A term used to distinguish fish with fins and gills, from shellfish, crayfish, jellyfish, etc. |
| Flood Tide | The period between low tide and the next high tide in which the sea is rising. |
| g | Gram |
| GDA | Geocentric Data of Australia |
| GEMS | Global Environmental Modelling Systems |
| Geostrophic | The horizontal movement of surface water arising from a balance between the pressure gradient force and the Coriolis force. |
| GIS | Geographic Information System |
| Globose | Having the shape of a sphere or ball. |
| Gorgon Gas Development | The Gorgon Gas Development as approved under Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178 as amended or replaced from time to time. |
| GPS | Global Positioning System |
| Ground Truth | To verify the correctness of remote sensing information by use of ancillary information such as field studies. |

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| ha | Hectare |
| Habitat | The area or areas in which an organism and/or assemblage of organisms lives. It includes the abiotic factors (e.g. substrate and topography) and the biotic factors. |
| HDD | Horizontal Directional Drilling |
| Hermatypic | Hermatypic corals are corals that contain and depend upon zooxanthellae (algae) for nutrients. |
| HES | Health, Environment and Safety |
| Hydrotest | Method whereby water is pressurised within pipes and vessels to detect leaks. |
| IMCRA | Integrated Marine and Coastal Regionalisation of Australia |
| Infauna | Benthic fauna (animals) living in the substrate and especially in a soft sea bottom. |
| ISO | International Organization for Standardization |
| Isobath | A line on a chart joining places of equal depth of water; a depth contour. |
| ITIS | Integrated Taxonomic Information System (http://www.itis.gov) |
| Jansz Feed Gas Pipeline | The Jansz Feed Gas Pipeline as approved in Statement No. 769 and EPBC Reference: 2005/2184 as amended or replaced from time to time. |
| Jet Sled | Equipment used for jetting. The equipment is towed (like a sled) along the route to be trenched and is equipped with high pressure water jets to perform subsea jetting. |
| Jetting Activities | A method of creating a subsea trench by injecting water under high velocity into the upper layer of the seabed sediments, resulting in fluidisation and displacement of the sediment. |
| KJVG | Kellogg Joint Venture Gorgon |
| km | Kilometre |
| km/h | Kilometres per hour |
| KP | Kilometre Points |
| L | Litre |
| LAC | Light Attenuation Coefficient |
| $LAC_n$ | Normalised LAC |
| $LAC_m$ | Measured LAC |

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| LADS | Laser Airborne Depth Sounder (used for bathymetry mapping) |
| LAT | Lowest Astronomical Tide |
| LECO | Laboratory Equipment Corporation; developer and manufacturer of elemental measurement and molecular mass spectrometry instrumentation |
| Light Attenuation | The absorption and scattering of light underwater |
| Littoral | A shore; the zone between high tide and low tide; of, or related to the shore, especially the seashore. |
| LNG | Liquefied Natural Gas |
| $Log_{10}$ | Common (base 10) logarithm |
| $Log_e$ | Natural (base e) logarithm |
| LTD | Light, Turbidity, and Deposition |
| m | Metre |
| m/s | Metres per second |
| $m^2$ | Square metre |
| $m^3$ | Cubic metre |
| Macroalgae | Benthic marine plants that are non-flowering and lack roots, stems and vascular tissue. Can be seen without the aid of a magnification; includes large seaweeds. |
| Macrofauna | Animals whose shortest dimension is greater than or equal to 0.5 mm and can be seen without the aid of magnification; includes polychaetes, snails and amphipods. |
| Macroinvertebrates | An invertebrate animal (an animal without a backbone [vertebral column]) large enough to be seen without the aid of magnification; includes sponges, crinoids, hydroids, sea pens, sea whips, gorgonians, snails, clams, crayfish and sea cucumbers. |
| Mangrove | Tropical evergreen trees or shrubs with stilt-like roots and stems that grow in shallow coastal water. |
| MARFL | Marine and Freshwater Research Laboratory |

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| Marine Disturbance Footprint | The area of the seabed to be disturbed by construction or operations activities associated with the Marine Facilities listed in Condition 14.3 of Statement No. 800 and Condition 11.3 in EPBC Reference: 2003/1294 and 2008/4178 (excepting that area of the seabed to be disturbed by the generation of turbidity and sedimentation from dredging and dredge spoil disposal) and as set out in the Coastal and Marine Baseline State and Environmental Impact Report (this Report) required under Condition 14.2 of Statement No. 800 and Condition 11.2 of EPBC Reference: 2003/1294 and 2008/4178. |
| Marine Facilities | In relation to Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178, the Marine Facilities are the:<br>• Materials Offloading Facility (MOF)<br>• LNG Jetty<br>• Dredge Spoil Disposal Ground<br>• Offshore Feed Gas Pipeline System and the marine component of the shore crossing<br>• Domestic Gas Pipeline<br>Condition 14.3 of Statement No. 800 relates only to components of the Marine Facilities within State waters (i.e. specifically the Offshore Feed Gas Pipeline System).<br>For the purposes of Statement No. 800 Marine Facilities also include:<br>• Marine upgrade of the existing WAPET landing. |
| Marine Facilities Footprint | The area of seabed associated with the physical footprint of the Marine Facilities, but excluding the area of the seabed disturbed by dredging an dredge spoil disposal, or for example, by anchoring. |
| Material Environmental Harm | Environmental Harm that is neither trivial nor negligible. |
| MaxN | Maximum number of fish belonging to each species, present in the field of view of the stereo-BRUVs at any time during the footage. |
| MBACI | Multiple Before–After, Control–Impact statistical design. |
| Mean MaxN | The mean (average) MaxN of a species recorded in the replicate stereo-BRUVs deployments at a specific site. |
| mg | Milligrams |
| $mg/cm^2$ | Milligrams per square centimetre |
| mg/L | Milligrams per litre |
| MGA 50, GDA 94 | Map Grid of Australia Zone 50 (WA); projection based on the Geocentric Datum of Australia 1994. |

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| Migratory species | Species listed as migratory under section 209 of the EPBC Act (Cth). |
| mL | Millilitre |
| mm | Millimetre |
| MOF | Materials Offloading Facility |
| MTPA | Million Tonnes Per Annum |
| NATA | National Association of Testing Authorities |
| Neap Tide | A less than average tide occurring at the first and third quarters of the moon. |
| Nearshore | Close to shore; or within three nautical miles of Barrow Island. |
| NES | National Environmental Significance |
| nm | Nautical miles |
| NTU | Nephelometric Turbidity Unit |
| NVIS | National Vegetation Information System |
| OBS | Optical Backscatter Sensor |
| OE | Operational Excellence |
| OEMS | Operational Excellence Management System |
| Operations (Gorgon Gas Development) | In relation to Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178, for the respective LNG trains, this is the period from the date on which the Gorgon Joint Venturers issue a notice of acceptance of work under the Engineering, Procurement and Construction Management (EPCM) contract, or equivalent contract entered into in respect of that LNG train of the Gas Treatment Plant; until the date on which the Gorgon Joint Venturers commence decommissioning of that LNG train. |
| Orders of Magnitude | Generally used to make approximate comparisons, a number rounded to the nearest power of 10 |
| PAR | Photosynthetically Active Radiation |
| Pelagic | Living in the open sea rather than in coastal or inland waters. |
| PER | Public Environmental Review for the Gorgon Gas Development Revised and Expanded Proposal dated September 2008, as amended or supplemented from time to time. |
| PERMANOVA | Permutational Multivariate Analysis of Variance |
| PGPA | Policy, Government and Public Affairs |

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| pH | Measure of acidity or basicity of a solution |
| Photomeasure | A software package used for measuring the lengths of fish from stereo imagery. |
| PIO | Pilbara Offshore (Marine Bioregion) |
| *Porites* | An important genus of long-lived, reef building corals. |
| ppt | Parts Per Thousand |
| Practicable | Practicable means reasonably practicable having regard to, among other things, local conditions and circumstances (including costs) and to the current state of technical knowledge.<br>For the purposes of the conditions of EPBC Reference: 2003/1294 and 2008/4178 that include the term ‘practicable’, when considering whether the draft plan meets the requirements of these conditions, the Commonwealth Minister will determine what is ‘practicable’ having regard to local conditions and circumstances including but not limited to personnel safety, weather or geographical conditions, costs, environmental benefit and the current state of scientific and technical knowledge. |
| PSD | Particle-size Distribution |
| PSU | Practical Salinity Units, equivalent to parts per thousand (ppt) |
| *p*-value | In statistical hypothesis testing, the probability of obtaining a result at least as extreme as the one that was actually observed, assuming that the null hypothesis is true. |
| QA/QC | Quality Assurance/Quality Control |
| Quadrat | A rectangle or square measuring area used to sample living things in a given site; can vary in size. |
| $R^2$ | The coefficient of determination, it gives the proportion of the variance (fluctuation) of one variable that is predictable from the other variable. |
| Reference Sites | Specific areas of the environment that are not at risk of being affected by the proposal or existing developments, that can be used to determine the natural state, including natural variability, of environmental attributes such as coral health or water quality. |
| Regionally Significant Areas | Are the regionally significant areas outside the Zones of High Impact, Moderate Impact and Influence on the eastern margins of the Lowendal Shelf to the southern boundary of the Montebello Islands Marine Park, and Dugong Reef, Batman Reef and Southern Barrow Shoals. |
| Relative Abundance | The abundance of a species within a given stereo-BRUVs sample, measured as MaxN. This measure is semi-quantitative and relative between samples as the unit of area measured is not strictly defined. Different to commonality. |

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| Root Mean Square water depth | Shows the variation in water depth within a time and is an indication of wave height. Calculated as follows: $$D_{rms} = \sqrt{\sum_{n=1}^{10} (D_n - \overline{D})^2 / n}$$ Where $D_n$ is the *nth* of 10 sequential readings and $\overline{D}$ is the mean water depth of the *n* readings. |
| ROV | Remotely Operated Vehicle |
| ROW | Right-of-Way |
| RVA | Rapid Visual Assessment |
| s | Second (time) |
| Scleractinian | Corals that have a hard limestone skeleton and belong to the order Scleractinia. |
| SE | Standard Error |
| SEACAT Profiler | Seabird Electronics SBE19 SEACAT Profiler |
| Seagrass | Benthic marine plants which have roots, stems, leaves and inconspicuous flowers with fruits and seeds much like terrestrial flowering plants. Unrelated to seaweed. |
| Secchi Depth | The depth at which a Secchi disc is no longer visible from the surface of ocean water. |
| Serious Environmental Harm | Environmental harm that is: a) irreversible, of a high impact or on a wide scale; or b) significant or in an area of high conservation value or special significance and is neither trivial nor negligible. |
| Sessile | Permanently attached directly to the substrate by its base (i.e. immobile), without a stalk or stem. |
| SEWPaC | Former Commonwealth Department of Sustainability, Environment, Water, Population and Communities (now DotE) |
| Significant Impact | An impact on a Matter of National Environmental Significance, relevant to EPBC Reference: 2003/1294, 2005/2185 and 2008/4178 that is important, notable or of consequence having regard to its context or intensity. |
| SIMPER | Similarity Percentages routine in PRIMER |
| Skewness | Measure of the degree of asymmetry of a distribution |
| SKM | Sinclair Knight Merz |

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| S-lay | The pipeline is laid from the pipelay barge using tensioner, stinger and roller support system. From the stern of the pipelay barge, the pipeline curves downward to the sea floor in an 'S-shaped' configuration. |
| sp. (plural: spp.) | Species |
| Spawning | The production or depositing of large quantities of eggs in water; typically by marine animals such as amphibians, fish, and corals. |
| Spoil Disposal Ground | The area where dredged and excavation material is to be disposed of at sea. |
| Spring tide | The highest tides in a lunar month, occurring near new and full moons. |
| SSBA | Surface-supplied Breathing Apparatus |
| SSC | Suspended Sediment Concentration |
| State Waters | The marine environment within three nautical miles of the coast of Barrow Island or the mainland of Western Australia. |
| Statement No. 748 | Western Australian Ministerial Implementation Statement No. 748 (for the Gorgon Gas Development) as amended from time to time [superseded by Statement No. 800]. |
| Statement No. 769 | Western Australian Ministerial Implementation Statement No. 769 (for the Jansz Feed Gas Pipeline) as amended from time to time. |
| Statement No. 800 | Western Australian Ministerial Implementation Statement No. 800 (for the Gorgon Gas Development) as amended from time to time. |
| Stereo-BRUV | Baited Remote Underwater Stereo-Video system |
| Stinger | A steel structure extending from the stern of the pipelay barge, equipped with rollers, to support and control the bend of the pipeline during S-lay pipeline installation. |
| Stressor | An environmental condition or influence that stresses (i.e. causes stress for) an organism. |
| Subdominant Coral Species | Species, excluding Dominant Coral Species, which have greater than or equal to 5% cover. Percentage cover is expressed as the proportion of total coral cover. |
| Substrate | The surface a plant or animal lives upon. The substrate can include biotic or abiotic materials. For example, encrusting algae that lives on a rock can be substrate for another animal that lives above the algae on the rock. |
| Surficial | Of or pertaining to the surface |
| SYSTAT | A statistics and statistical graphics software package |
| $S_{ZA}$ | Above-water solar zenith angle |

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| $S_{ZAUW}$ | Underwater solar zenith angle |
| TAPL | Texaco Australia Pty. Ltd. |
| Taxon (plural: taxa) | A taxon (plural taxa), or taxonomic unit, is a name designating an organism or a group of organisms. |
| Temporal | Relating to, or limited by, time |
| Threatened Ecological Communities | Ecological communities listed as critically endangered, endangered or vulnerable under section 181 of the EPBC Act (Cth). |
| Threatened Species | Species listed as extinct, extinct in the wild, critically endangered, endangered, vulnerable or conservation dependent under section 178 of the EPBC Act (Cth). |
| TIC | Total Inorganic Carbon |
| TOC | Total Organic Carbon |
| Towfish | A scientific instrument towed beneath the sea surface |
| Transect | The path along which a researcher moves, counts and records observations. |
| TSS | Total Suspended Solids |
| *t*-test | A statistical test to determine whether the difference between two sample means is statistically significant. |
| Turbidity | The cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality. |
| Umbilicals | Connections between topside equipment and subsea equipment. |
| UWA | University of Western Australia |
| Van Veen Grab | Used to take sediment samples from the seabed |
| Vegetation Association | Comprises unique flora assemblages, or unique vegetation communities, that help to identify the association. |
| Vessel | Craft of any type operating in the marine environment including hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms. Also includes seaplanes when present on and in the water. |
| Vouchering | Collection of fauna specimens for scientific purposes. |
| WA | Western Australia |
| WAPET | West Australian Petroleum Pty Ltd. |

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| WAPET Landing | Proper name referring to the site of the barge landing existing on the east coast of Barrow Island prior to the date of Statement No. 800. |
| Waters Surrounding Barrow Island | Refers to the waters of the Barrow Island Marine Park and Barrow Island Marine Management Area (approximately 4169 ha and 114 693 ha respectively) as well as the port of Barrow Island representing the Pilbara Offshore Marine Bioregion which is dominated by tropical species that are biologically connected to more northern areas by the Leeuwin Current and the Indonesian Throughflow, resulting in a diverse marine biota is typical of the Indo–West Pacific flora and fauna. |
| Wet season | Period of higher than average rainfall in the Pilbara region of Western Australia extending from late November through to early April. |
| WQ | Water Quality |
| WST | Western Standard Time (Australia) |
| Zone of High Impact | An area where long-term impacts to corals are predicted to result directly from disturbance during horizontal directional drilling, dredging or construction of infrastructure on the seabed and burial during dredge spoil disposal, or indirectly from smothering due to elevated sedimentation and/or from deterioration in water quality. As set out in Schedule 1 of Statement No. 800 and Schedule 5 of EPBC Reference: 2003/1294 and 2008/4178. |
| Zone of Influence | This area is predicted to be indirectly influenced by dredging and spoil disposal activities (e.g. marginal increases in turbidity and sedimentation), but at levels that will have no measurable impact on corals. As set out in Schedule 1 of Statement No. 800 and Schedule 5 of EPBC Reference: 2003/1294 and 2008/4178. |
| Zone of Moderate Impact | An area where short-term moderate impacts (e.g. some partial mortality of corals) is predicted to result indirectly from horizontal directional drilling, dredging, dredge spoil disposal, due to deterioration in water quality and/or an increase in sedimentation rates. Moderate impacts are likely to include some partial mortalities among fast growing, more sensitive coral species (e.g. *Acropora* spp.) but less, if any, mortality of longer living, generally more resilient species (e.g. *Porites* spp., *Turbinaria* spp.). As set out in Schedule 1 of Statement No. 800 and Schedule 5 of EPBC Reference: 2003/1294 and 2008/4178. |

# Executive Summary

This Coastal and Marine Baseline State and Environmental Impact Report – Domestic Gas Pipeline ('Marine Baseline Report') has been prepared to meet the requirements of Condition 14 of Ministerial Implementation Statement No. 800 (Statement No. 800), and Condition 11 of EPBC Reference: 2003/1294 and 2008/4178 specifically in respect to the (Offshore) Domestic Gas Pipeline (DomGas). Baseline surveys have been undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800 and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178.

The purpose of this Report is to:

- describe and map the hard and soft corals, non-coral benthic macroinvertebrates, macroalgae, seagrass, mangroves and surficial sediment characteristics that are at risk of Material or Serious Environmental Harm due to construction or operation of the DomGas Pipeline
- describe and map the hard and soft corals, non-coral benthic macroinvertebrates, macroalgae, seagrass, mangroves and surficial sediment characteristics of Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the DomGas Pipeline
- describe the demersal fish and water quality (including measures of turbidity and light attenuation) that are at risk of Material or Serious Environmental Harm due to construction or operation of the DomGas Pipeline
- describe the demersal fish and water quality (including measures of turbidity and light attenuation) of Reference Sites not at risk of Material or Serious Environmental Harm due to construction or operation of the DomGas Pipeline.

In the waters off the east coast of Barrow Island, the majority of the DomGas Pipeline route overlies habitat categorised as 'Soft Sediments with Sparse Sessile Taxa', including sparse sessile benthic macroinvertebrate taxa at subdominant levels of cover. The benthic habitats in the vicinity of the DomGas Pipeline route between Barrow Island and the mainland shore crossing were characterised by unvegetated or bare sand, with small, isolated areas of macroalgae (e.g. *Caulerpa*) and seagrass (e.g. *Halophila*) recorded along the pipeline route. There were no extensive areas of macroalgae or seagrass 'beds' observed. An area of low relief reef was recorded at one location along the pipeline, with live coral coverage <10% (*Acropora*, faviids, *Montipora* and *Turbinaria*). Low densities of non-coral benthic macroinvertebrates were also observed along the pipeline route.

The benthic habitats at the mainland shore crossing of the DomGas Pipeline were similarly characterised by unvegetated or bare sand. The highest diversity of benthic habitats and assemblages (coral, macroalgae and non-coral benthic macroinvertebrates) were recorded around the offshore islands with fringing coral reefs and isolated patch reefs. 'Mixed coral communities' was the dominant coral assemblage type in the DomGas Pipeline survey area, with coral cover ranging between 'medium' (i.e. 10–50% cover) and 'dense' (i.e. 51–75% cover).

Ten vegetation community types were mapped in the vicinity of the DomGas Pipeline mainland shore crossing. Four of these vegetation community types were predominantly mangrove vegetation community types; four were predominantly samphire vegetation community types; and two were unvegetated mud flats. *Avicennia marina* (the Grey Mangrove) dominated vegetation community types were the most prevalent, with the structure of these communities largely dependent on the size of the creek system and geographical location. The composition and structure of the vegetation communities are typical of the mangrove communities described elsewhere along the Pilbara coast.

## Hard and Soft Corals

The coral composition and diversity reported in the coral communities at the mainland end of the DomGas Pipeline route are typical of naturally turbid nearshore environments in the Pilbara region. The diversity of corals at these sites was markedly lower (118 species of hard coral from 42 genera in the order Scleractinia, and 10 species of soft coral) than the diversity of corals recorded from Barrow Island (196 species of hard coral from 48 genera in the order Scleractinia and seven soft coral genera from the suborder Alcyonnina). The recorded coral diversity is equivalent to that recorded from Dampier Harbour and within a regional context, the coral species recorded are a subset of those previously recorded in the Dampier Archipelago and at Barrow Island. In the surveys at the mainland end of the DomGas Pipeline route, *Turbinaria, Favites, Platygyra, Goniopora* and *Lobophyllia* were the most abundant genera and there was very little representation of *Acropora* and *Pavona.* At Barrow Island, the four most abundant genera recorded were *Acropora*, *Montipora*, *Porites* and *Platygyra*. The lower species diversity at the mainland sites was in part a reflection of general pattern of declines in diversity from offshore to inshore along the Western Australian coastline, and also in part a reflection of the lack of representation of *Acropora* species (eight species compared to the 46 species recorded in Barrow Island waters). There is a high diversity of habitat types at Barrow Island, including *Acropora*-thickets, which occur on the shallow reefs around the north-east and south-east of Barrow Island. In contrast, a variety of habitat types and *Acropora*-thickets were not recorded at the mainland end of the DomGas Pipeline route.

Eight species (A*cropora bushyensis*, *Favites micropentagona*, *Goniopora minor*, *Goniopora somaliensis*, *Goniopora norfolkensis*, *Alveopora fenestrata*, *Turbinaria radicalis* and *Psammocora profundacella*) recorded at sites at the mainland end of the DomGas Pipeline route have not previously been recorded from Dampier or Barrow Island. One of these species (*Turbinaria radicalis*) was recorded as 'rare' at one of the sites at risk of Material or Serious Environmental Harm, noting that these results are representative of surveys undertaken at a restricted number of sites on the inshore coral reefs along this part of the Pilbara coast.

The results from the baseline surveys of sites at risk of Material or Serious Environmental Harm associated with trenching and jetting activities at the mainland end of the DomGas Pipeline route and at Reference Sites, indicate that the sites were broadly similar in terms of coral community composition. The Faviidae, Dendrophylliidae and Poritidae consistently ranked as the most abundant coral families both in terms of percentage cover calculated from the photo-quadrats and the number of colonies recorded in the size-class frequency counts. Species of *Turbinaria*, *Porites* and Faviidae often collectively contribute the most to coral cover in naturally turbid shallow nearshore environments. There were very low levels of coral recruitment (one recruit) recorded at the sites at risk of Material or Serious Environmental Harm over the period of tile deployment (October 2010–March 2011).

Based on the generic similarity of the coral communities at sites at the mainland end of the DomGas Pipeline route to those characteristic of Dampier Harbour, it is inferred that the coral communities in the vicinity of the DomGas Pipeline route are likely to be reasonably tolerant to turbidity and sedimentation. The baseline surveys undertaken in September–October 2010 and February–April 2011 indicate that turbid conditions prevail year round at the inshore sites, and primarily during the wet season (or during periods of above average wind and/or swell during the dry season) at the sites further offshore. The species pool at these inshore sites also probably represents a more sediment-tolerant subset of the species occurring at the offshore sites.

The major differences between the October 2010 dry season and the February–April 2011 wet season surveys were the observed damage and dislodgement of coral colonies attributed to Tropical Cyclone Carlos. Cyclones are a recurring seasonal phenomenon in the Pilbara region, and are associated with high winds, large swells and extreme turbidity. The differences in the extent of coral damage observed at different sites is likely to be partly attributable to differences in site depth and orientation relative to the direction of the strongest winds; and also related to the type of corals present at each site. There was no damage observed to the large (up to several metres diameter) encrusting and massive (solid, dome-shaped) coral colonies that can withstand substantial wave impact. Smaller specimens of these robust corals were prevalent throughout the study area and their prevalence, together with the absence of the more delicate branching colonies, suggests that wave impacts are important in defining the coral communities, as would be expected in such a cyclone-prone area.

## Non-coral Benthic Macroinvertebrates

Benthic macroinvertebrates were generally sparsely distributed and relatively homogenous across broad areas of similar substratum in the waters off the east coast of Barrow Island, with distinct assemblages observed on the different substrate types (sand or soft sediment and limestone pavement). Benthic macroinvertebrate assemblages included ascidians, hydroids, sea whips, small corals (e.g. *Turbinaria* sp., *Montipora* sp.) and sponges. At the mainland end of the DomGas Pipeline route, sessile benthic macroinvertebrate assemblages were generally associated with the outer extremities of reef systems surrounding the offshore islands, in particular in areas with high currents. The sessile benthic macroinvertebrate assemblages were characterised by diverse sponge/octocoral (including sea fans and sea whips) ‘gardens’ and mainly occurred on sections of reef covered by a veneer of soft sediment. Sessile and mobile benthic macroinvertebrates were also recorded at very low densities on unvegetated soft sediments, which was the dominant habitat type within the study area.

The taxonomic composition of the observed benthic macroinvertebrate fauna at the mainland end of the DomGas Pipeline route was generally comparable to that observed in the waters surrounding Barrow Island, with a dominance of sponges, gorgonians and sea whips, and bryozoans, interspersed with occasional *Turbinaria* spp. and faviid corals. Benthic macroinvertebrates abundance was generally higher at the mainland end of the DomGas Pipeline route. Mean benthic macroinvertebrate abundances reported from Barrow Island did not exceed 50 organisms/15 $m^2$, whereas at the mainland end of the DomGas Pipeline mean abundances were often >100 organisms/15 $m^2$. These differences between Barrow Island waters and waters at the mainland end of the DomGas Pipeline are likely to reflect the relatively high turbidity, which prevails in the inshore areas compared to the offshore oceanic waters surrounding Barrow Island.

The overall diversity of benthic macroinvertebrates at sites at the mainland end of the DomGas Pipeline was largely consistent between surveys. Weather patterns in the period preceding the wet season survey were particularly severe, with three cyclones passing near the study area. Such weather events are likely to have influenced the benthic macroinvertebrate assemblages as a result of elevated turbidities and increased wave action. Broken and dislodged gorgonians were evident at some sites in the wet season survey, and were likely to have been dislodged during periods of cyclonic activity. An increased coverage of sediment on sessile benthic macroinvertebrates was also observed during the wet season survey.

While there were differences in sessile benthic macroinvertebrate assemblage structure between inshore and offshore sites at the mainland end of the DomGas Pipeline route, this was consistent between sites at risk of Material or Serious Environmental Harm and Reference Sites. Inshore/offshore variation persisted between the dry season and wet season surveys, with benthic macroinvertebrate abundance and diversity considerably higher at inshore sites than at sites further offshore. Differences in light regime, sedimentation levels, levels of nutrient matter and/or physical disturbance, which are key determinants of benthic macroinvertebrate assemblage structure, may all have contributed to the observed differences. There was no evidence of differences in the mean abundance or assemblage composition of benthic macroinvertebrates between sites at risk of Material or Serious Environmental Harm and Reference Sites at the mainland end of the DomGas Pipeline route. Patterns of broad equivalence between sites at risk of Material or Serious Environmental Harm and Reference Sites were maintained in both the dry and wet season surveys.

## Macroalgae and Seagrass

Macroalgal assemblages represent the most extensive ecological element in the waters off the east coast of Barrow Island. Percentage cover, biomass, and species richness (excluding turfing and crustose coralline algae) of macroalgae assemblages were spatially variable, both between and within sites; however, percentage cover and biomass were generally highest on the areas of shallow limestone pavements and lowest on soft sediments.

At the mainland end of the DomGas Pipeline route, macroalgal assemblages were associated with fringing reefs surrounding the offshore islands, where they formed dense beds with >70% macroalgal cover. *Sargassum* spp. was often the dominant taxa recorded. Areas of intertidal platform supported 'sparse' macroalgal cover (i.e. 5–25% cover). Seasonal trends in macroalgal percentage cover and biomass were generally minor and comparable between seasons for most of the survey sites. The greatest seasonal changes were observed at a site on an inshore reef within the area at risk of Material or Serious Environmental Harm. Macroalgal cover and biomass increased markedly at this site between the dry and wet season surveys, driven by *Sargassum illicifolium*. Seasonal trends in macroalgal abundance are commonly observed on tropical shallow reef systems, and have been recorded at Barrow Island and elsewhere in north-western Australia.

Macroalgal abundance and assemblage composition may also have been influenced by severe weather events. Weather patterns in the period preceding the wet season survey were particularly severe, with three cyclones passing near the study area. Elevated turbidities and wave action associated with such weather events are likely to have the potential to impact on macroalgal assemblages. However, despite the disturbance events likely to have occurred, there was no widespread loss of macroalgal assemblages recorded, indicative of their resilience to cyclonic disturbance.

Macroalgal percentage cover, biomass, and species diversity were generally comparable between macroalgal assemblages at risk of Material or Serious Environmental Harm and at Reference Sites at the mainland end of the DomGas Pipeline route. The number and composition of macroalgal taxa recorded at sites at risk of Material or Serious Environmental Harm was also comparable with those observed at Reference Sites. Most of the macroalgal species recorded at sites at risk of Material or Serious Environmental Harm have also been recorded in nearby offshore waters at Barrow Island.

Seagrass assemblages were recorded in soft sediment habitats and on veneers of sand overlying limestone pavement, generally as small sparse (≤5% cover) patches rather than distinct beds in the waters off the east coast of Barrow Island. *Halophila spinulosa* was the most common species recorded in soft sediments, although abundance was generally low with the seagrass occurring in small (<5 $m^2$) patches. The seagrass on the limestone pavement with sand veneers on the east coast of Barrow Island was most commonly small patches of *Halophila ovalis*, mixed with macroalgae and benthic macroinvertebrates. Seagrass assemblages were spatially variable in terms of their percentage cover, biomass, and species richness.

At the mainland end of the DomGas Pipeline route, while seagrass assemblages were present over a broad area within the study area, percentage cover was low, with seagrass typically present as small (<10 $m^2$) sparse (<5% cover) patches rather than continuous extensive seagrass beds. There was also an indication of marked temporal variability between the dry season and the wet season surveys, with a pronounced decline in seagrass abundance in the wet season survey. Whether the observed decline reflects seasonal variability typical of these communities is unknown. Cover of tropical seagrass assemblages is often ephemeral and highly variable with changing environmental conditions.

Overall, seagrass percentage cover, biomass, species composition and diversity were generally comparable between seagrass communities at risk of Material or Serious Environmental Harm and at Reference Sites. Importantly, the apparent seasonal decline in seagrass abundance from dry to wet season was consistent between the sites at risk of Material or Serious Environmental Harm and the Reference Sites.

## Mangroves

The mangroves at the mainland end of the DomGas Pipeline route were relatively healthy during the wet season survey. Visual Tree Health Scores translated into the 'Moderate' category for health, with scores ranging from 15.1 to 16.4. In addition, a considerable proportion of leaves (>40%) in the canopy of each tree generally had no pathological conditions present. High rainfall associated with the passage of cyclones in the two months that preceded the wet season survey may have benefited the health of mangroves in positions at or above the high tidal zone by leaching salts from the soil profile. The removal of salt and dust from leaf surfaces may also have benefited the health of mangroves in all positions. When compared to the results of the dry season survey, the wet season survey results indicate that the health of the mangroves had improved. The dry season survey values for the Tree Health Scores ranged from 11.9 to 14.7 within the area at risk of Material or Serious Environmental Harm, and from 11.5 to 12.7 within the Reference Sites. The very low rainfall recorded during the 2010 wet season followed by the period of low rainfall that defines the dry season, may account for the differences in the Tree Health Scores between the dry season and wet season surveys. In addition, there were more leaves without any pathological condition present in the wet season survey than recorded in the dry season survey. Overall, the results from the dry season and wet season surveys of the mangroves at the mainland end of the DomGas Pipeline route, indicate that for all the measures of mangrove health assessed there is a high degree of homogeneity within the region surveyed.

## Demersal Fish

The stereo Baited Remote Underwater Stereo-Video system (BRUVs) surveys identified clear differences in the composition, relative abundance and size structure of the demersal fish assemblages that characterised the different community types on the east coast of Barrow Island. The coral communities were characterised by particularly high species richness and increased occurrences of small Damselfish, schooling small Trevally, Snapper, Cod, Grouper and Emperor compared to other communities. High fish assemblage diversity associated with coral reefs has been widely documented and is a reflection of habitat quality, extent, and complexity. In addition to differences between the community types, the demersal fish assemblages differed to a lesser degree between surveys, and in some instances from site to site, indicative of a highly complex and dynamic marine ecosystem.

Similarly, there were differences in the composition, relative abundance, and size structure of the demersal fish assemblages that characterised the different communities at the mainland end of the DomGas Pipeline route. Fish assemblages associated with coral communities were characterised by a variety of species, which included Damselfish, Surgeonfish, Butterflyfish and Emperor. Fish assemblages associated with coral communities were found to be the most diverse in both the dry season and wet season surveys. The greatest numbers of fish were also recorded at these sites in the dry season. Fish assemblages associated with non-coral benthic macroinvertebrate sites were less diverse, and with a lower relative abundance during both the dry season and wet season surveys. However, the composition of the fish assemblages was variable with few species being characteristic of these communities. Fish assemblages associated with macroalgae sites were overall less diverse than those at coral and non-coral benthic macroinvertebrate communities, but had a higher relative abundance than at the other community types in the wet season survey. Emperor were abundant at macroalgae sites and these sites were also characterised by Goatfish species. Extensive seagrass beds were not observed at the mainland end of the DomGas Pipeline route, thus the seagrass community was dominated by fish more often associated with soft sediment habitats, and had low fish species diversity and relative abundance over both the dry season and wet season surveys.

In general, there were no consistent differences in the demersal fish assemblages characteristic of sites at risk of Material or Serious Environmental Harm and Reference Sites at the mainland end of the DomGas Pipeline route. Nevertheless, there were some significant differences in the relative abundance of the demersal fish assemblages between sites at risk of Material or Serious Environmental Harm and Reference Sites. The observed differences are likely to be driven by a more complex interaction between fish assemblage composition and the relative abundances of fish in different community types, rather than direct differences between the sites at risk of Material or Serious Environmental Harm and Reference Sites. Factors such as proximity to the shoreline and its associated tidal flats and mangrove habitats, with sites closer to the shoreline generally more turbid than sites further offshore and closer to deeper generally less turbid open water, may be expected to result in differences in both the benthic community and the associated demersal fish assemblages.

The results from seine netting surveys of the demersal fish assemblages characteristic of the mainland mangrove communities similarly indicated that the fish assemblages at sites at risk of Material or Serious Environmental Harm did not generally exhibit notable differences from those at Reference Sites in either the dry season or wet season surveys. The numbers of species, relative abundance, and assemblage diversity and evenness were broadly comparable between Reference Sites and those sites at risk of Material or Serious Environmental Harm during the dry season survey. Similarly, although mean fish density at Reference Sites was greater than that observed at sites at risk of Material or Serious Environmental Harm during the wet season survey, the mean numbers of species at sites at risk of Material or Serious Environmental Harm and those at Reference Sites were broadly similar, as was the overall species composition of the fish assemblages.

There were differences in the demersal fish assemblage composition between the dry season and wet season surveys. All sites surveyed showed marked increases in both species richness and total fish abundance between the dry season and the wet season surveys. Twenty species, which were not recorded during the dry season surveys, were recorded from seine net samples during the wet season surveys, including juveniles of ten larger, predatory species (e.g. *Carcharhinus cautus*, *Lutjanus russellii*, *Sphyraena forsteri*, and three species of carangid).

## Surficial Sediment Characteristics

Surficial sediments off the east coast of Barrow Island were dominated by sands. These sediments also had the highest levels of gravel found along the DomGas Pipeline route, ranging from 0.6% to 48.7%. Gravel content in sediments decreased further along the DomGas Pipeline route towards the Passage Islands, whilst levels of fine-medium sands increased. Surficial sediments located in the vicinity of the trenching and jetting area between the Passage Islands and the mainland were characterised by fine-medium sands and had higher levels of clay and silt compared to sediments located closer to Barrow Island. Sediments from the intertidal mangrove areas along the mainland coast were characterised by high levels of clay, silt, and fine sand, and very low levels of coarse sand and gravel.

The differences between the surficial sediment grain-size distributions are a reflection of the hydrodynamic characteristics along the DomGas Pipeline route. Sediments on the exposed pavement reef off the east coast of Barrow Island had relatively high sand and gravel contents, reflecting strong currents, which transport the finer sediment fractions away from the area. Similarly, the higher energy areas further along the DomGas Pipeline route were characterised by sediments that were relatively high in gravel and sand fractions, and low in clay, silt and fine sand content. Sediments in the nearshore, turbid waters adjacent to the mainland were characterised by higher levels of clay, silt and fine sand. The large tidal range in this area generates strong tidal currents, which transport sediments back and forth with each tidal cycle. Therefore, there is limited opportunity for net transport of sediments away from the coast, which effectively means that the finer sediment particles such as clay and silt are confined to the intertidal and estuarine habitats along the mainland.

## Water Quality (Turbidity and Light Attenuation)

Turbidity and concentrations of suspended sediments were generally low (<5 mg/L) in the waters around Barrow Island, indicative of clear water environments. Wave activity was significant in contributing to local resuspension of sediments, resulting in elevated turbidity and suspended sediment concentrations. In winter, easterly winds can generate wind seas that propagate into the east coast of Barrow Island. Thus, at the majority of the sites, there was a measurable effect on water quality, with suspended sediment concentrations generally higher during winter when easterly winds were more common. Extreme weather events, such as tropical cyclones, also had a strong influence on water quality. Short periods of elevated suspended sediment concentrations, reduced light levels and elevated light attenuation as a consequence of increased turbidity in the water column, coincided with the passage of tropical cyclones.

At the mainland end of the DomGas Pipeline route, water clarity was influenced by tidal cycle, water depth, the presence of tidal creeks and shallow intertidal areas, distance offshore, and weather. The greatest water clarity was typically recorded during neap and ebb tides (generally below ~10 NTU) compared to spring and flood tides (generally below ~20 NTU), with the lowest water clarity associated with spring flood tide conditions. Spring tides are likely to result in lower water clarity due to larger water movements, higher sediment resuspension, shallower water depths, and greater outflows from tidal creeks. Within the study area, the effect of tidal outflows on water clarity was more pronounced at those transects at risk of Material or Serious Environmental Harm than at Reference Transects, as they were adjacent to large tidal creeks and wide tidal flats. Water clarity may also be influenced by the presence of small islands (Solitary Island, Passage Island) and shallow intertidal areas. However, there were no strong or consistent patterns between the presence of islands or intertidal areas and water clarity.

Water clarity was lower inshore, increasing offshore, with significant differences in water clarity between sites located inshore and sites located offshore. Although the strength of the offshore gradient varied in intensity, the sites closest to shore were generally different to all other sites. Differences between near-surface and near-bottom turbidity and Total Suspended Solids (TSS) concentrations were typically small when compared against spatial, temporal and tidal cycle differences. Similarly, temperature and salinity profiles indicated that the waters were typically well mixed, with tidal forces largely overriding any tendency to vertical stratification in temperature and/or salinity due to the differential heating of land and water.

Differences in water clarity between transects at risk of Material or Serious Environmental Harm and Reference Transects were less pronounced in the wet season survey compared to the dry season survey. There were significant differences between the Reference Transects and transects at risk of Material or Serious Environmental Harm only during spring tides in both the dry season and wet season surveys, but the pattern varied between seasons. During the dry season survey, water clarity was lower at the transects at risk of Material or Serious Environmental Harm, largely due to lower water clarity at inshore sites. During the wet season survey, water clarity was lower at Reference Transects, largely due to lower water clarity at inshore sites. It is likely that the differences between Reference Transects and transects at risk of Material or Serious Environmental Harm during spring tides were at least partly caused by the timing of water quality surveys, rather than fully representing any spatial differences in water clarity.

Weather was a key driver of water clarity, with severe and variable weather conditions (such as the wind, squalls, and tropical cyclone associated with the February 2011 wet season survey) resulting in lower and more variable water clarity. High winds and rainfall result in sediment resuspension and increased sediment loads from tidal creeks, as well as a well-mixed water column, generally resulting in lower water clarity.

# 1.0 Introduction

## 1.1 Proponent

Chevron Australia Pty Ltd (Chevron Australia) is the proponent and the person taking the action for the Gorgon Gas Development on behalf of the following companies (collectively known as the Gorgon Joint Venturers):

- Chevron Australia Pty Ltd
- Chevron (TAPL) Pty Ltd
- Shell Development (Australia) Proprietary Limited
- Mobil Australia Resources Company Pty Limited
- Osaka Gas Gorgon Pty Ltd
- Tokyo Gas Gorgon Pty Ltd
- Chubu Electric Power Gorgon Pty Ltd

pursuant to Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178.

Chevron Australia is also the proponent and the person taking the action for the Jansz Feed Gas Pipeline on behalf of the Gorgon Joint Venturers, pursuant to Statement No. 769, and EPBC Reference 2005/2184.

## 1.2 Project

Chevron Australia proposes to develop the gas reserves of the Greater Gorgon Area (Figure 1-1).

Subsea gathering systems and subsea pipelines will be installed to deliver feed gas from the Gorgon and Jansz–Io gas fields to the west coast of Barrow Island. The feed gas pipeline system will be buried as it traverses from the west coast to the east coast of the Island where the system will tie in to the Gas Treatment Plant located at Town Point. The Gas Treatment Plant will comprise three Liquefied Natural Gas (LNG) trains capable of producing a nominal capacity of five Million Tonnes Per Annum (MTPA) per train. The Gas Treatment Plant will also produce condensate and domestic gas. Carbon dioxide ($CO_2$), which occurs naturally in the feed gas, will be separated during the production process. As part of the Gorgon Gas Development, Chevron Australia will inject the separated $CO_2$ into deep formations below Barrow Island. The LNG and condensate will be loaded from a dedicated jetty offshore from Town Point and then transported by dedicated carriers to international markets. Gas for domestic use will be exported by a pipeline from Town Point to the domestic gas collection and distribution network on the mainland (Figure 1-2).

## 1.3 Location

The Gorgon gas field is located approximately 130 km and the Jansz–Io field approximately 200 km off the north-west coast of Western Australia. Barrow Island is located off the Pilbara coast 85 km north-north-east of the town of Onslow and 140 km west of Karratha. The Island is approximately 25 km long and 10 km wide and covers 23 567 ha. It is the largest of a group of islands, including the Montebello and Lowendal Islands.

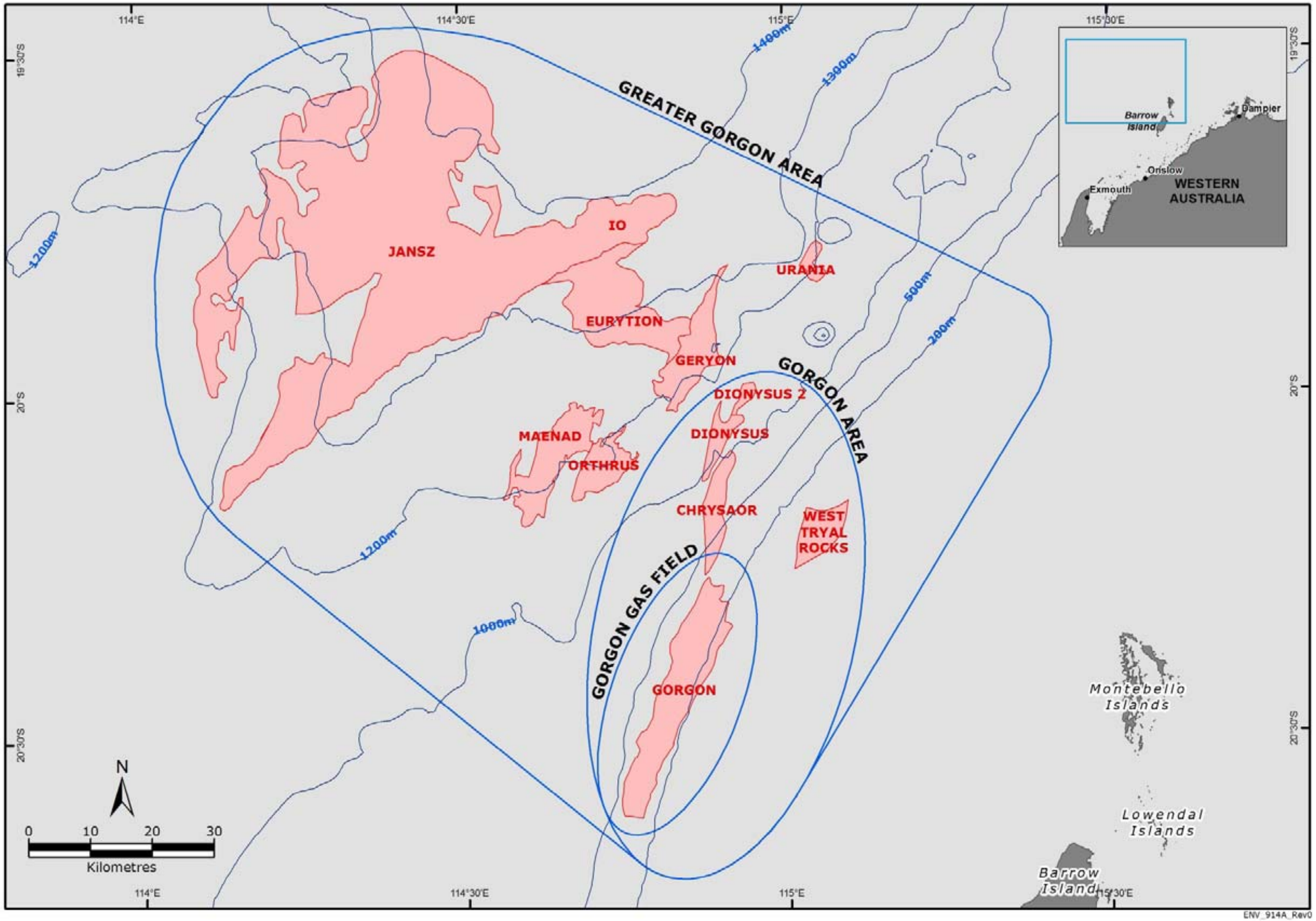



**Figure 1-1 Location of the Greater Gorgon Area**

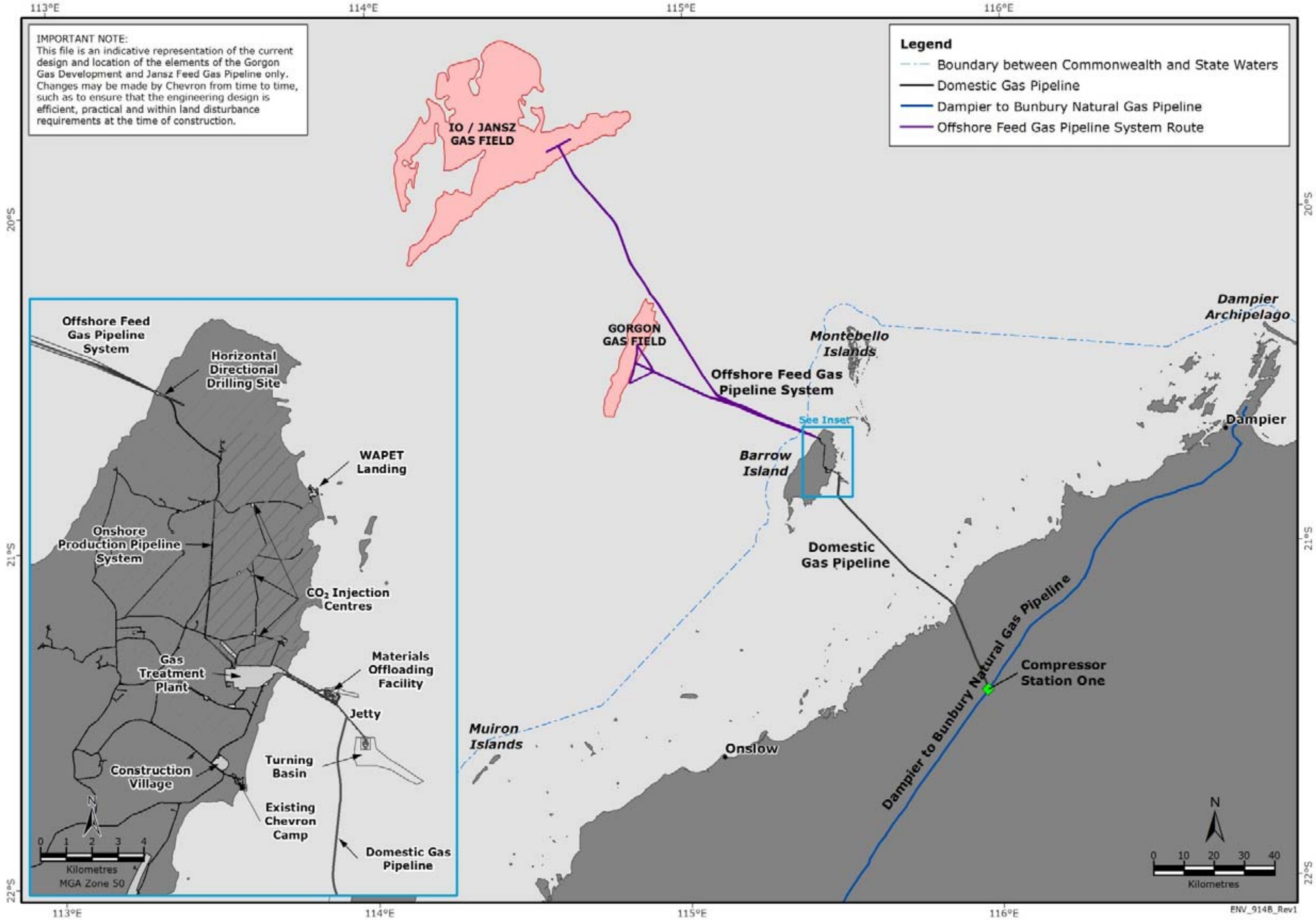



**Figure 1-2 Location of the Gorgon Gas Development and Jansz Feed Gas Pipeline**

## 1.4 Environmental Approvals

The initial Gorgon Gas Development was assessed through an Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) assessment process (Chevron Australia 2005, 2006).

The initial Gorgon Gas Development was approved by the Western Australian State Minister for the Environment on 6 September 2007 by way of Ministerial Implementation Statement No. 748 (Statement No. 748) and the Commonwealth Minister for the Environment and Water Resources on 3 October 2007 (EPBC Reference: 2003/1294).

In May 2008, under section 45C of the Western Australian *Environmental Protection Act 1986* (EP Act), the Environmental Protection Authority (EPA) approved some minor changes to the Gorgon Gas Development that it considered 'not to result in a significant, detrimental, environmental effect in addition to, or different from, the effect of the original proposal' (EPA 2008). The approved changes are:

- excavation of a berthing pocket at the Barge (WAPET) Landing facility
- installation of additional communications facilities (microwave communications towers)
- relocation of the seawater intake
- modification to the seismic monitoring program.

In September 2008, Chevron Australia sought both State and Commonwealth approval through a Public Environment Review (PER) assessment process (Chevron Australia 2008) for the Revised and Expanded Gorgon Gas Development to make some changes to 'Key Proposal Characteristics' of the initial Gorgon Gas Development, as outlined below:

- addition of a five MTPA LNG train, increasing the number of LNG trains from two to three
- expansion of the $CO_2$ Injection System, increasing the number of injection wells and surface drill locations
- extension of the causeway and the Materials Offloading Facility (MOF) into deeper water.

The Revised and Expanded Gorgon Gas Development was approved by the Western Australian State Minister for the Environment on 10 August 2009 by way of Ministerial Implementation Statement No. 800 (Statement No. 800). Statement No. 800 also superseded Statement No. 748 as the approval for the initial Gorgon Gas Development. Statement No. 800 therefore provides approval for both the initial Gorgon Gas Development and the Revised and Expanded Gorgon Gas Development, which together are known as the Gorgon Gas Development.

On 26 August 2009, the then Commonwealth Minister for the Environment, Heritage and the Arts issued approval for the Revised and Expanded Gorgon Gas Development (EPBC Reference: 2008/4178) and varied the conditions for the initial Gorgon Gas Development (EPBC Reference: 2003/1294).

Since the Revised and Expanded Gorgon Gas Development was approved, further minor changes have also been made and/or approved to the Gorgon Gas Development and are now part of the Development. Further changes may also be made/approved in the future. This Report relates to any such changes, and, where necessary, will be specifically revised to address the impacts of those changes.

The Jansz Feed Gas Pipeline was assessed via Environmental Impact Statement/Assessment on Referral Information (ARI) and EPBC Referral assessment processes (Mobil Australia 2005, 2006).

The Jansz Feed Gas Pipeline was approved by the Western Australian State Minister for the Environment on 28 May 2008 by way of Ministerial Implementation Statement No. 769 (Statement No. 769) and the then Commonwealth Minister for the Environment and Water Resources on 22 March 2006 (EPBC Reference: 2005/2184).

In respect of the Carbon Dioxide Seismic Baseline Survey Works Program, which comprises the only works approved under Statement No. 748 before it was superseded, and under EPBC Reference: 2003/1294 before the Minister approved a variation to it on 26 August 2009, note that under Condition 1A.1 of Statement No. 800 and Condition 1.4 of EPBC Reference: 2003/1294 and 2008/4178 this Program is authorised to continue for six months subject to the existing approved plans, reports, programs and systems for the Program, and the works under the Program are not the subject of this Report.

## 1.5 Purpose of this Report

### 1.5.1 Legislative Requirements

#### 1.5.1.1 State Ministerial Conditions

This Report is required under Condition 14.2 of Statement No. 800, which is quoted below:

> *Prior to commencement of construction of marine facilities as listed in Condition 14.3, the Proponent shall submit a Coastal and Marine Baseline State and Environmental Impact Report (the Report) that meets the purposes set out in Condition 14.6, as determined by the Minister, unless otherwise allowed in Condition 14.4.*

The Marine Facilities referred to are defined in Condition 14.3 of Statement No. 800 as the:

- Materials Offloading Facility (MOF)
- LNG Jetty
- Dredge Spoil Disposal Ground
- Offshore Feed Gas Pipeline System
- Domestic Gas Pipeline
- Marine upgrade of the existing WAPET Landing.

Condition 14.3 of Statement No. 800 relates only to components of the Marine Facilities within State waters.

#### 1.5.1.2 Commonwealth Ministerial Conditions

This Report satisfies the requirements of Condition 11.2 of EPBC Reference: 2003/1294 and 2008/4178, which is quoted below:

> *Prior to commencement of construction of marine facilities as listed in Condition 11.3, the person taking the action must submit a Coastal and Marine Baseline State and Environmental Impact Report (the Report) that meets the purposes set out in Condition 11.6, and the requirements set out in Conditions 11.7 and 11.8 as determined by the Minister, unless otherwise allowed in Condition 11.4.*

The Marine Facilities referred to are defined in Condition 11.3 of EPBC Reference: 2003/1294 and 2008/4178 as the:

- Materials Offloading Facility (MOF)
- LNG Jetty
- Dredge Spoil Disposal Ground
- Offshore Feed Gas Pipeline System in State waters
- Offshore Domestic Gas Pipeline.

### 1.5.2 Scope

Condition 14.4 of Statement No. 800 provides for this Marine Baseline Report to be submitted in a staged approach:

> *In the event that portions of the Report related to specific elements or sub-elements (the marine facilities listed in Condition 14.3) of the Proposal are not submitted as required by Condition 14.1, the Proponent shall submit the portion of the Report relevant to that element or sub-element to the Minister prior to the commencement of construction of that element or sub-element. All portions of the Report shall meet the purposes identified in Condition 14.6 and the requirements of Condition 14.7 and 14.8 as determined by the Minister.*

Condition 11.4 of EPBC Reference: 2003/1294 and 2008/4178 also provides for this Marine Baseline Report to be submitted in a staged approach:

> *In the event that portions of the Report related to specific elements or sub-elements (the marine facilities listed in Condition 11.3) of the action are not submitted as required by Condition 11.2, the person taking the action must submit the portion of the Report relevant to that element or sub-element to the Minister prior to the commencement of construction of that element or sub-element. All portions of the Report must meet the purposes identified in Condition 11.6 and the requirements of Condition 11.7 and 11.8 as determined by the Minister.*

**Table 1-1** summarises where baseline information relating to specific elements or sub-elements of the Marine Facilities is reported. Subsequent revisions of these Plan (**Table 1-1**) have since been approved by the former DEC and the former DEWHA under delegation from their respective Ministers.

**Table 1-1 Marine Baseline Reports**

<table>
<tr><th>Marine Baseline Report Title</th><th>Marine Facilities Addressed</th><th>Ministerial Statement</th><th>Ministerial Condition</th><th>Initial Approval</th></tr>
<tr><td rowspan="4">Coastal and Marine Baseline State and Environmental Impact Report (G1-NT-REPX0001838)</td><td>Marine upgrade of the existing WAPET Landing</td><td>Statement No. 800</td><td>Condition 14.3.vi</td><td>3 Nov 2009 (State)</td></tr>
<tr><td>Materials Offloading Facility (MOF)</td><td colspan="2" rowspan="3">Statement No. 800, Condition 14.3 i, ii, and iii<br><br>EPBC Reference: 2003/1294 and 2008/4178, Condition 11.3 I, II. and III</td><td rowspan="3">7 April 2010 (State)<br><br>14 April 2010 (Commonwealth)</td></tr>
<tr><td>LNG Jetty</td></tr>
<tr><td>Dredge Spoil Disposal Ground</td></tr>
<tr><td rowspan="3">Coastal and Marine Baseline State and Environmental Impact Report (Offshore Feed Gas Pipeline System and the Marine Component of the Shore Crossing) (G1-NT-REPX0002749)</td><td>Offshore Feed Gas Pipeline System and marine component of the shore crossing</td><td>Statement No. 769</td><td>Condition 12.3</td><td rowspan="3">19 August 2010 (State)<br><br>27 August 2010 (Commonwealth)</td></tr>
<tr><td>Offshore Feed Gas Pipeline System</td><td>Statement No. 800</td><td>Condition 14.3.iv</td></tr>
<tr><td>Offshore Feed Gas Pipeline System in State waters</td><td>EPBC Reference: 2003/1294 and 2008/4178</td><td>Condition 11.3.IV</td></tr>
<tr><td rowspan="2">Coastal and Marine Baseline State and Environmental Impact Report (Domestic Gas Pipeline)- this Report (G1-NT-REPX0002750)</td><td>Domestic Gas Pipeline</td><td>Statement No. 800</td><td>Condition 14.3.v</td><td rowspan="2">20 Dec 2011 (State)<br><br>19 Jan 2012 (Commonwealth)</td></tr>
<tr><td>Offshore Domestic Gas Pipeline</td><td>EPBC Reference: 2003/1294 and 2008/4178</td><td>Condition 11.3.V</td></tr>
</table>

This version of the Marine Baseline Report relates specifically to the Domestic Gas Pipeline (Condition 14.3.v, Statement No. 800; Condition 11.3.V, EPBC Reference: 2003/1294 and 2008/4178). Information in this version of the Marine Baseline Report relevant to all other Marine Facilities is provided for information only; no further approval is sought in relation to these other Marine Facilities.

### 1.5.3 Purpose

The purposes of this Marine Baseline Report as stated in Condition 14.6 of Statement No. 800, are to:

- describe and map the benthic ecological elements referred to in Condition 14.2 (i–vi) that are at risk of Material or Serious Environmental Harm due to the construction or operation of the Domestic Gas Pipeline
- describe and map the benthic ecological elements referred to in Condition 14.2 (i–vi) at Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline
- describe the ecological elements referred to in Condition 14.2 (vii and viii) that are at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline
- describe the ecological elements referred to in Condition 14.2 (vii and viii) of Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline.

The purposes of this Marine Baseline Report as stated in Condition 11.6 of EPBC Reference: 2003/1294 and 2008/4178 are to:

- describe and map the benthic ecological elements referred to in Condition 11.2 (I–VI) that are at risk of Material or Serious Environmental Harm due to construction or operation of the Offshore Domestic Gas Pipeline
- describe and map the benthic ecological elements referred to in Condition 11.2 (I–VI) at Reference Sites that are not at risk or Materials or Serious Environmental Harm due to construction or operation of the Offshore Domestic Gas Pipeline
- describe the ecological elements referred to in Condition 11.2 (VII and VIII) that are at risk of Material or Serious Environmental Harm due to construction or operation of the Offshore Domestic Gas Pipeline
- describe the ecological elements referred to in Condition 11.2 (VII and VIII) of Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the Offshore Domestic Gas Pipeline.

Baseline surveys have been undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1 of Statement No. 800, and Condition 11.1 of EPBC Reference: 2003/1294 and 2008/4178.

### 1.5.4 Requirements

The requirements of this Marine Baseline Report, as stated in Condition 14 of Statement No. 800 and Condition 11 of EPBC Reference: 2003/1294 and 2008/4178, in relation to the DomGas Pipeline, are listed in Table 1-2. Table 1-2 also references the specific sections of this Marine Baseline Report where each requirement is addressed. The requirements in relation to the marine upgrade of the existing WAPET Landing and the MOF, LNG Jetty, and the Dredge Spoil Disposal Ground and Offshore Feed Gas Pipeline in State waters and marine component of the shore crossing are addressed in previous revisions of the Marine Baseline Report and are not included in Table 1-2.

**Table 1-2 Requirements of this Marine Baseline Report**

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| Statement No. 800 | 14.1 | To establish the methodology to be used in the Report required by Condition 14.2, the Proponent shall submit to the Minister a Scope of Works reporting the methodologies to be used in the preparation of the Report that covers the following as determined by the Minister:<br>• Survey methods for each of the ecological elements as listed in Condition 14.2<br>• Location and establishment of survey sites<br>• Timing and frequency of surveys<br>• Habitat classification schemes<br>• Mapping methodologies, including Coral Assemblages<br>• Treatment of Survey data; and<br>• Method for hydrodynamics data acquisition and reporting | This requirement to establish the methodology is addressed in the Scope of Works Report (G1-NT-REPX0001436) |
| Statement No. 800 | 14.2 | Prior to the commencement of construction of the Marine Facilities listed in Condition 14.3, the Proponent shall submit a Coastal and Marine Baseline State and Environmental Impact Report that meets the purposes set out in Condition 14.6, as determined by the Minister, unless otherwise allowed in Condition 14.4. The Report shall cover the following ecological elements:<br>• Hard and soft corals<br>• Macroalgae<br>• Non-coral benthic macroinvertebrates<br>• Seagrass<br>• Mangroves<br>• Surficial sediment characteristics<br>• Demersal fish<br>• Water quality (including measures of turbidity and light attenuation). | <br><br>Section 6.0<br>Section 8.0<br>Section 7.0<br>Section 9.0<br>Section 10.0<br>Section 12.0<br>Section 11.0<br>Section 13.0 |
| Statement No. 800 | 14.5 | In preparing this Report the Proponent shall consult with the Construction Dredging Environmental Expert Panel (CDEEP), the Department of Environment and Conservation (DEC) (now DPaW), the Department of Transport (DoT), the Department of Fisheries (DoF) and the former Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA) (now DotE). | Section 1.5.7 |

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| Statement No. 800 | 14.6.i | The purpose of the Report is to:<br>• describe and map the ecological elements referred to in Condition 14.2(i–vi) within the Zones of High Impact and the Zones of Moderate Impact and representative areas in the Zones of Influence associated with the generation of turbidity and sediment deposition from dredging and dredge spoil disposal required for the MOF, LNG Jetty and Dredge Spoil Disposal Ground (DSDG). | Zones of High Impact and Zones of Moderate Impact relate directly to impacts associated with dredging and dredge spoil disposal.<br><br>This requirement is addressed in the Marine Baseline Report (G1-NT-REPX0001838) |
| Statement No. 800 | 14.6.ii | The purpose of the Report is to:<br>• describe and map the extent and distribution of Coral Assemblages within the Zones of High Impact and the Zones of Moderate Impact which are to be used to calculate the Area of Loss of Coral Assemblages according to the following formula:<br>$a = h + (m \times 30\%)$<br>where:<br>a = the area (ha) of loss of Coral Assemblages.<br>h = the area (ha) of Coral Assemblages within the Zones of High Impact.<br>m = the area (ha) of Coral Assemblages within the Zones of Moderate Impact. | Section 2.3.4<br><br>Zones of High Impact and Zones of Moderate Impact relate directly to impacts associated with dredging and dredge spoil disposal.<br><br>This requirement is addressed in the Marine Baseline Supplement: Area of Coral Assemblages (G1-NT-REPX0002539) |
| Statement No. 800 | 14.6.iii | The purpose of the Report is to:<br>• describe and map the benthic ecological elements referred to in Condition 14.2(i–vi) which are at risk of Material or Serious Environmental Harm due to the construction or operation of the Offshore Feed Gas Pipeline System, Domestic Gas Pipeline and Marine upgrade of the existing WAPET Landing. | This requirement is addressed for the Offshore Feed Gas Pipeline System in G1-NT-REPX0002749 and for the marine upgrade of the existing WAPET Landing in the Marine Baseline Report (G1-NT-REPX0001838. |
| | | i. Hard and soft corals | Sections 6.4.1.1, Figure 6-4, 6.4.1.3.1, Figure 6-7, Figure 6-8, 6.4.1.3.2, 6.4.2.2, 6.4.2.3, 6.4.3.1, 6.4.3.2, 6.4.4.1, 6.4.4.2.1, 6.4.4.4.1, 6.4.4.5, 6.4.5.1.1, 6.4.5.2, 6.4.6.1.1, 6.4.6.2 |
| | | ii. Macroalgae | Sections 8.4.1, 8.4.3, Figure 5-3, Figure 5-7 |
| | | iii. Non-coral benthic macroinvertebrates | Sections 7.4.2, 7.4.3, Figure 5-3, Figure 5-7 |
| | | iv. Seagrass | Sections 9.4.1, 9.4.3, Figure 5-3, Figure 5-7 |

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| | | v. Mangroves | Sections 5.5, 10.4.3, Figure 5-9 |
| | | vi. Surficial sediment characteristics | Section 12.4.1, Figure 12-2, Figure 12-3, Figure 12-4 |
| Statement No. 800 | 14.6.iv | The purpose of the Report is to:<br>• describe and map the benthic ecological elements referred to in Condition 14.2(i–vi) at Reference Sites which are not at risk of Material or Serious Environmental Harm due to construction or operation of the MOF, LNG Jetty, Dredge Spoil Disposal Ground, Offshore Feed Gas Pipeline System, Domestic Gas Pipeline and Marine upgrade of the existing WAPET Landing. | This requirement is addressed for the MOF, LNG Jetty, DSDG and Marine upgrade of the existing WAPET Landing in the Marine Baseline Report (G1-NT-REPX0001838), and for the Offshore Feed Gas Pipeline System in the Marine Baseline Report for the Feed Gas and Shore Crossing (G1-NT-REPX0002749) |
| | | i. Hard and soft corals | Sections 6.4.1.2, Figure 6-5, Figure 6-6, 6.4.1.3.3, Figure 6-9, 6.4.1.3.4, Figure 6-10, 6.4.2.4, 6.4.2.5, 6.4.3.3, 6.4.3.4, 6.4.4.3, 6.4.4.3.3, 6.4.4.6, 6.4.4.7, 6.4.5.3, 6.4.5.4, 6.4.6.3, 6.4.6.4 |
| | | ii. Macroalgae | Sections 8.4.1, 8.4.4, Figure 5-3, Figure 5-7 |
| | | iii. Non-coral benthic macroinvertebrates | Sections 7.4.2, 7.4.4, Figure 5-3, Figure 5-7 |
| | | iv. Seagrass | Sections 9.4.1, 9.4.4, Figure 5-3, Figure 5-7 |
| | | v. Mangroves | Sections 5.5, 10.4.4, Figure 5-10, Figure 5-11 |
| | | vi. Surficial sediment characteristics | Section 12.4.2, Figure 12-2, Figure 12-3, Figure 12-4 |
| Statement No. 800 | 14.6.v | The purpose of the Report is to:<br>• describe the ecological elements referred to in Condition 14.2(vii and viii) within the Zones of High Impact and the Zones of Moderate Impact and representative areas in the Zones of Influence, associated with the generation of turbidity and sediment deposition from dredging and dredge spoil disposal required for the MOF, LNG Jetty and Dredge Spoil Disposal Ground. | This requirement is addressed for the MOF, LNG Jetty and DSDG in the Marine Baseline Report (G1-NT-REPX0001838) |

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| Statement No. 800 | 14.6.vi | The purpose of the Report is to:<br>• describe the ecological elements referred to in Condition 14.2(vii and viii) which are at risk of Material or Serious Environmental Harm due to the construction or operation of the Offshore Feed Gas Pipeline System, Domestic Gas Pipeline and the Marine upgrade of the existing WAPET Landing. | This requirement for the Marine upgrade of the existing WAPET Landing is addressed in the Marine Baseline Report (G1-NT-REPX0001838) and for the Offshore Feed Gas Pipeline System in the Marine Baseline Report for the Feed Gas and Shore Crossing (G1-NT-REPX0002749) |
| | | vii. Demersal Fish | Section 11.4.3 |
| | | viii. Water quality (including measures of turbidity and light attenuation) | Sections 13.4.1, 13.4.3 |
| Statement No. 800 | 14.6.vii | The purpose of the Report is to:<br>• describe the ecological elements referred to in Condition 14.2(vii and viii) of Reference Sites which are not at risk of Material or Serious Environmental Harm due to construction or operation of the MOF, LNG Jetty, Dredge Spoil Disposal Ground, Offshore Feed Gas Pipeline System, Domestic Gas Pipeline and the Marine upgrade of the existing WAPET Landing. | This requirement is addressed for the MOF, LNG Jetty, DSDG and Marine upgrade of the existing WAPET Landing in the Marine Baseline Report (G1-NT-REPX0001838), and for the Offshore Feed Gas Pipeline System in the Marine Baseline Report for the Feed Gas and Shore Crossing (G1-NT-REPX0002749) |
| | | vii. Demersal Fish | Section 11.4.4 |
| | | viii. Water quality (including measures of turbidity and light attenuation) | Section 13.4.2, 13.4.4 |
| Statement No. 800 | 14.7 | The geographic extent of the Report shall be:<br>i. the Marine Facilities listed in Condition 14.3<br>ii. Dredge Management Areas including the Zones of High Impact, the Zones of Moderate Impact and areas in the Zones of Influence including those that contain significant benthic communities including coral assemblages<br>iii. the Marine Disturbance Footprint associated with the facilities listed in Condition 14.3 in State Waters<br>iv. Reference Sites outside the Zone of Influence. | Sections 2.1, Figure 2-1, 2.3.1, 2.3.4, 2.3.2, Figure 2-2, 2.3.5 |

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| Statement No. 800 | 14.8.i | The Report shall:<br>• contain spatially accurate (i.e. rectified and geographically referenced) maps showing the locations and spatial extent of the marine coastal facilities listed in Condition 14.3. | Figure 2-1 |
| Statement No. 800 | 14.8.ii | The Report shall:<br>• present the results of the surveys described in Condition 14.1. | Sections 5.0 (mapping and classification), 6.0 (hard and soft corals), 7.0 (non-coral benthic macroinvertebrates), 8.0 (macroalgae), 9.0 (seagrass), 10.0 (mangroves), 11.0 (demersal fish), 12.0 (surficial sediments), 13.0 (water quality) |
| Statement No. 800 | 14.8.iii | The Report shall record the:<br>• existing dominant and subdominant hard and soft coral species/taxa<br>• dominant species of macroalgae<br>• dominant species of non-coral benthic macroinvertebrates<br>• dominant species of seagrass<br>• dominant species of mangroves<br>• demersal fish assemblages that characterise these communities. | Section 6.4.2<br>Section 8.4.2<br>Section 7.4.2<br>Section 9.4.2<br>Sections 5.5.4, 10.4.2<br>Sections 11.4.1, 11.4.2 |
| Statement No. 800 | 14.8.iv.a | The Report shall record the:<br>• population structure of coral communities as colony size-class frequency distributions of dominant hard coral taxa. | Section 6.4.3 |
| Statement No. 800 | 14.8.iv.b | The Report shall record the:<br>• population statistics of survival and growth of dominant hard coral taxa and, if appropriate, selected other indicator coral taxa that characterise these communities. | Sections 6.4.4, 6.4.5 |
| Statement No. 800 | 14.8.iv.c | The Report shall record the:<br>• recruitment of hard coral taxa within these communities. | Section 6.4.6 |
| Statement No. 800 | 14.8.v | The Report shall:<br>• contain descriptions and spatially accurate (i.e. rectified and geographically referenced) maps in accordance with the purposes set out in Condition 14.6. | See maps in Sections 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 12.0 |

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| Statement No. 800 | 14.8.vi | The Report shall:<br>• present data in an appropriate Geographic Information System (GIS) format. | Maps presented in this Report represent GIS data. GIS data will be provided in digital format with Revision 0 of the Domestic Gas Pipeline Marine Baseline Report. |
| Statement No. 800 | 14.8.vii | The Report shall:<br>• establish and report on background water quality (including measures of turbidity and light attenuation), the natural rates and spatial patterns of sediment deposition, and the physical characteristics of the deposited sediment and characteristics of surficial sediments where dredging and dredge spoil disposal may affect the environment and at Reference Sites where the environment will not be affected. | This requirement is addressed in the Marine Baseline Report (G1-NT-REPX0001838) and in the Marine Baseline Report for the Feed Gas and Shore Crossing (G1-NT-REPX0002749) |
| Statement No. 800 | 14.9 | To meet the requirements of Condition 14.8, the Proponent shall collect water quality data and data on natural rates and spatial patterns of sediment deposition for at least one full annual cycle prior to the construction of the Marine Facilities listed in Condition 14.3. | Section 13.0<br>Note that dredging and dredge spoil disposal will not be undertaken as part of the construction activities for the Domestic Gas Pipeline. |
| EPBC Reference: 2003/1294 and 2008/4178 | 3.2.1 | A description of the EPBC listed species and their habitat likely to be impacted by the components of the action which are the subject of the Marine Baseline Report. | Appendix 1 |
| EPBC Reference: 2003/1294 and 2008/4178 | 3.2.2 | An assessment of the risk to these species from the components of the action the subject of that plan, relevant to the Marine Baseline Report. | Appendix 1 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.1 | To establish the methodology to be used in the Report required by Condition 11.2, the person taking the action must submit to the Minister for approval a Scope of Works reporting the methodologies to be used in the preparation of the Report that covers the following as determined by the Minister:<br>• Survey methods for each of the ecological elements as listed in Condition 11.2<br>• Location and establishment of survey sites<br>• Timing and frequency of surveys<br>• Habitat classification schemes<br>• Mapping methodologies, including Coral Assemblages<br>• Treatment of Survey data; and<br>• Method for hydrodynamics data acquisition and reporting | This requirement to establish the methodology is addressed in the Scope of Works G1-NT-REPX0001436 |

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| EPBC Reference: 2003/1294 and 2008/4178 | 11.2 | Prior to the commencement of construction of the Marine Facilities listed in Condition 11.3, the person taking the action must submit a Coastal and Marine Baseline State and Environmental Impact Report that meets the purposes set out in Condition 11.6, and the requirements in Conditions 11.7 and 11.8 as determined by the Minister, unless otherwise allowed in Condition 11.4. The Report must cover the following ecological elements: | |
| | | • Hard and soft corals | Section 6.0 |
| | | • Macroalgae | Section 8.0 |
| | | • Non-coral benthic macroinvertebrates | Section 7.0 |
| | | • Seagrass | Section 9.0 |
| | | • Mangroves | Section 10.0 |
| | | • Surficial sediment characteristics | Section 12.0 |
| | | • Demersal fish | Section 11.0 |
| | | • Water quality (including measures of turbidity and light attenuation) | Section 13.0 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.5 | In preparing the Report the person taking the action must consult with the Construction Dredging Environmental Expert Panel (CDEEP), the former Western Australian Department of Environment and Conservation (DEC) (now DPaW), the Western Australian Department of Transport (DoT), the Western Australian Department of Fisheries (DoF) and the former Department of Environment, Water, Heritage and the Arts (DEWHA) (now DotE). | Section 1.5.7 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.6.I | The purpose of the Report is to:<br>• describe and map the ecological elements referred to in Condition 11.2(I–VI) within the Zones of High Impact and the Zones of Moderate Impact and representative areas in the Zones of Influence associated with the generation of turbidity and sediment deposition from dredging and dredge spoil disposal required for the MOF, LNG Jetty and Dredge Spoil Disposal Ground. | Zones of High Impact and Zones of Moderate Impact relate directly to impacts associated with dredging and dredge spoil disposal.<br><br>This requirement is addressed in the Marine Baseline Report (G1-NT-REPX0001838) |

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| EPBC Reference: 2003/1294 and 2008/4178 | 11.6.II | The purpose of the Report is to:<br>• describe and map the extent and distribution of Coral Assemblages within the Zones of High Impact and the Zones of Moderate Impact which are to be used to calculate the Area of Loss of Coral Assemblages according to the following formula:<br>$a = h + (m \times 30\%)$<br>where:<br>a = the area (ha) of loss of Coral Assemblages.<br>h = the area (ha) of Coral Assemblages within the Zones of High Impact.<br>m = the area (ha) of Coral Assemblages within the Zones of Moderate Impact. | Section 2.3.4<br>Zones of High Impact and the Zones of Moderate Impact relate directly to impacts associated with dredging and dredge spoil disposal. |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.6.III | The purpose of the Report is to:<br>• describe and map the benthic ecological elements referred to in Condition 11.2(I–VI) which are at risk of Material or Serious Environmental Harm due to the construction or operation of the Offshore Feed Gas Pipeline System in state waters and Offshore Domestic Gas Pipeline. | This requirement is addressed in the Marine Baseline Report for the Feed Gas and Shore Crossing (G1-NT-REPX0002749) |
| | | I. Hard and soft corals | Sections 6.4.1.1, Figure 6-4, 6.4.1.3.1, Figure 6-7, Figure 6-8, 6.4.1.3.2, 6.4.2.2, 6.4.2.3, 6.4.3.1, 6.4.3.2, 6.4.4.1, 6.4.4.2.1, 6.4.4.4.1, 6.4.4.5, 6.4.5.1.1, 6.4.5.2, 6.4.6.1.1, 6.4.6.2 |
| | | II. Macroalgae | Sections 8.4.1, 8.4.3, Figure 5-3, Figure 5-7 |
| | | III. Non-coral benthic macroinvertebrates | Sections 7.4.2, 7.4.3, Figure 5-3, Figure 5-7 |
| | | IV. Seagrass | Sections 9.4.1, 9.4.3, Figure 5-3, Figure 5-7 |
| | | V. Mangroves | Sections 5.5, 10.4.3, Figure 5-9 |
| | | VI. Surficial sediment characteristics | Section 12.4.1, Figure 12-2, Figure 12-3, Figure 12-4 |

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| EPBC Reference: 2003/1294 and 2008/4178 | 11.6.IV | The purpose of the Report is to:<br>• describe and map the benthic ecological elements referred to in Condition 11.2(I–VI) at Reference Sites which are not at risk of Material or Serious Environmental Harm due to construction or operation of the MOF, LNG Jetty, Dredge Spoil Disposal Ground, Offshore Feed Gas Pipeline System in state waters and Offshore Domestic Gas Pipeline. | This requirement is addressed for the MOF, LNG Jetty, DSDG and Marine upgrade of the existing WAPET Landing in the Marine Baseline Report (G1-NT-REPX0001838), and for the Offshore Feed Gas Pipeline System in the Marine Baseline Report for the Feed Gas and Shore Crossing (G1-NT-REPX0002749) |
| | | I. Hard and soft corals | Sections 6.4.1.2, Figure 6-5, Figure 6-6, 6.4.1.3.3, Figure 6-9, 6.4.1.3.4, Figure 6-10, 6.4.2.4, 6.4.2.5, 6.4.3.3, 6.4.3.4, 6.4.4.3, 6.4.4.3.3, 6.4.4.6, 6.4.4.7, 6.4.5.3, 6.4.5.4, 6.4.6.3, 6.4.6.4 |
| | | II. Macroalgae | Sections 8.4.1, 8.4.4, Figure 5-3, Figure 5-7 |
| | | III. Non-coral benthic macroinvertebrates | Sections 7.4.2, 7.4.4, Figure 5-3, Figure 5-7 |
| | | IV. Seagrass | Sections 9.4.1, 9.4.4, Figure 5-3, Figure 5-7 |
| | | V. Mangroves | Sections 5.5, 10.4.4, Figure 5-10, Figure 5-11 |
| | | VI. Surficial sediment characteristics | Section 12.4.2, Figure 12-2, Figure 12-3, Figure 12-4 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.6.V | The purpose of the Report is to:<br>• describe the ecological elements referred to in Condition 11.2(VII and VIII) within the Zones of High Impact and the Zones of Moderate Impact and representative areas in the Zones of Influence, associated with the generation of turbidity and sediment deposition from dredging and dredge spoil disposal required for the MOF, LNG Jetty and Dredge Spoil Disposal Ground. | This requirement for the description of ecological elements is addressed in the Marine Baseline Report (G1-NT-REPX0001838) |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.6.VI | The purpose of the Report is to:<br>• describe the ecological elements referred to in Condition 11.2(VII and VIII) which are at risk of Material or Serious Environmental Harm due to construction or operation of the Offshore Feed Gas Pipeline System in state waters and the Offshore Domestic Gas Pipeline. | This requirement for the description of ecological elements is addressed in the Marine Baseline Report for the Feed Gas and Shore Crossing (G1-NT-REPX0002749) |

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| | | VII. Demersal fish<br>VIII. Water quality (including measures of turbidity and light attenuation) | Section 11.4.3<br>Sections 13.4.1, 13.4.3 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.6.VII | The purpose of the Report is to:<br>• describe the ecological elements referred to in Condition 11.2 (VII and VIII) of Reference Sites which are not at risk of Material or Serious Environmental Harm due to construction or operation of the MOF, LNG Jetty, Dredge Spoil Disposal Ground, Offshore Feed Gas Pipeline System in state waters and Offshore Domestic Gas Pipeline.<br>VII. Demersal Fish<br>VIII. Water quality (including measures of turbidity and light attenuation) | This requirement is addressed for the MOF, LNG Jetty, DSDG and Marine upgrade of the existing WAPET Landing in the Marine Baseline Report (G1-NT-REPX0001838), and for the Offshore Feed Gas Pipeline System in the Marine Baseline Report for the Feed Gas and Shore Crossing (G1-NT-REPX0002749)<br>Section 11.4.4<br>Sections 13.4.2, 13.4.4 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.7 | The geographic extent of the Report must be:<br>I. the Marine Facilities listed in Condition 11.3<br>II. Dredge Management Areas including the Zones of High Impact, the Zones of Moderate Impact and areas in the Zones of Influence including those that contain significant benthic communities including coral assemblages<br>III. the Marine Disturbance Footprint associated with the facilities listed in Condition 11.3 in State waters<br>IV. Reference Sites outside the Zone of Influence. | Sections 2.1, Figure 2-1, 2.3.1, 2.3.4, 2.3.2, Figure 2-2, 2.3.5 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.8.I | The Report must:<br>• contain spatially accurate (i.e. rectified and geographically referenced) maps showing the locations and spatial extent of the marine coastal facilities listed in Condition 11.3. | Figure 2-1 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.8.II | The Report must:<br>• present the results of the surveys described in Condition 11.1. | Sections 5.0 (mapping and classification), 6.0 (hard and soft corals), 7.0 (non-coral benthic macroinvertebrates), 8.0 (macroalgae), 9.0 (seagrass), 10.0 (mangroves), 11.0 (demersal fish), 12.0 (surficial sediments), 13.0(water quality) |
| EPBC | 11.8.III | The Report must record the: | |

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| Reference: 2003/1294 and 2008/4178 | | • existing dominant and subdominant hard and soft coral species/taxa<br>• dominant species of macroalgae<br>• dominant species of non-coral benthic macroinvertebrates<br>• dominant species of seagrass<br>• dominant species of mangroves<br>• demersal fish assemblages that characterise these communities. | Section 6.4.2<br>Section 8.4.2<br>Section 7.4.2<br>Section 9.4.2<br>Sections 5.5.4, 10.4.2<br>Sections 11.4.1, 11.4.2 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.8.IV.a | The Report must record the:<br>• population structure of coral communities as colony size-class frequency distributions of dominant hard coral taxa. | Section 6.4.3 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.8.IV.b | The Report must record the:<br>• population statistics of survival and growth of dominant hard coral taxa and, if appropriate, selected other indicator coral taxa that characterise these communities. | Sections 6.4.4, 6.4.5 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.8.IV.c | The Report must record the:<br>• recruitment of hard coral taxa within these communities. | Section 6.4.6 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.8.V | The Report must:<br>• contain descriptions and spatially accurate (i.e. rectified and geographically referenced) maps in accordance with the purposes set out in Condition 11.6. | See maps in Sections 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 12.0 |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.8.VI | The Report must:<br>• present data in an appropriate Geographic Information System (GIS) format. | Maps presented in this Report represent GIS data. GIS data will be provided in digital format with Revision 0 of the Offshore Domestic Gas Pipeline Marine Baseline Report. |
| EPBC Reference: 2003/1294 and 2008/4178 | 11.8.VII | The Report must:<br>• establish and report on background water quality (including measures of turbidity and light attenuation), the natural rates and spatial patterns of sediment deposition, the physical characteristics of the deposited sediment and characteristics of surficial sediments where dredging and dredge spoil disposal may affect the environment and at Reference Sites where the environment will not be affected. | This requirement is addressed in the Marine Baseline Report (G1-NT-REPX0001838)<br><br>Dredging and dredge spoil disposal will not be undertaken as part of the construction activities for the Offshore Domestic Gas Pipeline. |

| Ministerial Document | Condition No. | Requirement | Section Reference in this Report |
|---|---|---|---|
| EPBC Reference: 2003/1294 and 2008/4178 | 11.9 | To meet the requirements of Condition 11.8, the person taking the action must collect water quality data and data on natural rates and spatial patterns of sediment deposition for at least one full annual cycle prior to the construction of the Marine Facilities listed in Condition 11.3. | Section 13.0<br>Note that dredging and dredge spoil disposal will not be undertaken as part of the construction activities for the Domestic Gas Pipeline. |

Any matter specified in this Report is relevant to the Gorgon Gas Development only if that matter relates to the specific activities or facilities associated with that particular development.

The sections in this Report noted in Table 1-2 to meet the conditions of EPBC Reference: 2003/1294 and 2008/4178 shall be read and interpreted as only requiring implementation under EPBC Reference: 2003/1294 and 2008/4178 for managing the impacts of the Gorgon Gas Development on, or protecting, the EPBC Act matters listed in Appendix 1. The implementation of matters required only to meet the requirements of Statement No. 800 are not the subject of the EPBC Reference: 2003/1294 and 2008/4178.

### 1.5.5 Hierarchy of Documentation

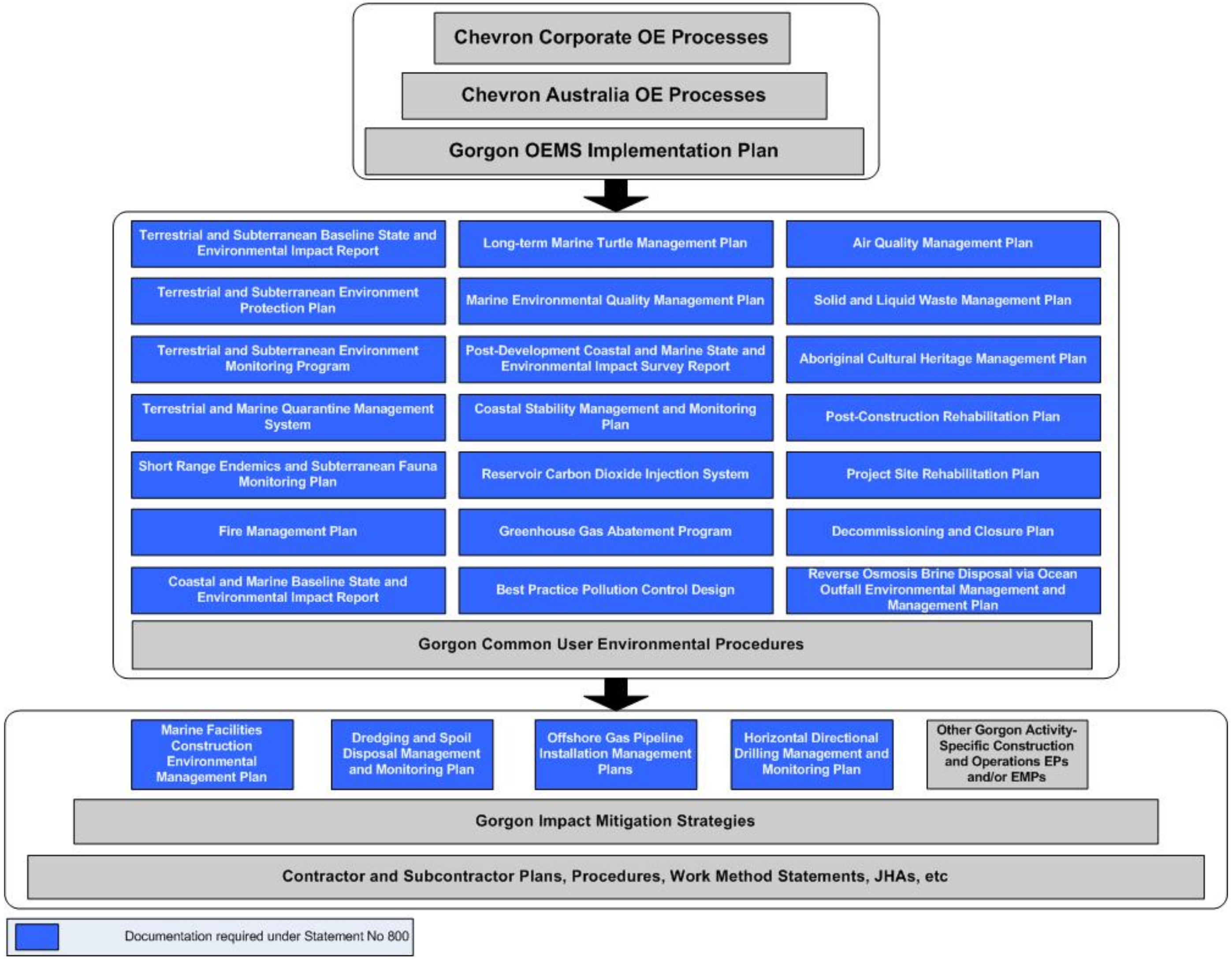
This Marine Baseline Report will be implemented for the Gorgon Gas Development via the Chevron Australasia Business Unit (ABU) Operational Excellence Management System (OEMS). The OEMS is the standardised approach that applies across the ABU in order to continuously improve the management of safety, health, environment, reliability and efficiency to achieve world-class performance. Implementation of the OEMS enables the Chevron ABU to integrate its Operational Excellence (OE) objectives, processes, procedures, values, and behaviours into the daily operations of Chevron Australia personnel and contractors working under Chevron Australia's supervision. The OEMS is designed to be consistent with and, in some respects, go beyond ISO 14001:2004 (Environmental Management Systems – Requirements with Guidance for Use) (Standards Australia/Standards New Zealand 2004).

Figure 1-3 provides an overview of the overall hierarchy of environmental management documentation within which this Report exists. Data collected during the Marine Baseline Program documented in this Report have been or will be used in the development and/or implementation of the following plans:

- Marine Facilities Construction Environmental Management Plan (Chevron Australia 2012) required under Condition 17 of Statement No. 800 and Condition 13 of EPBC Reference: 2003/1294 and 2008/4178
- Dredging and Spoil Disposal Management and Monitoring Plan (Chevron Australia 2011) required under Condition 20 of Statement No. 800 and Condition 14 of EPBC Reference: 2003/1294 and 2008/4178
- Horizontal Directional Drilling Management and Monitoring Plan (Chevron Australia 2011a) required under Condition 22 of Statement No. 800, Condition 13 of Statement No. 769, Condition 15 of EPBC Reference: 2003/1294, 2008/4178 and 2005/2184
- Offshore Feed Gas Pipeline Installation Management Plan (Chevron Australia 2013) required under Condition 23 of Statement No. 800, Condition 14 of Statement No. 769, Condition 16 of EPBC Reference: 2003/1294, 2008/4178 and 2005/2184
- Offshore Domestic Gas Pipeline Installation Management Plan (Chevron Australia 2014) required under Condition 23 of Statement No. 800 and Condition 16 of EPBC Reference: 2003/1294 and 2008/4178

- Marine Environmental Quality Management Plan (as required under Condition 23A of Statement No. 800)
- Post-development Coastal and Marine State and Environmental Impact Report as required under Condition 24 of Statement No. 800, Condition 15 of Statement No. 769, and Condition 17 of EPBC Reference: 2003/1294 and 2008/4178.

The links between these documents and the relevant conditions of Statement No. 800 are shown in Figure 1-4.




## Figure 1-3 Hierarchy of Gorgon Gas Development Environmental Documentation

*Note: The above figure refers to all Plans required for Statement No. 800. The Plans are only relevant to EPBC Reference: 2003/1294 and 2008/4178, if required for those Conditions of those approvals.*

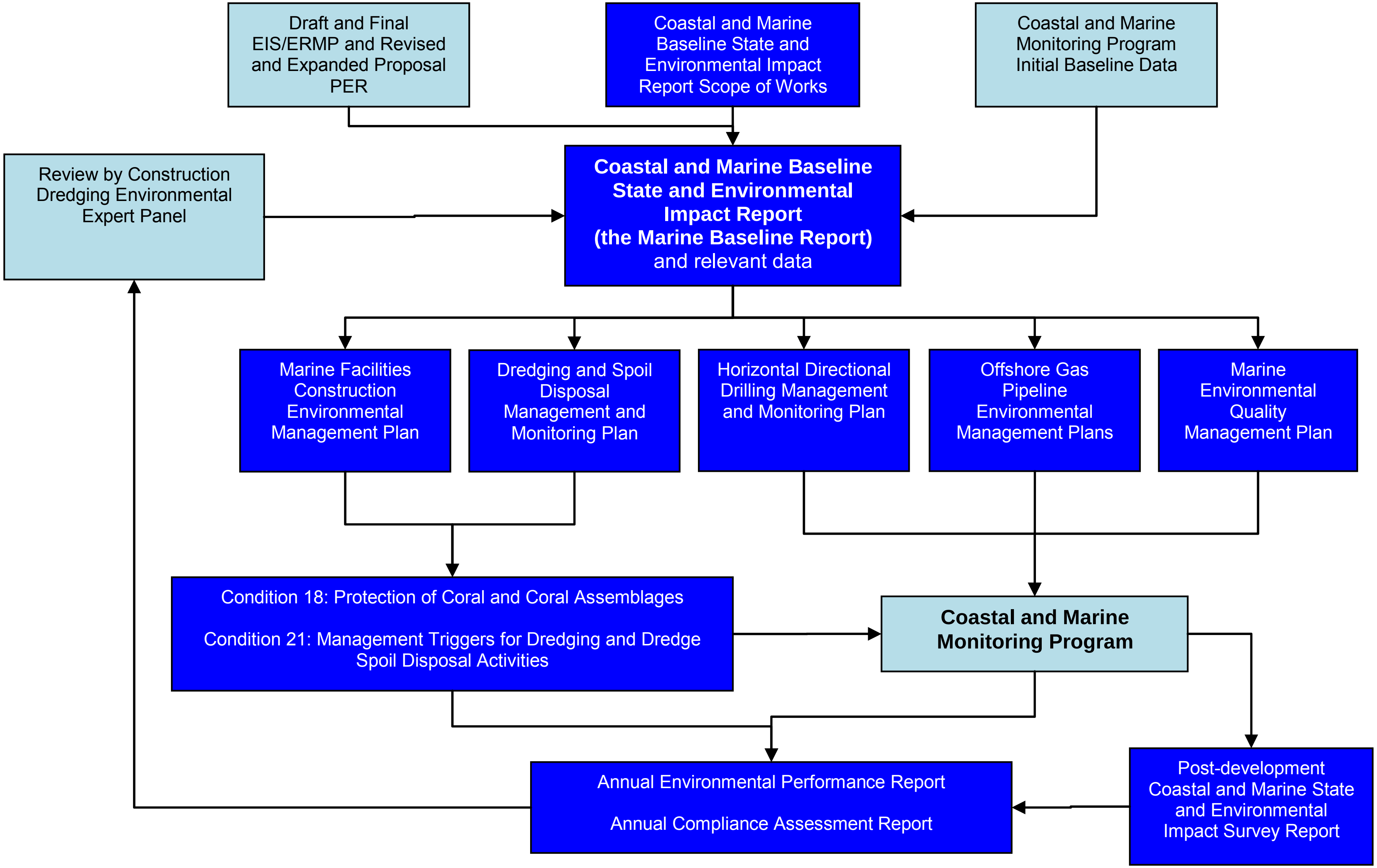



**Figure 1-4 Context of the Marine Baseline Report**

### 1.5.6 Relevant Standards and Guidelines

The following standards and guidelines have been taken into account in the development of this Marine Baseline Report:

- EPA Guidance Statement No. 1 – Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline (EPA 2001)
- EPA Guidance Statement No. 29 – Benthic Primary Producer Habitat Protection for Western Australia's Marine Environment (EPA 2004) and EPA Environmental Assessment Guideline No. 3 – Protection of Benthic Primary Producer Habitats in Western Australia's Marine Environment (EPA 2009)
- EPA Guidance Statement No. 51 – Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (EPA 2004a).

### 1.5.7 Stakeholder Consultation

Consultation with stakeholders has been undertaken by Chevron Australia on a regular basis throughout the development of environmental impact assessment management documentation for the Gorgon Gas Development and Jansz Feed Gas Pipeline. This has included engagement with the community, government departments, industry operators and contractors to Chevron Australia via planning workshops, risk assessments, meetings, teleconferences, and the PER and EIS/ERMP formal approval processes.

Under Condition 14.5 of Statement No. 800, the Construction Dredging Environmental Expert Panel (CDEEP), DEC (now DPaW), DoT, DoF and DEWHA (now DotE) shall be consulted in the preparation of this Marine Baseline Report. Under Condition 11.5 of EPBC Reference: 2003/1294 and 2008/4178, the DEC (now DPaW), DoT, DoF and SEWPaC (now DotE) must be consulted in the preparation of this Report.

This document has been prepared with input from:

- The former Western Australian Department of Environment and Conservation (DEC) (now DPaW): The DEC reviewed draft revisions of this Report and the DEC's comments have been incorporated or otherwise resolved.
- The former Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA) (now DotE) : The DEWHA reviewed draft revisions of this Report and their comments have been incorporated or otherwise resolved.
- The Construction Dredging Environmental Expert Panel (CDEEP): The CDEEP was provided with a briefing on the Marine Baseline Report at the Panel meeting on 31 October 2011, and their comments have been incorporated or otherwise resolved.
- The Western Australian Department of Fisheries (DoF): The DoF reviewed draft revisions of this Report and the DoF's comments have been incorporated or otherwise resolved.
- The Western Australian Department of Transport (DoT) : The DoT reviewed draft revisions of this Report and the DoT's comments have been incorporated or otherwise resolved.

The process for development, review and approval of this Marine Baseline Report is shown in Figure 1-5.

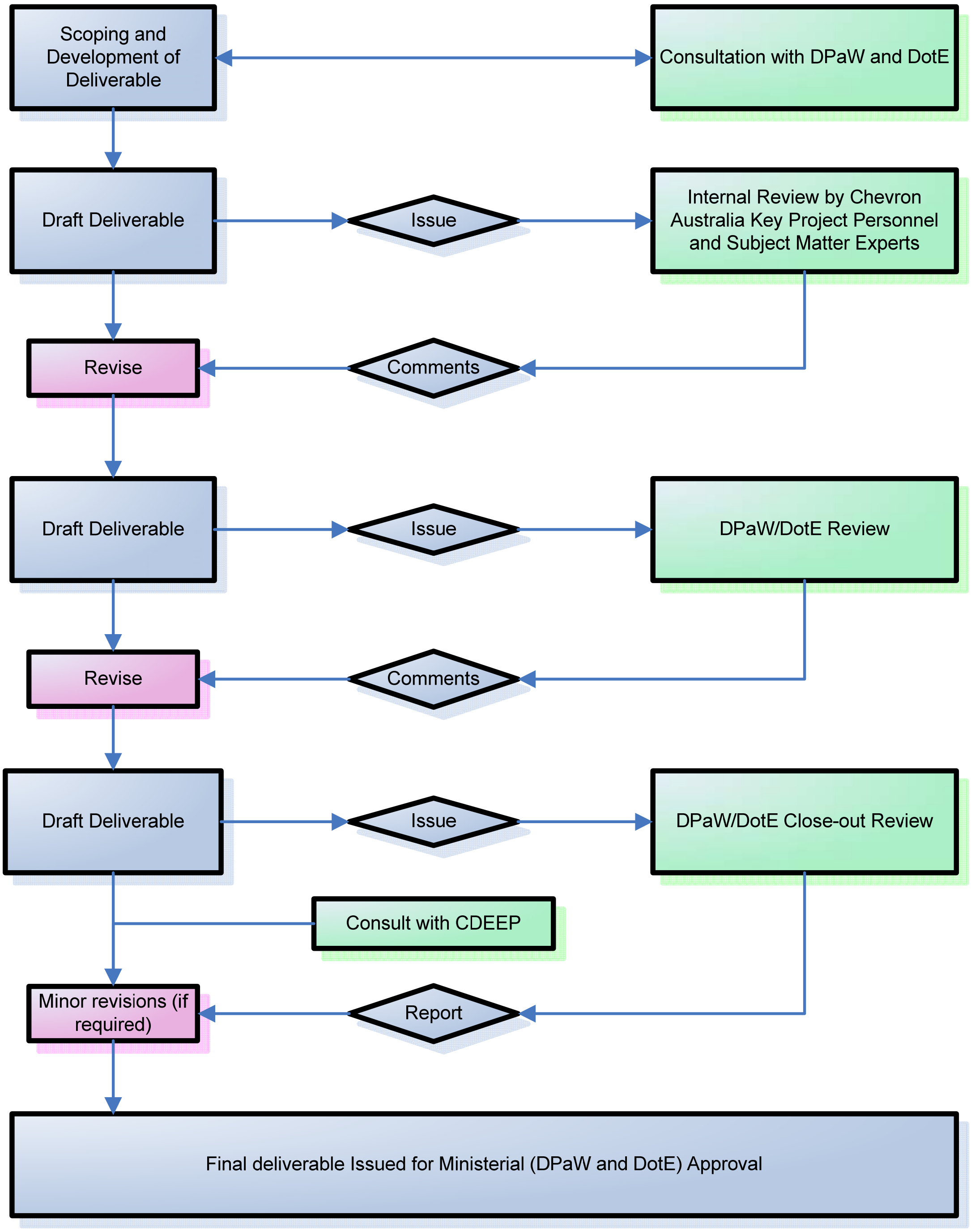



**Figure 1-5 Deliverable Development, Review and Approval Flow Chart**

### 1.5.8 Public Availability

This Marine Baseline Report will be made public as and when determined by the Minister, under Condition 35 of Statement No. 800 and Condition 22 of EPBC Reference: 2003/1294 and 2008/4178.

# 2.0 Relevant Facilities and Areas

## 2.1 Marine Facilities and Activities

### 2.1.1 Overview

The Marine Baseline Report addresses issues associated with the Marine Facilities of the Gorgon Gas Development and the Marine Facilities of the Jansz Feed Gas Pipeline which are shown in Figure 1-2 and Figure 2-1 of this Report. The Marine Facilities for the Gorgon Gas Development (Figure 2-1) are defined in Condition 14.3 of Statement No. 800 as the:

- Materials Offloading Facility (MOF)
- LNG Jetty
- Dredge Spoil Disposal Ground
- Offshore Feed Gas Pipeline System
- Domestic Gas Pipeline
- Marine upgrade of the existing WAPET Landing.

Condition 14.3 of Statement No. 800 relates only to components of the Marine Facilities within State waters (i.e. specifically the Offshore Feed Gas Pipeline System).

The Marine Facilities for the Gorgon Gas Development are defined in Condition 11.3 of EPBC Reference: 2003/1294 and 2008/4178 as the:

- Materials Offloading Facility (MOF)
- LNG Jetty
- Dredge Spoil Disposal Ground
- Offshore Feed Gas Pipeline System in State waters
- Offshore Domestic Gas Pipeline.

Additional details on the Marine Facilities can be found in the Draft EIS/ERMP (Chevron Australia 2005), the section 45C approval (EPA 2008), and the PER (Chevron Australia 2008).

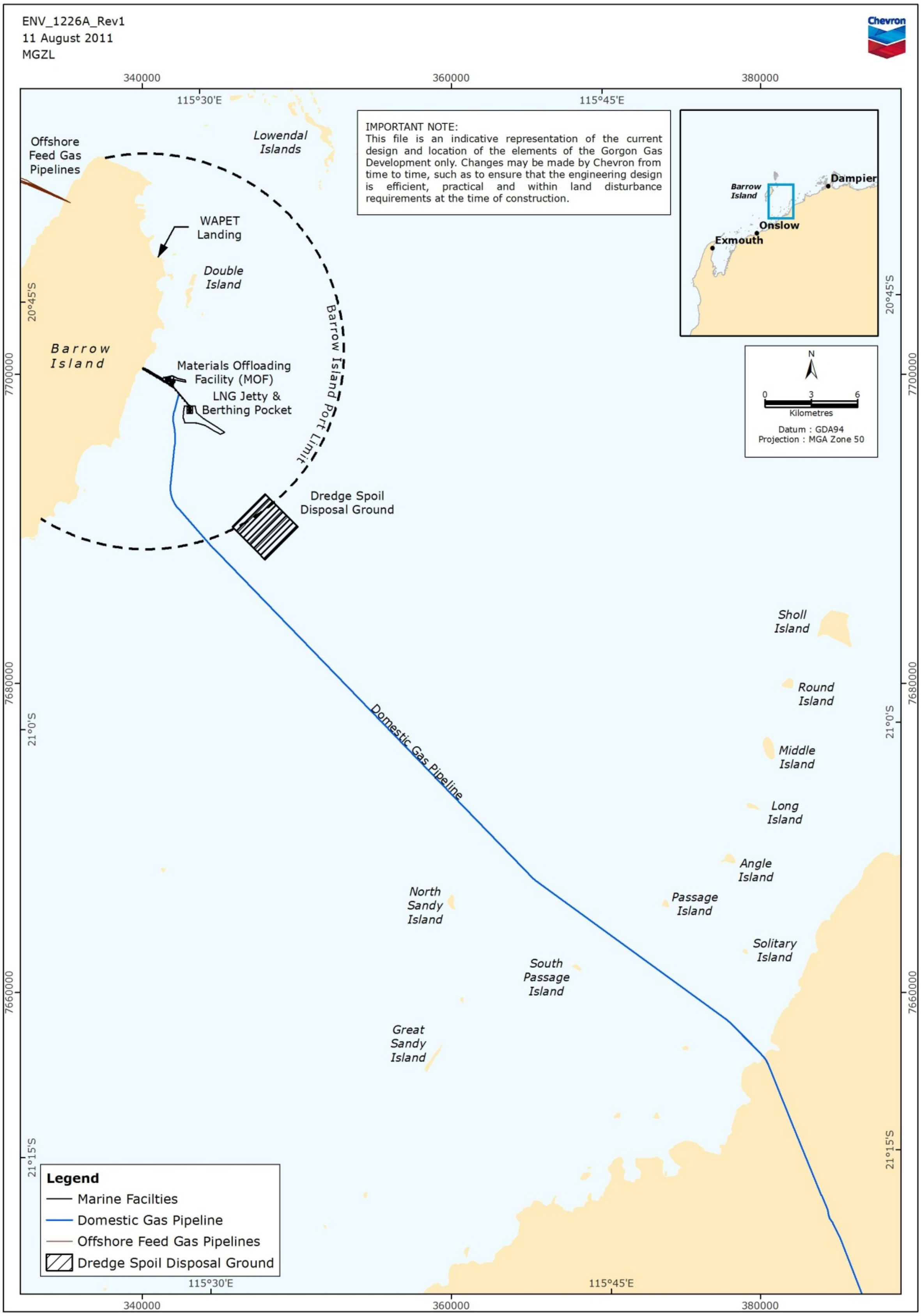



**Figure 2-1 Gorgon Gas Development Marine Facilities**

Please note that the description of the DomGas Pipeline provided in subsequent sections is as currently proposed and may be subject to change as design work progresses. More specific details are contained in various Gorgon Gas Development approval and assessment documents, which are issued from time to time.

### 2.1.2 (Offshore) Domestic Gas Pipeline

The DomGas Pipeline is a 20-inch diameter dry gas export line to supply domestic gas from the Gorgon Gas Development and Jansz Feed Gas Pipeline into the Dampier to Bunbury Natural Gas Pipeline.

The DomGas Pipeline route includes:

- an offshore pipeline section (approximately 59.4 km long) from the LNG Jetty on the east coast of Barrow Island to the Australian mainland shore crossing, located approximately 90 km north-east of Onslow and 120 km south-east of Karratha
- an intertidal pipeline section (approximately 12 km long) from the mainland shore crossing (low water mark), through the intertidal zone, to the high water mark, running adjacent to the existing Apache easement and the twin Sales Gas pipelines
- an onshore pipeline section (approximately 19.8 km long) from the high water mark, then across land to tie-in to the Dampier to Bunbury Natural Gas Pipeline south of Compressor Station One (this component is addressed in the Mainland Onshore Domestic Gas Pipeline Environmental Management Plan, [Chevron Australia 2014a, as amended from time to time]).

The DomGas Pipeline installation activities will include:

- shallow and deep water offshore pipelay extending from Offshore Kilometre Point (KP)[1] 0, at the Barrow Island LNG Jetty, to Offshore KP59.4 at the mainland shore crossing
- offshore pipeline stabilisation, including trenching and jetting and rock bolting
- riser installation and concrete mattressing
- intertidal pipeline installation extending from Onshore KP0 (Offshore KP59.4), at the mainland shore crossing, to approximately Onshore KP12, at the high water mark
- pre-commissioning.

Shallow and deep water pipelay will be undertaken predominantly using conventional S-lay techniques. The shallow water pipelay barge will undertake shallow water pipelay from Offshore KP59.4 at the mainland shore crossing to Offshore KP48.4. At Offshore KP48.4, the shallow water pipelay barge will lay down the pipeline for the deep water pipelay barge to pick up and complete the tie-in. The deep water pipelay barge will undertake deep water pipelay from Offshore KP0 to KP48.4. Welding, non-destructive testing, and field joint coating of the pipeline will be undertaken on board the pipelay barges. There will be a continual cycle of preparing pipe joints, welding pipe joints, performing non-destructive testing on the welds, repairing welds as necessary, applying field joint coating and moving the pipelay barges forward – one pipe joint at a time – along the pipeline route. The pipeline will be laid on the seabed using stinger and roller support systems, which can pivot and be adjusted to suit the pipelay profile. Tensioners will be used to hold the pipeline in position and let out one joint at a time as the pipelay barge moves forward. The tensioners will also monitor the tension in the pipeline to ensure the pipelay profile is maintained and the pipeline is not overstressed or buckled. A buckle detector will monitor the roundness of the pipeline and detect possible buckling of the pipeline. Air divers and/or a remotely operated vehicle (ROV) will be used to carry out regular inspections of the pipeline and stinger.

[1] For the description of pipeline installation activities, locations along the offshore and intertidal pipeline routes are described in Kilometre Points (KPs).

Concrete weight coating of the pipeline will be used for primary stabilisation along the offshore pipeline route, as well as in the intertidal zone from Onshore KP0 to KP0.3. For secondary stabilisation, trenching and jetting, or rock-bolting will be undertaken. Trenching and jetting will be undertaken at the mainland shore crossing from Offshore KP48.4 to KP59.4 (distance of approximately 11 km), and over two small offshore sections of the pipeline route (Offshore KP23.8 to KP24.5 [approximately 0.7 km between 34.9 and 35.6 km offshore from the mainland], Offshore KP26 to KP27 [approximately 1 km between 32.4 and 33.4 km offshore from the mainland]), and in other areas where there is sufficient soft sediment to achieve the required pipeline burial depth. From Offshore KP57 to KP59.4 (approximately 2.4 km) at the mainland shore crossing, trenching may be undertaken using an amphibious excavator and/or jet sled. For Offshore KP48.4 to KP57 (approximately 8.6 km) and for the offshore sections, jetting will be undertaken. A jet sled, towed from the pipelay barge or the stabilisation vessel, will be used to fluidise sediment beneath the laid pipeline, allowing the pipeline to sink into the seabed. The sediment from offshore trenching and jetting activities will be side-cast or displaced to either side of the pipeline trench, and the trench surrounding the pipeline will naturally backfill with sediment during tidal movement.

Rock-bolting of the pipeline will be undertaken from Offshore KP0 to KP38 following deep water pipelay. From Offshore KP0 to KP37.8, rock-bolt pairs either side of the pipeline (with an interlinking chain or beam) will be installed approximately every 20 to 40 m along the pipeline, dependent on the depth of sediment and seabed geology. The spacing of the rock-bolt pairs will be finalised following the completion of geotechnical surveys along the pipeline route. From Offshore KP37.8 to KP38, a bell-mouth of single rock bolts, curving away from the pipeline centreline on either side, will be installed to ensure that pipeline movement on the seabed does not result in unacceptable strains on the pipeline when transitioning to the fully restrained rock-bolted section. The bell-mouth curvature is designed to minimise spot loads on the pipeline during possible movement. Rock-bolt drilling rigs on the deep water pipelay barge and/or the stabilisation vessel will be used for the installation of the rock-bolts into the seabed. Grout will be used to fill the rock-bolts and cement the rock-bolts into the seabed, also filling any cavities in the drilled rock. Grout may also be used for free span correction identified during pre-lay and as-laid pipeline surveys, with grout bags installed by divers beneath the pipeline. From Offshore KP38 to KP48.4, the pipeline will be laid directly on the seabed with no secondary stabilisation.

The riser for the DomGas Pipeline will be installed on the Barrow Island LNG Jetty at Offshore KP0. The riser and tie-in spool will be assembled on the deck of the deep water pipelay barge, the laid pipeline end will be lifted to the surface alongside the barge to remove the temporary head installed during pipelay, and the riser and tie-in spool will be welded to the pipeline and stalked on to the riser clamps. After the completion of riser installation, concrete mattresses will be installed over the spool for protection. Near the LNG Jetty there is an existing trench from the installation of the jetty caissons. Additional material may be required to infill part of the trench to the natural seabed level to prevent spanning and support the pipeline. The infill area will be within the Marine Disturbance Footprint and will run from the edge of the existing trench to the caisson where the pipeline riser will be installed.

Pipeline installation within the intertidal zone at the mainland will be executed using specialised equipment, such as low ground pressure, swamp tracked equipment and/or a flat bottom barge from which equipment can be mobilised. Clearing will be undertaken to establish the stringing yard at approximately Onshore KP12 and the pipeline right-of-way. The stringing yard will include a roller system for stringing of the line pipe, welding, non-destructive testing and field joint coating, and to assist with the roll out of continuous pipe strings into the intertidal zone. Pipeline trenching will be undertaken from Onshore KP0 to KP12, with trench excavation scheduled to be undertaken around tidal movements. The trench will be excavated in segments and natural weirs and/or locks will be used to flood the trench and prevent water loss at low tide. Water will be pumped from lower trench segments to higher trench segments as required, to ensure all trench segments are flooded and to prevent trench collapse. Once the pipeline is in position, it will be lowered into the trench and bedding, padding and backfilling will be completed.

Pre-commissioning of the DomGas Pipeline will be undertaken once the onshore, intertidal and offshore sections have been installed and tie-ins between the sections have been completed. Pre-commissioning activities will include: water winning, flooding and cleaning, gauging, pressure testing (hydrotesting), dewatering, drying and purging. Following pressure testing, the pipeline will be dewatered to the mainland, with the chemically treated seawater disposed of offsite or to an onshore evaporation pond located adjacent to the DomGas meter station and Compressor Station One of the Dampier to Bunbury Pipeline.

A range of construction vessels will be required for these marine activities, including a shallow water pipelay barge and a deep water pipelay barge, which will undertake pipelay and stabilisation activities, operating on an 8-point mooring and supported by anchor handling vessels. In addition, a number of ancillary vessels will be required to support pipeline installation activities, including: pipe supply vessels and/or barges, survey vessels, cargo vessels, stabilisation vessels (if required), crew boats, and accommodation vessels (if required).

## 2.2 Activity Overview

A summary of the construction activities and their indicative timing for the offshore and intertidal installation of the DomGas Pipeline is provided in Table 2-1. More detailed information is provided in the 'Description of Activities' Section of the Offshore Domestic Gas Pipeline Installation Management Plan (Chevron Australia 2014). This schedule represents the current basis of design and is indicative only.

**Table 2-1 Indicative Construction Program**

| Activity | Start Date | Completion Date | Duration |
|---|---|---|---|
| Mobilisation to site | April 2012 | April 2012 | 1 month |
| Pre-lay survey | February 2012 | February 2012 | 1 month |
| As-laid survey | September 2012 | September 2012 | 1 month |
| As-built survey | October 2012 | October 2012 | 1 month |
| Shallow water pipelay | August 2012 | August 2012 | 1 month |
| Deep water pipelay | May 2012 | May 2012 | 1 month |
| Trenching and jetting (Shallow Water) | July 2012 | September 2012 | 2 months |
| Jetting (Deep Water) | June 2012 | June 2012 | 1 month |
| Rock-bolting | June 2012 | July 2012 | 2 months |
| Rock installation | November 2012 | November 2012 | 1 month |
| Riser installation and concrete mattressing | August 2012 | August 2012 | 1 month |
| Intertidal pipeline installation | May 2012 | July 2012 | 3 months |
| Pre-commissioning | October 2012 | October 2012 | 1 month |

The total duration of the DomGas Pipeline offshore and intertidal installation activities is approximately seven months, from April to October 2012. Offshore installation and pre-commissioning activities will occur 24 hours a day.

## 2.3 Marine Areas

### 2.3.1 Geographical Extent

The geographical extent for reports that cover the Gorgon Gas Development Marine Facilities is defined in Condition 14.7 of Statement No. 800 as the:

- Materials Offloading Facility (MOF)
- LNG Jetty
- Dredge Spoil Disposal Ground
- Offshore Feed Gas Pipeline System
- Domestic Gas Pipeline
- Marine Upgrade of the existing WAPET Landing
- Dredge Management Areas including the Zones of High Impact, the Zones of Moderate Impact and areas in the Zones of Influence, including those that contain significant benthic communities including coral assemblages
- the Marine Disturbance Footprint associated with the Marine Facilities in State waters
- Reference Sites outside the Zone of Influence.

The geographical extent for reports that cover the Gorgon Gas Development Marine Facilities is defined in Condition 11.7 of EPBC Reference: 2003/1294 and 2008/4178 as the:

- Materials Offloading Facility (MOF)
- LNG Jetty
- Dredge Spoil Disposal Ground
- Offshore Feed Gas Pipeline System in State waters
- Offshore Domestic Gas Pipeline
- Dredge Management Areas including the Zones of High Impact, the Zones of Moderate Impact and areas in the Zones of Influence, including those that contain significant benthic communities including coral assemblages
- the Marine Disturbance Footprint associated with the Marine Facilities in State waters
- Reference Sites outside the Zone of Influence.

### 2.3.2 Marine Disturbance Footprint

The Gorgon Gas Development Marine Disturbance Footprint is defined in Statement No. 800 as:

> *The area of the seabed to be disturbed by construction or operations activities associated with the marine facilities listed in Condition 14.3 (excepting that area of the seabed to be disturbed by the generation of turbidity and sedimentation from dredging and spoil disposal).*

The Gorgon Gas Development Marine Disturbance Footprint is defined in EPBC Reference: 2003/1294 and 2008/4178 as:

> *The area of the seabed to be disturbed by construction or operations activities associated with the marine facilities listed in Condition 11.3 (excepting that area of the seabed to be disturbed by the generation of turbidity and sedimentation from dredging and spoil disposal).*

The Marine Disturbance Footprint includes those areas of the seabed and the associated benthic ecological elements (hard and soft corals, non-coral benthic macroinvertebrates, macroalgae, seagrass, mangroves and surficial sediment characteristics) that may be directly affected by the planned construction and operation activities. Direct physical disturbance to the seabed and the associated benthic ecological elements within the Marine Disturbance Footprint may include pipe laying and stabilising directly on the seabed; as well as vessel anchoring and propeller wash. The levels of potential disturbance within the Marine Disturbance Footprint of the DomGas Pipeline may thus vary from negligible to Material Environmental Harm to Serious Environmental Harm (see Section 2.3.3.1 for further details).

The Marine Disturbance Footprint for the DomGas Pipeline includes:

- the Marine Facilities Footprint, which are the areas of the seabed associated with the physical footprint of the DomGas Pipeline, including rock-bolts and concrete mattresses
- the extent of the surrounding seabed in which the planned construction (pipelaying) and operation activities could be expected to disturb the seabed—this encompasses an area extending 100 m on both sides of the pipeline alignment (i.e. a 200 m wide corridor; Figure 2-2). Note that this includes areas that will not be disturbed (e.g. areas between anchor positions and between anchor positions and the vessel where no anchors or chains contact the seabed)
- areas of the seabed within the indicative anchoring areas that will be directly impacted by anchoring (anchors, wire and chain sweep) (Section 2.3.2.1)
- the areas of the seabed and the ecological elements that may be affected by temporary, localised increases in Suspended Sediment Concentrations (SSC) and sedimentation rates, generated by nearshore trenching and jetting activities associated with the stabilisation of the DomGas Pipeline (the trenching and jetting Marine Disturbance Footprint; Section 2.3.2.2; Figure 2-2).

The Marine Disturbance Footprint specific to the east coast Marine Facilities (the Marine upgrade of the existing WAPET Landing, the MOF, LNG Jetty and the Dredge Spoil Disposal Ground) is described in detail in Chevron Australia (2013a) and the Marine Disturbance Footprint specific to the west coast Marine Facilities (Offshore Feed Gas Pipeline System) is described in detail in Chevron Australia (2011b).

#### 2.3.2.1 Indicative Anchoring Areas

Figure 2-2 show the Marine Disturbance Footprint for the DomGas Pipeline and indicative anchoring areas. These include areas adjacent to the DomGas Pipeline Marine Disturbance Footprint where the pipelay barges, supported by anchor handling tugs, will anchor using an 8-point mooring during pipelay and stabilisation activities. In addition, a number of indicative anchoring areas have been identified for the ancillary vessels required to support pipeline installation activities. Anchoring activities will generally be restricted to within these areas. It is not proposed that the entire area identified as indicative anchoring areas will be disturbed. At this stage, the specific location of the anchoring point for the ancillary vessels within the indicative anchoring areas is subject to further investigation to identify those locations with suitable sediment cover with holding capacity for anchoring. It is not proposed that all the indicative anchoring areas will be used at all times. The selection of the location and the number of indicative anchoring areas was based on consideration of a number of factors, including the need for safe anchorages during prevailing metocean conditions, the availability of additional water depth during neap tides, and to enable the vessels to anchor as close as practicable to the pipelay barge. Anchoring points for pipe supply vessels and cargo barges may also be located approximately every 5 km along the pipeline route. These anchoring points are proposed to be located outside the 8-point mooring pattern, to avoid interference with pipelay and stabilisation activities and to minimise risk to the laid pipeline. In poor weather conditions, sea state and/or in an emergency, additional sites may be used for anchoring at the discretion of the Vessel Master(s) to provide for the safety of vessels and their crews. These sites may include more sheltered locations around the islands of the Passage Islands group and approved anchoring sites/moorings near Barrow Island.

The Marine Disturbance Footprint is considered to include areas of the seabed within the indicative anchoring areas that will be directly impacted by anchoring (anchors, wire and chain sweep). Each anchor will create localised and minor disturbance at the points of contact with the seabed only, and there will be areas between anchor positions and between the anchor positions and the vessel where no anchors or chains contact the seabed and thus there will be no disturbance. Furthermore, any disturbance from anchoring will be temporary for the duration of the marine works only. The levels of potential disturbance within the indicative anchoring areas may thus vary from negligible to Material Environmental Harm (see Section 2.3.3.1 for further details). Refer to the Offshore Domestic Gas Pipeline Installation Management Plan (Chevron Australia 2014) for details on the management of anchoring.

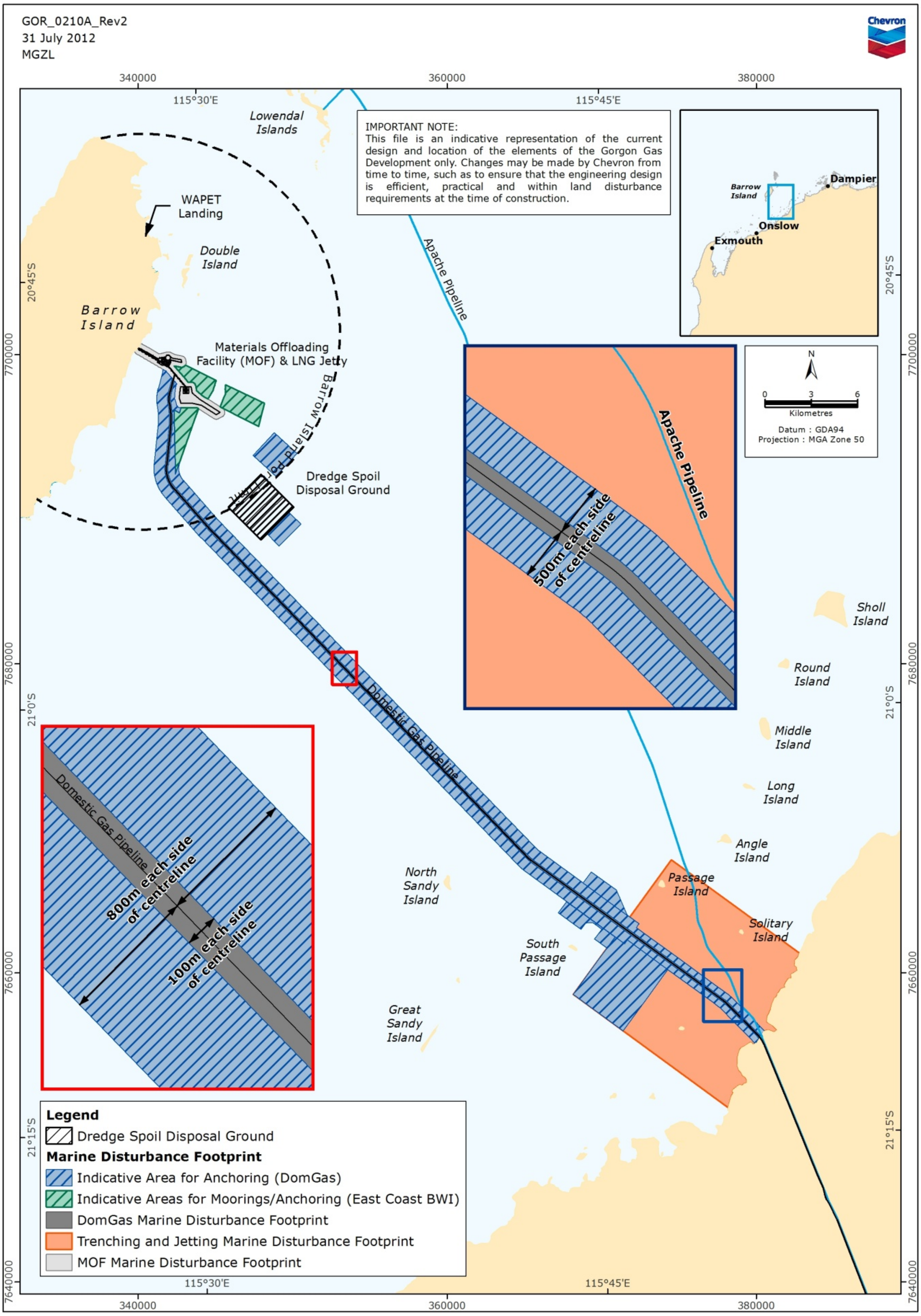



**Figure 2-2 Marine Disturbance Footprint**

#### 2.3.2.2 Determination of Areas of Seabed that may be Affected by Elevated Total Suspended Solids (TSS) Concentrations and Sedimentation Rates from Trenching and Jetting Activities

The Marine Disturbance Footprint for the DomGas Pipeline includes the areas of the seabed that may be affected by temporary, localised increases in Suspended Sediment Concentrations (SSC) and sedimentation rates, generated by nearshore trenching and jetting activities associated with the stabilisation of the DomGas Pipeline (the trenching and jetting Marine Disturbance Footprint; Figure 2-2). It is important to note that the trenching and jetting activities that may generate elevated SSC and sedimentation rates are scheduled to occur over three months in the naturally turbid waters near the mainland. Field studies have indicated that the nearshore region, where the majority of the trenching and jetting activities are to be undertaken, is a naturally turbid environment, with ambient SSC in the range of 5–30 mg/L in surface waters and 20–100 mg/L in bottom waters, characterised by high natural temporal and spatial variability (Asia-Pacific Applied Sciences Associates [APASA] 2009, 2010).

Numerical modelling was undertaken to predict spatial and temporal patterns of above-background SSC and sedimentation generated by trenching and jetting activities, accounting for subsequent resuspension due to current and wave forces (APASA 2010). The maximum instantaneous SSC at any vertical layer in the water column was used in the analyses (rather than depth averages or daily averages) to provide a conservative estimate of the likely SSC anywhere in the water column. The maximum values typically occurred near the seabed due to the combined effects of settlement of the suspended sediment (due to gravity) and resuspension of sediments into the water column (due to current and wave-induced shear stress). The results are presented in the form of contour plots that illustrate the footprint of the area affected by the sediment plumes, and that identify areas likely to experience the highest SCC.

The results from the modelling indicate that the SSC plume is typically concentrated within the immediate vicinity of the trenching activities. Concentrations >10 mg/L above background concentrations are limited to within 2 km of the discharge zone during the trenching operations. However, the high concentrations of fine sediments in the nearshore area results in a large number of suspended and resuspended sediment particles in the water column that will continually accumulate as trenching continues. During jetting activities, mobilisation of sediments is significantly higher than during trenching, resulting in a more rapidly expanding plume; the large tidal currents ensure that the fine materials remain suspended. The results from the modelling indicate that the SSC plume is transported predominantly to the west of the trenching area, driven by the dominant tidal currents. The sediments generated by the trenching and jetting activities are predicted to predominantly remain in the nearshore region, effectively retained by the tidal cycling and the wetting and drying cycles of the tidal flats. There is predicted to be sufficient energy generated by the strong tidal currents to resuspend the fine sediments, which were predicted to remain in the water column. Based on the hydrodynamic modelling it is expected that the extent of the plume will be seasonally consistent due to the tidally dominant current circulation patterns (APASA 2010). There is negligible predicted impact on SSC associated with the brief period of jetting in the small offshore sections along the pipeline route.

The 80$^{th}$ and 95$^{th}$ percentile contours of maximum water column TSS concentrations generated in the numerical modelling are shown in Figure 2-3. These show the relative frequency of occurrence of the plume throughout the area of interest (APASA 2010). The 80$^{th}$ percentile contours indicate the region where the TSS value will be exceeded for <20% of the 60-day simulation (i.e. 12 days), and the 95$^{th}$ percentile contours indicate the region where the TSS value will be exceeded for <5% of the simulation (i.e. three days). The results indicate that the plume with concentrations >5 mg/L above background will extend only as far as 5 to 9 km from the trenching and jetting area. The area affected by higher TSS (>25 mg/L) is restricted to within 2 km of the trenching area to the north-east and 5 km to the south-west.

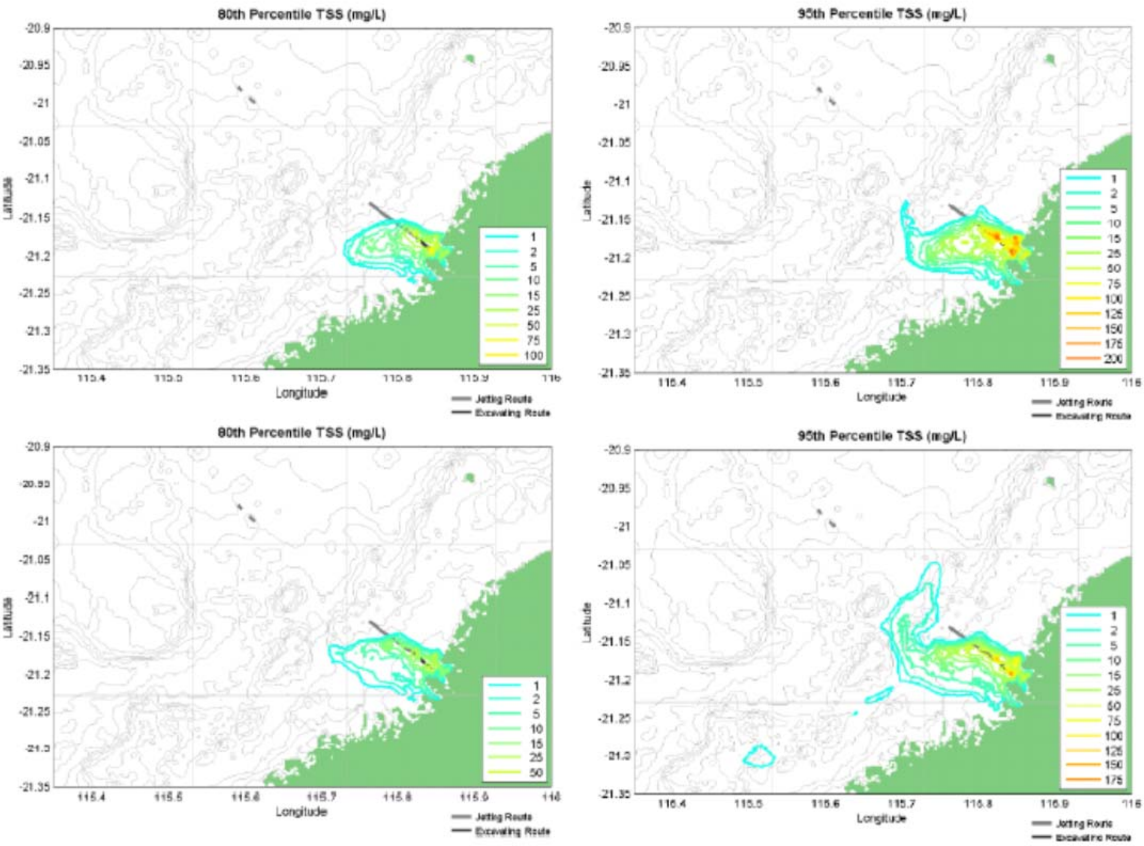



**Figure 2-3 Modelled 80th and 95th Percentiles for Maximum Water Column TSS (mg/L); Results for Scenario 1 (upper plots) and Scenario 2 (lower plots)**

*(Source: APASA 2010)*

*Note: APASA (2010) modelled two scenarios to predict the increases in TSS concentrations and sedimentation rates caused by trenching and jetting: (1) trenching for 2.43 km of the pipeline route (KP59.43 to KP57.0), followed by jetting for a further 8.7 km (KP57.0 to 48.3) and 1 km (KP27.0 to KP26.0) and 0.7 km (KP24.5 to KP23.8) offshore; and (2) trenching for 2.43 km of the pipeline route (KP59.43 to KP57.0), followed by jetting along the 2.43 km (KP59.43 to KP57.0) and a further 8.7 km (KP57.0 to 48.3) and 1 km (KP27.0 to KP26.0) and 0.7 km (KP24.5 to KP23.8) offshore.*

Analysis of the modelled sediment deposition patterns indicate that most deposition is predicted to occur close to the trenching activities, as the generally coarse material (>74 µm) will tend to settle within minutes of being suspended by the trenching and jetting activities (Figure 2-4). The results also predict that there will be some deposition of sediment in the mouth of the creek directly to the north of the pipeline route shore crossing.

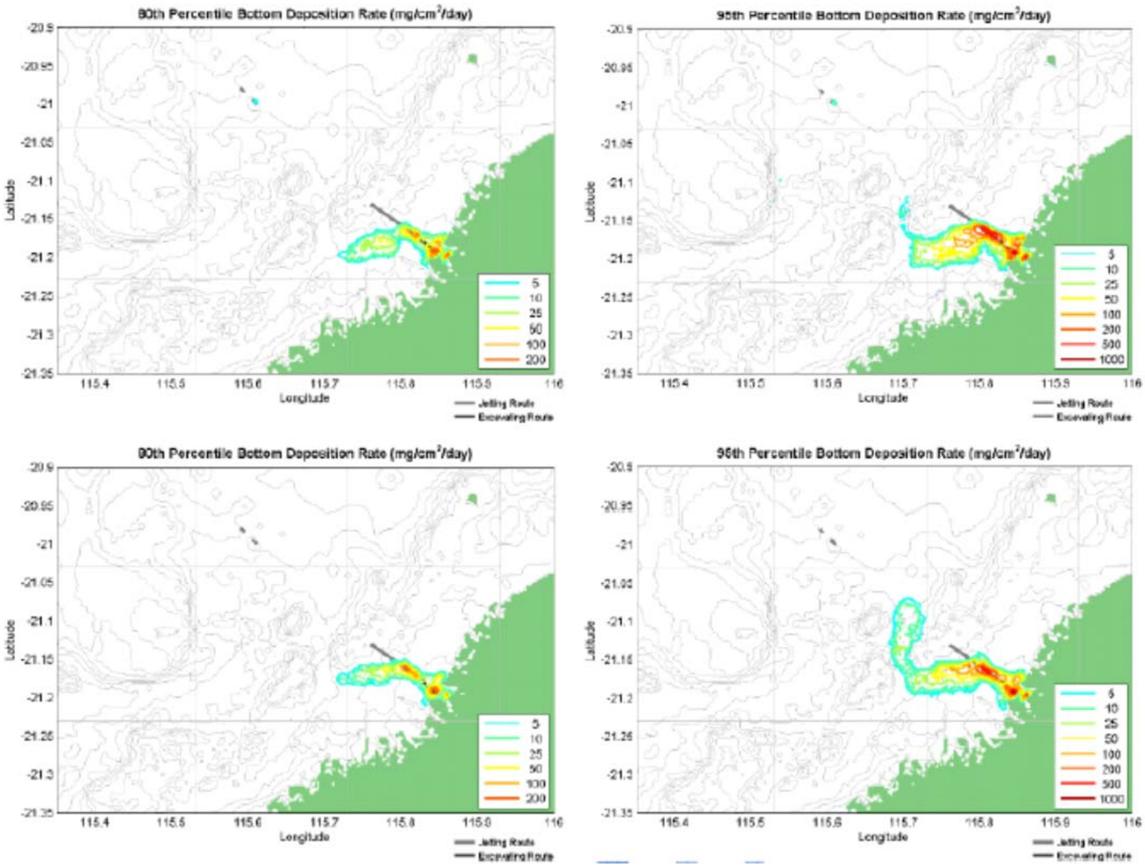



**Figure 2-4 Modelled 80th and 95th Percentiles for Maximum Sedimentation Rates (mg/cm$^2$/day); Results for Scenario 1 (upper plots) and Scenario 2 (lower plots)**

*(Source: APASA 2010)*

*Note: APASA (2010) modelled two scenarios to predict the increases in TSS concentrations and sedimentation rates caused by trenching and jetting: (1) trenching for 2.43 km of the pipeline route (KP59.43 to KP57.0), followed by jetting for a further 8.7 km (KP57.0 to 48.3) and 1 km (KP27.0 to KP26.0) and 0.7 km (KP24.5 to KP23.8) offshore; and (2) trenching for 2.43 km of the pipeline route (KP59.43 to KP57.0), followed by jetting along the 2.43 km (KP59.43 to KP57.0) and a further 8.7 km (KP57.0 to 48.3) and 1 km (KP27.0 to KP26.0) and 0.7 km (KP24.5 to KP23.8) offshore.*

### 2.3.3 Areas at Risk of Material or Serious Environmental Harm

Material Environmental Harm is defined as:

> *'Environmental harm that is neither trivial nor negligible'.*

Serious Environmental Harm is defined as:

> *'Environmental harm that:*
>
> *a. is irreversible, of a high impact or on a wide scale; or*
>
> *b. is significant or in an area of high conservation value or special significance and is neither trivial nor negligible'.*

#### 2.3.3.1 Construction and Operation of the Domestic Gas Pipeline

Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline, may occur within the Marine Disturbance Footprint for the DomGas Pipeline (described in Section 2.3.2). The level of environmental harm predicted at a particular location within the Marine Disturbance Footprint will be dependent on the types of stressors, the sensitivity of the ecological elements at any location, the likelihood of complete or partial recovery from the disturbance, and the management or mitigation measures taken to reduce impacts.

Serious Environmental Harm, caused by direct placement and rock-bolting of the pipeline onto the seabed, resulting in permanent and irreversible loss of the seabed, is predicted to affect all benthic ecological elements within the Marine Facilities Footprint of the DomGas Pipeline. Recovery to the original state will not be possible, although there will be some colonisation of the new hard substrates created by the pipeline. Installation of the DomGas Pipeline within the mangrove and onshore areas represents the area of Serious Environmental Harm for mangroves; long-term loss of mangroves will occur within this area.

Within the surrounding areas in the Marine Disturbance Footprint, beyond the Marine Facilities Footprint of the DomGas Pipeline, impacts associated with the construction and operation of the pipeline are likely to be highly localised, short-term and temporary, or sub-lethal; these impacts may remove or reduce the existing benthic ecological elements. Examples of impacts include anchor scouring in a macroalgal bed, seagrass bed, or benthic macroinvertebrate assemblages; and/or disturbance or resuspension of unconsolidated sediments by vessel propeller wash. Thus, the levels of disturbance within the Marine Disturbance Footprint will vary from negligible to what may be considered to represent Material Environmental Harm. In the disturbed areas, the substrate is likely to retain its ecological function as benthic habitat and the benthic ecological elements are predicted to recover in the short-term (within one to five years) following cessation of the disturbance. Macroalgae and seagrass are well adapted to cycles of disturbance and recovery, thus macroalgal-dominated limestone reefs, subtidal limestone reef platforms with macroalgae, and reef platform/sand with scattered seagrass, are predicted to be affected only temporarily (Chevron Australia 2006). Some hard corals, such as *Turbinaria* spp. and *Acropora* spp., are also predicted to recover or recolonise in the short term; while others will take longer periods to re-establish or regrow.

#### 2.3.3.2 Trenching and Jetting Activities

Those areas at risk of Material or Serious Environmental Harm due to trenching and jetting activities have been determined based on the results of numerical modelling (see Section 2.3.2.2) and available information for water quality (TSS) in the region.

##### 2.3.3.2.1 Benthic Ecological Elements and Water Quality

Available TSS data for the area in the vicinity of the DomGas Pipeline route are summarised in Table 2-2 and Table 2-3.

**Table 2-2 Summary of Total Suspended Solid (TSS) Measurements (mg/L) Collected in Nearshore Waters along the DomGas Pipeline Route**

| | **8 December 2008** falling neap tide (URS 2009)[1] | | **23 September 2009** spring tide (APASA 2009)[2] | | | |
|---|---|---|---|---|---|---|
| | **Inshore of Passage Islands** | | **Inshore of Passage Islands** | | **Offshore of Passage Islands** | |
| | **Surface Waters (n = 25)** | **Bottom Waters (n = 25)** | **Surface Waters (n = 6)** | **Bottom Waters (n = 6)** | **Surface Waters (n = 6)** | **Bottom Waters (n = 6)** |
| **Median** | 27.0 | 29.0 | 12.0 | 19.0 | 8.0 | 13.0 |
| **80th percentile** | 35.5 | 31.9 | 17.2 | 41.7 | 10.8 | 16.5 |
| **95th percentile** | 37.8 | 33.2 | 20.4 | 53.0 | 12.3 | 19.2 |

*Notes: (1) TSS measurements in surface and bottom waters sampled along three transects aligned with the pipeline route and 200 m either side and extending approximately 2, 4, 6, 8 and 10 km offshore. Triplicate samples were collected along the pipeline route transect.*

*(2) TSS measurements in surface and bottom waters at an inner site (approximately 8 km offshore) and an outer site (approximately 17 km offshore), with measurements made every two hours. The direct measurements of TSS were used to calibrate Acoustic Doppler Current Profilers (ADCPs) deployed for a month at the same sites, which generate a record of TSS concentrations every 30 minutes for the duration of deployment (refer to Table 2-3).*

**Table 2-3 Summary of Total Suspended Solid (TSS) Measurements (mg/L) Recorded from Acoustic Doppler Current Profilers (ADCPs) Deployed in Nearshore Waters Adjacent to the DomGas Pipeline Route**

| | 21 September – 27 October 2009 (APASA 2009) | | | |
|---|---|---|---|---|
| | Inshore of Passage Islands | | Offshore of Passage Islands | |
| | Surface Waters (n = 1730) | Bottom Waters (n = 1730) | Surface Waters (n = 1725) | Bottom Waters (n = 1725) |
| **Median** | 10.3 | 26.5 | 5.6 | 13.7 |
| **80th percentile** | 13.3 | 38.1 | 8.0 | 20.5 |
| **95th percentile** | 18.8 | 56.8 | 11.4 | 30.3 |

These data illustrate the high levels of turbidity characteristic of the nearshore waters in the vicinity of the DomGas Pipeline route, with median TSS concentrations of 10–30 mg/L recorded in the waters inshore of the Passage Islands, where all the trenching and the majority of the jetting activities will be undertaken. The 95th percentiles for TSS concentrations were 8.4–10.8 mg/L (surface waters) and 4.2–34.0 mg/L (bottom waters) above the median TSS concentrations recorded in inshore waters. These TSS concentrations are considerably higher than TSS reported for the inshore waters of Mermaid Sound (median 4.2 mg/L; MScience 2007) and Cape Lambert (mean 7.0 mg/L; Sinclair Knight Merz [SKM] 2008).

The benthic ecological elements in the vicinity of the DomGas Pipeline trenching and jetting activities are thus likely to comprise a relatively limited number of species that can survive in waters that are naturally turbid most of the time, and that are also able to survive and/or rapidly recolonise after periods of elevated turbidity, such as those associated with cyclones and/or run-off from the rivers and creeks in the area. For this reason, and the relatively short duration of the trenching and jetting activities (scheduled to occur over three months), the risk of Serious Environmental Harm is considered to be negligible.

Nevertheless, trenching and sand jetting may result in Material Environmental Harm. Based on an assessment of the 24-hour (75.5 mg/L) and 7-day (43.9 mg/L) TSS thresholds established for corals (considered to be the benthic primary producers most sensitive to changes in TSS and sedimentation rates) in turbid inshore waters at Cape Lambert (SKM 2008), and allowing for a background TSS concentration of the order of approximately 20–25 mg/L, the modelled contours for 25 mg/L and 50 mg/L approximate the 7-day and 24-hour thresholds, respectively. An area at risk of Material Environmental Harm defined by the modelled 95th percentile contour for 25 mg/L is potentially exceeded for a cumulative period of up to three days,[2] and thus includes values potentially as high as the 24-hour threshold (i.e. 75.5 mg/L). Outside this area, there would only be up to three cumulative days where values are higher than the 7-day threshold of 25 mg/L, and even shorter periods where values are higher than the 24-hour threshold. The area defined by the modelled 95th percentile contour for 25 mg/L is thus considered to represent the area at risk of Material Environmental Harm, with negligible risk of Material Environmental Harm outside this defined area. The area encompassed by the 95th percentile contour for 25 mg/L is shown in Figure 2-5. The area extends predominantly to the west up to approximately 5 km from the pipeline route and does not extend along the full length of the jetting activity. While the modelling and the derivation of the TSS thresholds are very conservative, and recognising that the turbidity generated by seabed disturbance may differ from the modelled predictions, the final area defined as at risk of Material Environmental Harm to benthic ecological elements and water quality has been extended approximately 5 km

[2] The modeled 80th and 95th percentiles results delineate areas within which TSS values were exceeded for cumulative periods of >12 days and >3 days, respectively, over the 60-day model simulation period. Outside these areas, exceedances would have happened for up to 12 days (80th percentile) or up ro three days (95th percentile) but this may or may not have happened on consecutive days.

either side of the pipeline route and along the full extent of the nearshore trenching and jetting activities (Figure 2-5).

There are no data available for sedimentation rates in the vicinity of the DomGas Pipeline trenching and jetting activities, thus thresholds identified for other areas (MScience 2007; SKM 2008) cannot be applied in a similar way to that adopted for water quality. It is, however, considered that the area at risk of Material Environmental Harm derived using TSS concentrations is sufficiently conservative as it encompasses the modelled 95$^{th}$ percentile for a sedimentation rate of 100 mg/cm$^2$/day, and the large majority of the 95$^{th}$ percentile for 50 mg/cm$^2$/day (Figure 2-4). This suggests that the sedimentation threshold suggested for inshore waters at Cape Lambert (24 hours: 103.1 mg/cm$^2$/day; 7-day: 85.9 mg/cm$^2$/day; 14-day 59.2 mg/cm$^2$/day; SKM 2008) would also be met.

#### 2.3.3.2.2 Mangroves

Mangroves are not vulnerable to low-light water regimes and are typically found in depositional sedimentary environments (Woodroffe 1992; Saenger 2002). However, excess input of sediment to mangroves can have sub-lethal or lethal consequences if the aerial roots are adversely affected by sediment burial, with impacts varying with the amount and type of sedimentation as well as the species impacted (Ellison 1999). The amount of sediment burial known to cause sub-lethal stress to mangroves was used to define the area where mangroves in the vicinity of the DomGas Pipeline route are at risk of Material Environmental Harm. *Avicennia marina*, the dominant mangrove species in the DomGas Pipeline area (Astron Environmental Services 2009), has been shown to become stressed when sediment burial of 5 cm above natural sedimentation levels occurred at a site in Queensland (Ellison 1999). The potential amount of sediment burial over a 60-day trenching and jetting period was conservatively estimated based on the density of the sediment material and approximate deposition porosity. Based on these calculations, a sedimentation rate of 100 mg/cm$^2$/day over 60 days would result in the accumulation of 4.8 to 5.1 cm of sediment.

The 80$^{th}$ and 95$^{th}$ percentile results for modelled sedimentation rates are shown in Figure 2-4. The 95$^{th}$ percentile of the 100 mg/cm$^2$/day sedimentation contour was selected to define the area of Material Environmental Harm to mangroves. This is considered to be very conservative given that: it is based on a level of sediment accumulation that causes sub-lethal stress; the analysis of the modelled results is conservatively based on maximum instantaneous readings at any level within the water column, not depth averages or daily averages; there is an assumption of continuous settling out and accumulation of sediment over 60 days, which is highly unlikely; and, for the majority of the area enclosed within the 95$^{th}$ percentile of the 100 mg/cm$^2$/day sedimentation contour, this sedimentation rate is only exceeded for three to 12 days, rather than 60 days (based on the 80$^{th}$ percentile contour). Thus the defined area provides for effects that may occur at levels lower than 5 cm (since the amount of sediment burial which may cause sub-lethal stress in *Avicennia marina* in the Pilbara Region has not been investigated). The area thus defined is within the area at risk of Material Environmental Harm defined for benthic ecological elements and water quality.

Given that mangroves are typically found in depositional sedimentary environments, and the relatively short duration of the trenching and jetting activities (scheduled to occur over three months), the risk of Serious Environmental Harm is considered to be negligible.

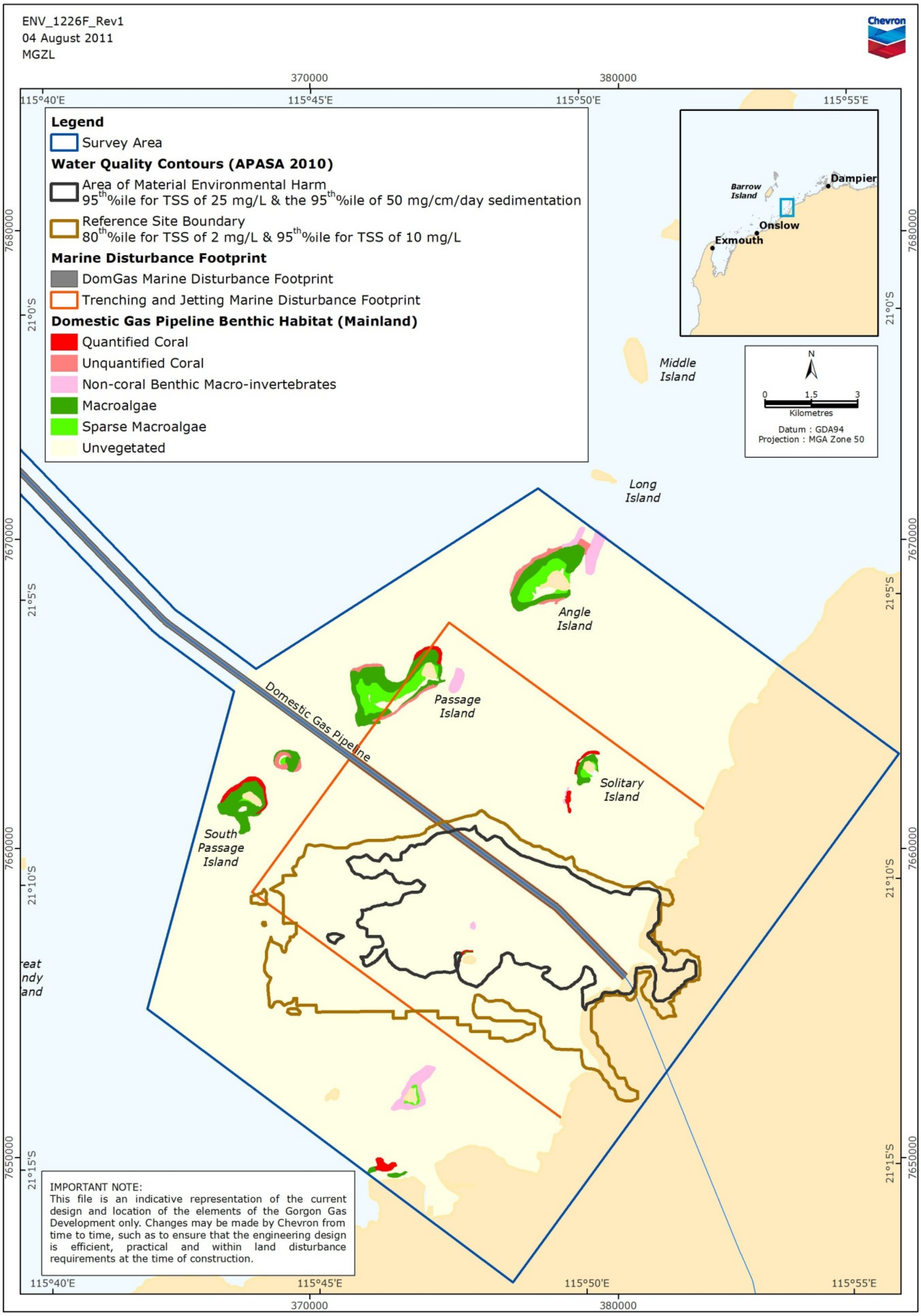



**Figure 2-5 Survey Area, Area of Material Environmental Harm and Marine Disturbance Footprint for Benthic Ecological Elements and Water Quality**

#### 2.3.3.2.3 Surficial Sediments

Trenching and jetting activities will cause reworking and settling out of sediments along the pipeline route, which may cause temporary, localised changes in particle size distribution (e.g. an increase in the silt and clay fractions) and carbon content (e.g. a lower proportion of organic carbon than natural sediments, which contain microphytobenthos and detritus). However, the available data indicate that these sediment characteristics are highly variable in the vicinity of the trenching and jetting activities (Section 12.0).

A sedimentation rate of 100 mg/cm$^2$/day over 60 days has been calculated to result in the accumulation of between 4.8 and 5.1 cm of sediment, if all the sediments settled out during that period; i.e. the surface 5 cm of sediment would be replaced. Therefore, the area at risk of Material Environmental Harm to surficial sediment characteristics has been conservatively defined as the modelled 95$^{th}$ percentile of the 100 mg/cm$^2$/day sedimentation contour (Figure 2-6). The area encompassed by the 95th percentile for the 100 mg/cm$^2$/day sedimentation contour extends predominantly to the west of the pipeline route. Therefore, consistent with the approach adopted for benthic ecological elements and water quality (see Section 2.3.3.2.1), the final area defined as at risk of Material Environmental Harm to surficial sediment characteristics has been extended the same distance to the east of the pipeline route (Figure 2-6). The area thus defined is within the area at risk of Material Environmental Harm defined for benthic ecological elements and water quality (Figure 2-5).

### 2.3.4 Dredge Management Areas

Hydrodynamic modelling has been undertaken to predict how fine sediments that are released during dredging and dredge spoil disposal activities associated with the construction of the MOF and the LNG Jetty at Town Point on the east coast of Barrow Island will disperse through the marine environment under the influence of oceanographic processes (for further information refer to Section 2.3.3 in Chevron Australia 2013a). Three zones (the Zones of High Impact, the Zones of Moderate Impact and the Zones of Influence) were established to reflect the different levels of predicted impact to corals (see Figure 2.3 in Chevron Australia 2013a). These zones were established based on sediment load and exposure time above background levels, and took into account published values for acute (short-term), medium-term, and chronic (long-term) responses of corals to both elevated Total Suspended Solids (TSS) and sedimentation (Chevron Australia 2005, 2006, 2008).

There are no trenching or jetting activities required to be undertaken at the Barrow Island end of the DomGas Pipeline. The pipelay activities and pipeline stabilisation, as well as riser installation and concrete mattressing, will generate little or no turbidity. There will be some turbidity generation due to rock-bolt installation, localised to each drill point, as well as thruster wash from anchor handling tugs.

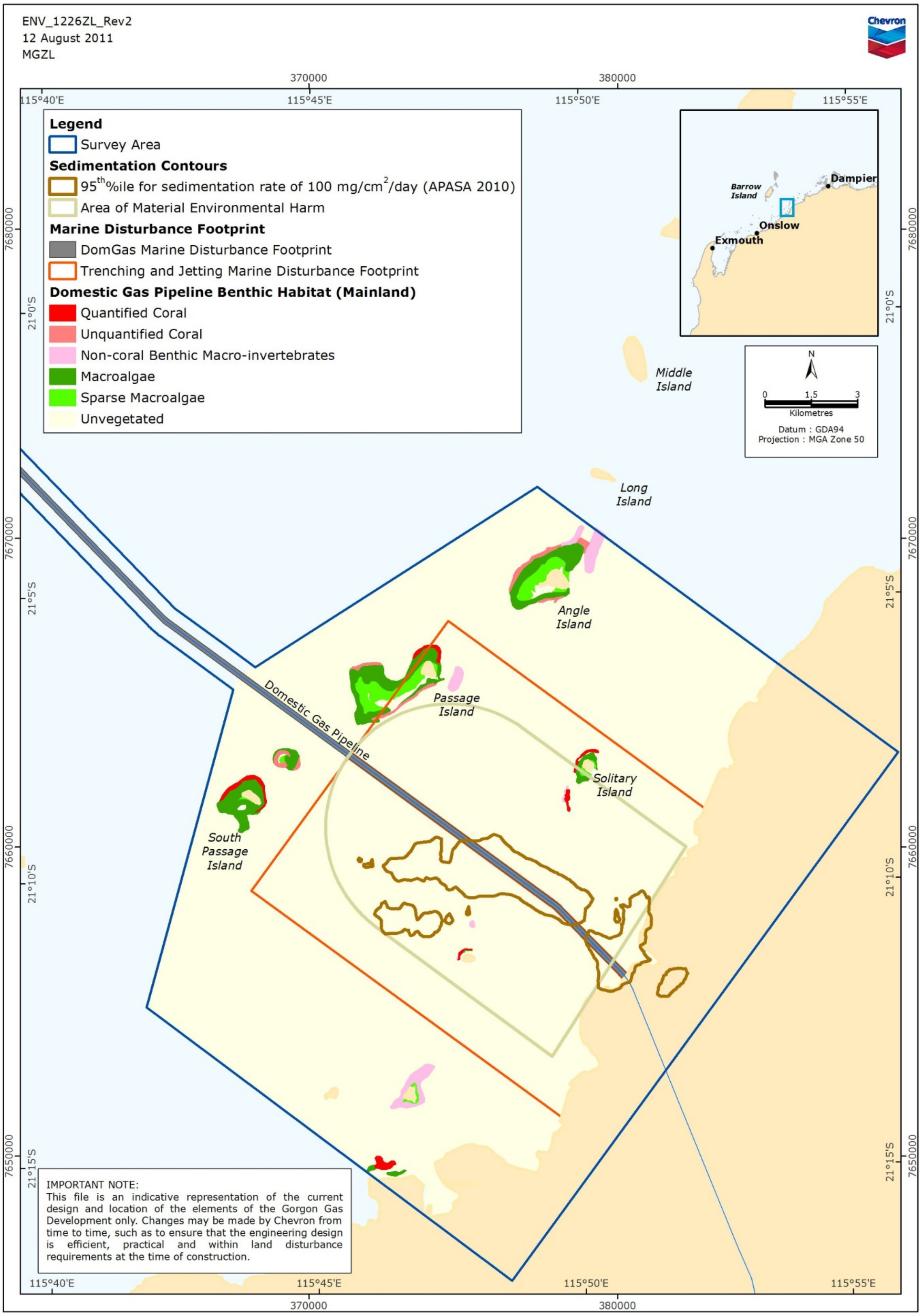



**Figure 2-6 Area of Material Environmental Harm for Surficial Sediment Characteristics**

### 2.3.5 Reference Sites outside the Zone of Influence

#### 2.3.5.1 Construction and Operation of the Domestic Gas Pipeline

Modelling (APASA 2010) indicates that the hydrodynamic and/or bathymetric characteristics adjacent to the pipeline route are reasonably similar for approximately 5–10 km either side. Thus, sites located 100 m to 500 m on either side of the pipeline route are considered as suitable areas for Reference Sites. Note that these sites will not be included as Reference Sites in any future analysis if there is evidence that they have been impacted by the construction of the DomGas Pipeline.

#### 2.3.5.2 Trenching and Jetting Activities

##### 2.3.5.2.1 Benthic Ecological Elements and Water Quality

To define suitable areas for the location of Reference Sites, which are not at risk of Material or Serious Environmental Harm due to trenching and jetting activities during the construction of the DomGas Pipeline, the modelled results for the 80$^{th}$ percentile of 2 mg/L and 95$^{th}$ percentile for 10 mg/L were used (Section 2.3.3.2.1). Given that the benthic ecological elements in the vicinity of the DomGas Pipeline trenching and jetting activities are likely to comprise a relatively limited number of species that can survive in waters that are naturally turbid most of the time, and that are also able to survive and/or rapidly recolonise after periods of elevated turbidity, such as those associated with cyclones and/or run-off from the rivers and creeks in the area, these are considered to represent a conservative interpretation of the level of natural variation in water quality that benthic ecological elements are adapted to, based on the available water quality data (Table 2-2 and Table 2-3). The area thus defined encompasses both contours and extends up to approximately 8 km to the west of the pipeline route; thus, where practicable this distance along the shore either side of the pipeline route was adopted as the minimum for the location of Reference Sites (Figure 2-5). Note that these sites will not be included as Reference Sites in any future analysis if there is evidence that they have been impacted by the generation of turbidity and sediment deposition from construction of the DomGas Pipeline.

Within this context, Reference Sites for each ecological element were, where practicable, selected based on:

- levels of abundance of the specific benthic ecological element at sites within the survey area, with sites selected to ensure that the benthic ecological element of interest was the dominant ecological element. For example, the coral survey sites were selected on the basis of high coral cover (preferably >20%) to maximise the number of replicate colonies available for survival and growth studies, with an area at least 10% coral cover extending at least 100 m to accommodate the transect-based survey design (Section 6.3.3)
- to encompass areas both north and south of the DomGas Pipeline route to achieve broad spatial coverage within the study area
- consideration of the environmental characteristics of the sites (e.g. water depth, distance offshore, exposure)
- Logistical constraints including suitability for vessel access and anchoring, tidal conditions, weather conditions and suitability for Surface-Supplied Breathing Apparatus (SSBA) diving operations (i.e. within reach of the umbilical).

A number of the Reference Sites were located offshore of the trenching and jetting Marine Disturbance Footprint.

##### 2.3.5.2.2 Mangroves

Noting the very conservative derivation of the area where mangroves are at risk of Material Environmental Harm, areas outside the 95$^{th}$ percentile of the 100 mg/cm$^2$/day sedimentation contour were considered to be suitable Reference Sites, which are not at risk of Material or Serious Environmental Harm due to trenching and jetting activities during the construction of the DomGas Pipeline (Section 2.3.3.2.1).

Two mangrove Reference Areas, one located to the south of the DomGas Pipeline and one to the north of the pipeline, were identified based an interpretation of available aerial imagery (1:5000) (Section 5.5; Figure 5-8). Reference Areas were selected to:

- encompass both the entrance and the immediate upper reach of the tidal creek system within which the baseline survey sites are located (Section 10.3.1)
- be of comparable extent as the area at risk of Material or Serious Environmental Harm, given both the size of the tidal creek systems and the number of baseline survey sites within the areas to be mapped
- contain a variety of mangrove locales, including areas of comparable composition, aspect and density, and areas of different composition, aspect and density to the baseline survey sites
- extend to the terrestrial margin of the mangrove population, in most cases.

Sites within the Reference Areas will not be included as Reference Sites in any future analysis if there is evidence that they have been impacted by the generation of turbidity and sediment deposition from construction of the DomGas Pipeline.

#### 2.3.5.2.3 Surficial Sediments

Noting the very conservative derivation of the area where surficial sediment characteristics are at risk of Material Environmental Harm, areas outside the 95$^{th}$ percentile of the 100 mg/cm$^2$/day sedimentation contour were considered to be suitable Reference Sites, which are not at risk of Material or Serious Environmental Harm due to trenching and jetting activities during the construction of the DomGas Pipeline (Section 2.3.3.2.3). Note that these sites will not be included as Reference Sites in any future analysis if there is evidence that they have been impacted by the generation of turbidity and sediment deposition from construction of the DomGas Pipeline.

#### 2.3.5.3 Reference Sites at Barrow Island

For ecological elements other than hard and soft corals, sites within the Zones of Influence associated with the generation of turbidity and sediment deposition from dredging and spoil disposal activities on the east coast of Barrow Island (Section 2.3.4), are considered to be Reference Sites because turbidity and sedimentation are not expected to cause Material or Serious Environmental Harm at these sites (Chevron Australia 2013a). Note that these sites will not be included as Reference Sites in any future analysis if there is evidence that they have been impacted by the generation of turbidity and sediment deposition from construction of, or dredging and spoil disposal activities required for, the Marine Facilities on the east coast of Barrow Island.

# 3.0 Marine Environment

## 3.1 Regional Overview

Barrow Island lies approximately 1200 km north of Perth and approximately 130 km west of Dampier and the Burrup Peninsula, within the Pilbara Offshore (PIO) Marine Bioregion (Integrated Marine and Coastal Regionalisation of Australia [IMCRA] Technical Group 1998) (Figure 3-1). Barrow Island is the largest of the group of islands, which include the Montebello and Lowendal Islands to the north-east. The Pilbara Offshore (PIO) Marine Bioregion covers an area of 41 491 $km^2$ west of the 10 m depth contour between North West Cape and Cape Keraudren (DEC 2007). The Pilbara Offshore (PIO) Marine Bioregion is characterised by a series of limestone islands on a wide continental shelf (IMCRA Technical Group 1998). The area around the Montebello Islands/Barrow Island contains reef ecosystems with Indonesian and Pacific affinities and is considered unique to this bioregion due to the complexity of substrate types, oceanographic conditions and habitat diversity (IMCRA Technical Group 1998; Brewer *et al*. 2007; DEC 2007). The area is considered to be relatively undisturbed due to low human use and successful management of industrial activities including oil and gas developments in the area (DEC 2007).

Waters inshore of the Pilbara Offshore (PIO) Marine Bioregion, from the mainland coast to 10 m water depth, comprise the Pilbara Near-shore Bioregion (IMCRA Technical Group 1998). This marine bioregion is comprised of intertidal mudflats and sand flats that have a high diversity of infauna, and are fringed by mangrove communities in protected bays and lagoons (IMCRA Technical Group 1998; Commonwealth Scientific and Industrial Research Organisation [CSIRO] 2007). There is a chain of small, offshore limestone islands, some of which are fringed by coral reefs (IMCRA Technical Group 1998). The shallow waters within the Pilbara Near-shore Bioregion experience relatively low wave energy, but are highly turbid due to the large tidal range (IMCRA Technical Group 1998; CSIRO 2007).

## 3.2 Conservation Areas

Barrow Island is a Class A nature reserve for the purposes of 'Conservation of Flora and Fauna' under the Western Australian (WA) *Conservation and Land Management Act 1984* (CALM Act). The *Barrow Island Act 2003* (WA) allows for the implementation of the Gorgon Gas Development and makes provision for areas on Barrow Island to be used for gas processing. Chevron Australia and predecessor companies have operated an oilfield on Barrow Island since the 1960s and this operation is expected to continue for another 15 to 20 years.

The State waters around Barrow Island are part of the Montebello Islands/Barrow Island Marine Conservation Reserves, with the exception of the Barrow Island Port Area on the east coast of the Island that contains most of the Gorgon Gas Development Marine Facilities (Figure 3-1). The Port of Varanus Island, located to the north-east of Barrow Island, is also excluded. These Conservation Reserves are reserved under the CALM Act (WA) and management of the reserves is guided by the Management Plan for the Montebello/Barrow Islands Marine Conservation Reserves 2007–2017 (DEC 2007). There are two categories of marine reserve in the waters around Barrow Island. The largest of these is the Barrow Island Marine Management Area, which includes one conservation area – the Bandicoot Bay Conservation Area located on the south coast of Barrow Island. The Bandicoot Bay Conservation Area includes the largest intertidal sand/mudflat community in the reserves and was established for the protection of benthic fauna and seabirds (DEC 2007). The remainder of the Barrow Island Marine Management Area is not zoned. The Barrow Island Marine Park lies on the west coast of Barrow Island, also within the Barrow Island Marine Management Area. The zoning of the Barrow Island Marine Park comprises one sanctuary zone, representing the entire marine park. The Western Barrow Island Sanctuary Zone includes Biggada Reef, an example of significant fringing reef that occurs in the reserves; and Turtle Bay, a significant aggregation/breeding area for Green Turtles (*Chelonia mydas*) and occasionally Hawksbill (*Eretmochelys imbricata*) and Flatback (*Natator depressus*) Turtles (DEC 2007).

The waters around Barrow Island support a diverse assemblage of tropical and subtropical marine fauna. Two major currents – the Leeuwin Current and the Indonesian Throughflow – have a strong influence on species distribution, recruitment and biological productivity in these waters (Kellogg Joint Venture Gorgon [KJVG] 2008). The Leeuwin Current and the Indonesian Throughflow create a biological connection between marine flora and fauna of the Montebello Islands/Barrow Island region and the more tropical environments to the north and east (DEC 2007). Consequently, most marine species in this region are widely distributed.

Located between Barrow Island and the mainland, the Great Sandy Islands Nature Reserve extends from Cape Preston to the mouth of the Robe River, and includes more than 30 small offshore islands (Chevron Australia 2010a). The Reserve covers the islands to the high water mark and does not include marine waters surrounding the islands. The islands are considered important nesting areas for some seabirds and turtles (Chevron Australia 2010a).

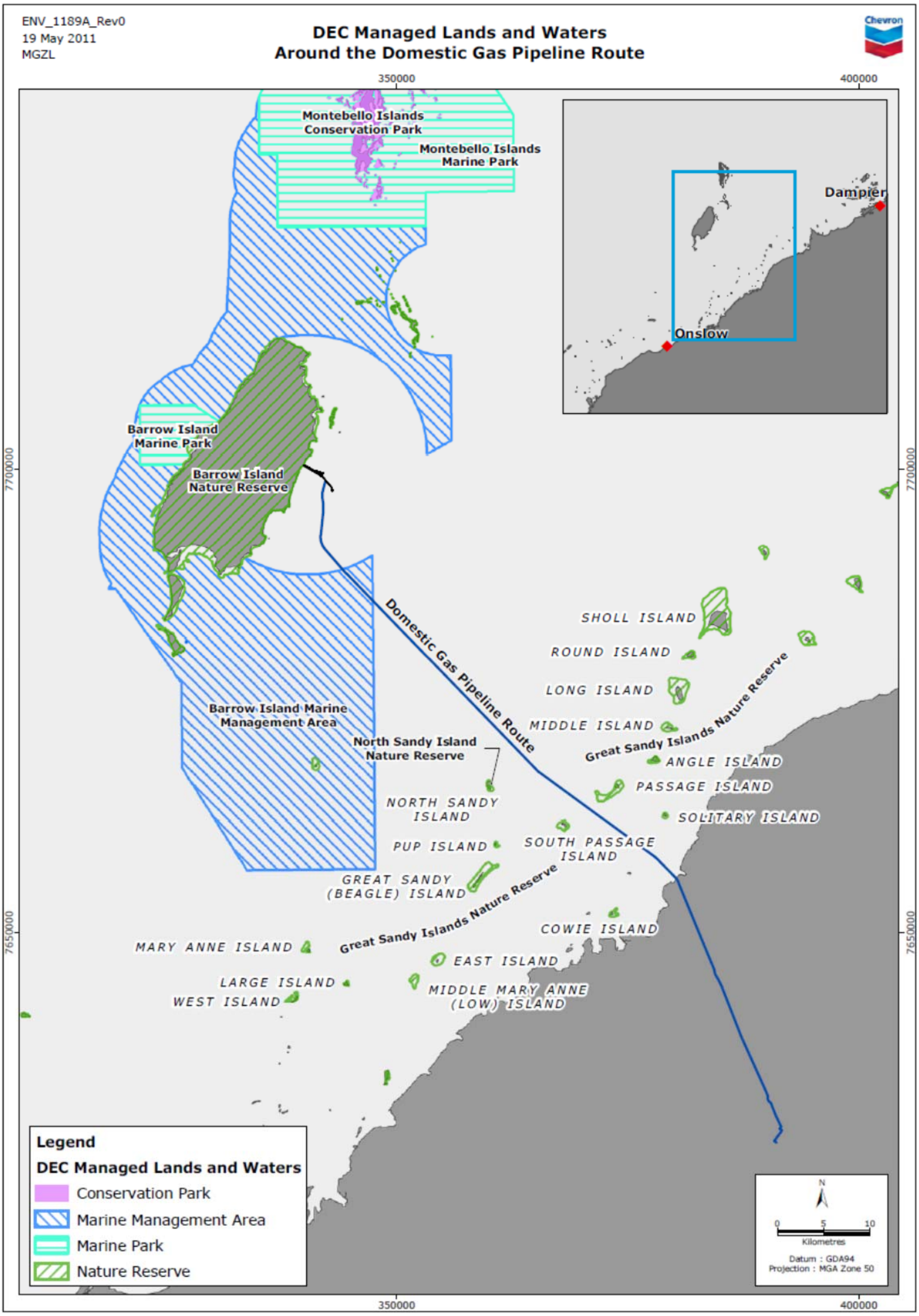



**Figure 3-1 Overview Map of Barrow Island, Gorgon Gas Development Marine Facilities and Marine Conservation Reserves**

### 3.2.1 Mangrove Management Areas

The EPA has defined a number of management areas for tropical arid zone mangroves along the Pilbara coast (EPA 2001). Four guidelines were established based on extent, diversity, ecological significance and nationally or internationally significant features. Each guideline is associated with specific requirements for management:

- Guideline 1: Regionally significant mangroves – Outside designated industrial areas and associated port areas.
- Guideline 2: Other mangrove areas – Outside designated industrial areas and associated port areas.
- Guideline 3: Regionally significant mangroves – Inside designated industrial areas and associated port areas.
- Guideline 4: Other mangrove areas – Inside designated industrial areas and associated port areas.

The nearest regionally significant mangrove area (included under Guideline 1) is approximately 6 km to the south of the DomGas Pipeline mainland shore crossing site, the Robe River Delta (Figure 3-2) (Chevron Australia 2005, 2006).

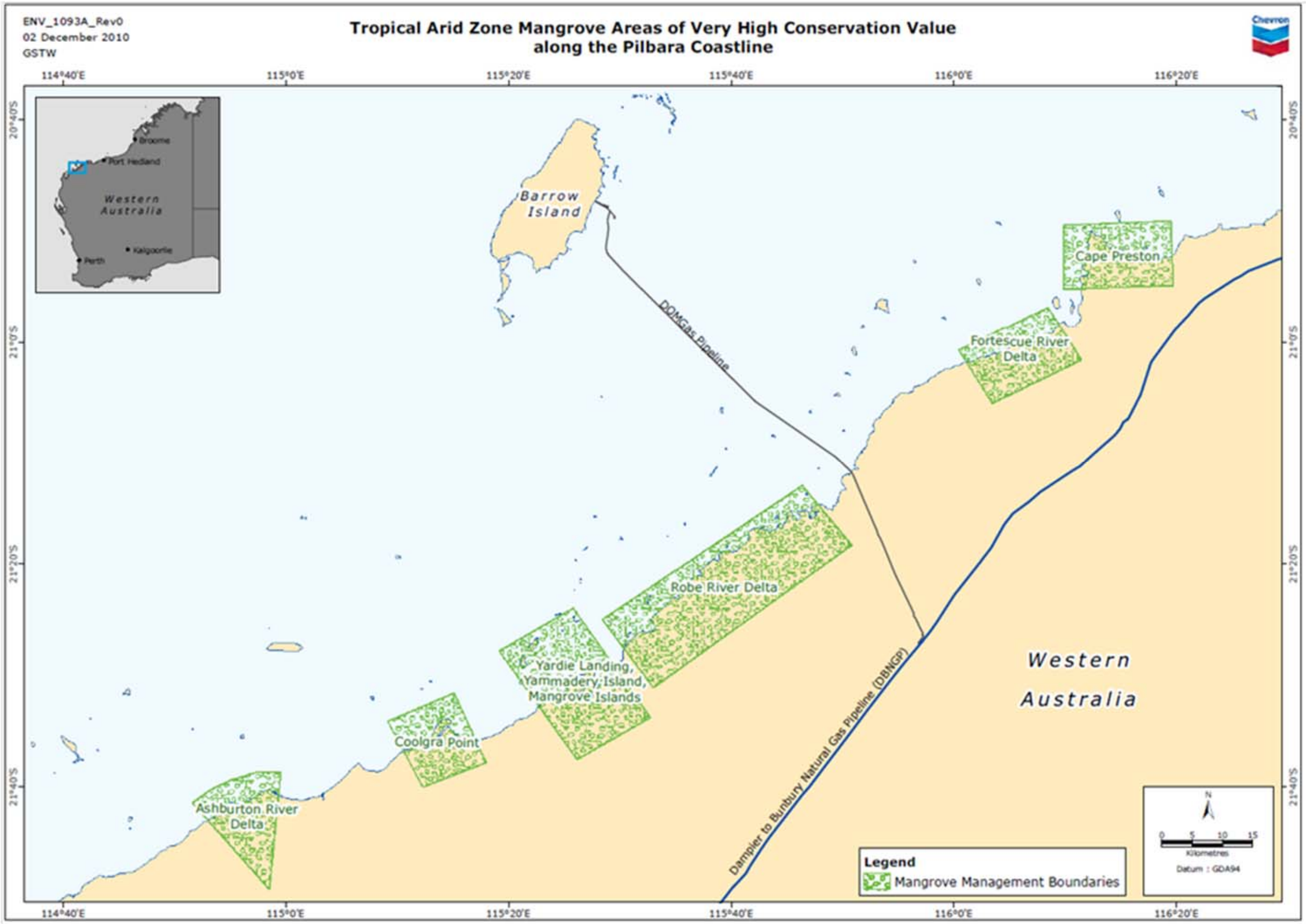



**Figure 3-2 Tropical Arid Zone Mangrove Areas of Very High Conservation Value along the Pilbara Coast (EPA 2001) and the Great Sandy Islands Nature Reserve**

## 3.3 Meteorology

Winds vary seasonally in north-western Australia, generally tending west in summer and south-east in winter (Pearce *et al.* 2003; APASA 2009a). The mean ambient wind speed around Barrow Island during the summer period (October–March) is 6.6 m/s and the maximum summer wind speed is 16.2 m/s (KJVG 2008). The dominant directions during summer are from the south-west and west. During winter (April–September), winds approach from the east, south, and south-west and have a mean speed of 5.8 m/s and a maximum speed of 19.4 m/s. The wind prevails from the south-west for more than 50% of the time (APASA 2009b). In general, wind speeds are <10 m/s for more than 90% of the time, but rarely fall below 1 m/s (2.2% of the time). Peak winds on Barrow Island occur in the range of 32 to 44 m/s and are associated with either very strong breezes or storms (APASA 2009b). Records from Onslow Airport Meteorological Station indicate that wind patterns on the mainland are consistent with those recorded at Barrow Island (APASA 2010).

The most extreme winds in the region occur during the passage of tropical cyclones that usually form in the Timor and Arafura seas between November and April (Pearce *et al.* 2003). They initially travel generally in a south-westerly direction, but their tracks become more variable as they travel further south (MetOcean Engineers 2006). Barrow Island is in a region of high tropical cyclone frequency, with an average of four cyclones passing within 400 nm of the Island each year (MetOcean Engineers 2006). Under extreme cyclone conditions, winds can reach over 250 km/h (APASA 2009b).

## 3.4 Climate

The mainland area where the DomGas Pipeline comes ashore is located within the arid, summer rainfall, subtropical zone and experiences moderate winters and very hot summers. The average maximum monthly temperature in summer (December to February) at the Bureau of Meteorology's station at Mardie (situated approximately half-way between Onslow and Karratha) is 37.7 °C and 28.5 °C in winter (June to August) (Bureau of Meteorology [BOM] 2011) Average annual rainfall over the period 1885 to 2011 is 272.2 mm (BOM 2011). On average, approximately 50% of all rainfall occurs between January and March, the majority of which is generated from cyclonic activity or rain-bearing tropical low pressure systems. Inter-annual variation in rainfall is large, with annual totals ranging from 8.7 mm in 1936 to 856.6 mm in 1995. Over the 12 months prior to the wet season surveys in March 2011, 718.4 mm was recorded at Mardie (BOM 2011). The majority of this rainfall (678.8 mm or 94.5%) fell in the three months prior to March. Overall, seasonal rainfall in the Pilbara region at the start of 2011 was above average, with some of the highest summer rainfall totals on record. This rainfall was primarily due to an active monsoon for much of the wet season. Four tropical cyclones were recorded off the Western Australian coast near Barrow Island during the 2010/2011 cyclone seasons (Figure 3-3):

- Tropical Cyclone Vince: Formed in the eastern Indian Ocean on 10 January 2011 and tracked west. Cyclone Vince reached Category 1 intensity and turned and tracked east/south-east between the 12 and 14 January, before weakening below cyclone intensity well offshore the northern WA coast (BOM 2011a).
- Tropical Cyclone Bianca: A tropical low that formed north of Broome intensified into Cyclone Bianca on 25 January 2011. Cyclone Bianca tracked west/south-west parallel to the Pilbara coast and intensified into a Category 3 cyclone on the 27 January 2011, north of Karratha. On 28 January 2011, Cyclone Bianca reached Category 4 west of Carnarvon, then tracked south/south-east towards Perth, while weakening in intensity, where the system further weakened to a low on 30 January 2011, approximately 375 km west/north-west of Perth (BOM 2011a).
- Tropical Cyclone Carlos: Formed near Darwin Harbour on 16 February 2011 and moved southwards to the WA/Northern Territory (NT) border on 19 February. After moving over Darwin, Cyclone Carlos weakened to a low then tracked across the northern Kimberley

offshore near Broome on 21 February 2011, where it rapidly regained intensity to a Category 1 cyclone. Cyclone Carlos intensified to Category 2 and crossed the coast at midday 22 February 2011 near Karratha. The cyclone continued to track along the Pilbara coast and passed over the north-west coast south of Exmouth on 23 February 2011. Cyclone Carlos generated heavy rainfall across the north-west, including Barrow Island, which recorded 283 mm of rainfall within a 24-hour period on 23 February 2011 (BOM 2011a).

- Tropical Cyclone Dianne: Formed on 16 February 2011 approximately 400 km north-west of Exmouth. Cyclone Dianne intensified into a Category 2 cyclone and tracked south-west as it intensified into a Severe Tropical Cyclone (Category 3) at 08:00 WST on 19 February 2011. Cyclone Dianne continued to track south-west to 1200 km west of Geraldton where it weakened steadily to below cyclone intensity on 22 February 2011 (BOM 2011a).

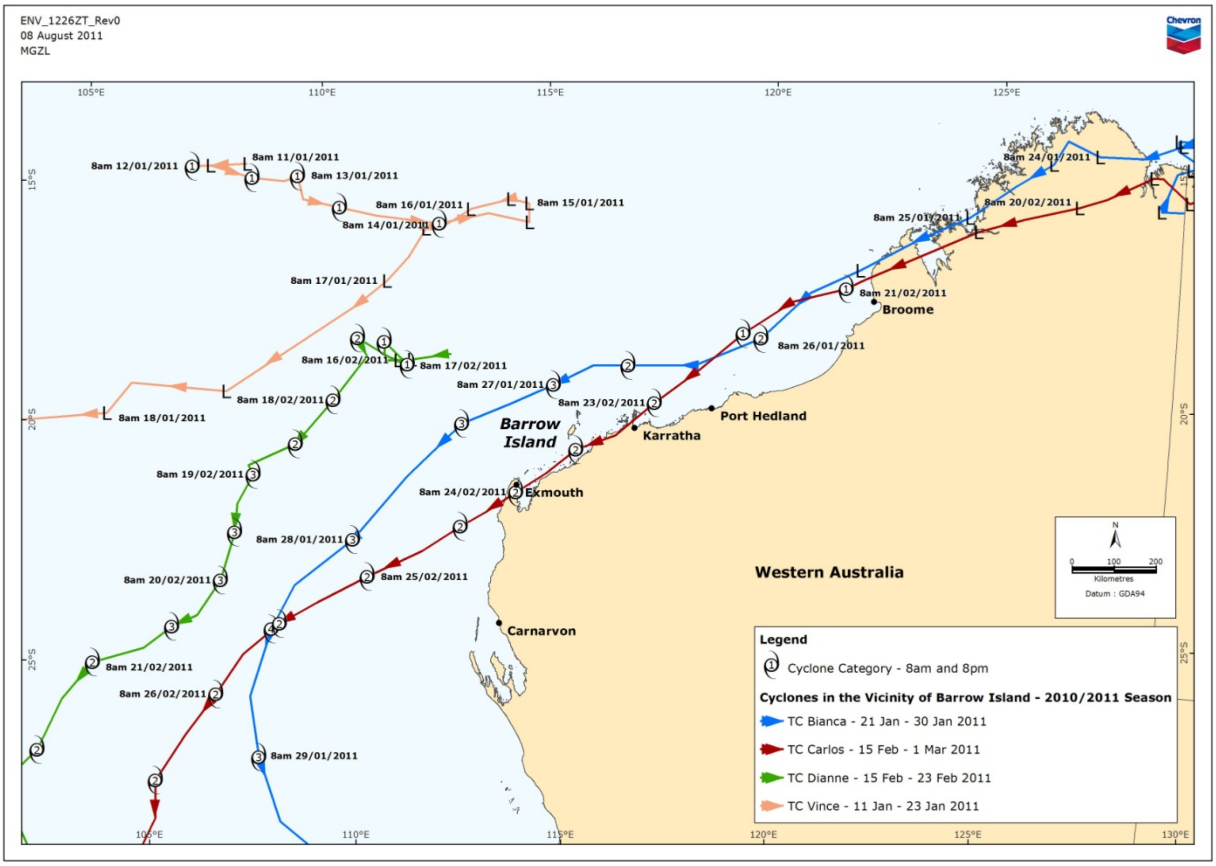



**Figure 3-3 Tracks of Tropical Cyclones that passed near Barrow Island during the 2010/2011 Cyclone Season**

## 3.5 Oceanography

### 3.5.1 Bathymetry

Barrow Island lies on the shallow (generally <5 m deep) limestone shelf that underlies the whole of the Montebello Islands/Barrow Island group. There is a broad intertidal platform adjacent to the Island, which grades slowly to the subtidal limestone shelf (Chevron Australia 2005). Water depths between the islands and the mainland generally do not exceed 20 m, with the majority of the DomGas Pipeline located in water depths 10–15 m (Chevron Australia 2005; URS 2009). Water depths on the west coast of Barrow Island increase rapidly from the shore down to the

20 m isobath. Water depths along the Offshore Feed Gas Pipeline System on the west coast of the Island reach approximately 25 m at the limit of State waters.

### 3.5.2 Tides

Astronomic tides in the Barrow Island region are semidiurnal, comprising two high tides and two low tides per day (Chevron Australia 2005; APASA 2009a). The tidal range varies significantly around Barrow Island with a maximum spring tide range on the east coast of just over 4 m, whilst on the west coast the tidal range is <2.5 m (Australian Geological Survey Organisation 1988; Australian Hydrographic Service 2008; KJVG 2008; APASA 2009a). The significant tidal ranges and shallow bathymetry result in large areas of exposed seabed at low tide (West Australian Petroleum 1989). The Pilbara is thought to have the strongest internal tides of the entire North-west Marine Region, extending from offshore Kalbarri to the WA/NT border (DEWHA 2007).

The direction of tidal currents at Barrow Island is a flood flow towards the south-west and an ebb flow towards the north-east (ChevronTexaco Australia 2003). As a result of the shallow bathymetry, the flood tide cannot fully propagate to the coast across the Barrow Island Shoals to the south-east, or through the channels between Barrow Island and the Montebello Islands. A large water flux is forced northward along the western side of Barrow Island and then flows to the coast around the northern end of the Montebello Islands. This produces a southward-flowing flood tide on the east coast of the Montebello Islands and Barrow Island. There is a region near the south-eastern end of Barrow Island where this flow meets the flow coming across the Barrow Island Shoals and these flow towards the coast. The ebb tide behaves approximately in reverse to the flood tide, with the majority of the water flux flowing up the eastern side of the Lowendal Shelf and around the northern end of the Montebello Islands. This tidal flow is the major flushing mechanism for waters from the eastern side of Barrow Island into the open sea.

Wind events also drive episodic non-tidal flow events in the nearshore and in deeper waters off the Montebello Islands/Barrow Island, where tidal influences are weaker, or during neap tides (APASA 2009b, 2010). The shallow waters along the DomGas Pipeline route are dominated by tidal forcing that is characteristic of a tide-dominated estuarine environment (APASA 2010). Strong tidal currents are generated by large tidal ranges (up to 6 m) along the Pilbara coast (Holloway 1983), which result in highly turbid waters (APASA 2010).

### 3.5.3 Currents

Long-term circulation patterns on the North West Shelf are influenced to the north by the Indonesian Throughflow (Cresswell *et al.* 1993) and to the west by the Leeuwin Current (Godfrey and Ridgway 1985). The surface water mass moves along the Pilbara coast in a predominantly southward direction, which becomes the source waters of the Leeuwin Current (DEWHA 2007). However, tidal motions generally dominate daily current patterns on the North West Shelf, with semidiurnal flows up to 1 m/s and tidal ranges up to 6 m on the Pilbara coast (Holloway 1983, 1995). These movements are mostly in the north–south direction, except in the vicinity of Montebello/Barrow Islands where they are orientated closer to the east–west direction (Margvelashvili *et al*. 2006). Wind-forced currents become dominant around the neap tide and during tropical cyclones when surface current speeds can exceed 3 m/s (Margvelashvili *et al*. 2006). Near-surface current speeds are generally in the range of 5 to 20 cm/s (Condi *et al*. 2006).

The instantaneous current patterns on the eastern side of Barrow Island are strongly dominated by the tide and its spring–neap cycle. Strong currents flow through the channel that separates Barrow Island and the Lowendal Islands. These currents flow east–west with each flooding/ebbing tidal cycle (APASA 2009a).

On the western side of Barrow Island, the balance of the driving forces for ocean currents can be more complex (Global Environmental Modelling Systems [GEMS] 2006). The tidal currents are weaker, particularly in the deeper waters, but satellite imagery indicates that phenomena associated with large-scale ocean circulations in the Indian Ocean, such as eddies and other geostrophic flows, can impinge on the region. The wave-driven longshore currents on the west coast of Barrow Island are mostly northward, with a peak magnitude of around 0.3 to 0.4 m/s (APASA 2009b). Episodic reversals of the longshore current direction occur during winter, as waves driven by north-west storm winds generate southward currents (APASA 2009b). Wave-driven longshore currents are likely to be an important contributor to sediment dispersion along the west coast of Barrow Island (APASA 2009b).

Tidal currents also appear to dominate along the DomGas Pipeline route. Current speeds are generally lower than those recorded at Barrow Island and current direction appears to vary (APASA 2009a). Modelling conducted by the Chevron Energy Technology Company (Chevron ETC 2008) indicates that the median tidal current along the DomGas Pipeline route is generally <0.20 m/s, and the 10% exceedance tidal current is 0.35 m/s. Wind-induced currents are likely to contribute to tidal current speeds, but are most likely only significant during storm events (Chevron ETC 2008).

### 3.5.4 Waves

Local wind-generated seas have variable wave heights, typically ranging from zero to 4 m under non-tropical cyclone conditions (APASA 2009b). Typically, wave heights at Barrow Island are within the range 0.2–0.5 m, with peak periods of 2–4 s (RPS MetOcean 2008). Maximum wave heights are mostly a result of tropical cyclones, which can generate waves in a radial direction out from the storm centre and may therefore generate swell from any direction, with wave heights ranging from 0.5 to 9.0 m (APASA 2009b).

The eastern side of Barrow Island is largely sheltered from ocean swells by Barrow Island, the Lowendal Shelf, and the shallow bathymetry between Barrow Island and the mainland (ChevronTexaco Australia 2003; KJVG 2008). The ambient nearshore wave climate is dominated by locally generated sea states derived from easterly sea breezes between the mainland and Barrow Island, which mostly occur during winter. These cause a direct setup of waves against the east coast of Barrow Island and are the most effective in directing wave energy onto the nearshore zone.

The south-western to north-western sides of Barrow Island are exposed to the open ocean and a relatively vigorous wave climate, bringing long-period Southern Ocean swells and shorter period local wind waves, particularly during times of sustained southerly winds. The Southern Ocean swell (also referred to as the Indian Ocean swell) typically arrives at the outer edge of the continental shelf from the south and south-west, before refracting over shallower parts of the shelf and approaching Barrow Island from the west, north-west, or north (APASA 2009b). At times, the Southern Ocean swell can refract around the northern and southern ends of Barrow Island, but the shallow bathymetry prevents significant propagation (ChevronTexaco Australia 2003). The surf zone in the vicinity of the shore crossing on the west coast of Barrow Island is generally 100–150 m wide, sometimes extending more than 200 m offshore (APASA 2009b).

Wave heights in the shallow waters adjacent to the Western Australian mainland are generally <1 m and only exceed this height during storm events (APASA 2010). The generally low wave heights are probably because the area is sheltered by Barrow Island, the shallow underwater ridges between Barrow Island and the mainland, and the islands along Mary Anne Passage (APASA 2010). Locally generated wind sea waves occur with mean periods of 4–8 s (APASA 2010). When the sea breeze is dominant, wind sea waves come from the south-west (APASA 2010).

### 3.5.5 Sea Surface Temperatures

Sea surface temperatures in the Barrow Island area vary seasonally, reaching temperatures of 28–29 °C during summer and cooling to 23–24 °C during winter (APASA 2009a). During the summer months, temperature profiles are thermally stratified to a depth of 50 m (APASA 2009a). By August (during winter), the water column is thermally uniform to the 50 m depth (APASA 2009a). Between Barrow Island and the mainland, temperatures range from 21–31 °C, with peak temperatures from late February to March, and minimum temperatures during July and August (Chevron ETC 2008). Mean temperatures of 24–25 °C have been recorded at approximately 4–5 m water depth. These are slightly lower than annual mean sea surface temperatures recorded off the west coast of Barrow Island (26.4 °C recorded at 0 m and 26.2 °C recorded at 20 m) (Santala 2008, 2008a; cited in Chevron ETC 2008).

## 3.6 Seabed Topography and Sediment Characteristics

Regionally, sediments are dominated by marine carbonates, with the highest carbonate contents associated with reefs and algal banks (DEWHA 2007). The outflow from rivers in the form of terrigenous sediments also influences the inner North West Shelf (Baker *et al.* 2008). Sediments in coastal waters that experience strong currents tend to exhibit higher gravel content in contrast to shallower areas, which have higher sand content (DEWHA 2007).

On the east coast of Barrow Island, the intertidal limestone reef flats and shallow pavement reef are variably covered by sand, gravel and coral, with scattered pinnacles. Bare sands overlay limestone pavements in many parts of the area, with exposed pavement and more rubble in areas where water currents are stronger (Chevron Australia 2005). The thickness of the unconsolidated sediments overlying the limestone pavements ranges between 0.5 m and 3 m (Chevron Australia 2005). The thicker sediment layers are in deeper water off the nearshore platform (Chevron Australia 2005).

Off the west coast of Barrow Island, the seabed topography in water depths <30 m is relatively level with some areas of relief between 25 and 20 m water depth (Fugro Survey 2005). The seabed then becomes undulating and slopes gently up from 20 m water depth (800 m offshore) to 5 m water depth (240 m offshore), with average seabed gradient ranging from approximately 0.1° in 20 m to 17 m water depth to 0.9° in shallower waters. In water depths <5 m, the seabed rises sharply, with a maximum gradient of 3° at a water depth of <2 m. The seabed off the west coast of Barrow Island consists of a patchy thin (<1 m) veneer of unconsolidated carbonate sand/fine gravel overlying variably cemented calcarenite/caprock in waters between 20 m and 40 m (Technip and JP Kenny 2009). Further offshore (to depths of 55 m) there are local depressions within which thicker (up to 5 m thick) layers of carbonate sand/gravely sand accumulate.

The substrate in the shallow coastal waters between the mainland and Barrow Island consists of gently inclined Pleistocene limestone, which extends a few kilometres offshore and is interspersed with limestone reefs and small islands that support coral communities (CSIRO 2007). Along the DomGas Pipeline route, the seabed is relatively flat and comprises areas of unconsolidated sediments overlying variably cemented calcarenite substrate, bare sand with occasional rocky outcrops, and limestone pavement reef with a veneer of sand (Chevron Australia 2005). The sediments are calcareous and range from fine sands through to coarse sands with shells and shell fragments (Chevron Australia 2005).

Intertidal areas adjacent to the Western Australian mainland are characterised by muddy substrates largely derived from land run-off (CSIRO 2007). Sand flats and mudflats cover pavement reef, which extends seaward of, and within, the mangrove zone that fringes the Pilbara coast (Chevron Australia 2005). The mangrove zone is regularly dissected by muddy tidal creeks that extend inland. These tidal creeks are highly turbid as a result of the large tidal range (Chevron Australia 2005; APASA 2010). The tides induce strong turbulence that results in sediment resuspension, and transports sediments back and forth with each tidal cycle (APASA 2010). Surveys near the DomGas Pipeline mainland shore crossing recorded levels of suspended sediments in the near-bottom waters ranging from 20 mg/L to 100 mg/L, and surface levels ranging from 5 mg/L to 30 mg/L (APASA 2009). Suspended sediment concentrations in the nearshore regions adjacent to the mainland are considered approximately one or two orders of magnitude greater than the ambient levels characteristic of the offshore marine environment surrounding Barrow Island.

Terrestrial run-off to the marine environment is generally very low in the Pilbara region, but shows strong peaks during cyclones (Condie *et al*. 2006; DEWHA 2007). Cyclones are a major climatic feature of the Pilbara region, and are known to enhance sediment resuspension rates and increase sediment loads in rivers, producing extremely turbid conditions (Margvelashvili *et al*. 2006). Sediment modelling under cyclonic conditions in the Pilbara region indicates that the presence of a cyclone significantly changed the thermohaline structure, circulation patterns and suspended sediment distribution in the region, and that peak fluxes in Total Suspended Sediments (TSS) coincided with cyclone events (Margvelashvili *et al*. 2006).

# 4.0 General Approach to Methods

## 4.1 Introduction

Coastal and marine baseline surveys for the Gorgon Gas Development have been conducted in Barrow Island waters since 2003. The Marine Baseline Program required under Condition 14 of Statement No. 800 and Condition 11 of EPBC Reference: 2003/1294 and 2008/4178, was initiated in November 2007 around Barrow Island, and in December 2008 in the vicinity of the mainland shore crossing for the Domestic Gas (DomGas) Pipeline.

The Marine Baseline Program has been designed to provide baseline data for the:

- Marine Facilities Construction Environmental Management Plan (Chevron Australia 2012) required under Condition 17 of Statement No. 800 and Condition 13 of EPBC Reference: 2003/1294 and 2008/4178
- Protection of Coral and Coral Assemblages (Chevron Australia 2010) required under Condition 18 of Statement No. 800
- Dredging and Spoil Disposal Management and Monitoring Plan (Chevron Australia 2011) required under Condition 20 of Statement No. 800 and Condition 14 of EPBC Reference: 2003/1294 and 2008/4178
- Initial Water Quality Criteria for Dredging and Spoil Disposal Activities (Chevron Australia 2010b) required under Condition 21 of Statement No. 800
- Horizontal Directional Drilling Management and Monitoring Plan (Chevron Australia 2011a) required under Condition 22 of Statement No. 800, Condition 13 of Statement No. 769, Condition 15 of EPBC Reference: 2003/1294, 2008/4178 and 2005/2184
- Offshore Feed Gas Pipeline Installation Management Plan (Chevron Australia 2013) required under Condition 23 of Statement No. 800, Condition 14 of Statement No. 769, Condition 16 of EPBC Reference: 2003/1294, 2008/4178 and 2005/2184
- Offshore Domestic Gas Pipeline Installation Management Plan (Chevron Australia 2014) required under Condition 23 of Statement No. 800 and Condition 16 of EPBC Reference: 2003/1294 and 2008/4178
- Marine Environmental Quality Management Plan (required by Condition 23A of Statement No. 800)
- Post-development Coastal and Marine State and Environmental Impact Report (required by Condition 24 of Statement No. 800, Condition 15 of Statement No. 769, and Condition 17 of EPBC Reference: 2003/1294 and 2008/4178).

## 4.2 Sampling Sites

The Marine Baseline Program has been designed to include sites that are potentially at risk of Material or Serious Environmental Harm due to the construction and operation of the DomGas Pipeline, as well as Reference Sites that are not at risk of Material or Serious Environmental Harm due to the construction and operation of the DomGas Pipeline (Section 2.3.3). Based on the findings from the benthic habitat mapping along the pipeline route, which indicates that for much of the pipeline route the offshore seabed is 'open bare sand with minimal biota' (Section 5.3), and that, with the exception of trenching and jetting activities at the mainland shore crossing, marine construction activities for the DomGas Pipeline involve activities (e.g. pipelaying) that generate little or no turbidity over most of the pipeline route (Section 2.3.3), the focus of the Marine Baseline Program for the DomGas Pipeline has therefore been on:

- describing and mapping the benthic ecological elements (i.e. hard and soft corals, non-coral benthic macroinvertebrates, macroalgae, seagrass, mangroves and surficial sediments) that are potentially at risk of Material or Serious Environmental Harm from pipeline installation activities (trenching and jetting) at the mainland shore crossing

- describing the ecological elements (i.e. demersal fish and water quality) that are potentially at risk of Material or Serious Environmental Harm from pipeline installation activities (trenching and jetting) at the mainland shore crossing
- describing and mapping the benthic ecological elements (i.e. hard and soft corals, non-coral benthic macroinvertebrates, macroalgae, seagrass, mangroves and surficial sediments) at Reference Sites that are not at risk of Material or Serious Environmental Harm from pipeline installation activities (trenching and jetting) at the mainland shore crossing
- describing the ecological elements (i.e. demersal fish and water quality) at Reference Sites that are not at risk of Material or Serious Environmental Harm from pipeline installation activities (trenching and jetting) at the mainland shore crossing
- describing and mapping the benthic ecological elements (i.e. hard and soft corals, non-coral benthic macroinvertebrates, macroalgae, seagrass and surficial sediments) that are potentially at risk of Material or Serious Environmental Harm from pipeline installation activities (pipelay and stabilisation) on the east coast of Barrow Island
- describing the ecological elements (i.e. demersal fish and water quality) that are potentially at risk of Material or Serious Environmental Harm from pipeline installation activities (pipelay and stabilisation) on the east coast of Barrow Island
- describing and mapping the benthic ecological elements (i.e. hard and soft corals, non-coral benthic macroinvertebrates, macroalgae, seagrass and surficial sediments) at Reference Sites that are not at risk of Material or Serious Environmental Harm from pipeline installation activities (pipelay and stabilisation) on the east coast of Barrow Island
- describing the ecological elements (i.e. demersal fish and water quality) at Reference Sites that are not at risk of Material or Serious Environmental Harm from pipeline installation activities (pipelay and stabilisation) on the east coast of Barrow Island.

The baseline survey information presented in this Report for the east coast of Barrow Island is that collected during the Marine Baseline Program for the MOF, LNG Jetty and Dredge Spoil Disposal Ground prior to the commencement of construction, dredging and spoil disposal activities in May 2010 (Chevron Australia 2013a). A number of the sites on the east coast of Barrow Island within the vicinity of the DomGas Pipeline are also located within the Dredge Management Areas (Section 2.3.4). These sites are thus predicted to be at risk of direct disturbance during dredging and spoil disposal activities or from infrastructure construction activities, or at risk of indirect disturbance due to increased sedimentation and/or deterioration in water quality associated with dredging and spoil disposal activities. This information is presented in this Report to provide a complete set of baseline data for the length of the DomGas Pipeline route from the east coast of Barrow Island to the mainland shore crossing to meet the requirements of Condition 14 of Statement No. 800 and Condition 11 of EPBC Reference: 2003/1294 and 2008/4178.

The location of the Marine Facilities and information from the existing broadscale benthic habitat map of the Montebello/Barrow Islands area (DEC 2007), a variety of remote sensing and ground-truthing data (Section 5.0), as well the output from sediment fate modelling of trenching and jetting activities at the mainland shore crossing (Section 2.3.2.2), were used to assist in the selection of baseline survey sites for all of the ecological elements. At the mainland end of the DomGas Pipeline route, where practicable, survey sites for each ecological element were selected in areas at risk of Material or Serious Environmental Harm within the Marine Disturbance Footprint associated with trenching and jetting activities (Section 2.3.3.2), as well as at Reference Sites not at risk of Material or Serious Harm and outside the Marine Disturbance Footprint associated with trenching and jetting activities (Section 2.3.5). Where practicable, sites were selected to encompass areas both north and south of the DomGas Pipeline route to achieve broad spatial coverage within the study area, and in comparable environmental conditions (e.g. water depth, distance off shore, wave exposure). The locations of the baseline survey sites were constrained by the suitability of sites for vessel anchoring, the reach of Surface-Supplied Breathing Apparatus (SSBA) umbilical hoses, water depth, tidal conditions, time constraints and site accessibility.

## 4.3 Sampling Frequency and Temporal Scope

The sampling frequency and temporal scope for each ecological element surveyed during the Marine Baseline Program at the mainland end of the DomGas Pipeline route are summarised in Table 4-1. For information on sampling frequency and temporal scope for each ecological element surveyed on the east coast of Barrow Island, refer to the relevant sections in this Report and the Coastal and Marine Baseline State and Environmental Impact Report (Chevron Australia 2013a). Sampling frequency was designed to account for predicted seasonal differences over one annual cycle, with the majority of surveys conducted during the Pilbara dry season (April to November) and wet season (late November to early April). Other ecological elements without predicted seasonal influences, such as surficial sediments, were sampled on different occasions during the baseline period.

**Table 4-1 Summary of the Marine Baseline Program for Sites at the Mainland Shore Crossing for the DomGas Pipeline**

| Ecological Element | Survey Type/Method | Sampling Program | Temporal Scope |
|---|---|---|---|
| Hard and soft corals (Section 6.0) | Mapping and ground-truthing | Throughout survey area | Dry season 2010 – Wet season 2011 |
| | Rapid Visual Assessment (RVA) | Once at 2 Reference Sites and 2 sites at risk of Material or Serious Environmental Harm | Wet season 2011 |
| | Coral size-class frequency transect surveys | Once at 2 Reference Sites and 2 sites at risk of Material or Serious Environmental Harm | Dry season 2010 |
| | Coral growth (photo-quadrats, tagged colonies) | Measured over approximately 5 months at 2 Reference Sites and 2 sites at risk of Material or Serious Environmental Harm | Dry season 2010 and Wet season 2011 |
| | Coral survival (photo-quadrats, tagged colonies) | | Dry season 2010 and Wet season 2011 |
| | Coral recruitment tiles | 8–10 weekly intervals at 2 Reference Sites and 2 sites at risk of Material or Serious Environmental Harm, with some tiles deployed for up to approximately 12 weeks | Dry season 2010 – Wet season 2011 |
| Non-coral benthic macroinvertebrates (Section 7.0) | Video transects | Twice at 3 Reference Sites and 3 sites at risk of Material or Serious Environmental Harm | Dry season 2010 and Wet season 2011 |
| Macroalgae (Section 8.0) | Photo-quadrats and biomass | Twice at 2 Reference Sites and 2 sites at risk of Material or Serious Environmental Harm | Dry season 2010 and Wet season 2011 |

| Ecological Element | Survey Type/Method | Sampling Program | Temporal Scope |
|---|---|---|---|
| Seagrass (Section 9.0) | | One Reference Site and 1 site at risk of Material or Serious Environmental Harm surveyed in the dry season, and 2 Reference Sites and 2 sites at risk of Material or Serious Environmental Harm surveyed in the wet season | Dry season 2010 and Wet season 2011 |
| Mangroves (Section 10.0) | Vegetation surveys | Twice at 4 Reference Sites and 4 sites at risk of Material or Serious Environmental Harm | Dry season 2010 and Wet season 2011 |
| Demersal fish (Section 11.0) | Baited remote underwater stereo-video (stereo-BRUVs) systems (coral, non-coral benthic macroinvertebrates, macroalgae and seagrass) | Fifteen sites (8 Reference Sites and 7 sites at risk of Material or Serious Environmental Harm) in the dry season, and 17 sites (9 Reference Sites and 8 sites at risk of Material or Serious Environmental Harm) in the wet season | Dry season 2010 and Wet season 2011 |
| | Seine nets and cast (throw) nets (mangroves) | Four Reference Sites and 3 sites at risk of Material or Serious Environmental Harm surveyed in the dry season, and 4 Reference Sites and 4 sites at risk of Material or Serious Environmental Harm surveyed in the wet season | Dry season 2010 and Wet season 2011 |
| Surficial sediments (Section 12.0) | Sediment sampling | 48 sites | Wet season 2011 |
| Water quality (Section 13.0) | Photosynthetically Active Radiation (PAR); Secchi depth; water column profiles: turbidity, depth, salinity and temperature; Total Suspended Solids | Fifteen sites along three shore-perpendicular transects at risk of Material or Serious Environmental Harm, and 10 sites along two shore-perpendicular Reference Transects | Dry season 2010 and wet season 2011 (spring and neap tides); reduced sampling post-cyclone event in February 2011 |

It is important to note that, while complementary and centred on the same sites, the different methods used in the Marine Baseline Program assessed coral communities at different scales. Thus, Rapid Visual Assessments qualitatively assessed coral communities over larger spatial scales (over hundreds of metres) and provide greater taxonomic resolution; while transects recorded coral community information more precisely on a more restricted spatial scale (50 m radius) with less taxonomic resolution.

## 4.4 Basis of Program Design

The Marine Baseline Program has been designed to provide a baseline dataset that may be used to underpin the development of a marine monitoring program to detect changes to ecological elements outside the Marine Disturbance Footprint for the (Offshore) Domestic Gas Pipeline, to meet the requirements of Condition 23.5.ix of Statement No. 800 and Condition 16.5.IX of EPBC Reference: 2003/1294 and 2008/4178. Baseline surveys were conducted in accordance with the methods described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800, Condition 12.1, Statement No. 769, and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178. Any variations to the approved methods, due to constraints associated with the specific conditions at the mainland end of the DomGas Pipeline route are described in the relevant Sections of this Report.

The basis of the design has been to provide the potential for pre- and post-construction data to be analysed using the Multiple Before–After, Control–Impact (MBACI) approach of Keough and Mapstone (1995). This approach involves statistical analyses that test for an interaction between predicted impact and reference areas across periods of time before and after predicted impacts occur. The design approach can be used to detect whether changes (before–after DomGas Pipeline construction activities) at one or more impact sites are greater than natural changes (before–after DomGas Pipeline construction activities) across reference sites. Potential impact and reference sites have been surveyed as part of the Marine Baseline Program during the period prior to the commencement of DomGas Pipeline construction activities. Sampling may then be repeated after the completion of DomGas Pipeline construction activities. The main hypothesis being tested is that there is a change at impact site(s) between before-and-after the DomGas construction activities, which are greater than the natural changes occurring over the same time period at reference sites.

## 4.5 Scientific Expertise

The Marine Baseline Program was undertaken by personnel from Aquenal, Oceanica Consulting Pty (water quality) and Astron Environmental Services (mangroves), supported by DOF Subsea. These surveys also drew extensively on the expertise of several technical specialists, as listed in Table 4-2.

**Table 4-2 Technical Specialists Involved in the Marine Baseline Program for the DomGas Pipeline**

| Ecological Element | Technical Specialists | Affiliation | Contribution to the Marine Baseline Program |
|---|---|---|---|
| Hard and soft corals | Dr David Blakeway<br>Mr Mike Byers<br><br>Dr Jim Stoddart | MScience | Implementation of coral field surveys, data analysis, interpretation and reporting<br>Technical review |
| | Ms Sasha Migus | Aquenal | Implementation of field surveys |
| | Dr Zoe Richards | Australian Museum | Implementation of RVA coral surveys, data analysis, interpretation and reporting |
| | Dr Terry Done | Australian Institute of Marine Science | Implementation of coral field surveys, taxonomic identifications |
| Non-coral benthic macroinvertebrates | Mr Sam Ibbott | Aquenal/Marine Solutions | Implementation of field surveys |
| | Dr Jane Fromont | Western Australian Museum | Specialist taxonomic identification of sponges |
| | Dr Philip Alderslade | CSIRO Marine Research | Specialist taxonomic identification of octocorals |
| | Dr Philip Bock | Specialist taxonomist | Specialist taxonomic identification of bryozoans |

| Ecological Element | Technical Specialists | Affiliation | Contribution to the Marine Baseline Program |
|---|---|---|---|
| | Dr Graham Edgar | Aquenal | Technical Review |
| Macroalgae and seagrass | Dr Joe Valentine<br>Dr Graham Edgar | Aquenal | Implementation of field surveys, data analysis, interpretation and reporting<br>Technical Review |
| | Dr John Huisman | Western Australian Herbarium/School of Biological Sciences and Biotechnology, Murdoch University | Specialist taxonomic identification of macroalgae and seagrass |
| | Dr Hugh Kirkman | Independent Specialist Consultant | Implementation of field surveys; specialist taxonomic identification of seagrass |
| Mangroves | Mr Brian French | Aquenal/ECOtas | Implementation of mangrove field surveys |
| | Associate Professor Norm Duke | University of Queensland | Implementation of mangrove field surveys; specialist taxonomic identification of mangroves |
| | Mr Julian Kruger<br>Mr Scott Walker<br>Dr Mark Garkaklis | Astron Environmental Services | Implementation of mangrove field surveys, data analysis, interpretation and reporting<br>Technical Review |
| Demersal fish | Associate Professor Euan Harvey<br>Mr Ben Saunders<br>Mr Jordan Goetze<br>Mr Connor Fitzpatrick<br>Mr Ben Ford | University of Western Australia (UWA) Oceans Institute and UWA School of Plant Biology | Input into demersal fish survey design and implementation<br>Analysis of stereo-BRUVs footage<br>Statistical analysis, interpretation of results, and reporting |
| | Dr Dianne Mclean | Mindabbie Marine Consulting | Technical Review |
| Demersal fish (mangroves) | Dr Chris Hallett | Centre for Fish Research, Murdoch University | Input into net sampling of fish in mangrove habitats<br>Statistical analysis, interpretation of results, and reporting |
| | Mr Ben Rome | Aquenal | Input into net sampling of fish in mangrove habitats<br>Taxonomic identification of fish |
| | Dr Susan Morrison | Western Australian Museum | Specialist taxonomic identification of fish |
| | Dr Dean Thorburn | Indo-Pacific Environmental | Technical Review |
| Water quality | Dr Karen Hillman<br>Ms Kellie Holloway<br>Dr Glenn Shiell | Oceanica Consulting | Input into design of the water quality sampling program and technical review Implementation of field surveys, data analysis, interpretation and reporting |
| | Mr Steve Cossington | Marine and Freshwater Research Laboratory (MAFRL) | Implementation of the field surveys |

The surveys conducted as part of the Gorgon Gas Development Marine Baseline Program have contributed to improving the knowledge of the Barrow Island marine environment and the Pilbara marine environment in and around the Mary Anne Passage and the Great Sandy Islands Nature Reserve.

# 5.0 Benthic Habitat Classification and Mapping

## 5.1 Scope

This Section provides information on the mapping methodologies and habitat classification schemes implemented to develop the maps of the extent and distribution of hard and soft corals, non-coral benthic macroinvertebrates, macroalgae, seagrass, mangroves and surficial sediments:

- that are at risk of Material or Serious Environmental Harm due to the construction or operation of the Marine Facilities (MOF, LNG Jetty, Offshore Feed Gas Pipeline System, Domestic Gas Pipeline and marine upgrade of the existing WAPET Landing) (Condition 14.6.iii, Statement No. 800; Condition 11.6.III, EPBC Reference: 2003/1294 and 2008/4178)
- at Reference Sites that are not at risk of Material or Serious Environmental Harm due to the construction or operation of the Marine Facilities (Condition 14.6.iv, Statement No. 800; Condition 11.6.IV, EPBC Reference: 2003/1294 and 2008/4178).

This Marine Baseline Report covers mapping methodologies and habitat classification schemes relevant to the construction and operation of the (Offshore) Domestic Gas Pipeline (DomGas Pipeline). The mapping methodologies and habitat classification schemes relevant to the east coast Marine Facilities (the Marine upgrade of the existing WAPET Landing, the MOF, LNG Jetty and the Dredge Spoil Disposal Ground) are described in Chevron Australia (2013a) and the mapping methodologies and habitat classification schemes relevant to the west coast Marine Facilities (Offshore Feed Gas Pipeline System) are described in Chevron Australia (2011b).

Mapping and habitat classification were undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800 and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178.

## 5.2 Mapping of Benthic Assemblages around Barrow Island

### 5.2.1 Background

The assessment of potential impacts on marine benthic habitats in the EIS/ERMP (Chevron Australia 2005, 2006) required the survey and mapping of the area potentially affected by marine infrastructure, dredging and dredge spoil disposal. The survey area, which covered thousands of hectares, covered the extent of the predicted Dredge Management Areas and the Barrow Island Management Units set up to assess the impacts. This necessitated broadscale qualitative assessment and mapping of marine benthic habitats. The objective of the mapping was to refine and confirm the distribution of major reef systems and other benthic habitats in the area likely to be affected by the proposed Marine Facilities. These maps were used primarily to guide marine infrastructure design, environmental impact assessment, and as the basis for Benthic Primary Producer Habitat (BPPH) loss calculations in accordance with EPA Guidance Statement No. 29 (EPA 2004; now superseded by Environmental Assessment Guideline No. 3, EPA 2009).

The broadscale, qualitative, maps of major benthic features and benthic habitats included in the EIS/ERMP (Chevron Australia 2005, 2006) were based on a Geographic Information System (GIS) version of an existing broadscale benthic habitat map of the Montebello/Barrow Islands area (Department of Conservation and Land Management [CALM] 2004; DEC 2007). Areas of potentially significant coral and other habitats near the east and west coast Marine Facilities and along the Offshore Feed Gas Pipeline in State waters and DomGas Pipeline routes, which required ground-truthing to confirm their classification, were identified from the broadscale map (CALM 2004) and geo-rectified aerial photographs.

Ground-truthing involved hundreds of kilometres of towed video camera transects and in-water surveys to confirm the identification of significant benthic communities within the areas covered by the Management Units for the BPPH assessment. The benthic habitat classifications were consistent with the scheme used in the existing broadscale map (CALM 2004), which was updated for the areas where new qualitative ground-truth data were collected. Only areas where coral cover was estimated to be representative of a coral community (nominally >10%, although this could not be directly measured at this scale) and the underlying and surrounding benthic substrate where corals were likely to be able to grow, were mapped as 'Coral Habitats'. Areas that were classified as 'Unconfirmed Coral' in the existing broadscale map (CALM 2004) and that had not been surveyed further for the EIS/ERMP (Chevron Australia 2005, 2006) remained as 'Unconfirmed Coral' in the EIS/ERMP. Consistent with the existing mapping of the large limestone shelf areas around Barrow Island and the Montebello and Lowendal Islands, isolated bombora were not classified as 'Coral Habitat'.

The benthic habitat maps in the Gorgon Gas Development Revised and Expanded Proposal PER (Chevron Australia 2008) were used primarily to guide the design of the marine infrastructure for the Revised and Expanded Proposal environmental impact assessment and for the associated revised BPPH loss calculations. The maps in the Revised and Expanded Proposal PER (Chevron Australia 2008) were developed by updating the existing EIS/ERMP maps (Chevron Australia 2005, 2006), incorporating improved or more recent imagery and by using additional ground-truthed data collected since mid-2005. More recent aerial photography and Laser Airborne Depth Sounder (LADS) imagery for some areas were used to identify additional benthic features that required ground-truthing. The imagery was also used to map the areas where it was proposed to establish Reference Sites (e.g. for the dredging and spoil disposal monitoring program) and to improve the definition of boundaries in the existing benthic habitat map. These features were ground-truthed using towed video camera transects and in-water surveys between 2007 and mid-2008. Benthic habitats were classified and BPPH impacts were assessed using the same methods as those documented in the EIS/ERMP (Chevron Australia 2005) to enable comparison of the extent of impacts predicted for the Approved and the Revised and Expanded Proposals.

Ministerial Implementation Statement No. 748 included the requirement to define and map the ecological elements (including 'hard and soft corals') within areas likely to be affected by the Gorgon Gas Development and at reference areas outside the areas predicted to be impacted. Thus, the survey area was extended to improve the definition of benthic habitats at potential Reference Sites and the accuracy of maps was improved in these areas. The requirement to 'define and map' ecological elements was addressed through further refinement of the EIS/ERMP (Chevron Australia 2005, 2006) and the Revised and Expanded Proposal PER (Chevron Australia 2008) maps, with a shift in emphasis from coral habitats to 'hard and soft corals' as the ecological element. This required refining the distribution of corals rather than the substrates they are likely to grow on (as required for the BPPH assessment). These maps show the distribution of coral assemblages in the appropriate areas without providing quantitative estimates of the percentage cover of corals within the assemblages.

Therefore, the focus of the mapping for the Marine Baseline Program has been improving the qualitative description ('map') of benthic ecological assemblages and refining the survey methods to enable coral assemblages to be quantified. The quantitative maps in the Marine Baseline Reports (Chevron Australia 2013a, 2011b) are based on the qualitative maps provided in the Revised and Expanded Proposal PER (Chevron Australia 2008), with the polygon boundaries refined on the basis of additional imagery, LADS data for Reference Sites and Multi-Beam Sonar data for the Marine Facilities, and redefined according to the level of quantification undertaken for each polygon. Benthic features identified from the imagery were ground-truthed using a combination of transects and photo-quadrats analysed using Coral Point Count with Excel extensions (CPCe) (Kohler and Gill 2006) for percentage cover and diver visual estimates. The boundaries of polygons were then redrawn to correspond with information from ground-truthing observations and remote sensing.

The definition of 'Coral Assemblages' was quantified (diver visual estimate of percentage cover or measured photo-quadrat estimate) as 'a cover of live coral of greater than 10%'. This is consistent with other recent large-scale coral mapping studies (Cochran-Marquez 2005; National Centers for Coastal Ocean Science 2005, 2008). Under this definition of 'Coral Assemblage' (>10% measured live coral cover), many of the polygons resulting from data collected during earlier surveys for the EIS/ERMP (Chevron Australia 2005, 2006) and the Revised and Expanded Proposal PER (Chevron Australia 2008), could not be confirmed to comply with this definition and therefore could not be classified as 'Coral Assemblages'. Thus, polygons for which there were no quantitative data to support their classification as 'Coral Assemblages' were relabelled as 'Unconfirmed Coral'. Although many were known to be dominated by coral from earlier qualitative ground-truthing surveys, there were insufficient quantitative data to classify them as 'Coral Assemblage' (>10% measured coral cover). Therefore, some polygons presented as 'Confirmed Coral' in the EIS/ERMP (Chevron Australia 2005, 2006) and the Revised and Expanded Proposal PER (Chevron Australia 2008) are now identified as 'Unconfirmed Coral' in maps in the Marine Baseline Reports (Chevron Australia 2013a, 2011b).

In summary, the maps in the Marine Baseline Reports (Chevron Australia 2013a, 2011b) the following terms are used:

- 'Quantified Coral': Classifies all polygons that have been either confirmed as Coral Assemblages in a quantitative manner (i.e. point census of photo-quadrats taken along transects at monitoring sites) or confirmed as Coral Assemblages in a qualitative manner (i.e. visual estimation during ground-truthing surveys), as having cover >10%.
- 'Unquantified Coral': Classifies those polygons that are, or may be, potential Coral Assemblages, which have been identified or refined as benthic features using survey data (e.g. remote imagery, in situ surveys). However, these polygons have not been ground-truthed and classified in accordance with the Barrow Island habitat classification scheme described in Section 5.2.2 and Appendix 2; thus, there are insufficient data for them to be classified as 'Quantified Coral'. These may be classified as 'Quantified Coral' in the future if ground-truthing confirms that live coral cover is >10% and the boundaries are refined such that only Coral Assemblages are present within the mapped polygon.
- 'Unconfirmed Coral', which is unchanged from the CALM (2004) map. Note that these may be classified as 'Quantified Coral' in the future if ground-truthing confirms that live coral cover is >10% and the boundaries are refined such that only Coral Assemblages are present within the mapped polygon.

### 5.2.2 Benthic Habitat Classification Scheme

Ground-truthed data were classified according to a hierarchical system of biophysical characteristics designed to facilitate consistent definition of benthic habitats in Barrow Island waters (Appendix 2).

The classification system uses attributes in five categories to describe the habitats:

- most common relief type of the underlying substrate (e.g. flat, gently sloping, steeply sloping, vertical wall, etc.)
- most common substrate type (e.g. silt, rubble, boulders, limestone pavement, low profile reef, high profile reef, etc.)
- most common or dominant ecological element found on the substrate (e.g. seagrass, coral, macroalgae, etc.)
- biological density or percentage cover of the most common taxa (e.g. sparse, medium, dense, etc.)
- most common or dominant taxa (family, genera or species where possible) within that assemblage (e.g. *Halophila* spp.), or physical descriptor where no biota were present.

Table 5-1 details the classification scheme categories and attributes.

**Table 5-1 Benthic Habitat Classification Categories and Attributes**

| Category | Attribute | Definition |
|---|---|---|
| Relief | Flat or micro-ripples | Slope 0–5° with ripples 0–0.5 m high |
| | Gently sloping | 5–35° |
| | Steeply sloping | 35–70° |
| | Vertical wall | 70–90° |
| | Macro-ripples | Slope 0–5° and ripples >0.5 m high |
| Substrate Type | Sand | Unconsolidated sediment 0.63–2 mm in diameter |
| | Silt | Unconsolidated sediment <0.63 mm in diameter |
| | Mud | Dense consolidated mixture of silt to sand sized particles |
| | Gravel | Unconsolidated sediment 2–10 mm in diameter |
| | Rubble | Unconsolidated sediment 10–250 mm in diameter |
| | Consolidated rubble | Sediment >10 mm in diameter with a covering of biotic or abiotic material which acts to keep the rubble in place |
| | Limestone pavement | Horizontal surface of exposed limestone rock |
| | Limestone pavement with sand veneer | Limestone rock patchily covered with sand; the sand may range in depth from centimetres to metres |
| | Boulders | Unconsolidated sediment >250 mm in diameter |
| | Reef – low profile | Reef of biotic or abiotic origin, ranging from flat to vertical; low profile: <1 m vertical change per 1 m horizontal |
| | Reef – high profile | Reef of biotic or abiotic origin, ranging from flat to vertical; high profile: >1 m vertical change per 1 m horizontal |
| | Sand with shell fragment | Unconsolidated sediment 0.63–2 mm in diameter, containing large, easily visible pieces of shell |
| | Silt with shell fragment | Unconsolidated sediment <0.63 mm in diameter, containing large, easily visible pieces of shell |
| Dominant Ecological Element | Macroalgae | Macroalgae greatest % cover, coral <10% |
| | Seagrass | Seagrass greatest % cover, coral <10% |
| | Non-coral benthic macroinvertebrates | Non-coral benthic macroinvertebrates greatest % cover, coral <10% |
| | Coral – hard and soft | Coral >10 % cover |
| | Mangroves | Mangrove forests and isolated mangrove trees |
| | Unvegetated | Benthic assemblages collectively <10% cover |
| % Cover | Sparse – macroalgae | 5–25% estimated cover |
| | Medium – macroalgae | 25–75% estimated cover |
| | Dense – macroalgae | >75% estimated cover |
| | Sparse – seagrass | 5–25% estimated cover |
| | Medium – seagrass | 25–75% estimated cover |
| | Dense – seagrass | >75% estimated cover |
| | Present – Non-coral benthic macroinvertebrates | Presence/absence recorded |
| | Sparse – coral | 0–10% estimated cover |
| | Medium – coral | 10–50% estimated cover |
| | Dense – coral | 50–75% estimated cover |
| | Very dense – coral | >75% estimated cover |
| | Present – mangrove | Presence/absence recorded for mangroves |
| | Unknown density | % cover not recorded |

Dominant and subdominant taxa were classified to the greatest practicable taxonomic resolution. For towed video camera surveys, the resolution of the video footage varied according to weather conditions and water clarity. In clear water, it was possible to classify the dominant and subdominant taxon descriptor of the habitat classification to the species level (e.g. flat, limestone pavement with macroalgae, dominated by sparse *Sargassopsis decurrens* [formerly *Sargassum decurrens*]). In turbid water, or with poor quality video footage, it was often only possible to identify the dominant/subdominant taxon to phylum or class (e.g. flat limestone pavement with macroalgae, dominated by medium unidentified Phaeophyceae). Less common taxa and associated species were also recorded, where possible. While this information increased the level of knowledge of the ecology of the study area, it did not inform habitat classification for mapping purposes.

The scheme is consistent with other habitat classification schemes used in Australia (see CALM 1994, 2000; Roob *et al.* 1995; Roob and Ball 1997; Australian and New Zealand Environment and Conservation Council Task Force on Marine Protected Areas 1998, 1999; Simpson and Bancroft 1998; Ferns 1999; Ferns and Hough 2000; Ball *et al.* 2006; Mount *et al.* 2007). While the hierarchy used is similar to that employed by other schemes (e.g. classifying by relief, then substrate, then biological modifiers such as dominant ecological elements and dominant taxa), the habitat classification scheme developed for Barrow Island waters is tailored around the ecological elements defined in Condition 14.2 of Statement No. 800 and Condition 11.2 of EPBC Reference: 2003/1294 and 2008/4178.

### 5.2.3 Field Survey Methods

To map at the 'benthic ecological element level' as required under Condition 14.6 of Statement No. 800 and Condition 11.6 of EPBC Reference: 2003/1294 and 2008/4178, seabed features were identified using existing broadscale habitat maps from around Barrow Island (CALM 2004; DEC 2007) and a variety of remote sensing data, including high resolution aerial imagery, LADS data, and Multi-Beam Sonar and Side-Scan Sonar data from across the study area, then entered into a Geographic Information System (GIS) (Figure 5-1). Note that not all data sources were available for all the areas mapped.

The seabed features identified from the remote imagery were then ground-truthed using towed video camera and in-water surveys (Figure 5-1). Bathymetric irregularities were more intensively ground-truthed than areas of bathymetric similarity (i.e. flat, featureless areas) as previous surveys around Barrow Island have found areas of bathymetric similarity to be more homogenous than areas of bathymetric dissimilarity. Underwater video footage was captured using a MAKO towed video unit fitted with a three charge-coupled device (3CCD) image sensor in a custom-built housing with a protective frame and with top and tail planes fitted for stability. Images were transmitted through an umbilical to a control box on the vessel. Positional information from a Garmin Global Positioning System (GPS) Unit was overlaid on the video footage before it was recorded to DVD. The extensive ground-truthing observations across the study area were plotted over the broadscale benthic habitat map (CALM 2004) and remote sensing data, in the GIS. Areas beyond the survey sites that were not adequately ground-truthed to enable classification are presented as the underlying habitat category from the existing broadscale benthic habitat map of the Montebello/Barrow Islands area (CALM 2004; DEC 2007).

The benthic habitats were classified in accordance with the Barrow Island habitat classification scheme described in Section 5.2.2 and Appendix 2. Benthic habitats were classified from the video imagery in real time using a custom interface in the Environmental Systems Research Institute (ESRI) ArcPad software, also connected to a Garmin GPS unit. Observations were recorded using drop-down menus containing the hierarchical table of biophysical characteristics that make up the habitat classification scheme. In areas of high seabed complexity, observations were recorded approximately every 30 seconds, or when a feature of interest or a change in habitat type was observed. At a towing speed of ~2 knots, observations made every 30 seconds were separated by ~30 m.

### 5.2.4 Treatment of Survey Data

The boundaries of polygons in the qualitative maps provided in the Revised and Expanded Proposal PER (Chevron Australia 2008) were refined and redrawn to correspond with information from the remote sensing and ground-truthing observations. The ground-truthing observations were plotted over a map of the polygons representing the identified seabed features, and the georeferenced observations were used to assign an ecological element classification (assemblage category) to each polygon. A decision tree was used to define and classify the polygons drawn around seabed features (Figure 5-2). Benthic features with >10% estimated live coral cover were mapped as ‘Coral Assemblage’ irrespective of the other assemblages present. For example, if a seabed feature had 20% live coral cover and 80% macroalgal cover, it was mapped as a ‘Coral Assemblage’. Where coral cover was <10%, but other ecological elements were present at >10% cover, then the ecological element that covered the greatest percentage of the substrate was recorded as the dominant ecological element. For example, if a seabed feature had 5% live coral cover and 95% macroalgal cover it was mapped as a ‘Macroalgal Assemblage’. Where no ecological element covered >10% of the area being described, the polygon was classified as ‘Unvegetated’.

High profile reefs, extensive rocky shelves, the surrounding expanses of unconsolidated soft sediments and mangroves have boundaries that can be distinguished from bathymetric data or aerial imagery and thus can be mapped as discrete polygons. Non-coral benthic macroinvertebrates and seagrass that were present in spatially and temporally varying (generally sparse) densities, with no distinct boundaries that can be reliably delineated using remote imagery, cannot readily be mapped as discrete polygons on maps of ecological elements. Point observations of non-coral benthic macroinvertebrates and seagrass are therefore presented on maps as presence/absence data. It is also difficult to delineate distinct boundaries between different surficial sediment types without losing much of the potentially important information on small-scale spatial variability and gradients between sediment types on larger scales. Surficial sediments are therefore presented graphically in terms of the sediment type recorded at each sampling location.

Because of the difficulties in drawing accurate polygon boundaries, a simplified mapping scheme was used with six mapping classes:

1. Quantified Coral
2. Unquantified Coral
3. Unconfirmed Coral
4. Macroalgae with Sparse Sessile Taxa
5. Soft Sediment with Sparse Sessile Taxa
6. Mangroves.

While they often exhibit distinct habitat associations, demersal fish assemblages are difficult to map because they are not always spatially restricted to the sampling sites and individual species within the assemblage exhibit varying levels of site attachment. The relative abundance and diversity of demersal fish characteristic of coral, macroalgae, soft sediments with sessile benthic macroinvertebrates and sand communities in Barrow Island waters are presented in the form of interactive Microsoft Excel charts.

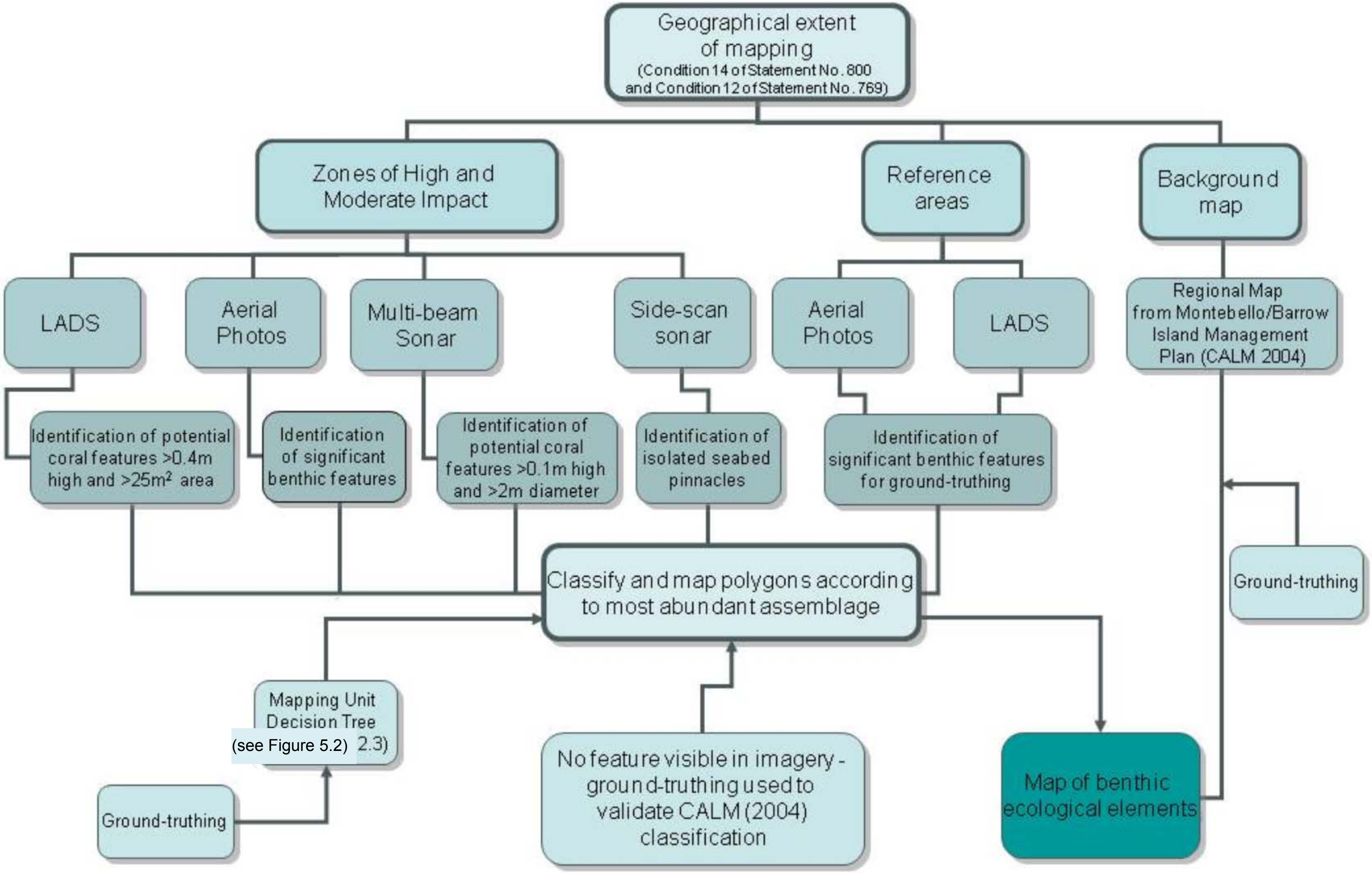



**Figure 5-1 Process for Identifying and Mapping Seabed Features**

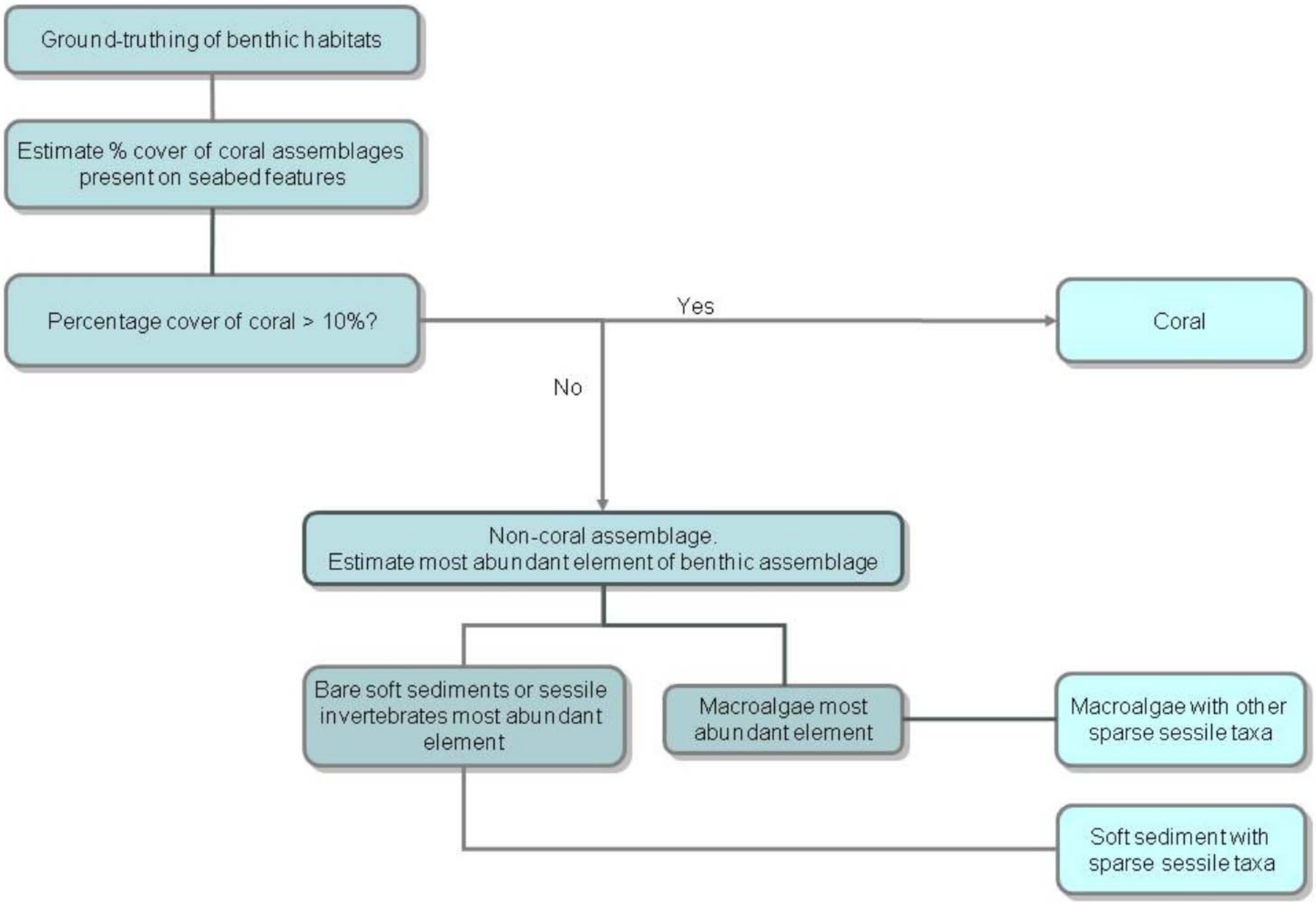



**Figure 5-2 Habitat Classification Unit Decision Tree**

### 5.2.5 Results and Mapping

A broadscale map of the benthic ecological assemblages in the marine waters around Barrow Island is shown in Figure 5-3. Features mapped using the 'Macroalgae with Sparse Sessile Taxa' class included assemblages dominated by macroalgae. Seagrass and non-coral benthic macroinvertebrates often co-existed in areas where macroalgae were the most common ecological element. This mapping class is used to indicate that the mapped area is dominated by macroalgae, but does contain some other sessile taxa at subdominant levels of cover. Note that this is consistent with the existing broadscale habitat maps from around Barrow Island (CALM 2004; DEC 2007), which do not include a seagrass or benthic macroinvertebrate category.

Features mapped using the 'Soft Sediment with Sparse Sessile Taxa' class were mostly composed of unvegetated sand, with no associated sessile biota. Patches of seagrass and non-coral benthic macroinvertebrates were present within this broader landscape of bare sand, but the boundaries of these patches could not be mapped accurately. This mapping class is used to indicate that the mapped area is dominated by unvegetated sand, but does contain some other sessile taxa at subdominant levels of cover.


**Figure 5-3 Benthic Ecological Assemblages around Barrow Island**

## 5.3 Mapping of Benthic Assemblages Associated with the DomGas Pipeline Route between the East Coast of Barrow Island and the Mainland Shore Crossing

### 5.3.1 Survey Methods

In December 2009, a survey of the DomGas Pipeline Route was undertaken by URS using a Stingray Remotely Operated Vehicle (ROV) (URS 2009). Twenty-seven transects, between approximately 15 m to 895 m in length (average length 505 m) and orientated approximately perpendicular to the pipeline route, were surveyed to cover the full range of benthic habitats identified on side-scan sonar soundings of the pipeline route (DOF Subsea 2008). Positional information from a GPS was overlaid on the ROV footage. In addition, the intertidal areas of the mainland shore crossing were visually surveyed at low tide.

In March 2011, detailed surveys of 38 'pinnacles' were undertaken by Geo Oceans and Oceanica (Geo Oceans and Oceanica 2011). The 'pinnacles', or raised bathymetric features, were identified in a geophysical survey of the DomGas Pipeline route (DOF Subsea 2008). The pinnacles were located in water depths of approximately 7 to 15 m and within 2–150 m of the pipeline route, and generally within 4–6 km of the east coast of Barrow Island; one of the pinnacles (Pinnacle 38) was located 22 km east of the Barrow Island coast. A qualitative assessment of the pinnacles and the surrounding seabed (within approximately 40 m to 100 m radius of the pinnacle location) was undertaken using a towed video system, with a Sony standard definition, high resolution, low light, underwater digital video camera with a wide-angle lens, mounted in an hydrodynamically shaped sled/housing. The camera was positioned approximately 1 m above the seabed, providing an image frame width of approximately 0.5 m, and a constant bearing and speed (0.5–1 knots) were maintained during the video transect. The video and audio tracks were encoded with latitude and longitude coordinates from a Furuno GP37 differential GPS and depth information from a Garmin Intelliducer echo sounder. At each pinnacle, four to seven approximately 80 m long video transects were surveyed, with a minimum of three parallel transects (orientated approximately north–south) and spaced approximately 10 m apart, and one perpendicular transect traversing the other three transects (in an approximately east–west orientation). Where pinnacles were located within 50 m of each other, they were surveyed as a cluster using a common set of transects. Additional transects were undertaken when field observations indicated that the pinnacles were larger than reported in the geophysical survey.

If the percentage cover of coral on a pinnacle was estimated between 5% and 50% from the qualitative video assessment, a further semi-quantitative assessment was undertaken to confirm the percentage cover and to reduce the chance of Coral Assemblage misclassifications. A semi-quantitative assessment was undertaken of one pinnacle, Pinnacle 38. The semi-quantitative survey employed a Sony HDR-CX550V photographic camera mounted in an housing at an angle of 90° to the seabed, to capture digital still images. The camera was remotely operated, enabling the operator to trigger still image and video recording and to confirm the camera was recording while it was in the water. The position and length of transects for the semi-quantitative survey were determined according to the size of the pinnacle, using data from the qualitative assessment to locate areas of coral cover on the pinnacle. To ensure the survey captured an adequate representation of the benthic habitats characteristic of Pinnacle 38, three 80 m long transects, spaced approximately 10 m apart and on an approximate north–south bearing were surveyed. Differential GPS was used to record the start and end points of each transect. The camera was towed over the pinnacle at slow speed (approximately 0.5 knots), with the camera positioned approximately 1.5 m above the seabed, resulting in an image frame area of approximately 1 $m^2$. The still images were captured at a predefined interval of one image every 10 s. At a tow speed of 0.5 knots, the camera moved approximately 2.8 m every 10 s. Thirty images were captured along each transect—20 images for analysis and ten images as contingency in the event of poor quality images.

### 5.3.2 Treatment of Survey Data

The classification of benthic habitats along the DomGas Pipeline route was consistent with the Barrow Island Benthic Habitat Classification Scheme (URS 2009). While the dominant and subdominant taxa for each of the surveyed transects were recorded, it is important to note that overall there were very little biota observed on the surveyed transects, with most transects scored as ‘bare’ cover.

The real time qualitative video surveys of the pinnacles used a video classification scheme that informed the subsequent classification into ecological elements (Geo Oceans and Oceanica 2011). Using a customised Visual Basic program, the video analyst assigned georeferenced habitat attributes into the data spreadsheet while the transect video was recorded. Depth and position data were received at approximately 1 s intervals and also captured in the spreadsheet, along with the combination of ecological elements and substrate attributes, including the visually assessed percentage cover of each ecological element (0–1%, 1–5%, 5–10%, 20–40%, 40–60%, 60–80%, and >80%) of each of the recorded ecological elements. The level of taxonomic detail recorded for each ecological element varied according to video quality, which in turn was dependent on the environmental conditions (e.g. turbidity, sea state) and the speed at which the video was filmed. In all cases, video quality was adequate to enable classification at the level of ecological elements.

The digital photographic images captured during the semi-quantitative assessment were scored for benthic percentage cover and composition using Coral Point Count with Excel extensions (CPCe) (Kohler and Gill 2006). Twenty points were randomly generated and overlaid onto each image. The substrate (sand, rock) or ecological element (e.g. macroalgae, seagrass, hard coral, soft coral, non-coral benthic macroinvertebrates) beneath each point was recorded. Points were classified as ‘Unidentified’ where it was unclear what was beneath a point. Macroalgae, coral and non-coral benthic macroinvertebrates were classified to the greatest taxonomic resolution possible using descriptions of morphological group, genus or species. Count data were exported to Microsoft Excel from the CPCe program and expressed as a percentage of the total cover recorded.

### 5.3.3 Results and Mapping

The DomGas Pipeline route between the east coast of Barrow Island to South Passage Island is predominantly unvegetated or bare subtidal coarse sand with <5% biotic cover (26 of the 27 transects), ranging in depth between 13 to 20 m (Figure 5-4; URS 2009). The seabed was essentially flat, with the largest change occurring at Transect 5 (Offshore KP23.4), where there was a depth increase of 3.7 m (from 14.6 m to 18.3 m). There were few areas of benthic assemblages identified along the pipeline route, with low abundances of benthic fauna, including sea whips, gorgonians, sea pens, anemones, sponges (including tubular sponges, basket sponges), soft and hard corals (e.g. small *Porites* [<1 m], *Acropora*, faviids and coral rubble), asteroids and echinoids. There was evidence of bioturbation and other biological activity in some areas, as well as areas of detached macroalgae on the seabed. At one location along the pipeline route (Transect 5), there were extensive patches of the macroalga *Caulerpa* (approximately 75% cover), with small amounts of the seagrass *Halophila* (1% cover) at one end of the transect and a small number (approximately five plants) of larger seagrass (cf. *Thalassodendron* ). This cover did not extend to the adjacent transects. Elsewhere, *Caulerpa* was recorded in isolated small patches on some transects. Similarly, small, isolated patches of the seagrass *Halophila* were recorded on some transects, but no seagrass ‘beds’ were observed on any of the transects. An area (<20% of the total length of the transect) of low relief reef was identified on Transect 4 (Offshore KP23.0), characterised by live *Acropora*, faviids, *Montipora* and *Turbinaria*. However, live coral coverage was <10%. At Transect 18 (Offshore KP47.0), there were accumulations of dead paired valves of the bivalve mollusc *Trisidos semitorta*, sometimes three to four shells deep. This species is commonly found in the beach drift along the Onslow coast, but little is known about the biology of this species (URS 2009).

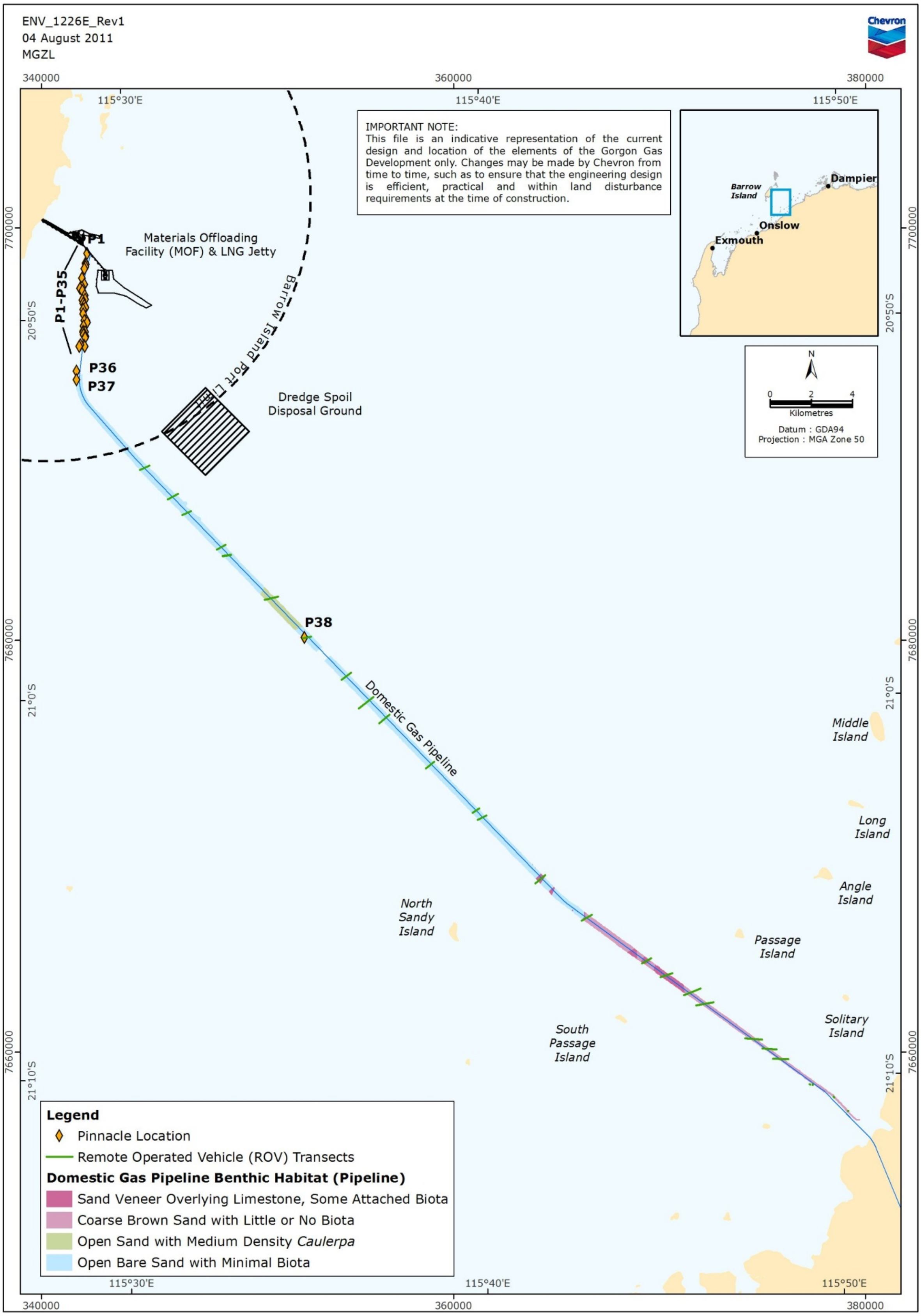



**Figure 5-4 Benthic Habitats along the proposed DomGas Pipeline route, including location of Pinnacles**

*Source: URS (2009) and Geo Oceans and Oceanica (2011)*

Near South Passage Island (Transects 15 to 17; Offshore KP39.3, KP42.2, and KP45.8) , where depths ranged from 8.5 m to 13.7 m, the seabed was a thin veneer of sand overlying a flat limestone platform, with small patches of the alga *Sargassum* (10–25% coverage), with individual *Caulerpa*, and some patchy turf algae. The benthic fauna were characterised by sea whips, sponges, hard corals (e.g. *Montipora*), crinoids, asteroids and echinoids. Inshore of Passage Island, the seabed was unvegetated sand, with scattered *Caulerpa*, low coverage of *Halophila*, and turfing algae. The benthic fauna was characterised by sea whips, sea pens, sponges, crinoids, asteroids and echinoids. No benthic fauna were observed in the shallowest (approximately 1.5 m depth) inshore transects (Transects 24 to 27; Offshore KP55.7, KP55.8, KP57.1, and KP58.0).

Extensive mudflats of firm 'muddy sand' characterise the intertidal area at the shore crossing (URS 2009). The seaward mangrove trees are a monospecific stand of *Avicennia marina*, reaching heights of approximately 5 m, with an extensive pneumatophore zone seaward of the mangroves. Further shoreward, there is an increase in tree density and a decrease in tree height (maximum height 1.5 m). No plant material was recorded on the mudflats seaward of the mangroves, and the fauna were characterised by the gastropods *Cerithidea cingulata*, *Haminoea* sp., *Nassarius dorsatus*, *Littoraria* sp. and *Nassarius* sp.

Of the 38 pinnacles surveyed, coral assemblages were only recorded at Pinnacle 37 and Pinnacle 38,[3] the two most southerly located pinnacles in approximately 10–15 m water depth (Figure 5-4; Geo Oceans and Oceanica 2011). Details on the ecological elements and the benthic habitat classification for the other 36 pinnacles surveyed are summarised in Table 5-2. Pinnacles 1 to 36 were small in area (no greater than 6 $m^2$, with dimensions of <4.5 m by <1.5 m) and height (<1.5 m), surrounded by sand with sparse rock (reef) supporting sparse non-coral benthic macroinvertebrates and macroalgae, with coral cover recorded at <5%.

**Table 5-2 Summary of the Pinnacle Survey Habitat Classification (Pinnacles 1 to 36)**

| Pinnacle No. | Habitat Classification |
|---|---|
| 1, 29, 30, 31, 35, 36 | Unvegetated sediment |
| 5, 7, 11, 12, 13, 14, 15, 16, 17, 18, 23, 24, 28, 32, 33, 34 | Unvegetated with non-coral benthic macroinvertebrates (<1–5%) on reef with sand veneer |
| 19, 20, 21, 22, 25, 26, 27 | Unvegetated with non-coral benthic macroinvertebrates (1–5%) and soft coral (1–5%) on reef with sand veneer |
| 2, 3, 4, 10 | Non-coral benthic macroinvertebrates (5–20%) with macroalgae (1–10%) on reef with sand veneer |
| 6, 8, 9 | Macroalgae (10–40%) with non-coral benthic macroinvertebrates (1–5%) on reef with sand veneer |

Pinnacles 37 and 38 were dominated by coral growing on high profile reef substrate and were classified as coral assemblages. Pinnacles 37 and 38 were higher (2.5 m and 3 m, respectively) and longer (1 m and 3 m, respectively), than the other pinnacles surveyed.

The Coral Assemblage at Pinnacle 37 supported a dense coral cover with up to 50% coverage, dominated by large (up to 8 m diameter) massive *Porites* spp., and foliose and encrusting corals (e.g. acroporids, including *Montipora* spp., and faviids). The Coral Assemblage at Pinnacle 37 covered an estimated area of 506 $m^2$ (0.05 ha) and was surrounded by low profile patchy reef habitat supporting an overall 5–10% cover of macroalgae (e.g. *Sargassum* spp.), and up to 20% macroalgal cover in some patches.

[3] Pinnacle 38 was located approximately 25 m away from Transect 4 (Offshore KP23.0).

CPCe analysis of images collected on Pinnacle 38, recorded a total hard coral cover of 24% ± 4 Standard Error (SE). Coral cover was dominated by poritids and faviids, approximately 26% and 23%, respectively of the total coral cover; with acroporids (including *Montipora* spp.) making up approximately 7% cover; merulinds, mussids, pectinids and dendrophylliids each representing 1–5% of the cover, and <1% bleached coral recorded.[4] Bare or turfing algae-covered rock or rubble represented 51% ± 3 SE of the cover of Pinnacle 38, and sand 25% ± 6 SE. Seagrass, soft coral or non-coral benthic macroinvertebrates were not recorded in the CPCe analysis and only a low cover of unidentified macroalgae (<1%) was recorded. The Coral Assemblage at Pinnacle 38 was estimated to cover an area of 6060 $m^2$ (0.61 ha) and was surrounded by unvegetated soft sediment.

## 5.4 Mapping of Benthic Assemblages at the Mainland End of the DomGas Pipeline Route

### 5.4.1 Survey Area

The extent of the baseline survey area for the mainland end of the DomGas Pipeline route, defined by the trenching and jetting Marine Disturbance Footprint (i.e. the area at risk of Material or Serious Harm from trenching and jetting activities) and Reference Areas outside the trenching and jetting Marine Disturbance Footprint (i.e. not at risk of Material or Serious Environmental Harm from trenching and jetting activities), is shown in Figure 5-5. The survey area extended over 351.2 $km^2$, incorporating 119.0 $km^2$ in the area at risk of Material or Serious Environmental Harm and 232.2 $km^2$ not at risk of Material or Serious Environmental Harm.

[4] Note that approximately 34% of the hard coral cover could not be classified into taxonomic groups.

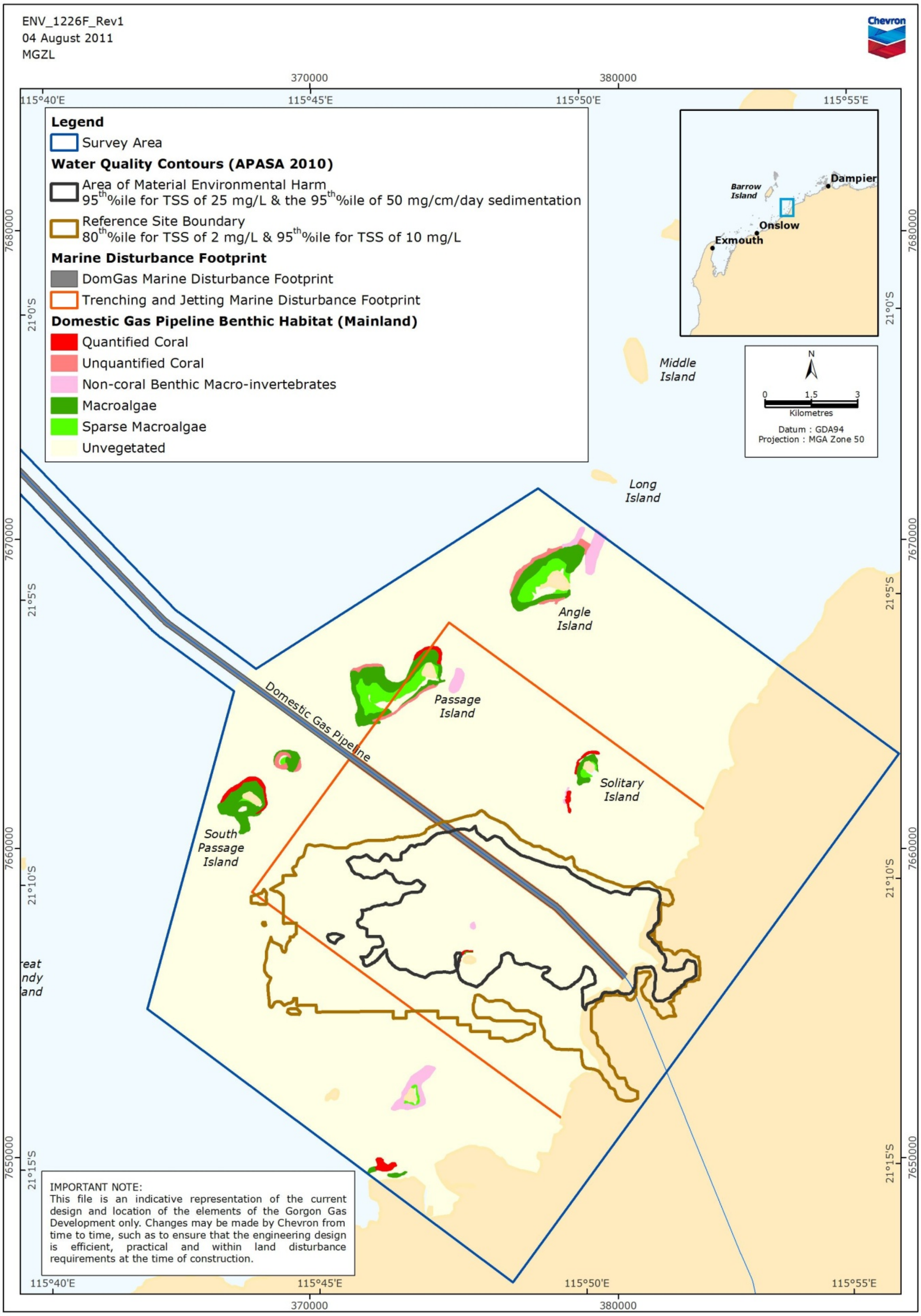



**Figure 5-5 Geographic Extent of the Baseline Survey Area, the area of Material Environmental Harm, the Marine Disturbance Footprint and the Reference Site Boundary for Benthic Ecological Elements and Water Quality for the DomGas Pipeline**

### 5.4.2 Field Survey Methods

#### 5.4.2.1 Overview

To map at the 'benthic ecological element level' as required under Condition 14.6 of Statement No. 800 and Condition 11.6 of EPBC Reference: 2003/1294 and 2008/4178A, a two-staged approach was implemented. A broadscale assessment was undertaken first, followed by more detailed ground-truthing to map specific benthic habitats and assemblages, focusing on the coral communities associated with fringing reefs near islands within the survey area. The broadscale distribution of subtidal benthic habitat and assemblages across the survey area was initially assessed in August 2010 using towed video surveys (Section 5.4.2.2). In September and October 2010, and February and April 2011, ground-truthing techniques were used to supplement these data and to confirm habitat characteristics present at over 500 locations within the survey area. Ground-truthing involved visual assessments of benthic habitats undertaken by towed video (Section 5.4.2.2), drop camera observations (Section 5.4.2.3) or snorkelling, bathyscope and remote video surveys (Section 5.4.2.4). A summary of the timing, method and extent of ground-truthing is presented in Table 5-3. Ground-truthing information from each of these different data sources was combined with aerial imagery (Google Earth Pro as at 11 August 2010), and available mapping (e.g. URS 2009) to produce GIS benthic habitat maps for the survey area.

**Table 5-3 Summary of the Timing, Method and Areas Surveyed used to Ground-truth the Survey Area**

| Season | Date | Methods | Areas Surveyed |
|---|---|---|---|
| Dry Season | August 2010 | Towed Video | Transects within the area at risk of Material or Serious Environmental Harm and the area not at risk of Material or Serious Environmental Harm |
| Dry Season | August 2010 | Snorkelling and Bathyscope Observations | Angle Island, Passage Island, South Passage Island, Solitary Island and an unnamed reef located south-west of the pipeline route and north-east of Cowle Island |
| Dry Season | August 2010 | Drop Camera | Widely spaced locations within the area at risk of Material or Serious Environmental Harm and the area not at risk of Material or Serious Environmental Harm |
| Wet Season | February 2011 | Snorkelling, Bathyscope and Remote Video Observations | South Passage Island, Passage Island |
| Wet Season | April 2011 | Snorkelling and Bathyscope Observations | South Passage Island, Passage Island, Angle Island, Solitary Island, an unnamed reef located south-west of the pipeline route and north-east of Cowle Island, and an unnamed reef located on the south-western boundary of the survey area |

#### 5.4.2.2 Towed Video

Towed video surveys were undertaken in August 2010, along ten long (8–12 km) transects aligned either parallel or perpendicular to the DomGas Pipeline route and ten short (0.8–1.2 km) transects radiating from the centre of the islands in the study area (Figure 5-6). Six of the long transects were within the area at risk of Material or Serious Environmental Harm, with the remainder located in areas not at risk of Material or Serious Environmental Harm. The arrangement of survey transects ensured good spatial coverage of the survey area, with particular focus around the island systems where the diversity of habitats was anticipated to be high.

Video footage was captured using a towed video camera unit designed for low light environments thus eliminating the need for external light sources (0.01 lux high-resolution colour camera Sony Super HAD CCD). The video camera was mounted either in a custom-built 'towfish' housing with a working depth of 1–2 m off the seabed, providing a swathe width of 2–5 m, depending on water clarity; or on a purpose-built sled, with the video unit mounted in a fixed position approximately 50 cm from the seabed providing a swathe width of approximately 1 m. The sled allowed closer inspection of benthic habitats compared to the towfish, since the vessel could be slowed while still maintaining the video camera at a constant height above the seabed. It also enabled the video to be operated under conditions of poor water visibility as it was closer to the seabed. The sled was not suitable for certain habitats, where there was a risk of damage to marine flora and fauna. The towfish could be raised or lowered to enable surveys in areas of high topographic complexity. At a towing speed of 2 knots, observations were made every 30 seconds and separated by approximately 30 m. In areas of high seabed complexity, or when a feature of interest or a change in habitat type was observed, vessel speed was reduced to as low as practicable and observations were recorded every 15–20 m.

Images were transmitted via an umbilical to the vessel and the video footage overlaid with date, time, water depth, and GPS positional information (GPSMAP® 451S chartplotter), before being recorded to DVD. The benthic habitats were classified in accordance with the Barrow Island habitat classification scheme described in Section 5.2.2 and Appendix 2. Real time benthic habitat classification was undertaken from the video imagery using a custom interface in Environmental Systems Research Institute (ESRI) ArcPad software, also connected to the Garmin GPS unit. Observations were recorded using drop-down menus containing the hierarchical table of biophysical characteristics that make up the habitat classification scheme. Where there was uncertainty involved with the habitat assessments, the vessel was slowed to enable closer inspection of the benthic habitats.

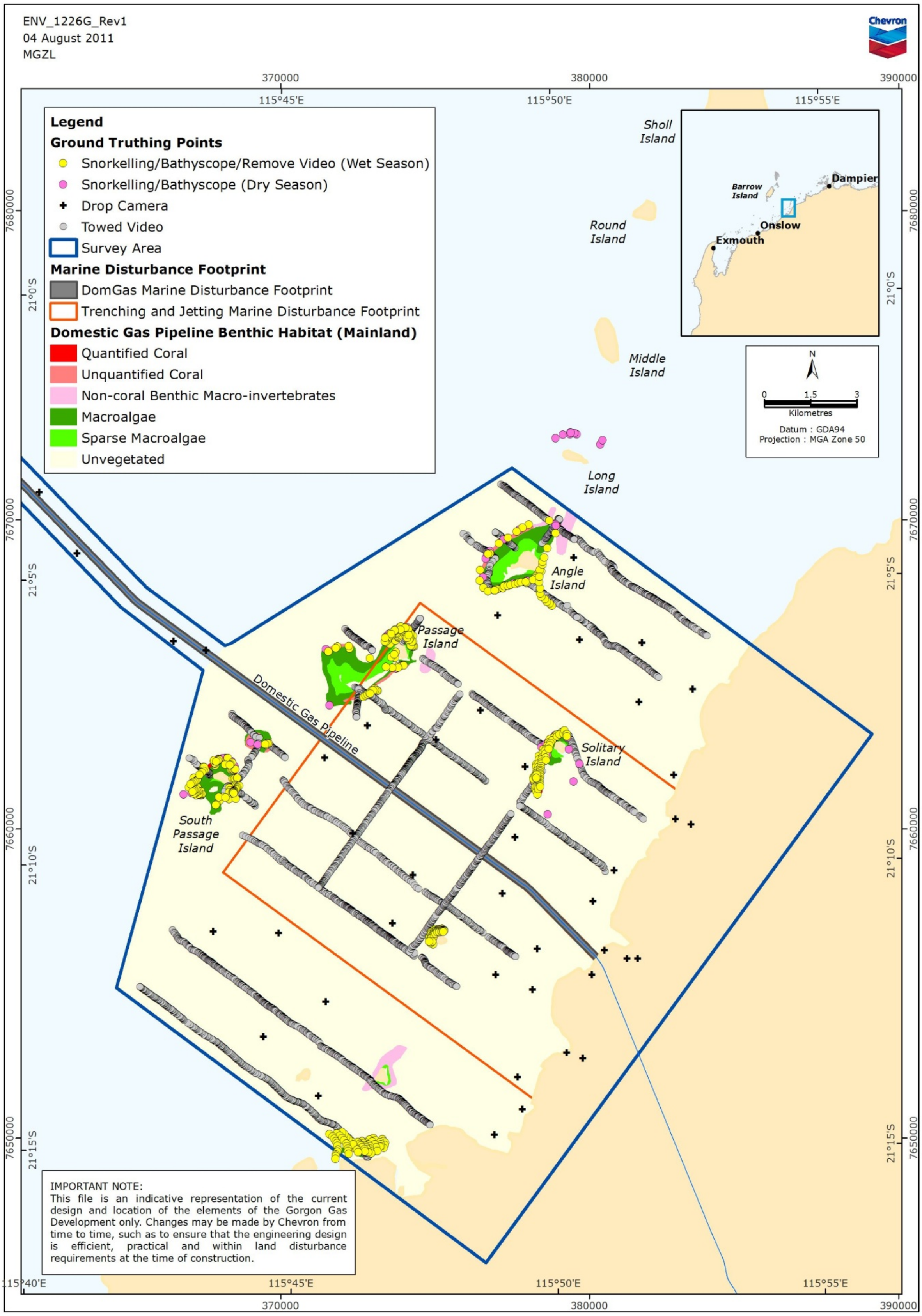



**Figure 5-6 Ground-truthing Points Surveyed within the Baseline Survey Area for the DomGas Pipeline**

#### 5.4.2.3 Drop Camera

Ground-truthing of the seabed characteristics was undertaken at several widely spaced locations within the area at risk of Material or Serious Environmental Harm and at sites not at risk of Material or Serious Environmental Harm (Figure 5-6). A high-resolution drop camera (Canon Powershot G7) mounted in a frame to face vertically downwards and incorporating infill lighting (Ikelite strobe system) was used to collect digital still images at each of site. The image from the camera was transmitted to a Visual Display Unit (VDU) on the vessel to enable adjustment of camera position to optimise image quality. The camera was connected to the surface via an umbilical and triggered remotely from a laptop computer. The field of view of the images was 0.5 × 0.5 m (i.e. 0.25 $m^2$). Seabed characteristics were classified according to the Barrow Island Habitat Classification Scheme (Section 5.2.2; Appendix 2).

#### 5.4.2.4 Snorkel, Bathyscope and Remote Video Observations

Snorkel and bathyscope (i.e. underwater viewer) surveys were undertaken in August 2010 to assist with the selection of survey sites at Angle Island, Passage Island, South Passage Island, Solitary Island and an unnamed reef located south-west of the pipeline route and north-east of Cowle Island. These locations were identified as potential survey sites from towed video surveys. At each snorkel diving/bathyscope point, approximately 400 $m^2$ (20 × 20 m) of seabed was surveyed and the dominant ecological element was recorded according to the Barrow Island Habitat Classification Scheme (Section 5.2.2; Appendix 2). Where hard and soft corals were recorded, the coral cover within the surveyed area was visually estimated and the dominant genera present recorded. The geographic coordinates, depth and time were also logged for each location.

Snorkel and bathyscope surveys were also undertaken in February and April 2011 at Angle Island, Passage Island, South Passage Island, Solitary Island and an unnamed reef located south-west of the pipeline route and north-east of Cowle Island. Under the poor visibility conditions that prevailed during these surveys, it was not practicable to survey a 20 × 20 m area at each location. Therefore, an area of approximately 100 $m^2$ (10 × 10 m) was surveyed by snorkel along a linear transect and/or by making repeated snorkel dives across the area. On occasions when limited visibility prevented safe snorkel operations, a remote video connected to a screen on board the vessel was lowered to the seabed to enable habitat descriptions to be made in the same manner as snorkel and bathyscope observations.

### 5.4.3 Treatment of Survey Data

Benthic habitat maps were produced by combining information from aerial imagery (Google Earth Pro as at 11 August 2010), nautical charts, available habitat maps (e.g. URS 2009) and ground-truthing observations. Ground-truthed data were classified according to the Barrow Island Habitat Classification Scheme (Section 5.2.2; Appendix 2). Given the proximity to Barrow Island (i.e. approximately 50 km), this classification scheme was considered appropriate for the DomGas Pipeline study area and provides consistency in habitat definitions across the Gorgon Project.

In accordance with the Barrow Island Habitat Classification Scheme, benthic features with >10% estimated live coral cover were mapped as either 'Quantified' or 'Unquantified Coral' irrespective of the other assemblages present. Where coral cover was <10%, but other ecological elements were present at >10% cover, then the ecological element that covered the greatest percentage of the substrate was recorded as the dominant ecological element. Where no ecological element covered >10% of the area being described, the habitat was classified as 'unvegetated'. Mapping categories were, however, slightly different to those in the maps presented for Barrow Island. The shallow, turbid inshore areas of the survey area at the mainland end of the DomGas Pipeline route differ from those around Barrow Island, and consequently the same suite of dominant ecological elements does not exist. For example, the category 'Macroalgae with Sparse Sessile Taxa' mapped around Barrow Island was not mapped in the study area at the mainland end of the DomGas Pipeline route. The category 'Unconfirmed Coral', which was identified in the CALM (2004) map and thus not relevant to the mainland end of the DomGas Pipeline route, was not included as a mapping category as all the coral assemblages within the study area were either 'Quantified Coral' or 'Unquantified Coral'

Six benthic habitat classes were mapped, with habitat classes based on the dominant ecological elements identified in the Barrow Island Habitat Classification Scheme:

- 'Quantified Coral': Mixed coral community (10–50% cover).
- 'Unquantified Coral': Potential coral assemblages, identified or refined as benthic features using survey data (e.g. remote imagery, in situ surveys), but that have not been ground-truthed in sufficient detail to be confidently classified as Quantified Coral.
- Macroalgae: Habitats dominated by macroalgal communities (contingent on <10% coral cover).
- Sessile non-coral benthic macroinvertebrates: Mapping focused on sessile, attached, habitat-forming taxa. Mobile organisms (e.g. asteroids, crinoids) were not mapped as these organisms were observed to be aggregated, patchy and transient at sites within the survey area.
- Unvegetated.
- Intertidal platform: Sparse macroalgae (5–25%).

Polygons corresponding with the benthic habitat classes were constructed. Because of the difficulties in identifying habitat boundaries for ecological elements that were not near the islands (e.g. non-coral benthic macroinvertebrates and seagrass), these data are presented on maps as presence/absence point observations on the maps.

To map each habitat class, texture and colour characteristics from aerial imagery were combined with the georeferenced ground-truthed data to interpolate between points. Where aerial imagery could not be reliably used to infer habitat classes (typically >1 km from shallow reef systems), habitat classes were inferred based on trends derived from ground-truthing observations. Prior to the generation of final habitat maps, the distribution of ground-truthing points and the dominant ecological elements were mapped and the mapping output cross-referenced against field notes and observations. Potential geographical outliers in the habitat maps were examined to identify data transcription errors, and, where necessary, the GPS coordinates in the mapping database were adjusted.

### 5.4.4 Results and Mapping

The broadscale map of the benthic ecological elements in the survey area at the mainland end of the DomGas Pipeline route is presented in Figure 5-7. A summary of the area of each of the six mapped habitat classes within the area at risk of Material or Serious Environmental Harm and the areas not at risk of Material or Serious Environmental Harm is provided in Table 5-4.

**Table 5-4 Approximate Area (ha) of the Dominant Benthic Habitats within the Baseline Survey Area for the DomGas Pipeline**

| Dominant Benthic Habitats | Total Survey Area | | At risk of Material or Serious Environmental Harm | | Not at risk of Material or Serious Environmental Harm | |
|---|---|---|---|---|---|---|
| | Area (ha) | % | Area (ha) | % | Area (ha) | % |
| Unvegetated | 27518 | 96.2 | 11677 | 98.2 | 15841 | 94.8 |
| Coral (Quantified and Unquantified) | 143 | 0.5 | 37 | 0.3 | 106 | 0.6 |
| Macroalgae | 509 | 1.8 | 78 | 0.7 | 431 | 2.6 |

| Dominant Benthic Habitats | Total Survey Area | | At risk of Material or Serious Environmental Harm | | Not at risk of Material or Serious Environmental Harm | |
|---|---|---|---|---|---|---|
| | Area (ha) | % | Area (ha) | % | Area (ha) | % |
| Intertidal platform (unconfirmed sparse macroalgae) | 265 | 0.9 | 63 | 0.5 | 202 | 1.2 |
| Sessile non-coral benthic macroinvertebrates | 160 | 0.6 | 31 | 0.3 | 129 | 0.8 |
| **Total** | **28595** | **100** | **11886** | **100** | **16709** | **100** |

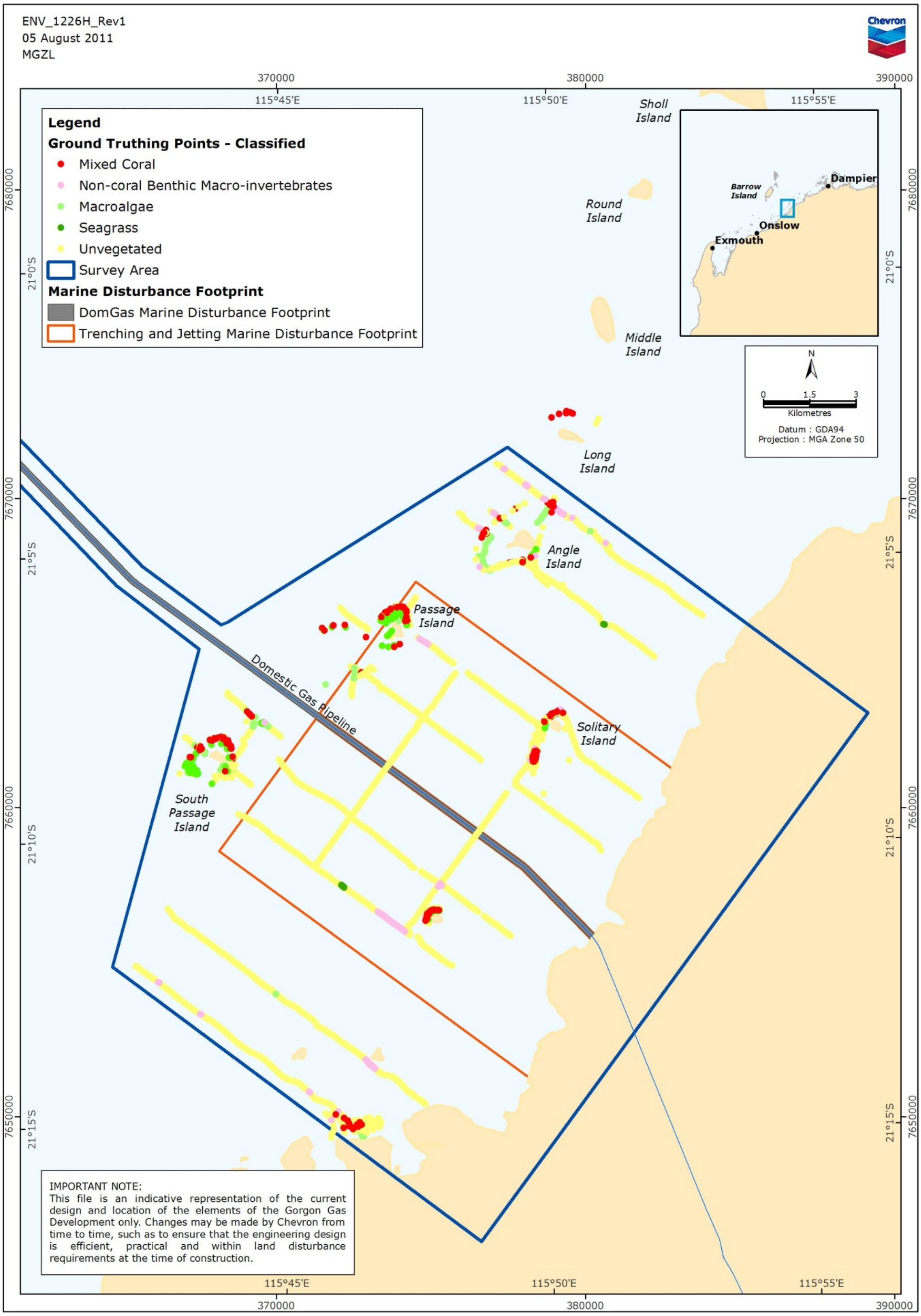



**Figure 5-7 Benthic Ecological Assemblages in the Baseline Survey Area at the Mainland End of the DomGas Pipeline Route**

The benthic habitat in the survey area was predominantly unvegetated or bare sediments which covered 275.2 km$^2$ (96.2%) of the total survey area. Unvegetated sediments represented an estimated 116.8 km$^2$ (98.2%) of the area at risk of Material or Serious Environmental Harm and 158.4 km$^2$ (94.8%) of the area not at risk of Material or Serious Environmental Harm (Table 5-4). Unvegetated sediments classified in accordance with the Barrow Island Habitat Classification Scheme (Section 5.2.2; Appendix 2) were typically gently sloping and 75–100% unvegetated. Coral, macroalgae and benthic macroinvertebrate dominated benthic assemblages covered approximately 2.1 km$^2$ (1.8%) of benthic habitat within the area at risk of Material or Serious Environmental Harm.

A number of offshore islands with fringing coral reefs and isolated patch reefs occur within the survey area. Coral-dominated benthic assemblages generally occurred as semi-continuous bands around the outer edge of the reef flats surrounding the islands (Figure 5-7). Reef development was typically greatest on the seaward (north-west facing) sides of the intertidal platforms; within a depth range of approximately 0 to 6 m below Lowest Astronomical Tide (LAT). Reefs sloped gently seaward at approximately 5° to 15° and no steep reef walls were recorded in the survey area. Coral-dominated assemblages covered an estimated 0.4 km$^2$ (0.3%) of the benthic habitats within the area at risk of Material or Serious Environmental Harm and 1.1 km$^2$ (0.6%) of the area not at risk of Material or Serious Environmental Harm. Of the ground-truthed areas of coral, >98% were classified as ‘medium’ density coral cover (i.e. 10–50% cover) and <2% were classified as ‘dense’ coral cover (i.e. 51–75% cover). ‘Mixed coral communities’ (e.g. *Echinophyllia*, faviids, *Goniopora*, *Lobophyllia*, *Montipora*, *Porites*, *Turbinaria*) were the dominant Coral Assemblage type in the DomGas Pipeline survey area; no bombora or *Acropora*-dominated assemblages were identified in the field surveys.

Macroalgal-dominated benthic assemblages covered an estimated 0.8 km$^2$ (0.7%) of the area at risk of Material or Serious Environmental Harm and 4.3 km$^2$ (2.6%) of the area not at risk of Material or Serious Environmental Harm (Table 5-4). Macroalgae-dominated assemblages were typically recorded at shallower depths (0.5–4 m) than the ‘mixed coral communities’ on the outer edges of the reef flat (Figure 5-7). *Sargassum* spp. was often the dominant taxa recorded. Macroalgae-dominated assemblages within the survey area were typically characterised by ‘medium’ density algal cover (i.e. 25–75% cover). Areas of intertidal platform supported ‘sparse’ macroalgal cover (i.e. 5–25% cover) and were estimated to represent 2.7 km$^2$ (0.9%) of the survey area. Seagrass was recorded on soft sediments within the survey area; however, seagrass was rarely observed as the dominant ecological element and could not be mapped as discrete polygons. Seagrass was typically ‘sparse’ in cover (<5% cover) and patchy in distribution (typical patch size estimated to be <10 m$^2$). Due to the small size and the ephemeral nature of the above-ground portions of the seagrass typical of communities in this region (e.g. *Halophila* spp.), even when present, seagrass may not have been observed on the video footage. Nevertheless, extensive seagrass beds were not observed in the survey area.

Habitats dominated by assemblages of sessile non-coral benthic macroinvertebrates (e.g. sponges, hydroids, cerianthid anemones, sea whips, sea pens, gorgonians, bryozoans, crinoids) were typically located on the northern or eastern sides of the islands in the survey area (Figure 5-7). These habitats contributed an estimated 0.3 km$^2$ (0.3%) of the area at risk of Material or Serious Environmental Harm and 1.3 km$^2$ (0.8%) of the area not at risk of Material or Serious Environmental Harm within the survey area (Table 5-4). Habitats dominated by sessile non-coral benthic macroinvertebrates were generally associated with high current areas that reflected localised hydrodynamic movements around the islands. The greatest areas of benthic macroinvertebrate dominated assemblages were recorded near Angle Island and Cowle Island, where low lying areas at the extremity of the reef systems were dominated by sessile non-coral benthic macroinvertebrate assemblages (Figure 5-7).

Patterns of dominant benthic habitat classes were broadly comparable between the different reef systems in the survey area; however, the spatial extent of coral reef areas, macroalgal habitats, and sessile non-coral benthic macroinvertebrate dominated assemblages tended to increase offshore. For example, Passage Island and South Passage Island both had larger areas of coral-dominated assemblages than the unnamed reef located south-west of the pipeline route and north-east of Cowle Island and Solitary Island, located further inshore. Similarly, the extent of macroalgal-dominated assemblages was greater on the offshore reefs. Patterns of benthic habitat cover for ecological elements not at risk of Material or Serious Environmental Harm were broadly comparable to those at risk of Material or Serious Environmental Harm. The most notable difference was the greater area of coral, macroalgae and sessile non-coral benthic macroinvertebrate assemblages in the area not at risk of Material or Serious Environmental Harm. The offshore reefs in the vicinity of South Passage Island and Angle Island were comparable to those described for Passage Island, while the distribution of ecological elements at Cowle Island was more similar to those at Solitary Island. A small section of reef was also observed in shallow water immediately adjacent to the mainland at the southern border of the survey area. On these reefs, bands of coral and macroalgae were recorded as the dominant ecological elements.

## 5.5 Mapping of Mangroves at the Mainland Shore Crossing for the DomGas Pipeline Route

### 5.5.1 Survey Areas

The extent of the baseline survey area for the mapping of mangroves at the mainland end of the DomGas Pipeline route, defined by the trenching and jetting Marine Disturbance Footprint (i.e. the area at risk of Material or Serious Harm from trenching and jetting activities) and Reference Areas outside the trenching and jetting Marine Disturbance Footprint (i.e. not at risk of Material or Serious Environmental Harm from trenching and jetting activities), is shown in Figure 5-8. The survey area extended over 6.3 $km^2$, incorporating 3.5 $km^2$ in the area at risk of Material or Serious Environmental Harm and 2.8 $km^2$ not at risk of Material or Serious Environmental Harm. The northern Reference Area was located approximately 4.5 km, and the southern Reference Area approximately 3.5 km, from the area at risk of Material or Serious Environmental Harm. The mangrove mapping presented in this Report expands on the littoral zone mapping undertaken by Astron Environmental Services along the DomGas Pipeline route in October 2009 (Astron Environmental Services 2009). The central corridor of the survey area has been mapped by Astron Environmental Services; and much of the terminology and nomenclature used by Astron Environmental Services has been used here for consistency in project outputs.

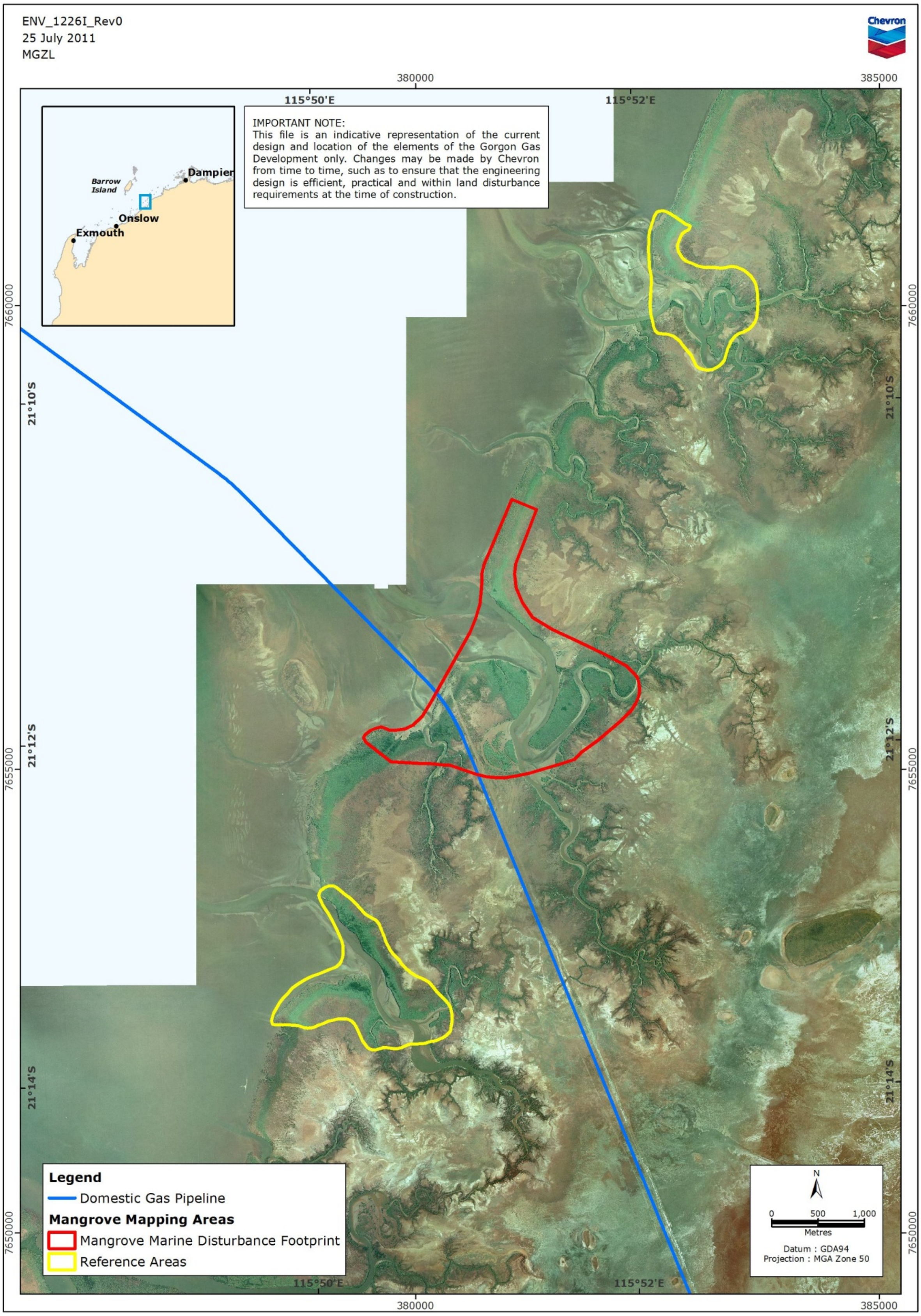



**Figure 5-8 Mangrove Mapping Locations at the Mainland End of the DomGas Pipeline Route**

### 5.5.2 Survey Methods

#### 5.5.2.1 Desktop Mapping

Aerial photographs, Google Earth Pro imagery (as at 11 August 2010), topographic maps (Yarraloola 5006 1:250 000 scale), and pre-mapped vegetation associations (Astron Environmental Services 2009) were used to construct a preliminary map of likely vegetation community types in the area at risk of Material or Serious Environmental Harm. High-resolution (1:5000) aerial photography was available for a strip of land 2 km wide along the pipeline corridor. This covered approximately 70% of the survey area. Imagery available for the remaining portion of the survey area was of 1:16 000 resolution. The 1:5000 aerial photography was at a scale where individual trees were discernible. Distinct foliage colour and apparent textures of different mangrove species were interpreted to delineate boundaries between associations.

Preliminary desktop mapping of the Northern and Southern Reference Areas was undertaken to identify the likely vegetation community types. This was based on the interpretation of the previous mapping undertaken within the area at risk of Material or Serious Environmental Harm through the visual assessment of transparent overlays of the mapped extents on vegetation communities on aerial photographs. Distinctions between vegetation types within the two Reference Areas were then identified on colour aerial photographs, with patterns observed within the area at risk of Material or Serious Environmental Harm being used as a reference.

#### 5.5.2.2 Field Surveys

Field surveys of mangroves in the area at risk of Material or Serious Environmental Harm were undertaken in August 2010. During the field surveys, the entire shoreward extent of the area at risk of Material or Serious Environmental Harm, as well as accessible areas within the downstream reaches of the tidal creek systems were traversed by boat or on foot. During these transits of the survey area, species lists were compiled, and the species associated with specific vegetation communities and habitat features recorded. In addition, within each of the identified vegetation community types, a 10 m radius plot was systematically assessed to record all vascular species, vegetation structures, and site characteristics. The condition of the mangroves was also assessed using the vegetation condition scale used by Astron Environmental Services (2009), which was adapted from Keighery (1994) and Kaesehagen (1994).

During the field surveys undertaken in March 2011, the entire visible shoreward extent of the Northern and Southern Reference Areas was driven by boat with mapping notes taken at regular intervals. Mapping note points were selected to capture all accessible representative stands of different vegetation community types within the survey area, as well as to mark transition and boundary areas between different vegetation community types. Details captured at each mapping note point included GPS location, photographs and a description of vegetation community type, including mangrove species composition and visual estimates of tree height and density.[5] These were selected to capture all accessible representative stands of different vegetation community types within the Reference Area, as well as to mark transition and boundary areas between different vegetation community types. Mapping of the Reference Areas was supplemented by site observations made during the detailed site surveys at the baseline survey sites, field notes made during boat and foot transit through the areas, and remote observations of inaccessible areas taken from vantage points whilst on the survey vessels. Mapping points were also collected within the area at risk of Material or Serious Environmental Harm mapped in August 2010 as a means of map verification.

Vegetation classifications conform with those used by Astron Environmental Services in their mapping of the DomGas Pipeline corridor (Astron Environmental Services 2009), which in turn

[5] Descriptions of vegetation community types followed the height and density classifications given in Specht (1970), as modified by Alpin (1979).

were based on the National Vegetation Information System (NVIS) (National Land and Water Resources Audit 2000). An additional classification, *Rhizophora stylosa* closed low woodland (Rz1), was added because this vegetation was clearly visible and easily distinguishable from the dominant *Avicennia marina* woodlands that surround or abut it. Vegetation descriptions in this Report are predominantly presented at the NVIS hierarchical level of 'Association' (Level V).[6]

### 5.5.3 Treatment of Survey Data

All ground-truthing data (e.g. mapping points, site observations, field notes, and remote observations) were overlaid on aerial photographs and used to refine and finalise the mapped extent of different vegetation community types throughout the survey areas. Much of the terrestrial extent of the Reference Areas and the area at risk of Material or Serious Environmental Harm was mapped using aerial photograph interpretation assisted by remote observations taken during the field surveys. As with any mapping exercise that is reliant on interpretation of aerial photographs, some degree of error in the resultant vegetation community composition and boundary delineation was expected to occur.

All mapping point, transit route and vegetation community type data collected within each of the areas, were digitised and entered into a spatial database using ArcGIS.

### 5.5.4 Results and Mapping

Ten vegetation community types were identified throughout the area at risk of Material or Serious Environmental Harm and the Northern and Southern Reference Areas; these are detailed in Table 5-5. The species composition of each vegetation community type is provided in Table 5-6.

[6] Dominant growth form, cover, height and broad floristic code, usually dominant genus and family of the three traditional strata (i.e. upper, mid and ground) are recorded.

### Table 5-5 Vegetation Communities Identified at the Mainland End of the DomGas Pipeline Route

| Broad floristic formation | Vegetation association | | Area at risk of Material or Serious Environmental Harm | | Northern Reference Area | | Southern Reference Area | |
|---|---|---|---|---|---|---|---|---|
| | Code | Description | Mapped area (ha) | Mapped (%) | Mapped area (ha) | Mapped (%) | Mapped area (ha) | Mapped (%) |
| Scattered to low shrublands of samphire on saline flats | Ltf1 | *Tecticornia* spp. sterile low shrubland | 17.0 | 7.3 | 0.3 | 0.4 | 16.3 | 14.7 |
| | Ltf2 | *Tecticornia* spp. sterile scattered to very open low shrubland with scattered trees of *Avicennia marina* | 18.2 | 7.9 | 6.0 | 7.8 | - | - |
| | Ltf3 | *Tecticornia* spp. sterile low open heath with scattered trees of *Avicennia marina* and *Ceriops australis* fringing outer creek lines | 1.7 | 0.7 | 14.5 | 18.9 | 10.8 | 9.8 |
| | Ltf4 | *Tecticornia* spp. open low shrubland | 8.9 | 3.8 | 4.8 | 6.2 | - | - |
| Open to closed woodland of mangrove along coastline and tidal inlets | Lm1 | *Avicennia marina* open low woodland | 30.7 | 13.2 | 6.9 | 9.0 | 8.3 | 7.5 |
| | Lm2 | *Avicennia marina* closed low woodland | 57.4 | 24.8 | 23.4 | 30.4 | 31.0 | 28.0 |
| | Lm3 | *Avicennia marina* low woodland over *Tecticornia* spp. sterile patchy open low shrubland | 82.3 | 35.5 | 14.6 | 19.0 | 27.3 | 24.7 |
| | Rz1 | *Rhizophora stylosa* closed low woodland | 5.7 | 2.5 | - | - | 9.9 | 8.9 |
| No vegetation present | Usf | Unvegetated saline flat located on sheltered margins | 4.1 | 1.8 | 4.4 | 5.7 | 3.6 | 3.3 |
| | Utf | Unvegetated tidal flat located on exposed margins | 5.7 | 2.5 | 2.0 | 2.6 | 3.5 | 3.2 |
| **Total** | | | **231.7** | **100** | **76.9** | **100** | **110.7** | **100** |

**Table 5-6 Species Composition of each Vegetation Community Type Identified at the Mainland End of the DomGas Pipeline Route**

| Family | Species | Vegetation Association | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Lm1 | Lm2 | Lm3 | Rz1 | Ltf1 | Ltf2 | Ltf3 | Ltf4 |
| Acanthaceae | *Avicennia marina* | X | X | X | X | | X | X | |
| Chenopodiaceae | *Suaeda arbusculoides* | X | X | X | | | | | |
| | *Tecticornia* spp. | | | X | | X | X | X | X |
| Myrsinaceae | *Aegiceras corniculatum* | | X | | | | | | |
| Plumbaginaceae | *Aegialitis annulata* | | X | X | | | | X | |
| | *Muellerolimon salicorniaceum* | | | X | | | | X | X |
| Rhizophoraceae | *Bruguiera exaristata* | | X | | | | | | |
| | *Ceriops australis* | | | X | | | | X | |
| | *Rhizophora stylosa* | | X | X | X | | | | |

Four of the ten vegetation community types were predominantly mangrove vegetation community types, four were predominantly samphire vegetation community types, and two were unvegetated mud flats. All of the dominant vegetation community types were generally well represented across the three survey areas, with the exception of the *Rhizophora stylosa* vegetation community type (Rz1), which was found to be absent from the Northern Reference Area. The Northern Reference Area also contained a greater number of mixed *Avicennia marina*/*Ceriops australis* stands in comparison to the other areas, particularly along the fringes of the upper reaches of the northern tidal creek. *Avicennia marina* dominated vegetation community types were the most prevalent across all three survey areas. The structure of these communities varied both within and between the survey areas, largely dependent on the size of the creek system and geographical location within an area. Coastal fringe *A. marina* dominated vegetation communities typically contained larger (>2 m), open (typically 10–30% cover) and older stands of *A. marina*. This vegetation community type was present within all three survey areas. In contrast, *A. marina* dominated vegetation communities within the upper tidal creek areas were typically comprised of low stands of *A. marina* (<1.5 m), with canopy densities varying from ‘dense’ (>70% cover) to ‘scattered’ (<2% cover), depending on the thickness of the fringing mangroves as well as proximity to the samphire vegetation or unvegetated saline flats.

A map showing the distribution of vegetation community types within the area at risk of Material or Serious Environmental Harm is presented in Figure 5-9. A total of ten vegetation community types were identified within this area. The total area of each community type and the proportion contribution of each community type to the total area at risk of Material or Serious Environmental Harm, are presented in Table 5-5.

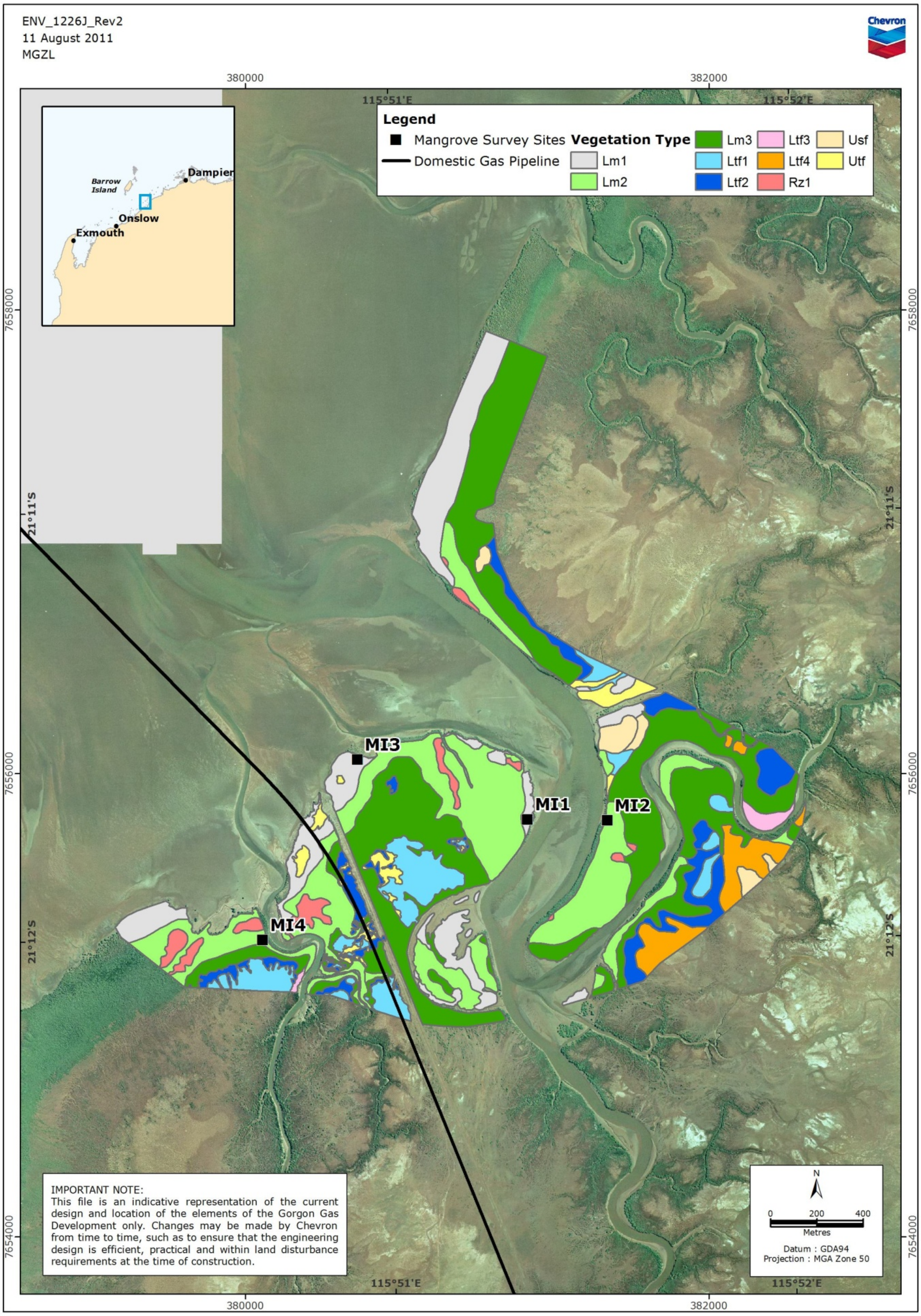



**Figure 5-9 Mangrove Vegetation Community Types in the Area at Risk of Material or Serious Environmental Harm**

A map showing the distribution of vegetation community types within the Northern Reference Area is presented in Figure 5-10. A total of nine vegetation community types were identified within this area, with the total area of each vegetation community type and the proportion contribution of each vegetation community type to the total Northern Reference Area presented in Table 5-5. A map showing the distribution of vegetation community types within the Southern Reference Area is presented in Figure 5-11. A total of eight vegetation community types were identified within this area, with the total area of each vegetation community type and the proportion contribution of each vegetation community type to the total Southern Reference Area presented in Table 5-5.

The composition and structure of the vegetation communities described within the area at risk of Material or Serious Environmental Harm and the Northern and Southern Reference Areas are typical of the mangrove communities describe elsewhere along the Pilbara coast (e.g. Craig 1983; Jones 2004; Paling *et al*. 2003, 2008). Studies elsewhere indicate that *Avicennia marina*, *Rhizophora stylosa*, and *Ceriops australis* comprise the dominant species through the broader region, while *Aegialitis annulata*, *Aegiceras corniculatum,* and *Bruguiera exaristata* are less common but nevertheless widespread in the Pilbara region. *Avicennia marina,* the variety found most commonly in north-western Western Australia (Duke 1991), was the dominant species in the survey areas. Three species not previously recorded by Astron Environmental Services (2009) were identified in these surveys, increasing the number of mangrove species observed in the area to six. These species were *Bruguiera exaristata*, *Aegiceras corniculatum* and *Aegialitis annulata*. Of these, *Bruguiera exaristata* and *Aegiceras corniculatum* are new records for the region, extending the southern limit of these species more than 150 km further south than previously recorded at Cossack, near Point Samson (Semeniuk *et al*. 1978; Duke 2006). These species were common in the survey areas.

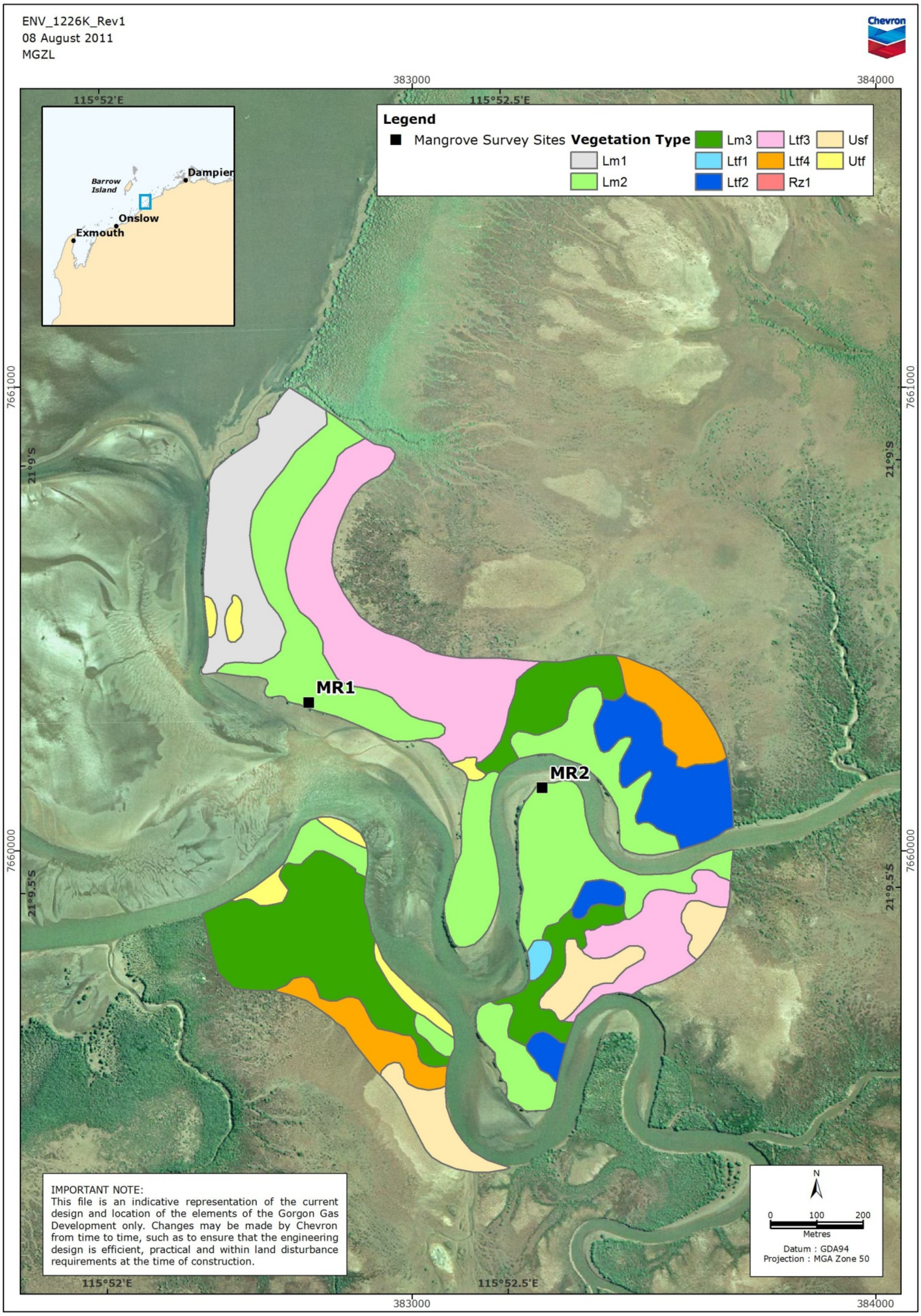



**Figure 5-10 Mangrove Vegetation Community Types in the Northern Reference Area**

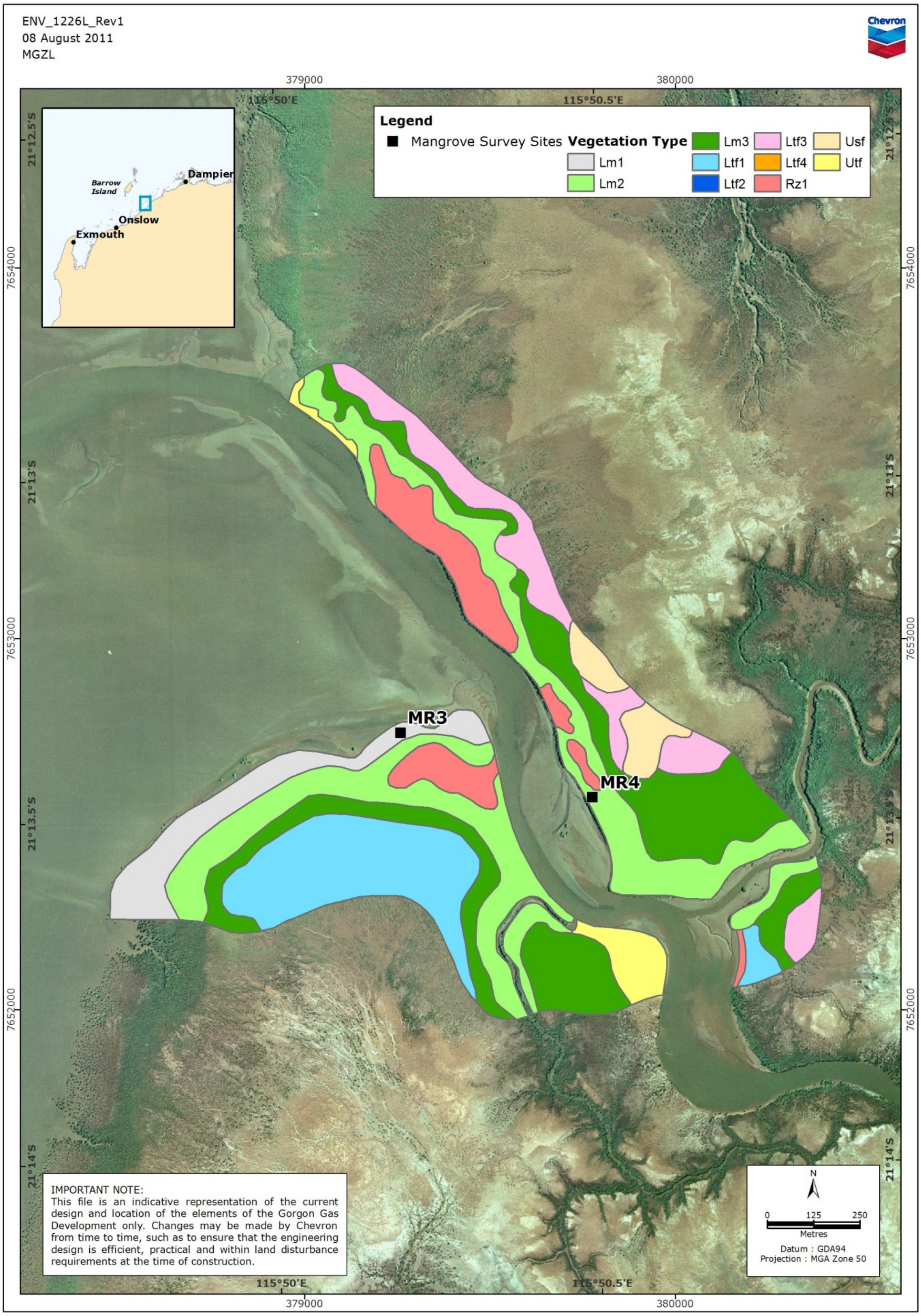



**Figure 5-11 Mangrove Vegetation Community Types in the Southern Reference Area**

## 5.6 Conclusions

The benthic habitats near the DomGas Pipeline between Barrow Island and the mainland shore crossing were characterised by unvegetated or bare sand. Macroalgae (*Caulerpa*) were the dominant ecological element recorded in one location along the pipeline route; otherwise, macroalgae were only recorded in isolated small patches. Similarly, small, isolated patches of seagrass (*Halophila*) were recorded in some areas, but no seagrass 'beds' were observed. An area of low relief reef was recorded at one location along the pipeline route, with live coral coverage <10% (*Acropora*, faviids, *Montipora* and *Turbinaria*). Low densities of non-coral benthic macroinvertebrates were also observed along the pipeline route.

The benthic habitats near the mainland shore crossing of the DomGas Pipeline were similarly characterised by unvegetated or bare sand. The highest diversity of benthic habitats and assemblages (coral, macroalgae and non-coral benthic macroinvertebrates) were recorded around the offshore islands with fringing coral reefs and isolated patch reefs. 'Mixed coral communities' was the dominant Coral Assemblage type in the DomGas Pipeline survey area, with coral cover ranging between 'medium' (i.e. 10–50% cover) and 'dense' (i.e. 51–75% cover).

A total of ten vegetation community types were mapped throughout the area at risk of Material or Serious Environmental Harm and the Northern Reference Area and Southern Reference Area, four of which were predominantly mangrove vegetation community types. All the dominant vegetation community types were generally well represented across the three survey areas. The greatest diversity of vegetation community types occurred within the area at risk of Material or Serious Environmental Harm, which was also the larger mapped area. *Avicennia marina* dominated vegetation community types were the most prevalent throughout the three survey areas, although the structure of these community types varied both within and between survey areas.

# 6.0 Hard and Soft Corals

## 6.1 Introduction

The marine habitats in the Pilbara region support a variety of coral species that vary spatially, with the clearer waters in offshore areas having higher coral density and diversity than that of the highly turbid nearshore areas (Woodside 2006). Coral surveys in north-western Australia have generally been concentrated in areas associated with industrial development. Approximately 318 hermatypic coral species from 70 genera are known to occur in Western Australia (Woodside 2006). Surveys conducted in the Dampier Archipelago in 2004 found that four coral genera dominated the coral assemblages: *Acropora* (especially plate *Acropora*), *Porites*, *Pavona* and *Turbinaria* (Blakeway and Radford 2005). The fifth most abundant type of coral assemblage was a 'mixed' assemblage, consisting of *Turbinaria*, faviids and other scleractinian corals. A total of 229 species of coral from 57 hermatypic coral genera have been recorded in the Dampier Archipelago (Griffith 2004).

At least 150 species of hard corals from 54 genera were recorded in the Montebello/Barrow Island region during a survey conducted by the Western Australian Museum (Marsh 1993). The fringing reefs in the relatively clear and high energy conditions to the west and south-west of the Montebello Islands, as well bomboras and patch reefs in the more turbid and lower energy waters along the eastern edge of the Montebello Islands, are believed to support the best developed coral communities in the Montebello/Barrow Island region (DEC 2007). For Barrow Island specifically, the most significant coral reefs are located at Biggada Reef on the west coast, Dugong Reef and Batman Reef off the south-east coast, and along the edge of the Lowendal Shelf on the east side of Barrow Island (DEC 2007). Surveys undertaken in the waters around Barrow Island have identified 196 species of hard corals in 48 genera, and seven soft coral genera from the suborder Alcyoniina (Chevron Australia 2013a). These included six new records for Australia (although unpublished information indicates *Platygyra acuta* has been previously recorded in Western Australia), nine new records for Western Australia, and three new records for the North West Shelf.

The intertidal pavement reef on the east coast of Barrow Island supports the growth of hard corals and soft corals (Chevron Australia 2005, 2008). The coral assemblage in this area is dominated by various species of the hard coral *Goniastrea* with some colonies exceeding 80 cm in diameter (Chevron Australia 2008). Less common hard corals in this area include *Porites*, *Euphyllia*, *Lobophyllia*, *Plesiastrea*, *Favia*, *Favites*, *Platygyra* and *Acanthastrea* (Chevron Australia 2005). Soft corals recorded in this area include *Sarcophyton*, *Lobophytum*, *Sinularia*, *Nephthea* and *Dendronephthya* (Chevron Australia 2005).

Coral communities on the subtidal pavement reef and the deeper offshore areas vary from almost exclusively coral-dominated assemblages, to areas dominated by macroalgae, but with scattered small hard corals such as *Acropora* and soft corals such as *Rumphella* (Chevron Australia 2005). *Porites* bombora up to 1 m high are either interspersed as isolated elements throughout the subtidal reef area or grouped together to form bombora communities (Chevron Australia 2005, 2008).

On the west coast of Barrow Island, coral reefs are limited to the southern and central parts of the west coast. Biggada Reef on the central west coast of Barrow Island is an extensive, largely intertidal coral reef that extends to the subtidal zone (DEC 2007). The reef crest and lagoon areas support extensive expanses of corals that are exposed on very low tides. Surveys of the intertidal component of Biggada Reef in 1995 revealed a diverse fauna that included at least 64 species of hard coral (Bowman Bishaw Gorham 1996; Chevron Australia 2013a). The limestone pavement reef off North Whites Beach, in the vicinity of the marine component of the shore crossing, supports a variable cover of macroalgae and small, sparsely scattered corals (*Acropora* and *Turbinaria*) (RPS Bowman Bishaw Gorham 2007). In the vicinity of the Offshore Feed Gas Pipeline System in State waters and the marine component of the shore crossing, corals are limited to small scattered corals, such as *Turbinaria* sp., and soft corals, which are considered part of the macroalgae dominated Benthic Primary Producer Habitat unit (Chevron Australia 2005, 2013a, 2011b).

Hard corals recorded as occurring adjacent to the Domestic Gas Pipeline route included occasional coral bomboras (*Porites*, *Montipora*), supporting hydroids, sea whips, gorgonians and scattered small soft corals (*Turbinaria*) (Chevron Australia 2005). Soft corals were more commonly found in shallow waters (<7 m depth) near the mainland coast. Isolated patches of reef supporting live coral (including *Porites* spp., *Montipora* spp., *Turbinaria* spp., faviids) have been observed along the Domestic Gas Pipeline route (Section 5.3; URS 2009; GeoOceans and Oceanica 2011). In the intertidal areas adjacent to the Apache Gas Pipeline, corals were restricted to very occasional *Trachyphyllia* and *Duncanopsammia* colonies, unattached on sandy sediments (Chevron Australia 2005). Soft corals were similarly limited and poorly represented, with occasional *Dendronephthya* colonies.

## 6.2 Scope

This Section records the existing dominant and subdominant hard and soft coral species/taxa (Condition 14.8.iii, Statement No. 800 and Condition 11.8.III, EPBC Reference: 2003/1294 and 2008/4178) and describes and maps the hard and soft coral species/taxa:

- that are at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iii, Statement No. 800; Condition 11.6.III, EPBC Reference: 2003/1294 and 2008/4178)
- at Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iv, Statement No. 800; Condition 11.6.iv, EPBC Reference: 2003/1294 and 2008/4178).

In addition, the following are reported:

- the existing dominant and subdominant hard and soft coral species/taxa (Condition 14.8.iii, Statement No. 800; Condition 11.8.III, EPBC Reference: 2003/1294 and 2008/4178) (Section 6.4.2)
- the population structure of coral communities as colony size-class frequency distributions of dominant hard coral taxa (Condition 14.8.iv.a, Statement No. 800; Condition 11.8.IV.a, EPBC Reference: 2003/1294 and 2008/4178) (Section 6.4.3)
- the population statistics of survival of dominant hard coral taxa and, if appropriate, selected other indicator coral taxa that characterise these communities (Condition 14.8.iv.b, Statement No. 800; Condition 11.8.IV.b, EPBC Reference: 2003/1294 and 2008/4178) (Section 6.4.4)
- the population statistics of growth of dominant hard coral taxa and, if appropriate, selected other indicator coral taxa that characterise these communities (Condition 14.8.iv.b, Statement No. 800; Condition 11.8.IV.b, EPBC Reference: 2003/1294 and 2008/4178) (Section 6.4.5)
- the recruitment of hard coral taxa within these communities (Condition 14.8.iv.c, Statement No. 800; Condition 11.8.IV.c, EPBC Reference: 2003/1294 and 2008/4178) (Section 6.4.6.).

Baseline surveys have been undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800 and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178.

For the purposes of the Marine Baseline Program, 'hard corals' are considered to be the reef-building corals within the order Scleractinia. Corals were classified according to the online Integrated Taxonomic Information System (ITIS) (http://www.itis.gov) or other recognised coral identification tools (e.g. Australian Institute of Marine Sciences Monograph Series *Scleractinia of Eastern Australia*, Volumes 1–5). Recent taxonomic regrouping of some species and genera into new clades and families based on genetic analyses (Kerr 2005; Fukami *et al.* 2008) are only just being developed and are not yet commonly recognised.

The hard coral *Turbinaria* spp. is a widespread and common genus of hard coral that also occurs outside coral habitats in benthic macroinvertebrate dominated assemblages in Barrow Island waters and at the mainland end of the Domestic Gas Pipeline route. *Turbinaria* spp. are more similar to other benthic macroinvertebrates (i.e. solitary with a low profile and low benthic cover) than the reef-building corals within the order Scleractinia, and are therefore also described in Section 7.0 (non-coral benthic macroinvertebrates) as well as in this Section.

'Soft corals' have no skeleton and are not considered reef-building organisms. For the purposes of the Marine Baseline Program, 'soft corals' are those within the order Alcyonacea (soft corals) and suborder Alcyoniina ('true soft corals') (http://www.itis.gov). Identifying soft corals is generally difficult except for the suborder Alcyoniina, and even then the species are difficult to distinguish (Dinesen 1983). Soft corals were identified only to suborder or genus. The other organisms within the order Alcyonacea include sea whips (suborder Calcaxonia) and sea fans (suborders Holaxonia and Scleraxonia) (http://www.itis.gov). Soft corals also occur outside coral-dominated communities in benthic macroinvertebrate dominated assemblages in Barrow Island waters and at the mainland end of the Domestic Gas Pipeline route. They are considered to be an important part of the sessile benthic macroinvertebrate assemblages and are therefore described in Section 7.0 (non-coral benthic macroinvertebrates) as well as in this Section. Non-scleractinian corals (e.g. *Millepora* sp.; class Hydrozoa) were recorded only if they were dominant or subdominant and were identified only to genus level.

Condition 14.8.iv.b of Statement No. 800 and Condition 11.8.IV.b of EPBC Reference: 2003/1294 and 2008/4178 require the recording of the survival and growth of dominant hard coral taxa and, if appropriate, selected other indicator coral taxa that characterise the communities. Key indicator species are interpreted as 'sensitive' species (e.g. sensitive to sedimentation, turbidity or bleaching) and 'representative' species that occur at all sites to facilitate future comparisons between sites.

## 6.3 Methods

### 6.3.1 Site Locations: East Coast of Barrow Island

Coral survey sites off the east coast of Barrow Island were established to meet Ministerial Conditions requiring the description and mapping of benthic ecological elements and recording of coral species and population information (Section 6.2) prior to the commencement of marine construction activities for the MOF and LNG Jetty (Chevron Australia 2013a). Three of these sites are in the vicinity of the DomGas Pipeline route, but outside the DomGas Pipeline Marine Disturbance Footprint, and information on these sites is presented in this Report (Table 6-1; Figure 6-1). One of the sites (MOF1) is located within the Zone of Moderate Impact associated with the generation of turbidity and sediment deposition from dredging and spoil disposal activities on the east coast of Barrow Island (Section 2.3.4). Two of the sites (LNG3 and Dugong Reef [DUG]) are Reference Sites which are not at risk of Material or Serious Environmental Harm due to the construction or operation of the Marine Facilities. For information on other coral survey sites on the east coast of Barrow Island refer to Chevron Australia (2013a).

**Table 6-1 Hard and Soft Coral Survey Sites in the Vicinity of the DomGas Pipeline Route in Waters off the East Coast of Barrow Island**

| Location | Site Code | Easting | Northing | Latitude | Longitude | Depth (m) |
|---|---|---|---|---|---|---|
| | | (GDA94, MGA Zone 50) | | (GDA94) | | |
| At risk of Material or Serious Environmental Harm | MOF1* | 342089 | 7698785 | 20° 48.249' S | 115° 28.961' E | 6.00 |
| Reference Sites | LNG3 | 343157 | 7692657 | 20° 51.575' S | 115° 29.544' E | 6.50 |
| | DUG | 340099 | 7687998 | 20° 54.085' S | 115° 27.755' E | 6.25 |

** Denotes a sampling site located in a Dredge Management Area. Source: Chevron Australia (2013a).*

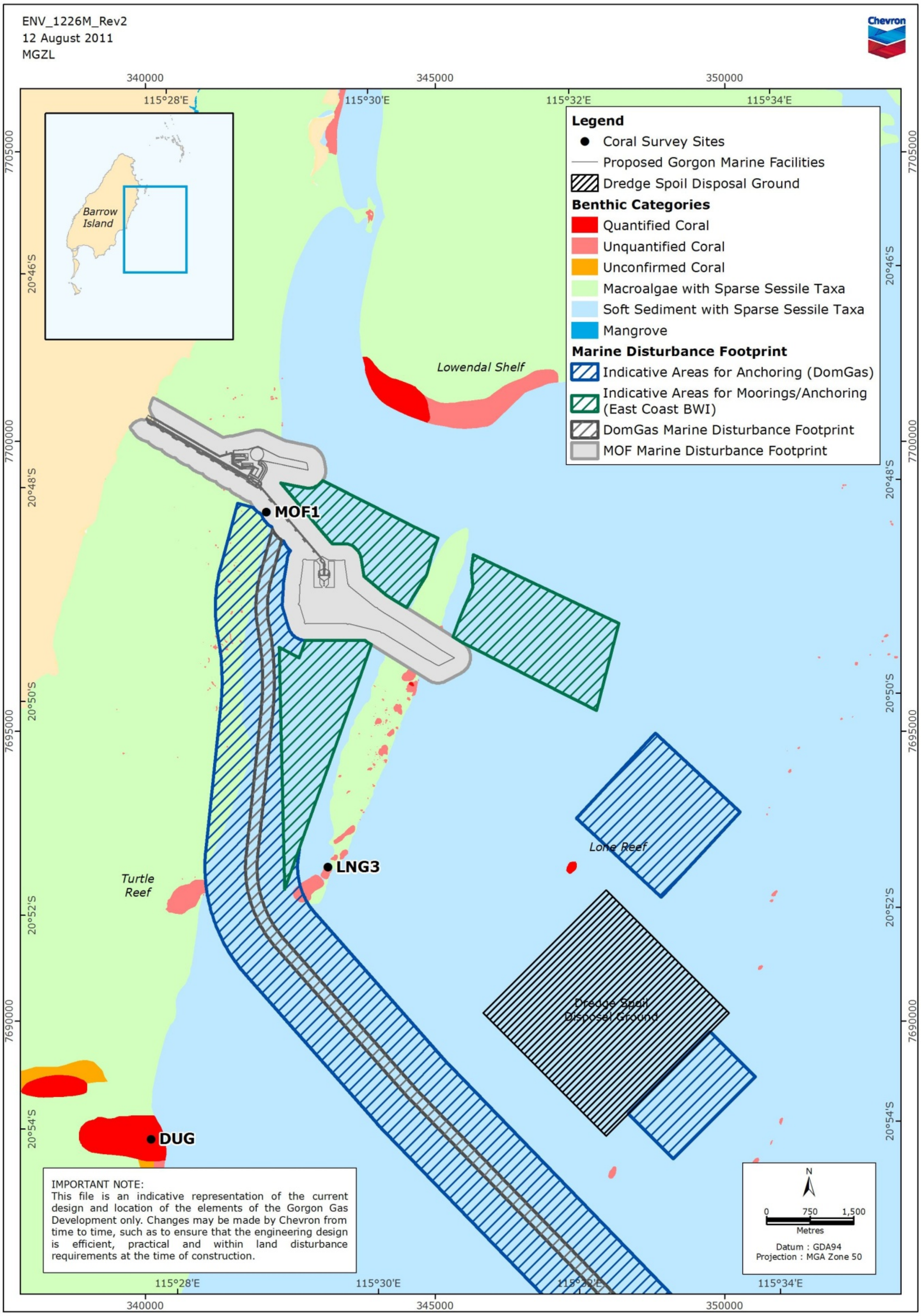



**Figure 6-1 Coral Survey Sites in the Vicinity of the DomGas Pipeline Route in Barrow Island Waters**

### 6.3.2 Site Locations: Mainland End of the DomGas Pipeline Route

Four coral survey sites were located within areas where corals were identified as being present through broadscale mapping and ground-truthing (Section 5.4) at the mainland end of the DomGas Pipeline route (Table 6-2; Figure 6-2). Two sites (CI1, CI2)[7] were located in areas at risk of Material or Serious Environmental Harm within the trenching and jetting Marine Disturbance Footprint; and two Reference Sites (CR1, CR2) were located in areas not at risk of Material or Serious Environmental Harm, outside the trenching and jetting Marine Disturbance Footprint (Section 2.3.3.2).

Sites were selected to be representative of the overall population being monitored in the vicinity of the DomGas Pipeline (in this case, coral assemblages, defined as benthic areas [minimum 10 $m^2$] or raised seabed features over which the average live coral cover is ≥10% coral cover). Where possible, sites were established in areas of high coral cover (preferably >20%, based on visual estimates during broadscale mapping and ground-truthing) to maximise the number of replicate colonies of each species that could be selected to measure coral survival and growth. All the coral survey sites were located in the vicinity of the offshore islands (an unnamed reef located south-west of the pipeline route and north-east of Cowle Island, Solitary Island, Passage Island and South Passage Island) as no significant coral assemblages were identified elsewhere in the study area. The sites CI1 and CI2 were located within the only areas of coral communities encountered within the area at risk of Material or Serious Environmental Harm and were located approximately 4 km from the mainland shore. The two Reference Sites represented sites either side of the DomGas Pipeline route and were located approximately 9 km from the shore. The sites were located in depths of <1 m to approximately 2.5 m.

**Table 6-2 Coral Survey Sites at the Mainland End of the DomGas Pipeline**

| Location | Site | Easting | Northing | Latitude | Longitude | Depth (m) |
|---|---|---|---|---|---|---|
| | | (GDA94, MGA Zone 50) | | (GDA94) | | |
| At risk of Material or Serious Environmental Harm | CI1 | 374881 | 7656522 | 21° 11.306' S | 115° 47.679' E | 0.8 |
| | CI2 | 378978 | 7663075 | 21° 07.771' S | 115° 50.075' E | 1.4 |
| Reference Sites | CR1 | 373545 | 7666308 | 21° 05.996' S | 115° 46.941' E | 2.6 |
| | CR2 | 368230 | 7662300 | 21° 08.146' S | 115° 43.862' E | 2.0 |

[7] CI1 and CI2 were the only areas of coral identified with the area at risk of Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline.

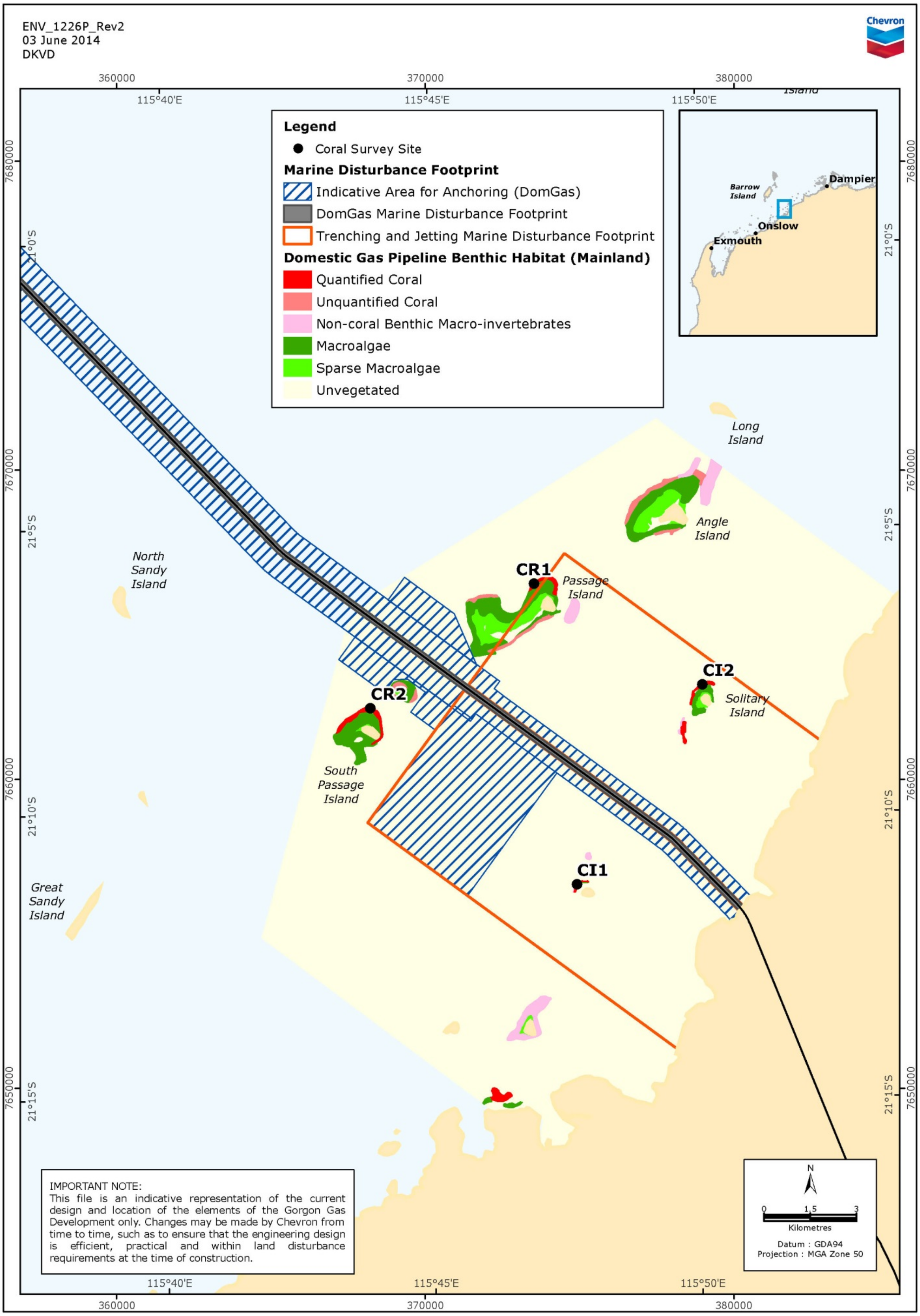



**Figure 6-2 Coral Survey Sites at the Mainland End of the DomGas Pipeline**

### 6.3.3 Survey Methods

#### 6.3.3.1 Mapping

##### 6.3.3.1.1 Coral Assemblage Classification

There are no standard mapping methodologies for coral reefs. The classification scheme used in the Marine Baseline Program followed the general hierarchical approach developed by Mumby and Harborne (1999) for mapping coral reefs in the Caribbean, where coral cover and coral diversity are generally low (<10% cover and approximately 10 species typically present). At Barrow Island, the variation in coral cover and high species diversity of corals required the development of a specific Benthic Habitat Classification Scheme (Section 5.2.2; Appendix 2).

##### 6.3.3.1.2 Mapping of Coral Assemblages in Waters off the East Coast of Barrow Island

In summary, within the immediate vicinity of the project area adjacent to Town Point on the east coast of Barrow Island, remote sensing data (Multi-Beam Sonar, Laser Airborne Depth Sounder [LADS], Side-Scan Sonar) were used to map the boundaries of potential coral features (Chevron Australia 2013a). Where available, data from a Multi-Beam Sonar survey were interrogated to locate coral patch reefs using a semi-automated method (Fugro Survey 2007). This identified the boundaries of potential coral features at least 0.1 m high with a diameter of at least 2 m. Where these data were not available, a semi-automated method was used to locate potential coral features from the LADS data. This identified potential coral features at least 0.4 m high with an area of at least 25 $m^2$, or at least 0.2 m high and with an area of 50 $m^2$. Additional information about the location of potential coral features was determined from a Side-Scan Sonar survey. This information was capable of identifying areas of increased coral density, but was known to have some positional inaccuracies. Therefore, the potential coral features identified using this dataset were merged with potential coral features identified using the other two datasets, which were considered to have greater positional accuracy.

The majority of the potential coral features identified from remote imagery were mapped as 'Unconfirmed Coral' (Chevron Australia 2013a); however, classification of the benthic assemblages was undertaken at the coral survey sites within these areas. The ground-truthing of the potential coral features included the quantitative assessment of live coral cover. Quantitative assessment of live coral cover involved the analysis of photo-quadrats along transects using the software program Coral Point Count with Excel extensions (CPCe) (Kohler and Gill 2006) to assess percentage composition of coral assemblages.

In summary, outside the immediate vicinity of the project area, potential coral features were identified visually using the LADS data and aerial photographs (Chevron Australia 2013a). The aerial photographs were used to identify features that could then be traced around bathymetric contours provided by the LADS data. The aim of mapping the coral assemblages was to obtain a general description of the reef areas around the coral survey sites. Areas of reef were surveyed at each site to identify general assemblage types and their percentage cover. The extent of mapping at each site was determined where a boundary could be delineated using the combined information from existing broadscale benthic habitat maps (CALM 2004), remote imagery, and ground-truthing (e.g. English *et al*. 1997; Hill and Wilkinson 2004). Ground-truthing methods included spot dives, manta tows, and video camera tows. These methods were used interchangeably depending on the spatial extent and depth of the area being surveyed.

Sampling grids were overlaid over areas of potential coral assemblages identified from aerial imagery and LADS data using GIS (Chevron Australia 2013a). The distance between grid points varied between 50 and 500 m, and the number of grid points overlaid on an area of reef ranged between 28 and 65, depending on the size of the area. During ground-truthing surveys, the dominant benthic assemblage type and percentage cover at each grid point was classified according to the Benthic Habitat Classification Scheme (Section 5.2.2; Appendix 2). An area of approximately 7850 $m^2$ was surveyed at each grid point (a circular area of approximately 100 m diameter, which represents the reach of the hoses of divers on SSBA). Additional ground-truthing was undertaken at grid points where surface observations along the track lines between the grid points indicated a change in the composition or cover of the dominant assemblages. Boundaries were drawn around the dominant assemblage types for mapping; information on subdominant components of assemblages is also provided within the site descriptions.

#### 6.3.3.1.3 Mapping of Coral Assemblages at the Mainland End of the DomGas Pipeline Route

Mapping of coral assemblages at the mainland end of the DomGas Pipeline used a combination of aerial imagery (Google Earth Pro as at 11 August 2010), nautical charts, available habitat maps (e.g. URS 2009), and the results from ground-truthing (Section 5.4). Broadscale mapping of benthic ecological elements initially occurred in August 2010 using towed video surveys. In February and April 2011, ground-truthing (snorkel, bathyscope and remote video surveys) of additional survey points was undertaken to refine estimates of the spatial extent and species composition of areas of coral. Given the fringing nature of the reef systems in the study area, sampling effort was directed towards identifying the reef edges to enable accurate maps of reef extent to be generated. To better define the spatial extent of subtidal benthic habitats at each of the coral survey sites, a sampling boundary generated from the broadscale mapping was overlaid around each of the reef areas. Survey points were widely distributed within the sampling boundaries to ensure adequate coverage of these reefs.

The distance between survey points varied from 30 m to 500 m depending on the size of the reef and its corresponding sampling boundary. Survey points on larger reefs were separated by greater distances to allow coverage of the reef extent within the available survey time. Additional ground-truthing survey points were included if surface observations (i.e. bathyscope observations or depth sounder readings) suggested a change in the composition or cover of the dominant assemblages while the vessel was in transit between survey points. As many individual points as possible were surveyed for each reef within the constraints of field time, the prevailing weather, and water clarity conditions. At each survey point an area of approximately 100 $m^2$ was surveyed and records were made of dominant ecological elements, substrate type, estimated live coral cover, dominant and subdominant coral taxa and other noteworthy features. Geographic coordinates from a handheld GPS and water depth were also recorded for each surveyed point. Benthic assemblages and percentage cover at each point were classified in accordance with the Barrow Island Habitat Classification Scheme (Section 5.3; Appendix 2).

### 6.3.3.2 Rapid Visual Assessment Surveys

Rapid Visual Assessment (RVA) surveys of coral biodiversity (Oxley *et al.* 2003; Kospartov *et al.* 2006) were undertaken at each of the coral survey sites to estimate the relative abundance of hard and soft coral species/taxa that characterise the coral communities.

The diversity and abundance of hard and soft corals were recorded during 120-minute timed swims (RVA) or until species saturation was reached (a situation whereby no new species has been recorded for 15 minutes). Surveys were undertaken on snorkel or using Surface Supplied Breathing Apparatus (SSBA) with video footage viewed in real time by a coral specialist aboard the vessel who provided direction to the divers and recorded coral abundance.[8] Undertaking the RVA surveys on snorkel would likely provide an underestimate of the number of species at a site because some rare species (i.e. species with an abundance scale of <3) may not have been recorded and deeper sites were not able to be surveyed as comprehensively as the shallower sites. While the area surveyed by SSBA would likely be less than that achieved using snorkel (an area of approximately 100–200 m radius) due to the restrictions imposed by hose length, SSBA allows more thorough inspection of reef habitats within the area surveyed, while also facilitating specimen collection. Thus the use of divers under the direction of a coral

[8] Note that SSBA was used to undertake the RVA surveys at the mainland end of the DomGas Pipeline route because of health and safety consdierations with respect to undertaking these surveys on snorkel by the coral specialist. The methodology that has been implemented is nevertheless consistent with the methodologies of the Scope of Works (RPS 2009) as Condition 14.1 of Statement No. 800 and Condition 11.1 of EPBC Reference 2003/1294 and 2008/4178 requires.

specialist is considered to deliver outcomes as the surveys being undertaken on snorkel (Dr Zoe Richards, Australian Museum, pers. comm. June 2011).

The relative abundance of each species was estimated on a standard five-point Dominant-Abundant-Frequent-Occasional-Rare (DAFOR) scale, which is commonly used in flora and fauna surveys (Table 6-3). The definition of dominant and subdominant species in Schedule 2 of Statement No. 800 and Schedule 2 of EPBC Reference: 2003/1294 and 2008/4178, specifically refers to the relative percentage cover, expressed as the proportion of total cover, of individual species; thus, the size of colonies was also taken into account in the RVA surveys. In the case of colonies estimated to be >1 m in diameter, each square metre of the colony was counted as one colony (e.g. a large *Porites* colony approximately 5 $m^2$ was counted as five colonies).

**Table 6-3 Abundance Scale for Hard and Soft Corals used in the Rapid Visual Assessment Surveys**

| Abundance Scale | Number of Colonies | Abundance Term |
|---|---|---|
| 5 | 51+ | Most Common |
| 4 | 21–50 | Common |
| 3 | 6–20 | Frequent |
| 2 | 3–5 | Infrequent |
| 1 | 1–2 | Rare |

For species that were new, uncommon or difficult to identify in the field, a small (5–10 cm diameter) skeletal sample was collected and bleached for verification of field identifications using taxonomic literature (Australian Institute of Marine Sciences 1976, 1977, 1980, 1982, 1984) or taxonomic experts. All hard coral samples have had registration numbers allocated in preparation for deposition of the samples into the Australian Museum Marine Invertebrates Collection. Soft corals were photographed to facilitate identification using taxonomic literature (Fabricius and Alderslade 2001); the identification of two soft corals was verified by Dr Philip Alderslade (CSIRO, Marine Research).

To assess whether species identified in the RVA surveys as dominant and subdominant in terms of abundance were also dominant or subdominant in terms of percentage cover, the percentage cover of hard coral families was measured from photo-quadrats (Section 6.3.3.4). Corals were identified to family level in the photo-quadrats and the data were cross-referenced with the RVA survey data to determine the species/taxa that contributed most to the percentage cover of each family and thus represented the dominant and subdominant species/taxa in the assemblages.

#### 6.3.3.3 Size-class Frequency Distributions

Size-class frequency distributions of dominant and subdominant hard coral taxa were recorded along belt transects at each of the coral survey sites. Colonies were measured along five randomly placed 10 m long belt transects radiating out from the anchor point of the vessel in waters off the east coast of Barrow Island.

At each coral survey site at the mainland end of the DomGas Pipeline route, five 20 m × 1 m fixed belt transects were established. The transects were located within the ‘band’ of maximum coral cover at each site, with transects orientated in a consistent direction within each site. Successive transects were separated by between two and seven metres, and were alternately offset to the left and right to include most of the area of coral. Occasionally transects were required to be located on an opposite offset to maintain their position within the area of coral, or to avoid large projections or gullies. Size-class frequency distributions were recorded along the first 10 m of each fixed transect.

The maximum linear dimension ('diameter') of colonies >10 cm was measured in a belt transect 1 m wide on the right side of the transect, while colonies <10 cm were measured in a belt transect 25 cm wide on the left side of the transect (Smith *et al.* 2005). Colonies were categorised into the following size-classes based on maximum colony linear (plan view) dimension: 0.1–2.0 cm, 2.1–5.0 cm, 5.1–10.0 cm, 10.1–20 cm, 20.1–50.0 cm, 50.1–100.0 cm, 100.1–200.0 cm, 200.1–500.0 cm, and 500.1–1000.0 cm, which is consistent with other studies of size-class frequency distributions (e.g. van Woesik and Done 1997).

To avoid bias associated with boundary effects, if ≥50% of a colony was within the belt transect, it was included in the measurements; if <50% was within the belt transect it was excluded (Zvuloni *et al.* 2008). If a colony was divided by partial mortality into separate patches of living tissue but remained structurally intact as a single entity, it was considered to be one colony (Bak and Meesters 1998). In these cases, the longest linear dimension of the entire colony, including the separate patches, was measured.

Generally, information on coral population structure is collected at the species or genus level due to inherent differences in population structure among coral taxa (Bak and Meesters 1998); however, because of difficulties in identifying corals to the species level in-water, data collected in the Marine Baseline Program were predominantly at the genus level. Where colonies could not be identified to genus level, they were identified to family level; some smaller colonies (<1 cm in diameter) could not be identified to family level. The classification system used for coral identification is shown in Table 6-4.

**Table 6-4 Classification System Used for Corals in Size-class Frequency Distribution**

| Family | Genera |
|---|---|
| Acroporidae | *Acropora, Astreopora, Montipora* |
| Agariciidae | *Pachyseris, Pavona,* 'agariciids' genera unknown |
| Caryophylliidae | *Euphyllia* |
| Dendrophylliidae | *Tubastrea, Turbinaria,* 'Dendrophylliid' genera unknown |
| Faviidae | *Caulastrea, Cyphastrea, Diploastrea, Echinopora,* Faviidae genera unknown, *Favia, Favites, Goniastrea, Leptastrea, Leptoria, Montastrea, Moseleya, Platygyra, Plesiastrea* |
| Fungiidae | *Fungia, Herpolitha, Lithophyllon,* 'fungiids' genera unknown |
| Merulinidae | *Hydnophora, Merulina* |
| Milleporidae | *Millepora* |
| Mussidae | *Acanthastrea, Lobophyllia, Symphyllia,* 'mussids' genera unknown |
| Oculinidae | *Galaxea* |
| Pectiniidae | *Echinophyllia, Mycedium, Oxypora, Pectinia* |
| Pocilloporidae | *Pocillopora, Seriatopora, Stylophora* |
| Poritidae | *Goniopora, Porites* |
| Siderastreidae | *Coscinaraea, Psammocora, Pseudosiderastrea* |
| 'Unidentified' | Family Unknown |
| Alcyoniidae | *Lobophytum, Sarcophyton, Sinularia* |

### 6.3.3.4 Photo-quadrats

At the coral survey sites on the east coast of Barrow Island, five 20 m-long random transects were set out and a 1 $m^2$ quadrat was photographed every 2 m along each transect.[9] Photographs were taken with a Canon IXUS 860 IS digital camera fixed in a frame mounted to

[9] Five 20 m long fixed transects were also established at Dugong Reef, for further information refer to Chevron Australia (2013a).

the quadrat to maintain a consistent distance and orientation above the seabed. Taking the photographs at 2 m intervals along each transect ensured that no part of the transect was photographed twice and that there was no bias as to where a photograph was taken.

At each coral survey site at the mainland end of the DomGas Pipeline route, 1 $m^2$ quadrats were photographed along each of the five 20 m × 1 m fixed belt transects (Section 6.3.3.2), using a Canon A650is digital camera in polycarbonate Ikelite housing. In areas of good visibility, the entire 1 $m^2$ was photographed; however, under conditions of poor visibility, quadrats were photographed in 0.25 $m^2$ sub-quadrats.[10] Spirit levels attached to the quadrat and the camera were used to ensure the camera was perpendicular to the quadrat.

#### 6.3.3.5 Tagged Colonies

At each coral survey site where colonies were tagged, where practicable a minimum of ten colonies of each genus were tagged. At some sites there were, however, insufficient numbers of colonies of each genus present to achieve this level of tagging. Colonies were randomly selected with no pre-selection criteria other than that they appeared healthy (i.e. no signs of bleaching, predation, or significant partial mortality). Where practicable, additional colonies were tagged as contingency colonies in the event that some colonies died. The colonies were photographed from directly above with a digital camera (e.g. Canon IXUS 860 IS or Canon A650is), with colonies centred in the field of view and photographed from a consistent distance and orientation, ensuring that the entire colony was in the field of view. A graduated scale-bar was included in the photographs of tagged colonies to enable calibration of the area measurements (Plate 6-1). Permanent photo-quadrats were established at DUG to measure the growth of individual colonies. In each photo-quadrat the maximum number of colonies of each selected genus was monitored. Photographs of colonies within quadrats included the quadrat for scale.

The genera and number of colonies measured at each site are presented in Table 6-5. Colonies were identified to genus level due to the difficulty of identifying corals to species level in-water. Note that the numbers of tagged colonies declined between the survey periods because of coral mortality and/or tag loss. No branching colonies were tagged for growth measurements at the survey sites at the mainland end of the DomGas Pipeline route because branching colonies were present in very low numbers at all the survey sites.[11]

**Table 6-5 Genus/Family and Number of Colonies Measured for Growth and Survival at each Site**

| Location | Site | No. Colonies of each Genus/Family Measured and Alive at Time 0 |
|---|---|---|
| At risk of Material or Serious Environmental Harm | CI1 | • 1 × *Favites*<br>• 2 × *Goniopora*<br>• 1 × *Lobophyllia*<br>• 1 × *Platygyra*<br>• 1 × *Porites*<br>• 1 × *Psammocora*<br>• 5 × *Turbinaria* |
| | CI2 | • 2 × *Favites* |

[10] Note that the use of sub-quadrats introduced errors into the measurement of coral growth (Dr David Blakeway, MScience, pers. comm. July 2011). Photo-quadrats that were photographed as 1 $m^2$ in the first survey and as 0.25 $m^2$ sub-quadrats in the second survey consistently recorded colonies with negative growth, even though it was apparent that the colonies had not decreased in size. This result is thought to be due to a parallax-related scaling discrepancy when using the different sized quadrats.

[11] Only three branching colonies (one *Acropora* sp. and two *Hydnophora rigida*, all <10 cm in diameter) were observed in the 220 photo-quadrats from all four survey sites in the October 2010 survey.

| Location | Site | No. Colonies of each Genus/Family Measured and Alive at Time 0 |
|---|---|---|
| | | • 1 × *Goniopora*<br>• 1 × *Mycedium*<br>• 2 × *Platygyra*<br>• 6 × *Turbinaria* |
| Reference Sites at the mainland end of the DomGas Pipeline route | CR1 | • 1 × *Acropora*<br>• 1 × *Favia*<br>• 1 × *Favites*<br>• 1 × *Goniastrea*<br>• 1 × *Platygyra*<br>• 2 × *Porites*<br>• 5 × *Turbinaria* |
| | CR2 | • 3 × *Acropora*<br>• 1 × *Astreopora*<br>• 3 × *Favia*<br>• 2 × Lobophyllia<br>• 1 × Platygyra<br>• 2 × Turbinaria |
| At risk of Material or Serious Environmental Harm | MOF1[1] | • 9 × *Acropora*<br>• 7 × *Lobophyllia* |
| Reference Sites off the east coast of Barrow Island | LNG3[1] | • 10 × *Acropora*<br>• 8 × *Lobophyllia* |
| | DUG[2] | • 5 x *Acropora*<br>• 10 x *Montipora*<br>• 3 x *Lobophyllia*<br>• 6 x *Pectinia* |

*Notes:*

1. *Non-branching tagged colonies.*
2. *Photo-quadrats of non-branching colonies.*

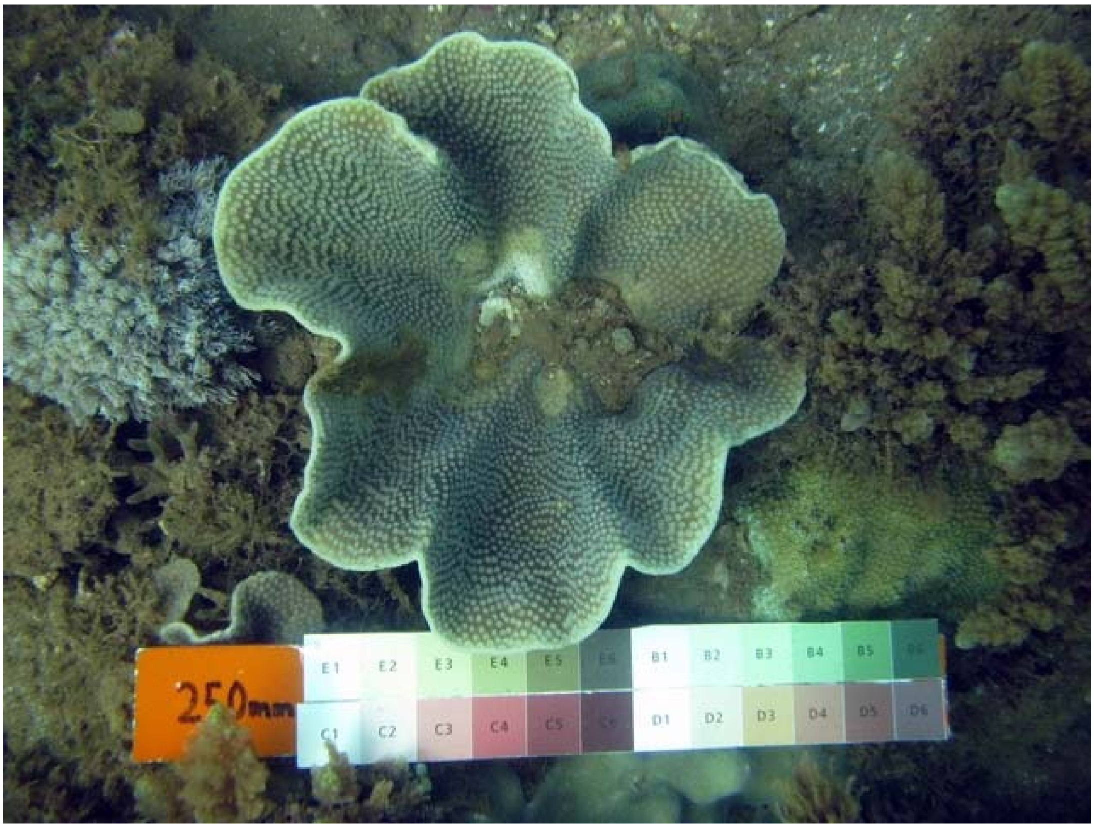



**Plate 6-1 250 mm Scale Bar included in all Individual Colony Images to Calibrate Colony Measurements**

#### 6.3.3.6 Coral Recruitment

At each site, 12 terracotta tiles (145 × 145 × 12 mm [east coast of Barrow Island] or 155 × 155 × 11 mm[12] [mainland end of the DomGas Pipeline route]) were deployed as uniform artificial recruitment substrates (Wallace 1985; English *et al.* 1997; Mundy 2000). At the coral survey sites at the mainland end of the DomGas Pipeline route, an additional 12 tiles were deployed on the initial deployment, with the intent to retrieve the first 12 tiles early in the wet season and the remaining 12 tiles later in the wet season, providing information on the effects of post-settlement mortality.

The tiles were anchored to blocks positioned on the seabed to prevent disturbance by water movement and to maintain a consistent tile orientation. Each tile was anchored with a 2.5 cm spacer between the anchor block and the tile to permit water flow and coral recruitment, while restricting herbivore access to the underside of the tiles (Mundy 2000). At the sites on the east coast of Barrow Island, the tiles were distributed in three groups of four at a consistent depth across each site over a distance of ~150 m, with at least three metres between each tile. At sites at the mainland end of the DomGas Pipeline route, the tiles were distributed in three groups of eight located alongside coral survey transects at each site; the tiles within groups were separated by a minimum distance of 0.5 m and tile groups within sites were separated by 50 m. Tiles were deployed in the mid-depth range of the coral at each site, at depths approximately 1 m below LAT at CI1 and CI2, and 2 m below LAT at CR1 and CR2.

Tiles for assessing coral recruitment were deployed for approximately 8–12 week intervals to monitor temporal variation in the recruitment of hard corals. On each sampling occasion, the

[12] The methodology that has been implemented is nevertheless consistent with the methodologies of the Scope of Works (RPS 2009) as Condition 14.1 of Statement No. 800 and Condition 11.1 of EPBC Reference 2003/1294 and 2008/4178 requires

12 tiles were collected and replaced with a new set of tiles. At sites on the east coast of Barrow Island, tiles were deployed throughout the year to monitor the recruitment of planula brooding species, and deployments were timed to coincide with periods of larval settlement following predicted major broadcast spawning events in spring and autumn (Chevron Australia 2013a). Coral larvae require the presence of bacteria and filamentous algae (microflora) on a surface to stimulate settlement (e.g. Loya 1976; Tomascik 1991); therefore, tiles were deployed approximately two weeks prior to predicted mass spawning periods in autumn and spring to allow time for the establishment of microflora to encourage larval settlement (Heyward *et al*. 2002).

Timing and retrieval of recruitment tiles relative to the timing of coral spawning periods is a major determinant of estimates of recruitment. The most recent published information describing coral spawning in Pilbara coastal waters indicates that the major spawning period occurs in autumn, with a few coral species spawning in spring and one or two groups in the wet season (Stoddart and Gilmour 2005; Baird *et al*. 2010). However, based on the composition of the coral communities at the survey sites at the mainland end of the DomGas Pipeline route, a spring spawning event is likely to be the most significant. In addition, given that turbidity-generating activities at the mainland end of the DomGas Pipeline are scheduled to occur over the period July–September 2012 (Section 2.2), the focus of the present study was to sample during spring and in the wet season, but did not extend into the predicted autumn spawning event in late March 2011. Note that the final tile retrieval, originally scheduled to be undertaken in February 2011, was divided over two field surveys because Tropical Cyclone Carlos and bad weather prevented the retrieval of tiles from CI2 and CR1 until March 2011.

On retrieval, the tiles were bleached for 12 to 24 hours, washed in fresh water, dried and examined under a dissecting microscope. The number of recruits on the lower or underside and side surfaces (total area approximately 0.028 $m^2$ or 0.031 $m^2$) of each tile were counted and each recruit was classified into one of three taxonomic groups (Acroporidae, Pocilloporidae, Poritidae) or 'Unidentified' or 'Other' (English *et al*. 1997). 'Unidentified'/'Other' recruits are those lacking distinguishing skeletal structures by which they can be identified to taxonomic group.

## 6.3.4 Timing and Frequency of Sampling

### 6.3.4.1 East Coast of Barrow Island

Ground-truthing and mapping of coral assemblages at MOF1 was undertaken in October 2008, Dugong Reef (DUG) in November–December 2008 and at LNG3 in December 2008 (Chevron Australia 2013a). The timing and frequency of the surveys to record the existing dominant and subdominant hard and soft coral species/taxa, the population structure of the coral communities, the population statistics of survival and growth of the dominant hard coral taxa and coral recruitment within the communities at MOF1 and LNG3, are summarised in Table 6-6.

**Table 6-6 East Coast of Barrow Island Survey Dates**

| Activity / Site | Time 0 | Time 1 | Time 2 | Time 3 | Time 4 | Time 5 | Time 6 |
|---|---|---|---|---|---|---|---|
| **RVA Surveys** | | | | | | | |
| MOF1 | Oct 2008 | - | - | - | - | - | - |
| LNG3 | Oct 2008 | - | - | - | - | - | - |
| DUG | Oct 2008 | - | - | - | - | - | - |
| **Size-class Frequency Distributions** | | | | | | | |
| MOF1 | Oct 2008 | - | - | - | - | - | - |
| LNG3 | Oct 2008 | - | - | - | - | - | - |
| DUG | Oct 2008 | - | - | - | - | - | - |

| Activity / Site | Time 0 | Time 1 | Time 2 | Time 3 | Time 4 | Time 5 | Time 6 |
|---|---|---|---|---|---|---|---|
| **Photo-quadrats** | | | | | | | |
| MOF1 | Oct 2008 | April 2009 | Oct 2009 | - | - | - | - |
| LNG3 | Sept 2008 | March 2009 | Aug 2009 | Nov 2009 | - | - | - |
| DUG | May 2008 | Nov 2008 | Jun 2009 | - | - | - | - |
| **Tagged Colonies** | | | | | | | |
| MOF1 | Oct 2008 | April 2009 | Oct 2009 | - | - | - | - |
| LNG3 | Sept 2008 | March 2009 | Nov 2009 | - | - | - | - |
| DUG | Jun 2008 | Dec 2008 | Jun 2009 | - | - | - | - |
| **Coral Recruitment (Month of Deployment)** | | | | | | | |
| MOF1 | Mar 2008 | Jun 2008 | Sep 2008 | Dec 2008 | Mar 2009 | May 2009 | - |
| LNG3 | Mar 2008 | Jun 2008 | Sep 2008 | Dec 2008 | Mar 2009 | May 2009 | - |
| DUG | Mar 2008 | May 2008 | Jul 2008 | Sep 2008 | Dec 2008 | Mar 2009 | May 2009 |

#### 6.3.4.2 Mainland End of the DomGas Pipeline Route

Ground-truthing and mapping of coral assemblages at the mainland end of the DomGas Pipeline route were undertaken during September 2010, February 2011, and April 2011. The surveys to record the existing dominant and subdominant hard and soft coral species/taxa, the population structure of the coral communities, the population statistics of survival and growth of the dominant hard coral taxa and coral recruitment within the communities at the sites at the mainland end of the DomGas Pipeline route, were focused around sampling in the dry season and wet season. The dates of the surveys are provided in Table 6-7. Note that some field activities in the wet season were delayed until April 2011 due to the passage of tropical cyclones, adverse weather conditions or logistical constraints.

**Table 6-7 Mainland End of the DomGas Pipeline Route Survey Dates**

| Activity | | Time 1 | Time 2 | Time 3 |
|---|---|---|---|---|
| Rapid Visual Assessment | | Feb 2011 | - | - |
| Size-class Frequency Distributions | | Sept – Oct 2010 | - | - |
| Photo-quadrats | | Oct 2010 | April 2011 | - |
| Tagged Colonies | | Oct 2010 | April 2011 | - |
| Coral Recruitment | CI1 | Oct 2010 | Dec 2010 | Feb 2011 |
| | CI2 | Oct 2010 | Dec 2010 | Mar 2011 |
| | CR1 | Oct 2010 | Dec 2010 | Mar 2011 |
| | CR2 | Oct 2010 | Dec 2010 | Feb 2011 |

*Note: Collection of some tiles during the February 2011 survey was postponed until March 2011 due to Tropical Cyclone Carlos.*

### 6.3.5 Treatment of Survey Data

#### 6.3.5.1 Rapid Visual Assessment Surveys

Species lists and estimated relative abundances were compiled for each coral survey site. The species lists compiled in the Marine Baseline Program were compared to existing species lists for the North West Shelf, Western Australia, and Australia to identify any new taxonomic records.

The following information was recorded for each site:

- Dominant coral species: The dominant coral species, as defined in Schedule 2, Statement No. 800 and Schedule 2, EPBC Reference: 2003/1294 and 2008/4178, is the species with the highest relative percentage cover, where percentage cover is expressed as the proportion of total coral cover. In the Marine Baseline Program, this equates to the highest abundance scale from the RVA surveys in combination with the percentage cover of families. If there were multiple species with equal maximum abundance scales, there was no one dominant species.
- Subdominant coral species: The subdominant coral species, as defined in Schedule 2, Statement No. 800 and Schedule 2, EPBC Reference: 2003/1294 and 2008/4178, are species, excluding dominant coral species, that have ≥5% cover. In the Marine Baseline Program, this equates to an abundance scale of 3, 4, or 5 from the RVA surveys. There can be numerous subdominant species.
- ‘Species of interest’: Includes new records for the region or species that were recorded at only one site.

Estimates of percentage cover of hard and soft coral species/taxa from photo-quadrats were used to complement the results from the RVA surveys. Each family was expressed as a percentage of the total numbers of points classified from photo-quadrats (Section 6.3.3.4) and also as a percentage of the total cover of hard corals in accordance with the definitions of dominant and subdominant species.

#### 6.3.5.2 Size-class Frequency Distributions

Coral colony size data were used to produce size-class frequency distribution plots for each family and each site. Genera were grouped into families for data analysis because few genera occurred in sufficient abundance to be analysed separately. In general, families were examined individually when there were data for >20 colonies, or where the family constituted >5% of all colonies measured at a site. Thus, sites at which colony densities were low were not excluded from the analyses, and subdominant species were included. The remainder of the genera, as well as the unidentified colonies present at each site, were grouped together as ‘Other’ corals.

Several statistical measures were calculated for each family at each site to describe the size-class frequency distributions of the coral populations (Table 6-8). The modal size-class, coefficient of variation (CoV), and skewness were calculated for each family at each site, when there were ten or more individuals at the site. For further information refer to Chevron Australia (2013a).

**Table 6-8 Statistical Measures of Change in Size-class Frequency Distribution**

| Resolution | Data Type | Statistical Measure | Population Structure Attribute |
|---|---|---|---|
| Site and family level | Count Data | Mode | Represents most frequently occurring colony diameter at a site. |
| | | Skewness | Describes the shape of the distribution of the diameter of colonies at a site. In general, if the distribution is symmetric, skewness will be close to zero. A negative value indicates skew to the left where there are relatively few values in the lower size-classes; a positive value indicates skew to the right where there are relatively few values in the upper size-classes. |
| Transect and genus/family level | | Number of Corals | Mean colony density at a site, calculated as an average density over the mean of five transects. |
| | | Mean number of juveniles ≤5 cm | Estimates the number of small (presumed newly recruited) colonies at a site, calculated over the mean of the number |

| Resolution | Data Type | Statistical Measure | Population Structure Attribute |
|---|---|---|---|
| | | | of transects where each genus/family were recorded. |
| | | Mean number of colonies >200 cm | Estimates the number of large (presumably older) colonies at a site, calculated over the mean of the number of transects where each genus/family were recorded. |
| Transect and genus/family level | Size Data | Arithmetic mean | Mean diameter of colonies at a site. |
| | | Coefficient of Variation | Describes variation in colony diameter, standardised by the mean diameter of colonies at a site; allows a comparison of the relative variation in colony diameter among sites with different mean diameters. |

### 6.3.5.3 Live Coral Cover and Coral Survival (Photo-quadrats)

Digital images of the 1 $m^2$ quadrats were analysed by randomly allocating 30 points over each 1 $m^2$ and then classifying the substrate or organism beneath each point. At sites where sub-quadrats were photographed under conditions of low visibility (Section 6.3.3.4), 30 points were randomly distributed over each 0.25 $m^2$ image. The complete quadrat was analysed using 120 points randomly allocated over each 1 $m^2$ to maintain a consistent point density. The program CPCe was used to automate the random point count analysis process (Kohler and Gill 2006).

The following categories were used in scoring the photographs:

- sand, rock, rubble
- 'Coral' (e.g. Acroporidae, Agariciidae, Pocilloporidae, unidentified)
- 'Fauna' (e.g. Milleporidae, Alyconiidae, Sponges, other benthic invertebrates)
- 'Flora' (e.g. macroalgae, turf algae, coralline algae, seagrass).

Organisms were classified to the greatest taxonomic resolution possible, with corals identified to family level. Where it was unclear what was beneath a point, the point was classified as 'Unknown'; other points were classified as 'equipment' or 'tape, wand or shadow' – both of these classifications were excluded from subsequent analyses. Count data were exported to Microsoft Excel from the CPCe program and estimates of mean percentage cover (± Standard Error [SE]) of the major taxonomic groups (each scleractinian family, bleached coral, *Millepora* spp., soft corals, other sessile benthic macroinvertebrates, macroalgae, turfing algae, coralline algae), as well as hard substratum and sand, were calculated as the number of points in each category over the total of all classified points for each site/time. Coral taxa were also expressed as a percentage of the total cover of hard corals, in accordance with the definitions of dominant and subdominant species. Coral survival was assessed as the change in the percentage of live coral tissue cover at each site through time.[13] Site averages and standard errors were based on the mean of the five transects within each site, with all quadrats summed for each transect.

### 6.3.5.4 Coral Survival (Tagged Colonies)

Survival was measured as the change in the proportion of live coral (partial mortality) of individual tagged colonies or selected colonies in photo-quadrats (Chevron Australia 2013a). For measurement of partial mortality, 60 randomly allocated points were overlaid over a digital image of each colony using CPCe (Kohler and Gill 2006) and each point was classified as live coral, bleached live coral, dead coral (applied only to recently dead colonies with a bare skeleton), fauna, algae, sediment, or 'Other' (if the point was outside the colony or could not be

[13] Note that this measure represents the change in the overall live coral cover, which is not strictly survival but *loss-(growth + recruitment)*, rather than the survival of individual colonies (see Section 6.3.5.4).

clearly classified). Count data were exported to Microsoft Excel from the CPCe program and the percentage of live tissue was calculated from the total number of points scored as live coral, bleached live coral and dead coral (the ‘other’ points were excluded). Estimates of colony survival were measured as the change in mean (± SE) percentage of live tissue of colonies between time intervals for each family/genus at each site.

#### 6.3.5.5 Coral Growth (Tagged Colonies)

Coral growth was calculated from photographs using CPCe (Kohler and Gill 2006) to quantify the change (positive or negative) in the planar area of live tissue on each tagged coral colony or selected colonies in photo-quadrats (Chevron Australia 2013a). Estimates of colony growth were measured as the mean (± SE) percentage change in colony size by family/genus at each site. Data are presented as change in size per month for five- to six-month periods for all sites, as well as for data over 12 months at sites off the east coast of Barrow Island.

#### 6.3.5.6 Recruitment

Estimates of recruitment were measured as the mean (± SE) number of coral recruits per tile (lower [underside] and side surfaces) across all tiles from each site over each deployment period. The numbers of recruits were also standardised to the number of recruits per $m^2$ to enable comparison with the results from other studies.

## 6.4 Results

### 6.4.1 Mapping

#### 6.4.1.1 Distribution of Coral Assemblages in Areas at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

In summary, the DomGas Pipeline Marine Disturbance Footprint lies predominantly within an area of soft sediment habitat comprised of coarse- to fine-grained sand, with sparse sessile taxa at subdominant levels of cover (including sparse cover of macroalgae and seagrass and benthic macroinvertebrates), in the channel between the limestone pavement adjacent to Town Point and the East Barrow Ridge (Figure 6-3) (Chevron Australia 2013a). Sea whips and sponges were the most abundant of the benthic macroinvertebrates in this area. The dominant ecological element characterising the outer part of the reef platform was macroalgal assemblages with sparse sessile taxa, comprising ascidians, hydroids, sea whips, scattered small hard corals (e.g. *Turbinaria* sp., *Montipora* sp.) and sponges. Bomboras in this area were comprised mostly of *Diploastrea heliopora* (Faviidae); as well as *Porites australiensis* (Poritidae) and *Lobophyllia diminuta* (Mussidae). While most bomboras were small, several bombora assemblages 3–10 m in diameter were present. The East Barrow Ridge (a raised limestone platform in approximately 7 m water depth) was characterised by areas mapped as ‘Macroalgae with Sparse Sessile Taxa’, coral assemblages and patches of sediment (largely unvegetated bare sand), with subdominant levels of cover of seagrass and benthic macroinvertebrates. The ridge was characterised by sparse coral cover and several large bomboras, some of which had live coral. The biotic cover on the bomboras was variable, with many bombora comprising a mixture of coral, macroalgae and benthic macroinvertebrates. The benthic macroinvertebrate assemblages present on the ridge were characterised by sea whips, small hard corals (*Turbinaria* sp.), sponges and soft corals.


**Figure 6-3 Benthic Ecological Assemblages around Barrow Island**

##### 6.4.1.1.1 MOF1

The Coral Assemblages at MOF1 were dominated by Coral Bombora—Non *Porites* Assemblages, characterised by *Diploastrea heliopora* (faviid) bombora, with a percentage cover of 10–50% (Figure 6-4). This assemblage type covered approximately 0.1 ha in the area of detailed mapping undertaken at this site. There were three subdominant assemblage types identified: a Mixed Coral Assemblage of 10–50% cover; a Mixed Turfing Algae Assemblage of 5–25% cover; and non-coral benthic macroinvertebrates, including taxa such as ascidians and sponges, of 5–25% cover.

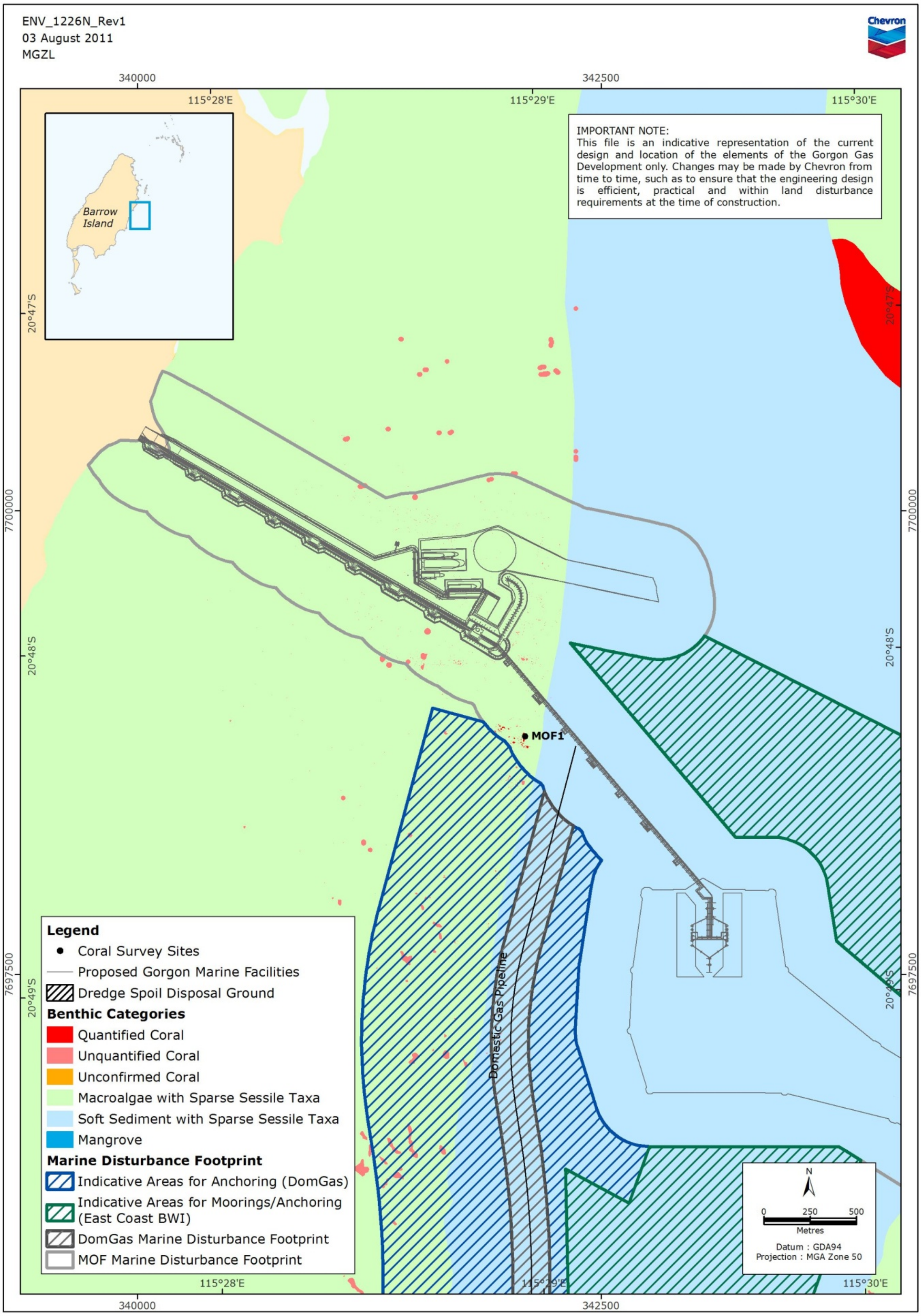



**Figure 6-4 Coral Assemblages in the Vicinity of the Materials Offloading Facility, East Coast of Barrow Island**

#### 6.4.1.2 Distribution of Coral Assemblages at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

##### 6.4.1.2.1 LNG3

LNG3, located on the southern end of the East Barrow Ridge, was one of the larger raised benthic features that occurs along the Ridge (Figure 6-5). The dominant assemblage type was Coral Bombora—*Porite*s (predominantly *P. lutea* and *P. australiensis*) with a percentage cover of 10–50%. Some *Porites* colonies at this site were very large (up to 20 m across and 7 m high) and are estimated to be between 700 and 1000 years old (Chornesky and Peters 1987). This assemblage type covered approximately 0.4 ha in the area of detailed mapping undertaken at this site. There were three subdominant assemblage types identified. A Mixed Coral Assemblage (10–50% cover) consisting of small corals (<30 cm) of genera such as *Lobophyllia* and *Pocillopora* were observed growing on the top of the bombora (Plate 6-2). Other subdominant assemblage types present were sparse (5–25% cover) Mixed Turfing Algae Assemblage and non-coral benthic macroinvertebrates.

**Plate 6-2 Porites lutea and Other Corals (e.g. Pocillopora and Lobophyllia) at LNG3**

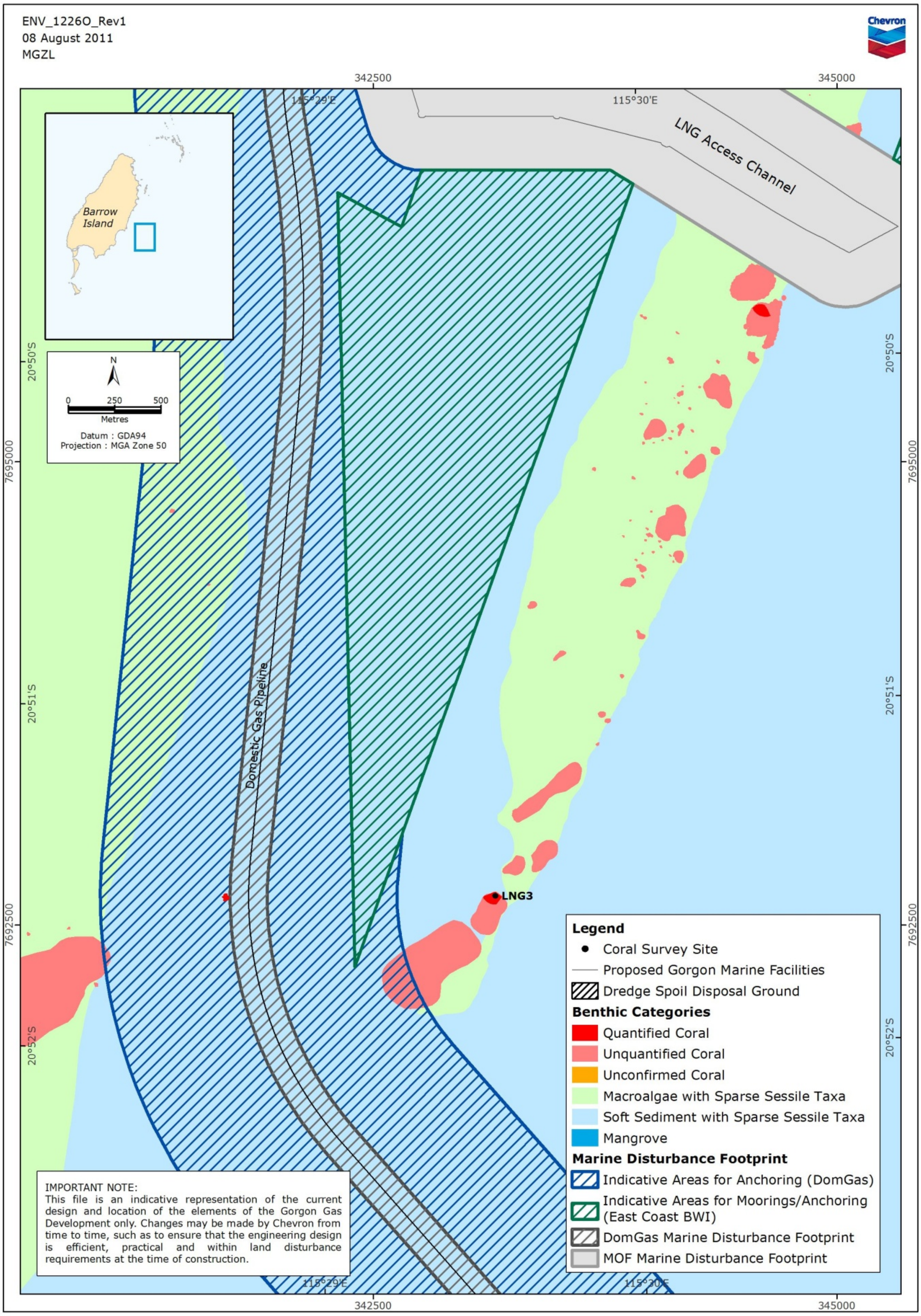



**Figure 6-5 Coral Assemblages on the East Barrow Ridge, East Coast of Barrow Island**

#### 6.4.1.2.2 Dugong Reef [DUG]

Dugong Reef on the south-eastern side of Barrow Island is a limestone structure surrounded by 'Macroalgae with Sparse Sessile Taxa' on the north, west and southern boundaries, with a deeper channel of 'Soft Sediment with Sparse Sessile Taxa' on the eastern boundary (Figure 6-6). Dugong Reef was mapped as intertidal or shallow/limestone and subtidal coral reef communities by the DEC (2007).

In the surveys undertaken for the Marine Baseline Program, four dominant assemblage types were identified at Dugong Reef (Figure 6-6):

- Mixed Coral Assemblage—Coral cover 51–75%

  The eastern area of Dugong Reef, where the monitoring site (DUG) is located, was a high profile reef characterised by high coral percentage cover and diversity, with acroporids, agariciids, faviids, oculinids, pectiniids and poritids occurring in relatively high abundances. There were also shallower areas of high coral cover dominated by *Acropora* and *Montipora* plates. This assemblage type covered approximately 96 ha in the area of detailed mapping undertaken at this site. The subdominant assemblage types were sparse (5–25%) Mixed Turfing Algae Assemblage and non-coral benthic macroinvertebrates.

- Mixed Coral Assemblage—Coral cover 10–50%

  On the northern boundary of the extent of detailed mapping for Dugong Reef there was a Mixed Coral Assemblage with 10–50% cover that was bounded by 'Unconfirmed Coral' and Mixed Turfing Algae Assemblages. This area was slightly deeper than the higher cover area to the south-east; however, species composition was similar in both areas. This assemblage type covered approximately 35.2 ha in the area of detailed mapping undertaken at this site.

- Mixed Turfing Algae—Algal cover 25–75%; Coral cover <10%

  Previous reports indicate the majority of Dugong Reef was characterised by live coral (LeProvost *et al.* 1990). During the present survey, extensive areas of coral rubble and limestone reef covered with Mixed Turfing Algae (25–75%) were recorded. Coral cover was <10%.

- Mixed Phaeophyceae—Algal cover 25–75%; Coral cover <10%

  The southern part of Dugong Reef was characterised by a medium cover (25–75%) of brown macroalgae with low coral cover (<10%).

The areas of Dugong Reef presently dominated by Mixed Turfing Algae and Phaeophyceae were reported to support live coral cover in the early 1990s (LeProvost *et al.* 1990). High levels of bleaching and coral mortality were reported on Dugong Reef in March 1991, which were presumed to have been caused by anoxia associated with slicks of decomposing coral spawn, in conjunction with elevated water temperatures during a period of very calm weather (LeProvost Environmental Consultants 1992).

Note that there were three areas of Dugong Reef that were not ground-truthed due to depth limitations on spot-diving. These areas are mapped as 'Unconfirmed Coral' in Figure 6-6. There is also a large area mapped as 'Unquantified Coral'.

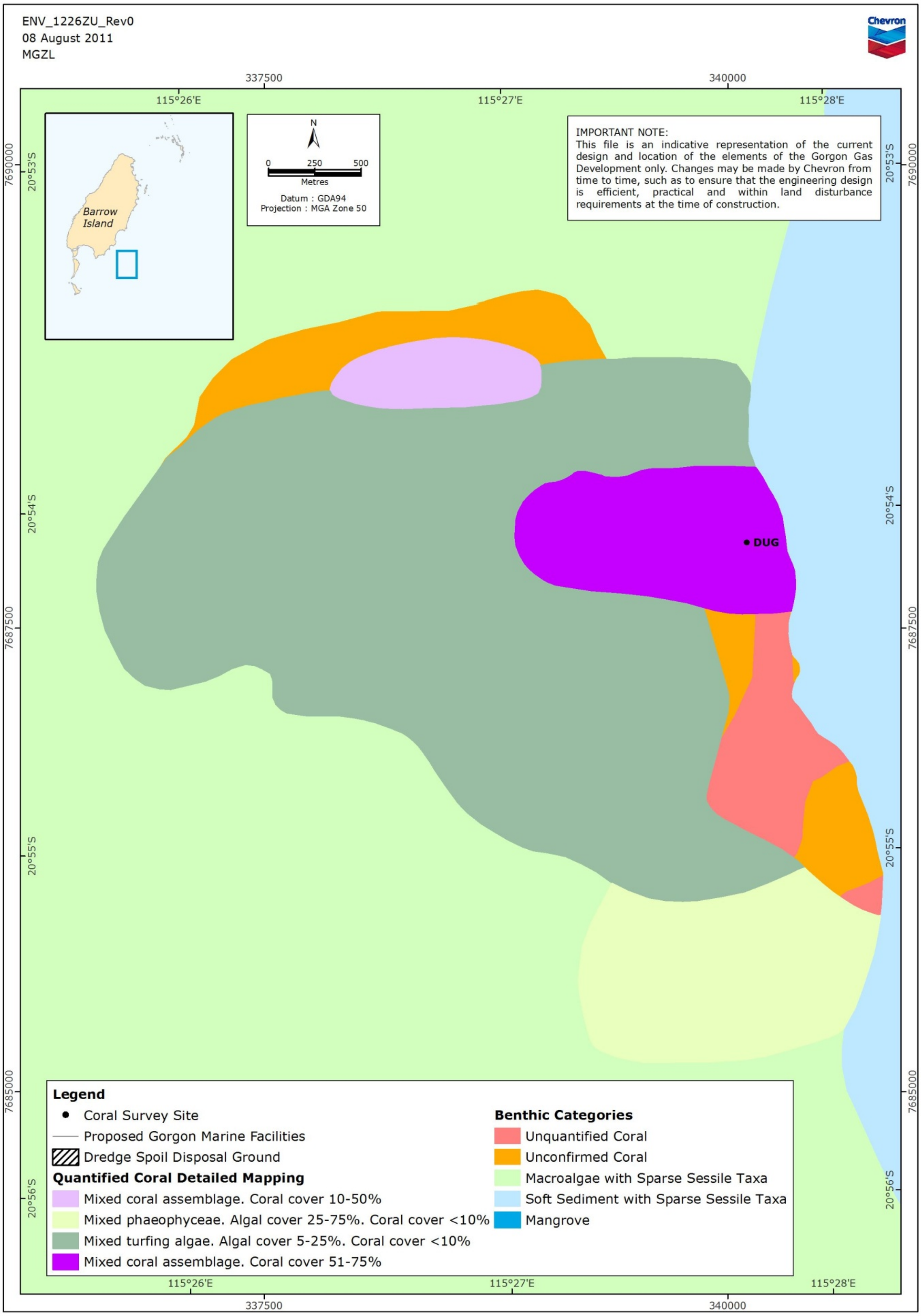



**Figure 6-6 Coral Assemblages at Dugong Reef (Regionally Significant Area)**

#### 6.4.1.3 Distribution of Coral Assemblages at the Mainland End of the DomGas Pipeline Route

A number of offshore islands with fringing coral reefs and isolated patch reefs occur within the study area at the mainland end of the DomGas Pipeline route (Figure 5-7). The highest diversity of benthic habitats within the study area was associated with these structures. Coral-dominated benthic assemblages generally occurred as semi-continuous bands around the outer edge of macroalgal-dominated habitats surrounding the islands. Coral represented an estimated 0.37 $km^2$ or 0.31% of the benthic habitats within the area at risk of Material or Serious Environmental Harm, and 1.06 $km^2$ or 0.63% of the area not at risk of Material or Serious Environmental Harm. Of the ground-truthed areas of coral, >98% were classified as ‘medium’ density coral cover (i.e. 10–50% cover), and <2% were classified as ‘dense’ coral cover (i.e. 51–75% cover). ‘Mixed coral communities’ were the dominant Coral Assemblage type in the study area at the mainland end of the DomGas Pipeline route, and no bombora or *Acropora*-dominated habitats were identified in the field surveys.

##### 6.4.1.3.1 Sites at Risk of Material or Serious Environmental Harm at the Mainland End of the DomGas Pipeline: Unnamed reef Located South-west of the Pipeline Route and North-east of Cowle Island (CI1)

Site CI1 was located on a shallow, curving inshore coral reef approximately 650 m long and up to 75 m wide (Figure 6-7). The reef extends from the south to the east, and bordered habitat dominated by benthic macroinvertebrates in the south-west and macroalgae in the north-east. The site was characterised by low isolated limestone outcrops. There was a large amount of rubble, in addition to open sandy areas. There was a fine >5 mm layer of silt covering the sediment. Turf and coralline algae were observed to dominate the benthic cover; however, sponges were also common, along with other benthic macroinvertebrates such as ascidians.

In the area of ‘quantified coral’, percentage cover of coral averaged 14% from visual assessments at ground-truthed locations. This area was classified as a Mixed Coral Assemblage, with a percentage cover of 10–50%. The coral genera present included (in order of declining relative abundance): *Turbinaria*, *Montipora*, *Porites*, soft corals (mostly *Sinularia*), *Goniopora*, *Acropora*, *Galaxea* and *Echinophyllia*.

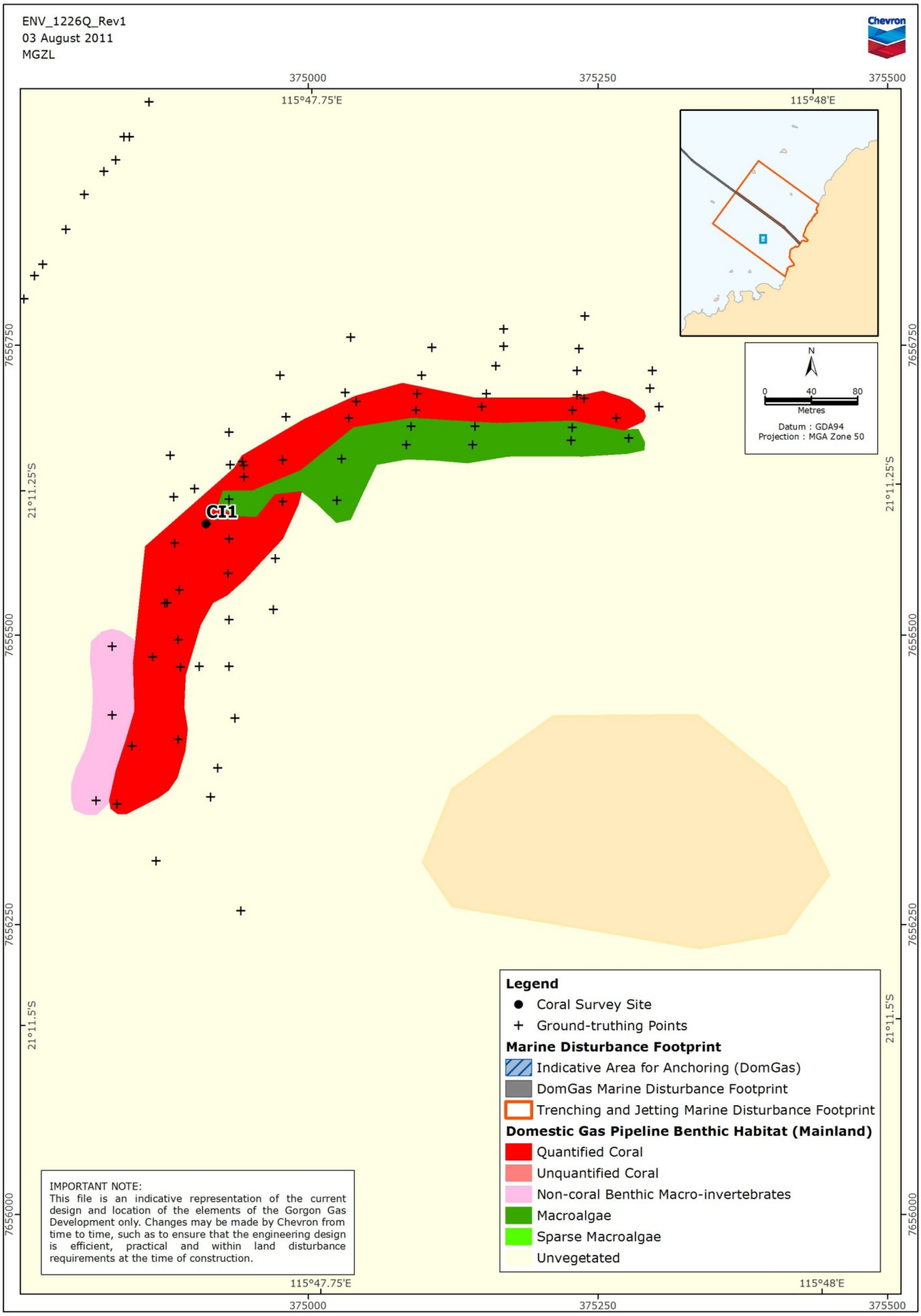



**Figure 6-7 Coral Assemblages at an Unnamed Reef Located South-west of the Pipeline Route and North-east of Cowle Island**

###### 6.4.1.3.2 Sites at Risk of Material or Serious Environmental Harm at the Mainland End of the DomGas Pipeline: Solitary Island (CI2)

Mixed coral communities, benthic macroinvertebrates, macroalgae and an intertidal platform with sparse macroalgae dominated the benthic habitats near Solitary Island (Figure 6-8). There were two areas of reef around Solitary Island. The northern fringing reef (approximately 1200 m long and up to 90 m wide) bordered macroalgae beds, and extends from the south to the east on the offshore side of the island; for much of its length it was separated from macroalgae-dominated habitats by an area of unvegetated sediments. The second area of reef (approximately 700 m long and up to 150 m wide) was orientated north-to-south and bordered habitat dominated by sessile benthic macroinvertebrates. The site was dominated by sediment and featured isolated limestone outcrops in rubble and shell gravel. A thin surface layer of fine sediment with evidence of a lot of biological activity covered most of the substrate. Turf and coralline algae dominated the benthic cover. Sponges were abundant, including branching, encrusting and barrel varieties. Hydroids and ascidians were also present. An octocoral-dominated habitat (*Sinularia* sp.) was encountered in the deeper parts of the site, and was not observed at the other locations surveyed.

Within the area of ‘quantified coral’, the percentage cover of coral averaged 30% from visual assessments at ground-truthed locations – the highest average cover of all the sites surveyed at the mainland end of the DomGas Pipeline. This coral-dominated habitat was classified as a Mixed Coral Assemblage, with a percentage cover of 10–50% cover. The coral genera present included (in order of declining relative abundance): soft corals (mostly *Sinularia*), *Turbinaria*, Faviids, *Porites* and *Duncanopsammia*.

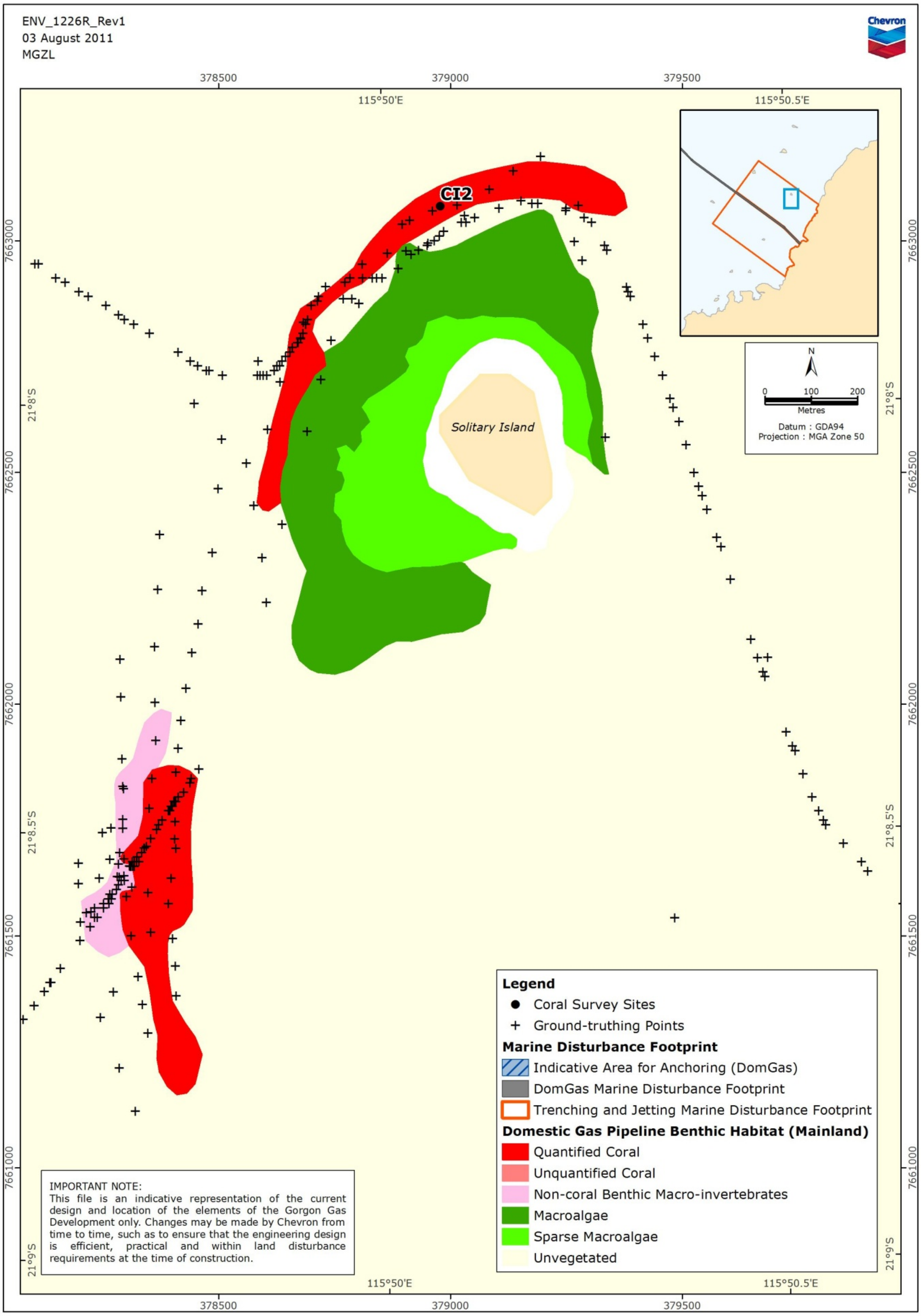



**Figure 6-8 Coral Assemblages at Solitary Island**

#### 6.4.1.3.3 Reference Sites not at Risk of Material or Serious Environmental Harm at the Mainland End of the DomGas Pipeline Route: Passage Island (CR1)

Mixed coral communities, benthic macroinvertebrates, macroalgae and an elongated intertidal platform covered with sparse macroalgae dominated the benthic habitats near Passage Island (Figure 6-9). The site was predominately flat featuring low undulating coral bombora at approximately 4 m depth surrounded by open patches of sand. Turf algae dominated the benthic cover, along with hard corals and sponges.

In the area of ‘quantified coral’, the percentage cover of coral averaged 11% from visual assessments at ground-truthed locations. The area was classified as a Mixed Coral Assemblage, though on average the coral cover was three-fold lower than the Mixed Coral Assemblage at Solitary Island (Section 6.4.1.3.2). The coral genera recorded included (in order of declining relative abundance): *Turbinaria*, Faviids, *Porites*, *Montipora*, *Acropora*, *Lobophyllia* and *Echinophyllia*.

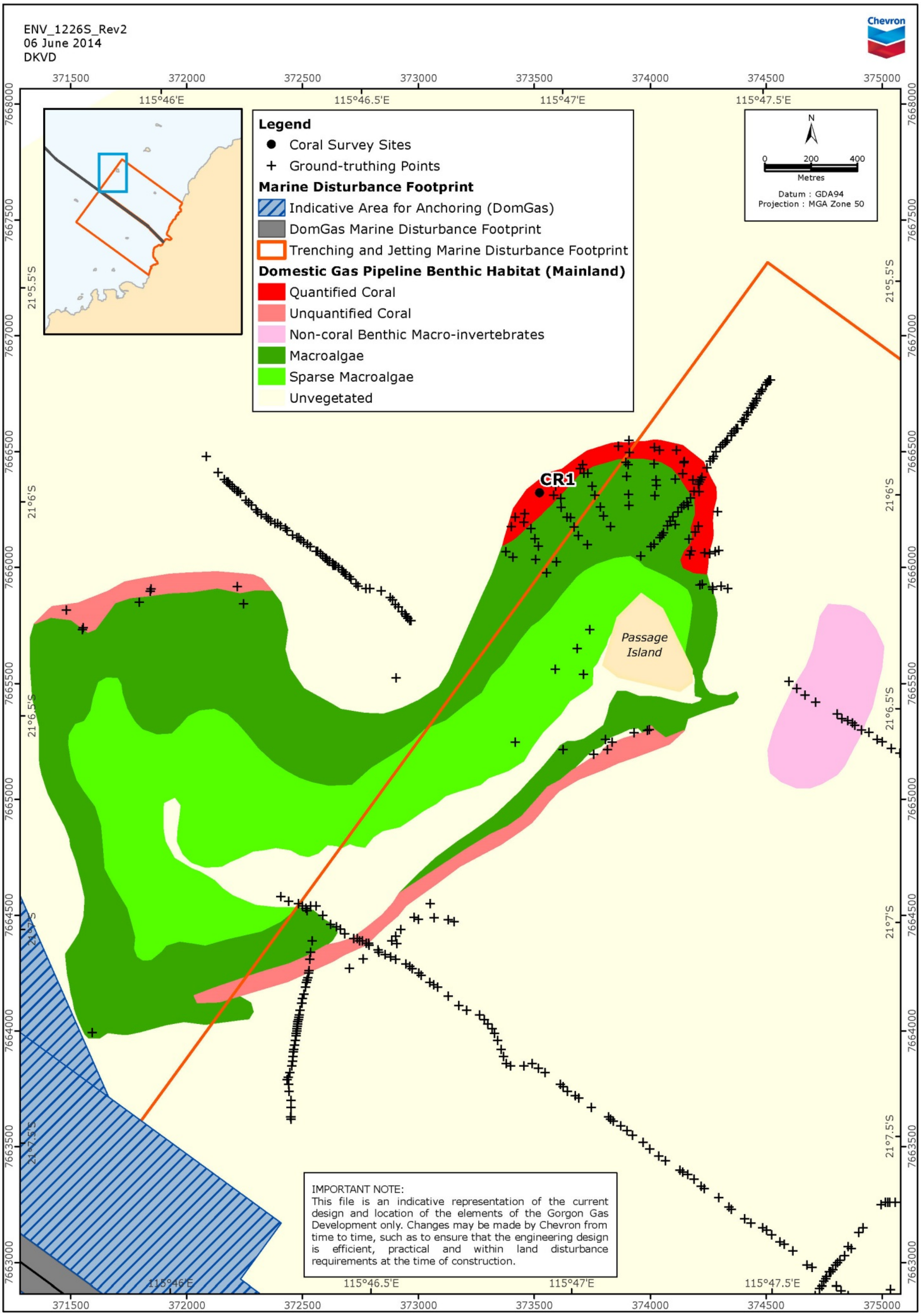



**Figure 6-9 Coral Assemblages at Passage Island**

#### 6.4.1.3.4 Reference Sites not at Risk of Material or Serious Environmental Harm at the Mainland End of the DomGas Pipeline Route: South Passage Island (CR2)

Mixed coral communities, macroalgae and an intertidal platform covered with sparse macroalgae dominated the benthic habitats near South Passage Island (Figure 6-10). The site was predominantly undulating coral bombora rising from 6 m depth to approximately 2 m, at an average slope of 20°. Correspondingly, the topography of the site was relatively complex with small overhangs and crevices providing habitat for hard and soft corals. A small number of soft corals were also present, along with sponges and extensive macroalgae.

In the area of 'quantified coral', the percentage cover of coral averaged 17% from visual assessments at ground-truthed locations. The area was classified as a Mixed Coral Assemblage, though on average the coral cover was approximately half that of the Mixed Coral Assemblage at Solitary Island (Section 6.4.1.3.2). Macroalgae habitats were typically moderate (25–75% cover) and dense (>75% cover) in the vicinity of the South Passage Island. The coral genera recorded included (in order of declining relative abundance): *Turbinaria*, Faviids, *Porites*, *Acropora*, *Lobophyllia*, *Goniopora*, *Merulina*, *Galaxea* and *Pectinia* (Plate 6-3).

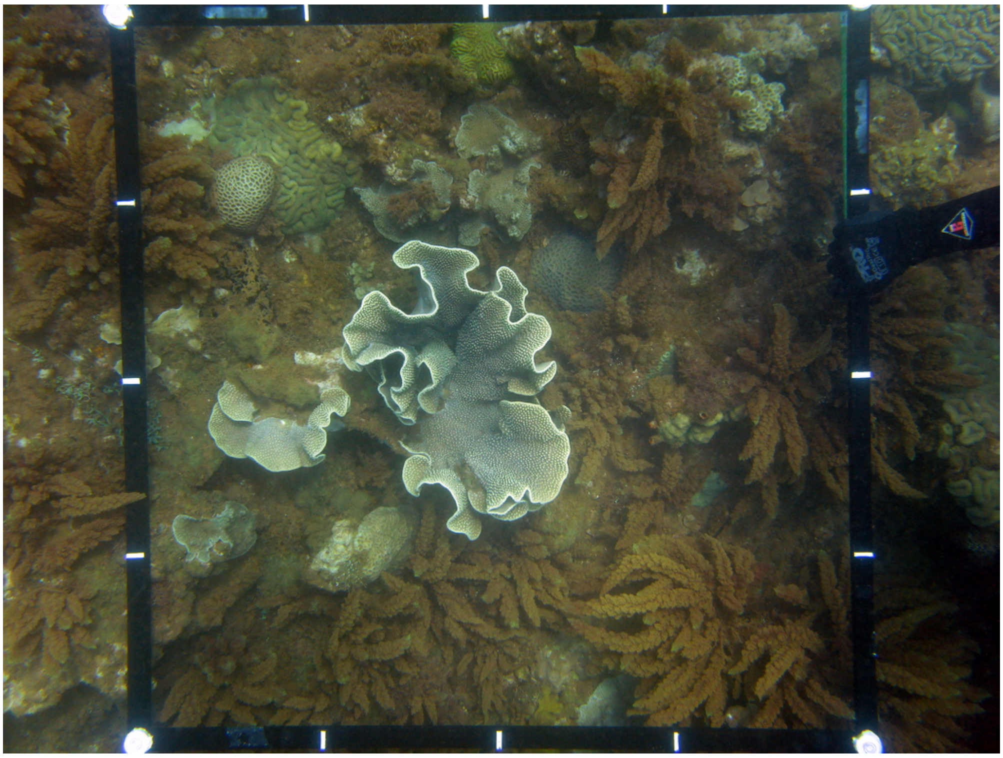


**Plate 6-3 Photo-quadrat from South Passage Island (CR2) in October 2010. The coral colony in the centre is *Turbinaria mesenterina*; the macroalga is *Asparagopsis taxiformis***

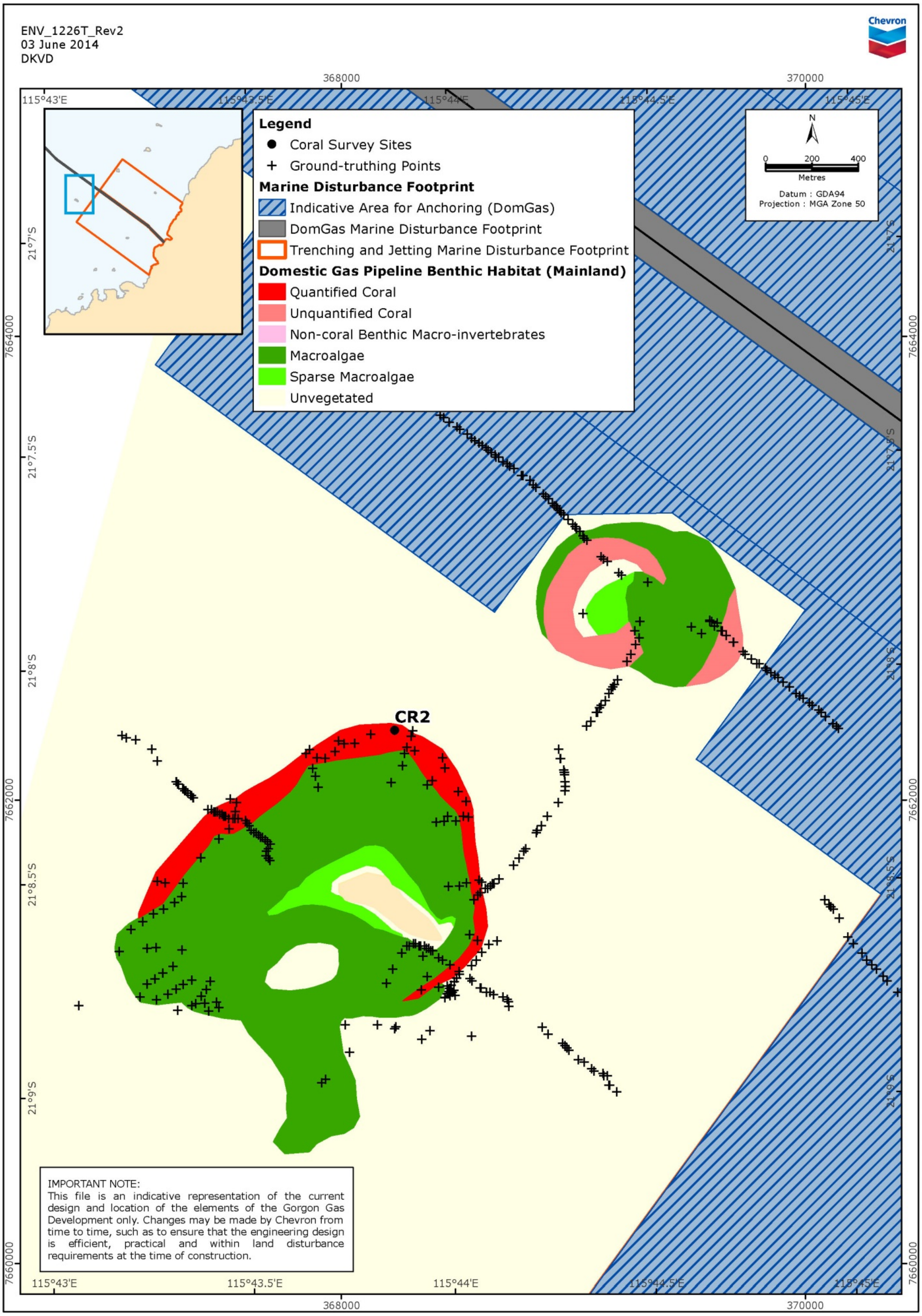



**Figure 6-10 Coral Assemblages at South Passage Island**

### 6.4.2 Dominant and Subdominant Species

#### 6.4.2.1 All Reefs Surveyed

In summary, the RVA surveys at sites around Barrow Island identified 196 species of hard coral from 48 genera from the order Scleractinia and seven soft coral genera from the suborder Alcyoniina (Refer to Appendix 3 in Chevron Australia 2013a for the complete species list). There were 17 new taxonomic records identified during the RVA surveys, including six new records for Australia (although unpublished information indicates *Platygyra acuta* has been previously recorded in Western Australia), nine new records for Western Australia, and three new records for the North West Shelf (Chevron Australia 2013a).

The RVA surveys at MOF1, LNG3 and DUG identified 125 species of hard coral in 40 genera from the order Scleractinia, six soft coral genera from the order Alcyonacea and one in the order Hydrozoa. The RVA surveys at the mainland end of the DomGas Pipeline route identified 118 species of hard coral from 42 genera in the order Scleractinia, including one species of Hydrozoa, and 10 species of soft coral genera (seven species from the suborder Alcyoniina and one species each from the three suborders Calcaxonia, Holaxonia and Scleraxonia) (refer to Appendix 3 for the complete species list). Note that species saturation was reached at CI1 and CI2 after 105 minutes, whereas saturation was not reached at CR1 and CR2 (i.e. the species accumulation curves did not reach an asymptote), so the full 120-minute survey was undertaken at these sites. Therefore, it is likely that the species richness of corals in the vicinity of the DomGas survey sites is higher than that reported in these RVA surveys.

There were nine new taxonomic records identified during the RVA surveys at MOF1, LNG3 and DUG and at the mainland end of the DomGas Pipeline route (Table 6-9). These included two new records for Australia (although unpublished information indicates *Platygyra acuta* has been previously recorded in Western Australia), five new records for Western Australia, and two new records for the North West Shelf. In terms of the sites at the mainland end of the DomGas Pipeline route, one species was recorded in Australia for the first time, there were no new records for the region (North West Shelf) and three species had only been recorded in the region once before at Barrow Island.

**Table 6-9 New Coral Species Recorded During RVA Surveys at MOF1, LNG3 and DUG off the East Coast of Barrow Island and at the Mainland End of the DomGas Pipeline Route**

| Species | Site(s) Where Species Were Recorded |
|---|---|
| **New records for Australia** | |
| *Platygyra acuta* Veron 2000 | DUG, MOF1 |
| *Favites micropentagona* Veron 2000 | CR1, CI1, CI2 |
| **New records for Western Australia** | |
| *Acanthastrea hemprichii* (Ehrenberg, 1834) | MOF1, CR1, CR2, CI1, CI2 |
| *Favia maritime* (Nemenzo, 1971) | MOF1 |
| *Hydnophora grandis* Gardiner, 1904 | DUG, LNG3, CR1 |
| *Lobophyllia robusta* Yabe and Sugiyama, 1936 | DUG, MOF1 |
| *Montastrea colemani* Veron, 2000 | LNG3, CR2 |
| **New records for the North West Shelf** | |
| *Acropora* cf. *arafura* (new species discovered in the Kimberley in 2008 by Dr C. Wallace, yet to be published) | LNG3 |
| *Pavona duerdeni* Vaughan, 1907 | DUG |

*Note: Unpublished information indicates* Platygryra acuta *has been recorded previously in Western Australia.*

The coral survey sites were varied and covered a range of coral community types that could be classified into three broad groups according to the species compositions:

- Sites dominated by *Porites* species, mostly *P. lutea*, *P. australiensis* and *P. cylindrica* and also including *P. lichen*, *P. rus* and *P. nigrescens*: LNG3
- Sites dominated by *Turbinaria* species, mostly *T. mesenterina* and including *T. peltata*, *T. bifrons* and *T. reniformis*: CI1 and CR1
- Sites with no one obvious dominant genus and the most abundant hard coral species were from several coral families, including *Diploastrea heliopora* (Faviidae), *Pachyseris speciosa* (Agariciidae) and *Porites australiensis* (Poritidae) at MOF1; *Acropora* spp. (Acroporidae), *Porites* spp. (Poritidae), *Montipora aequituberculata* (Acroporidae), *Galaxea astreata* (Oculinidae), *Pectinia lactuca* (Pectiniidae) and *Goniastrea pectinata* (Faviidae) at Dugong Reef; *Platygyra daedalea* (Faviidae), *Turbinaria mesenterina* and *T. peltata* (Dendrophylliidae) at CI2; and *Favites complanata*, *Platygyra daedalea* (Faviidae) and *Lobophyllia hemprichii* (Mussidae) at CR2.

#### 6.4.2.2 Dominant and Subdominant Corals at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

##### 6.4.2.2.1 MOF1

At MOF1, *Diploastrea heliopora*, *Pachyseris speciosa* and *Porites australiensis* were the most commonly recorded hard corals (Table 6-10). *Porites australiensis* was common on the west and south-west bombora, while *D. heliopora* was common on the bomboras to the east. *Pachyseris speciosa* was common among many of the bombora.

*Acropora listeri*, *Favia maxima* and *Moseleya latistellata* were recorded only at MOF1. *Favia maritima*, a new record for Western Australia, was recorded only at MOF1 and another site in Barrow Island waters (Table 6-9; Chevron Australia 2013a). *Acanthastrea hemprichii*, also a new record for Western Australia, was recorded only at MOF1 and another site in Barrow Island waters. The attached fungiid species, *Lithophyllon undulatum* and *Podobacia crustacea*, were also recorded at MOF1. These species are usually rare and their presence at this site is noteworthy considering other free-living fungiid species were absent.

The percentage cover of hard corals with quadrats was 18.9% ± 3.0 SE at MOF1. The faviids comprised 7.9% ± 2.1 SE, representing 42% of the cover of all the hard corals; and the acroporids 5.2% ± 1.2 SE, or 27.5% of the cover of all hard corals.

**Table 6-10 Relative Abundance of Hard Coral Species at MOF1**

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Faviidae | *Diploastrea heliopora* | 4 |
| Agariciidae | *Pachyseris speciosa* | 4 |
| Poritidae | *Porites australiensis* | 4 |
| Acroporidae | *Acropora divaricata* | 3 |
| Mussidae | *Lobophyllia diminuta* | 3 |

*Note: 4 = Common (21–50 colonies); 3 = Frequent (6–20 colonies).*

#### 6.4.2.3 Dominant and Subdominant Corals in Areas at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route

The total number of coral species recorded at each site is presented in (Table 6-11). The site with the greatest coral species diversity was CR2 (84 species) and the sites with the lowest species diversity were CI1 and CI2 (50 and 51 species, respectively). Overall, 19% of the species were recorded at all four sites, and 43% of species were recorded at one site only. The allocation of dominant and subdominant species in the RVA was supported by the photo-quadrat analyses (Section 6.4.4). All the species that dominated the RVA surveys were in the families Dendrophylliidae and Faviidae, which were the two families with the highest percentage cover at each of the sites. Many of the species recorded as subdominant were also in these families. The remaining species that were recorded as subdominant were recorded within families that had the highest percentage cover.

**Table 6-11 Diversity of Hard and Soft Coral Species Recorded at Sites at the Mainland End of the DomGas Pipeline**

| | Sites at risk of Material or Serious Environmental Harm | | Reference Sites | |
|---|---|---|---|---|
| | CI1 | CI2 | CR1 | CR2 |
| Hard Coral | 48 | 45 | 74 | 80 |
| Soft Coral | 4 | 8 | 4 | 4 |
| **Total coral species** | **52** | **53** | **78** | **84** |

##### 6.4.2.3.1 CI1

Among the hard corals, *Turbinaria* spp., were by far the most prevalent genera of coral recorded. *Favites*, *Platygyra* and *Cyphastrea* were also recorded in abundance (Table 6-12). Of particular interest at this site was the presence of a large number of juvenile corals (approximately two years old, <10 cm greatest diameter) from a variety of genera; this is the only site where juvenile corals were prevalent. The presence of juveniles indicates there has been successful recent recruitment to this site. Note that the juvenile corals could not be identified from the video and were too small to sample. There was some evidence of stress (i.e. bleached, pale colonies) observed in some individuals of *Goniopora*, *Merulina*, *Moseleya*, *Montastrea*, *Montipora*, *Turbinaria*, *Porites* and *Platygyra*.

**Table 6-12 Relative Abundance of Hard Coral Species at CI1**

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Dendrophylliidae | *Turbinaria mesenterina* (Lamarck, 1816) | 5 |
| Faviidae | *Favites abdita* (Ellis and Solander, 1786) | 4 |
| Faviidae | *Platygyra daedalea* (Ellis and Solander, 1786) | 4 |
| Dendrophylliidae | *Turbinaria peltata* (Esper, 1794) | 4 |
| Faviidae | *Cyphastrea microphthalma* (Lamarck, 1816) | 4 |
| Mussidae | *Acanthastrea hemprichii* (Ehrenberg, 1834) | 3 |
| Poritidae | *Goniopora tenuidens* (Quelch, 1886) | 3 |
| Faviidae | *Barabattoia amicorum* (Milne Edwards and Haime, 1850) | 3 |
| Faviidae | *Favia pallida* (Dana, 1846) | 3 |
| Faviidae | *Favites complanata* (Ehrenberg, 1834) | 3 |
| Faviidae | *Favites pentagona* (Esper, 1794) | 3 |

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Faviidae | *Goniastrea aspera* Verrill, 1905 | 3 |
| Faviidae | *Montastrea curta* (Dana, 1846) | 3 |
| Acroporidae | *Montipora crassituberculata* Bernard, 1897 | 3 |
| Faviidae | *Moseleya latistellata* Quelch, 1884 | 3 |
| Poritidae | *Porites annae* Crossland, 1952 | 3 |
| Poritidae | *Porites lobata* Dana, 1846 | 3 |
| Siderastreidae | *Psammocora superficialis* Gardiner, 1898 | 3 |
| Dendrophylliidae | *Turbinaria bifrons* Brüggemann, 1877 | 3 |
| Dendrophylliidae | *Turbinaria reniformis* Bernard, 1896 | 3 |

*Note: 5 = Most Common (51+ colonies); 4 = Common (21–50 colonies); 3 = Frequent (6–20 colonies).*

#### 6.4.2.3.2 CI2

*Turbinaria* and *Platygyra* dominated the hard corals and *Sinularia* sp. and *Juncella* sp. dominated the soft corals (Table 6-13). There was some evidence of stress (i.e. bleached, pale colonies) observed in some individuals of *Cyphastrea*, *Favites*, *Goniastrea*, *Goniopora*, *Moseleya* and *Turbinaria*. There was also evidence of storm damage with numerous overturned *Turbinaria* observed. This site had the greatest diversity of soft coral species (eight species recorded).

**Table 6-13 Relative Abundance of Hard and Soft Coral Species at CI2**

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Alcyoniidae | *Sinularia* sp. | 5 |
| Faviidae | *Platygyra daedalea* (Ellis and Solander, 1786) | 4 |
| Dendrophylliidae | *Turbinaria mesenterina* (Lamarck, 1816) | 4 |
| Dendrophylliidae | *Turbinaria peltata* (Esper, 1794) | 4 |
| Ellisellidae | *Juncella* sp. | 4 |
| Faviidae | *Cyphastrea microphthalma* (Lamarck, 1816) | 3 |
| Pectiniidae | *Echinophyllia aspera* (Ellis and Solander, 1788) | 3 |
| Pectiniidae | *Echinophyllia orpheensis* Veron and Pichon, 1980 | 3 |
| Faviidae | *Favia pallida* (Dana, 1846) | 3 |
| Faviidae | *Favites abdita* (Ellis and Solander, 1786) | 3 |
| Faviidae | *Favites pentagona* (Esper, 1794) | 3 |
| Faviidae | *Goniastrea aspera* Verrill, 1905 | 3 |
| Poritidae | *Goniopora djboutiensis* Vaughan, 1907 | 3 |
| Poritidae | *Goniopora minor* Crossland, 1952 | 3 |
| Merulinidae | *Hydnophora exesa* (Pallas, 1766) | 3 |
| Faviidae | *Moseleya latistellata* Quelch, 1884 | 3 |
| Faviidae | *Barabattoia amicorum* (Milne, Edwards and Haime, 1850) | 3 |
| Siderasteridae | *Psammocora superficialis* Gardiner, 1898 | 3 |
| Dendrophylliidae | *Turbinaria bifrons* Brüggemann, 1877 | 3 |
| Anthothelidae | *Alertigorgia mjobergi* (Broch 1916) | 3 |
| Plexauridae | *Paraplexuria* sp. | 3 |

*Note: 5 = Most Common (51+ colonies);4 = Common (21–50 colonies); 3 = Frequent (6–20 colonies). Soft corals in blue font.*

CI1 and CI2 support a similar level of coral diversity (n = 52 spp. and 53 spp.). Three species are particularly abundant (dominant) at both of these inshore sites (*Platygyra daedalea, Turbinaria mesenterina* and *Turbinaria peltata*) (Table 6-12 and Table 6-13). However, there are notable differences in the species composition at these two sites: eight species of soft coral were recorded at CI2, compared to the four recorded at CI1. There was an abundance of *Favites abdita* and *Goniopora tenuidens* recorded at CI1, whilst CI2 was the only site where the scleractinian corals *Montipora mollis, Acanthastrea hillae, Turbinaria radicalis, Favites paraflexuosa* and *Porites lichen* were recorded.

#### 6.4.2.4 Dominant and Subdominant Corals at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

##### 6.4.2.4.1 LNG3

The most commonly recorded species at LNG3 was *Porites lutea* (Table 6-14). *Montastrea colemani*, a new record for Western Australia, was recorded only at LNG3 and another site in Barrow Island waters (Table 6-9; Chevron Australia 2013a).

The percentage cover of hard corals with quadrats was 15.7% ± 3.6 SE at LNG3. The poritids comprised 11.6% ± 3.6 SE, representing 74% of the cover of all the hard corals; and the faviids 1.1% ± 0.4 SE, or 7% of the cover of all hard corals.

**Table 6-14 Relative Abundance of Hard Coral Species at LNG3**

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Poritidae | *Porites lutea* | 5 |
| Acroporidae | *Acropora divaricata* | 3 |
| Oculinidae | *Galaxea astreata* | 3 |
| Mussidae | *Lobophyllia hemprichii* | 3 |
| Faviidae | *Platygyra pini* | 3 |
| Poritidae | *Porites australiensis* | 3 |

*Note: 5 = Most Common (51 + colonies); 3 = Frequent (6–20 colonies).*

##### 6.4.2.4.2 Dugong Reef [DUG]

*Galaxea astreata* and *Porites rus* formed large stands in some parts of the reef. There were eight hard coral species all recorded as 'frequent' at DUG (Table 6-15). *Pavona duerdeni* was a new record for the North West Shelf recorded only at DUG (Table 6-9). Other species recorded only at DUG were *Montipora informis* and *M. turtlensis*. *Acropora* cf. *arafura*, a new record for the North West Shelf, was observed outside of the RVA survey area at the Dugong Reef site.

The percentage cover of hard corals with quadrats was 66.8% ± 2.9 SE at DUG. The oculinids comprised 14.5% ± 2.8 SE, representing 22% of the cover of all the hard corals; the poritids 12.2% ± 2.6 SE, or 18% of the cover of all hard corals; and the acroporids 8.2% ± 1.8 SE, or 12% of the cover of all hard corals.

**Table 6-15 Relative Abundance of Hard Coral Species at DUG**

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Acroporidae | *Acropora florida* | 3 |
| Acroporidae | *Acropora muricata* | 3 |
| Oculinidae | *Galaxea astreata* | 3 |
| Faviidae | *Goniastrea pectinata* | 3 |
| Acroporidae | *Montipora aequituberculata* | 3 |
| Pectiniidae | *Pectinia lactuca* | 3 |
| Poritidae | *Porites lutea* | 3 |
| Poritidae | *Porites rus* | 3 |

*Note: 3 = Frequent (6–20 colonies).*

#### 6.4.2.5 Dominant and Subdominant Corals at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route

##### 6.4.2.5.1 CR1

*Turbinaria*, *Platygyra* and *Porites* were the most commonly recorded hard corals (Table 6-16). Single individuals of *Porites*, *Turbinaria*, *Symphyllia*, *Galaxea* and *Goniopora* were observed to be wholly, or in the case of *Symphyllia*, partially bleached. All four colonies of *Moseleya latistellata* were observed to be stressed or dying, although the causal mechanism is unknown.

**Table 6-16 Relative Abundance of Hard and Soft Coral Species at CR1**

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Dendrophylliidae | *Turbinaria mesenterina* (Lamarck, 1816) | 5 |
| Faviidae | *Platygyra daedalea* (Ellis and Solander, 1786) | 4 |
| Poritidae | *Porites lobata* Dana, 1846 | 4 |
| Mussidae | *Acanthastrea hemprichii* (Ehrenberg, 1834) | 3 |
| Acroporidae | *Acropora bushyensis* Veron and Wallace, 1984 | 3 |
| Acroporidae | *Astreopora myriophthalma* (Lamarck, 1816) | 3 |
| Faviidae | *Cyphastrea microphthalma* (Lamarck, 1816) | 3 |
| Pectiniidae | *Echinophyllia orpheensis* Veron and Pichon, 1980 | 3 |
| Faviidae | *Favia favus* (Forskål, 1775) | 3 |
| Faviidae | *Favia speciosa* Dana, 1846 | 3 |
| Faviidae | *Favites abdita* (Ellis and Solander, 1786) | 3 |
| Faviidae | *Favites halicora* (Ehrenberg, 1834) | 3 |
| Faviidae | *Favites pentagona* (Esper, 1794) | 3 |
| Oculinidae | *Galaxea astreata* (Lamarck, 1816) | 3 |
| Poritidae | *Goniopora lobata* Milne Edwards and Haime, 1860 | 3 |
| Poritidae | *Goniopora stutchburyi* Wells, 1955 | 3 |
| Poritidae | *Goniopora tenuidens* (Quelch, 1886) | 3 |
| Merulinidae | *Hydnophora exesa* (Pallas, 1766) | 3 |
| Mussidae | *Lobophyllia hemprichii* (Ehrenberg, 1834) | 3 |
| Acroporidae | *Montipora crassituberculata* Bernard, 1897 | 3 |
| Pectiniidae | *Mycedium elephantotus* (Pallas, 1766) | 3 |
| Faviidae | *Platygyra lamellina* (Ehrenberg, 1834) | 3 |
| Siderastreidae | *Psammocora superficialis* Gardiner, 1898 | 3 |
| Dendrophylliidae | *Turbinaria bifrons* Brüggemann, 1877 | 3 |

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Dendrophylliidae | *Turbinaria peltata* (Esper, 1794) | 3 |
| Dendrophylliidae | *Turbinaria reniformis* Bernard, 1896 | 3 |
| Alcyoniidae | *Sinularia* sp. | 3 |
| Alcyoniidae | *Sarcophyton ehrenbergi* von Marenzellar, 1886 | 3 |

*Note: 5 = Most Common (51+ colonies);4 = Common (21–50 colonies); 3 = Frequent (6–20 colonies). Soft corals in blue font.*

#### 6.4.2.5.2 CR2

Corals from the genera *Lobophyllia*, *Platygyra*, *Favites* and *Turbinaria* were the most commonly recorded hard coral (Table 6-17). There was evidence of recent physical damage affecting foliose plate *Turbinaria* corals and *Lobophyllia* colonies, potentially associated with Tropical Cyclone Bianca. There was also evidence of bleaching of *Porites* colonies, and one suspected case of black-band disease was recorded on a faviid colony.

**Table 6-17 Relative Abundance of Hard and Soft Coral Species at CR2**

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Faviidae | *Favites complanata* (Ehrenberg, 1834) | 4 |
| Mussidae | *Lobophyllia hemprichii* (Ehrenberg, 1834) | 4 |
| Faviidae | *Platygyra daedalea* (Ellis and Solander, 1786) | 4 |
| Dendrophylliidae | *Turbinaria mesenterina* (Lamarck, 1816) | 4 |
| Mussidae | *Acanthastrea hemprichii* (Ehrenberg, 1834) | 3 |
| Pectiniidae | *Echinophyllia orpheensis* Veron and Pichon, 1980 | 3 |
| Faviidae | *Favia favus* (Forskål, 1775) | 3 |
| Faviidae | *Favia pallida* (Dana, 1846) | 3 |
| Faviidae | *Favia speciosa* Dana, 1846 | 3 |
| Faviidae | *Favites abdita* (Ellis and Solander, 1786) | 3 |
| Faviidae | *Favites flexuosa* (Dana, 1846) | 3 |
| Faviidae | *Favites halicora* (Ehrenberg, 1834) | 3 |
| Faviidae | *Goniastrea pectinata* (Ehrenberg, 1834) | 3 |
| Poritidae | *Goniopora lobata* Milne Edwards and Haime, 1860 | 3 |
| Merulinidae | *Hydnophora exesa* (Pallas, 1766) | 3 |
| Merulinidae | *Merulina ampliata* (Ellis and Solander, 1786) | 3 |
| Milleporidae | *Millepora* spp. | 3 |
| Faviidae | *Montastrea curta* (Dana, 1846) | 3 |
| Acroporidae | *Montipora crassituberculata* Bernard, 1897 | 3 |
| Pectiniidae | *Mycedium elephantotus* (Pallas, 1766) | 3 |
| Faviidae | *Platygyra lamellina* (Ehrenberg, 1834) | 3 |
| Fungiidae | *Podabacia crustacea* (Pallas, 1766) | 3 |
| Poritidae | *Porites lobata* Dana, 1846 | 3 |
| Dendrophylliidae | *Turbinaria bifrons* Brüggemann, 1877 | 3 |
| Dendrophylliidae | *Turbinaria reniformis* Bernard, 1896 | 3 |
| Alcyoniidae | *Lobophytum* sp. | 3 |

*Note: 4 = Common (21-50 colonies); 3 = Frequent (6–20 colonies). Soft corals in blue font.*

CR2 was the most diverse site surveyed, with a total of 84 species recorded; 78 species of coral were recorded at CR1. While there were a number of coral species common to both sites (e.g. the high abundance of *Platygyra daedalea* at both sites), CR1 was characterised by large numbers of *Turbinaria mesenterina* and *Porites lobata*, whereas CR2 was the only site where *Lobophyllia hemprichii* scored a relative abundance score of '4' indicating it was 'common'. This species forms unusual and large phaceloid shaped colonies, and thus the high abundance of *L. hemprichii* at this site is unique.

### 6.4.3 Size-class Frequency Distribution of Hard Coral Species/Taxa

#### 6.4.3.1 Size-class Frequency Distribution at Sites at Risk of Material or Serious Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

##### 6.4.3.1.1 MOF1

A total of 315 hard coral colonies were measured at MOF1 (Table 6-19), with a mean number per transect of 63.0 ± 12.7 SE (Table 6-18). The most abundant colonies were *Acropora* (19.2 per transect ± 3.1 SE) and unidentified faviids (15.0 per transect ± 4.0 SE). All other taxa were recorded at densities of ≤5 colonies per transect.

The mean colony size was 32.1 cm, which varied between a mean of 12.8 cm ± 5.0 SE for the unidentified fungiids and 160.9 cm ± 27.3 SE for *Diploastrea* (Table 6-18). The only colonies >200 cm in size were *Diploastrea*, massive *Porites* and *Pachyseris,* with counts of five, one, and one respectively.. There were a total of eight small, <5 cm in size, colonies in four taxonomic groups (including unidentified). *Acropora* and unidentified *Faviidae* and *Fungiidae* each had counts of two, whilst the remaining genera had counts of one small colony in total. Skewness, which varied between 1.0 (merulinids) and 5.2 ('Other'), was positive for all the families, indicating that there were greater numbers of colonies in the smaller size-classes and relatively few colonies in the larger size-classes (Table 6-19).

The majority (72%) of the colonies measured at MOF1 were in the 10.1–20.0 and 20.1–50.0 cm size-classes, with this value varying from 64% to 87% among families (Table 6-19; Figure 6-11). The modal size-class was relatively small for all families, indicating a greater proportion of colonies in the smaller (and generally younger) size-classes and fewer in the large size-classes. The modal size class of faviids and mussids was 10.1–20.0 cm; and 20.1–50.0 cm for acroporids and poritids. The modal size-classes for the merulinids and 'Others' were 10.1–20 cm and 20.1–50 cm.

**Table 6-18 Mean (± SE) Size-Class Frequency Count and Size Statistics of Hard Corals at MOF1**

| Family | Genera | Mean (± SE) number of colonies per transect (n=5) | Number of colonies <5 cm | Mean (± SE) colony size (cm) |
|---|---|---|---|---|
| Acroporidae | *Acropora* | 19.2 ± 3.1 | 2 | 29.5 ± 2.5 |
| Acroporidae | *Astreopora* | 0.2 ± 0.2 | 0 | 26.0 |
| Acroporidae | *Montipora* | 5.0 ± 1.9 | 1 | 28.4 ± 4.2 |
| Agariciidae | *Pachyseris* | 1.6 ± 0.9 | 0 | 56.4 ± 28.2 |
| Dendrophylliidae | *Turbinaria* | 1.6 ± 0.9 | 0 | 14.4 ± 2.9 |
| Faviidae | *Unidentified* | 15.0 ± 4.0 | 2 | 23.0 ± 2.1 |
| Faviidae | *Diploastrea* | 2.2 ± 0.9 | 0 | 160.9 ± 27.3 |
| Faviidae | *Goniastrea* | 0.6 ± 0.4 | 0 | 23.3 ± 4.6 |
| Fungiidae | *Unidentified* | 1.6 ± 0.8 | 2 | 12.8 ± 5.0 |
| Merulinidae | *Hydnophora* | 0.2 ± 0.2 | 0 | 48.0 |

| Family | Genera | Mean (± SE) number of colonies per transect (n=5) | Number of colonies <5 cm | Mean (± SE) colony size (cm) |
|---|---|---|---|---|
| Merulinidae | *Merulina* | 3.0 ± 1.0 | 0 | 24.4 ± 3.3 |
| Mussidae | *Lobophyllia* | 3.8 ± 1.0 | 0 | 22.3 ± 3.9 |
| Oculinidae | *Galaxea* | 1.0 ± 0.5 | 0 | 20.2 ± 4.3 |
| Pectiniidae | *Oxypora* | 2.6 ± 0.9 | 0 | 33.1 ± 5.1 |
| Pectiniidae | *Pectinia* | 0.2 ± 0.2 | 0 | 20.0 |
| Pocilloporidae | *Stylophora* | 0.2 ± 0.2 | 0 | 16.0 |
| Poritidae | *Porites* (Massive) | 2.0 ± 0.5 | 0 | 60.5 ± 23.1 |
| Poritidae | *Porites* (Branching) | 0.2 ± 0.2 | 0 | 23.0 |
| Unidentified | Unidentified | 2.8 ± 1.0 | 1 | 20.4 ± 4.9 |
| **Total** | | **63.0 ± 12.7**[1] | **8** | **32.1**[2] |

*Note: n = number of transects for which mean is calculated; 1 = total value calculated by pooling counts of all taxa per transect and averaging over five transects; 2 = mean colony size (cm) across the site (the sum of all colony sizes averaged by the total number of colonies present).*

### Table 6-19 Total Count, Modal Size-class (cm), Coefficient of Variation (CoV) and Skewness for Hard Coral Size-class Frequency Data at MOF1

| Family | Count | Modal size-class (cm) | CoV | Skewness |
|---|---|---|---|---|
| Acroporidae | 122 | 20.1–50.0 | 1.3 | 2.3 |
| Faviidae | 89 | 10.1–20.0 | 1.4 | 2.7 |
| Merulinidae | 16 | 10.1–20.0, 20.1–50.0 | 0.5 | 1.0 |
| Mussidae | 19 | 10.1–20.0 | 0.8 | 2.0 |
| Poritidae | 11 | 20.1–50.0 | 1.2 | 2.0 |
| Others | 58 | 10.1–20.0, 20.1–50.0 | 1.2 | 5.2 |
| **Total** | **315** | **20.0–50.0** | **1.2** | **10.6** |

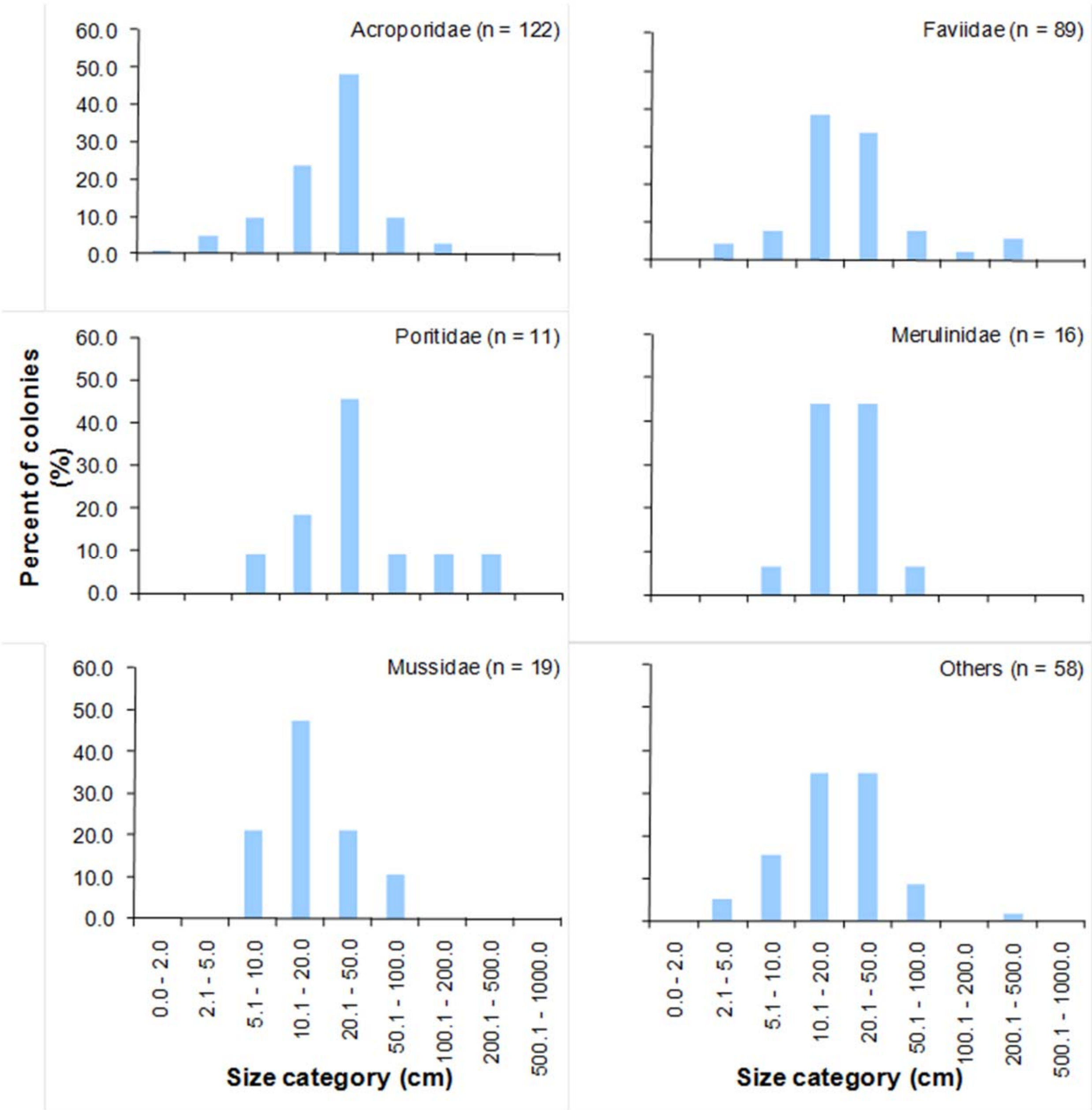



**Figure 6-11 Size-class Frequency Distribution of Hard Corals at MOF1**

### 6.4.3.2 Size-class Frequency Distribution at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route

#### 6.4.3.2.1 CI1

A total of 429 hard coral colonies were measured at CI1 (Table 6-21), with a mean number per transect of 85.8 ± 10.5 SE (Table 6-20). The most abundant colonies were *Turbinaria* (40.8 per transect ± 6.5 SE).

The mean colony size was 17.5 cm ± 0.9 SE, which varied between a minimum of 2.0 cm for *Moseleya* and a maximum of 30.0 cm for *Astreopora* (Table 6-20). There was a total of 29 small, <5 cm in size, colonies. The greatest in number were *Turbinaria* (five colonies) and all the other genera had counts of ≤ four small colonies in total. There were small numbers of corals >1 m in size; one poritid was >1 m and one dendrophylliid was >2 m (3.23 m). Skewness, which varied between 0.1 (acroporids) and 11.3 (dendrophylliids), was positive for all the families, indicating that there were greater numbers of colonies in the smaller size-classes and relatively few colonies in the larger size-classes (Table 6-21).

The overall modal size-class was 10.1–20.0 cm, comprising 56.2% of the 429 colonies (Table 6-21; Figure 6-12). The most abundant families were dendrophylliids (almost exclusively *Turbinaria*) and faviids, comprising 47.6% and 25.6% of the colonies, respectively. The modal size-class of the dendrophylliids and faviids was 10.1–20.0 cm. Similarly, the modal size-class was 10.1–20.0 cm for poritids and siderastreids; and 20.1–50.0 cm for acroporids. The modal size-class was relatively small for all families, indicating a greater proportion of colonies in the smaller (and generally younger) size-classes and fewer in the large size-classes.

**Table 6-20 Mean (± SE) Size-Class Frequency Count and Size Statistics of Hard corals at CI1**

| Family | Genera | Mean (± SE) number of colonies per transect (n=5) | Number of colonies <5 cm | Mean (± SE) colony size (cm) |
|---|---|---|---|---|
| Acroporidae | *Acropora* | 0.2 ± 0.2 | 0 | 15.0 |
| Acroporidae | *Astreopora* | 0.2 ± 0.2 | 0 | 30.0 |
| Acroporidae | *Montipora* | 5.8 ± 2.5 | 2 | 19.7 ± 2.1 |
| Dendrophylliidae | *Turbinaria* | 40.8 ± 6.5 | 5 | 20.7 ± 1.6 |
| Faviidae | *Cyphastrea* | 3.6 ± 0.2 | 2 | 16.4 ± 2.1 |
| Faviidae | *Favia* | 6.0 ± 1.0 | 4 | 10.4 ± 0.8 |
| Faviidae | *Favites* | 9.2 ± 1.5 | 4 | 13.5 ± 1.2 |
| Faviidae | *Goniastrea* | 0.2 ± 0.2 | 0 | 11.0 |
| Faviidae | *Leptastrea* | 0.4 ± 0.4 | 2 | 3.0 ± 0.0 |
| Faviidae | *Montastrea* | 0.2 ± 0.2 | 0 | 12.0 |
| Faviidae | *Moseleya* | 0.2 ± 0.2 | 1 | 2.0 |
| Faviidae | *Platygyra* | 2.0 ± 0.5 | 1 | 13.7 ± 2.2 |
| Faviidae | *Plesiastrea* | 0.2 ± 0.2 | 1 | 3.0 |
| Mussidae | *Lobophyllia* | 0.2 ± 0.2 | 0 | 18.0 |
| Pectiniidae | *Mycedium* | 0.2 ± 0.2 | 0 | 17.0 |
| Poritidae | *Goniopora* | 3.4 ± 1.1 | 2 | 11.0 ± 1.9 |
| Poritidae | *Porites* | 4.8 ± 1.9 | 3 | 18.4 ± 4.2 |
| Siderastreidae | *Psammocora* | 7.8 ± 2.9 | 1 | 15.2 ± 1.0 |
| Unidentified | Unidentified | 0.4 ± 0.2 | 1 | 4.5 ± 2.2 |
| **Total** | | **85.8 ± 10.5**[1] | **29** | **17.5 ± 0.9**[2] |

*Note: n = number of transects for which mean is calculated; 1 = total value calculated by pooling counts of all taxa per transect and averaging over five transects; 2 = mean colony size (cm) across the site (the sum of all colony sizes averaged by the total number of colonies present).*

**Table 6-21 Total Count, Modal Size-class (cm), Coefficient of Variation (CoV) and Skewness for Hard Coral Size-class Frequency Data at CI1 and CI2**

| Family | CI1 | | | | CI2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Count | Modal size-class | CoV | Skewness | Count | Modal size-class | CoV | Skewness |
| Acroporidae | 31 | 20.1–50.0 | 0.6 | 0.1 | 2 | - | - | - |
| Dendrophylliidae | 204 | 10.1–20.0 | 1.1 | 11.3 | 52 | 10.1–20.0 | 0.8 | 1.8 |
| Faviidae | 110 | 10.1–20.0 | 0.6 | 1.3 | 89 | 10.1–20.0 | 1.0 | 2.7 |

| Family | CI1 | | | | CI2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Count | Modal size-class | CoV | Skewness | Count | Modal size-class | CoV | Skewness |
| Merulinidae | 0 | - | - | - | 1 | - | - | - |
| Mussidae | 1 | - | - | - | 2 | - | - | - |
| Oculinidae | 0 | - | - | - | 0 | - | - | - |
| Pectiniidae | 1 | - | - | - | 11 | 20.1–50.0 | 0.6 | 0.5 |
| Poritidae | 41 | 10.1–20.0 | 1.1 | 4.8 | 30 | 10.1–20.0 | 0.9 | 2.9 |
| Siderastreidae | 39 | 10.1–20.0 | 0.4 | 1.0 | 12 | 10.1–20.0 | 1.2 | 3.1 |
| Other | 2 | - | - | - | 1 | - | - | - |
| **Total** | **429** | **10.1–20.0** | **1.0** | **12.3** | **200** | **10.1–20.0** | **1.0** | **3.5** |

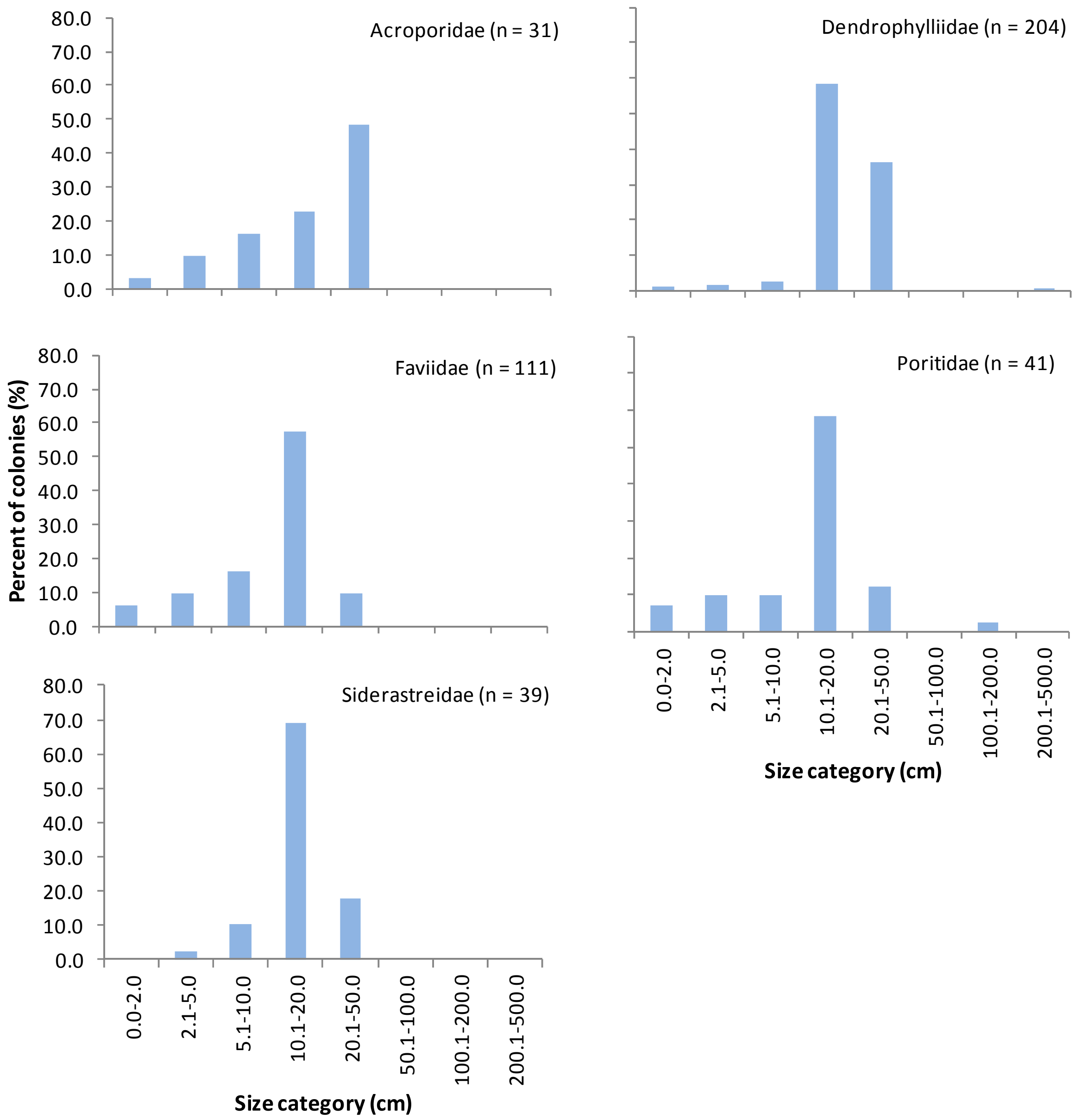



**Figure 6-12 Size-Class Frequency Distribution of Hard Corals at CI1**

#### 6.4.3.2.2 CI2

A total of 200 hard coral colonies were measured at CI2 (Table 6-21), with a mean number per transect of 40.0 ± 6.5 SE (Table 6-22). The most abundant colonies were *Turbinaria* (10.4 per transect ± 4.0 SE).

The mean colony size was 21.2 cm ± 1.5 SE, which varied between 1.0 cm for *Pseudosidastrea* and 'Unidentified', and 184.0 cm for *Hydnophora* (Table 6-22). There was a total of 30 small, <5 cm in size, colonies. The greatest in number were *Favia* and *Favites* (each with eight colonies) and, with the exception of *Turbinaria* (seven colonies) all the other genera had counts of ≤2 small colonies. There were small numbers of corals >1 m in size; one each of faviid, poritid, and merulinid were >1 m. Skewness, which varied between 0.5 (pectinids) and 3.1 (siderastreids), was positive for all the families, indicating that there were greater numbers of colonies in the smaller size-classes and relatively few colonies in the larger size-classes (Table 6-21).

The overall modal size-class was 10.1–20.0 cm, comprising 38.0% of the 200 colonies (Table 6-21; Figure 6-13). Faviids were numerically dominant at this site, comprising 44.5% of the colonies. Their modal size-class was 10.1–20.0 cm. Dendrophylliids (exclusively *Turbinaria*) comprised 26.0% of the colonies, and the modal size-class was 10.1–20.0 cm. Poritids (*Porites* and *Goniopora*) made up 15.0% of the colonies, with a modal size class of 10.1–20 cm. The modal size-class of the pectiniids was 20.1–50.0 cm.

**Table 6-22 Mean (± SE) Size-Class Frequency Count and Size Statistics of Hard Corals at CI2**

| Family | Genera | Mean (± SE) number of colonies per transect (n=5) | Number of colonies <5 cm | Mean (± SE) colony size (cm) |
|---|---|---|---|---|
| Acroporidae | *Acropora* | 0.2 ± 0.2 | 0 | 43.0 |
| Acroporidae | *Montipora* | 0.2 ± 0.2 | 0 | 33.0 |
| Dendrophylliidae | *Turbinaria* | 10.4 ± 4.0 | 7 | 19.8 ± 2.1 |
| Faviidae | *Cyphastrea* | 0.4 ± 0.2 | 0 | 40.0 ± 4.4 |
| Faviidae | *Favia* | 4.0 ± 1.0 | 8 | 9.5 ± 2.0 |
| Faviidae | *Favites* | 7.8 ± 1.8 | 8 | 16.6 ± 2.2 |
| Faviidae | *Goniastrea* | 2.2 ± 0.4 | 1 | 27.1 ± 9.4 |
| Faviidae | *Montastrea* | 0.2 ± 0.2 | 0 | 32.0 |
| Faviidae | *Moseleya* | 0.6 ± 0.4 | 0 | 8.3 ± 1.5 |
| Faviidae | *Platygyra* | 2.6 ± 1.2 | 0 | 21.9 ± 3.8 |
| Merulinidae | *Hydnophora* | 0.2 ± 0.2 | 0 | 184.0 |
| Mussidae | *Acanthastrea* | 0.2 ± 0.2 | 0 | 14.0 |
| Mussidae | *Lobophyllia* | 0.2 ± 0.2 | 0 | 31.0 |
| Pectiniidae | *Mycedium* | 2.2 ± 0.8 | 1 | 37.8 ± 6.5 |
| Poritidae | *Goniopora* | 4.4 ± 0.7 | 1 | 24.8± 4.7 |
| Poritidae | *Porites* | 1.6 ± 0.5 | 2 | 19.3 ± 4.9 |
| Siderastreidae | *Psammocora* | 2.2 ± 0.6 | 0 | 20.4 ± 6.8 |
| Siderastreidae | *Pseudosidastrea* | 0.2 ± 0.2 | 1 | 1.0 |
| Unidentified | Unidentified | 0.2 ± 0.2 | 1 | 1.0 |
| **Total** | | **40.0 ± 6.5**[1] | **30** | **21.2 ± 1.5**[2] |

*Note: n = number of transects for which mean is calculated; 1 = total value calculated by pooling counts of all taxa per transect and averaging over five transects; 2 = mean colony size (cm) across the site (the sum of all colony sizes averaged by the total number of colonies present).*

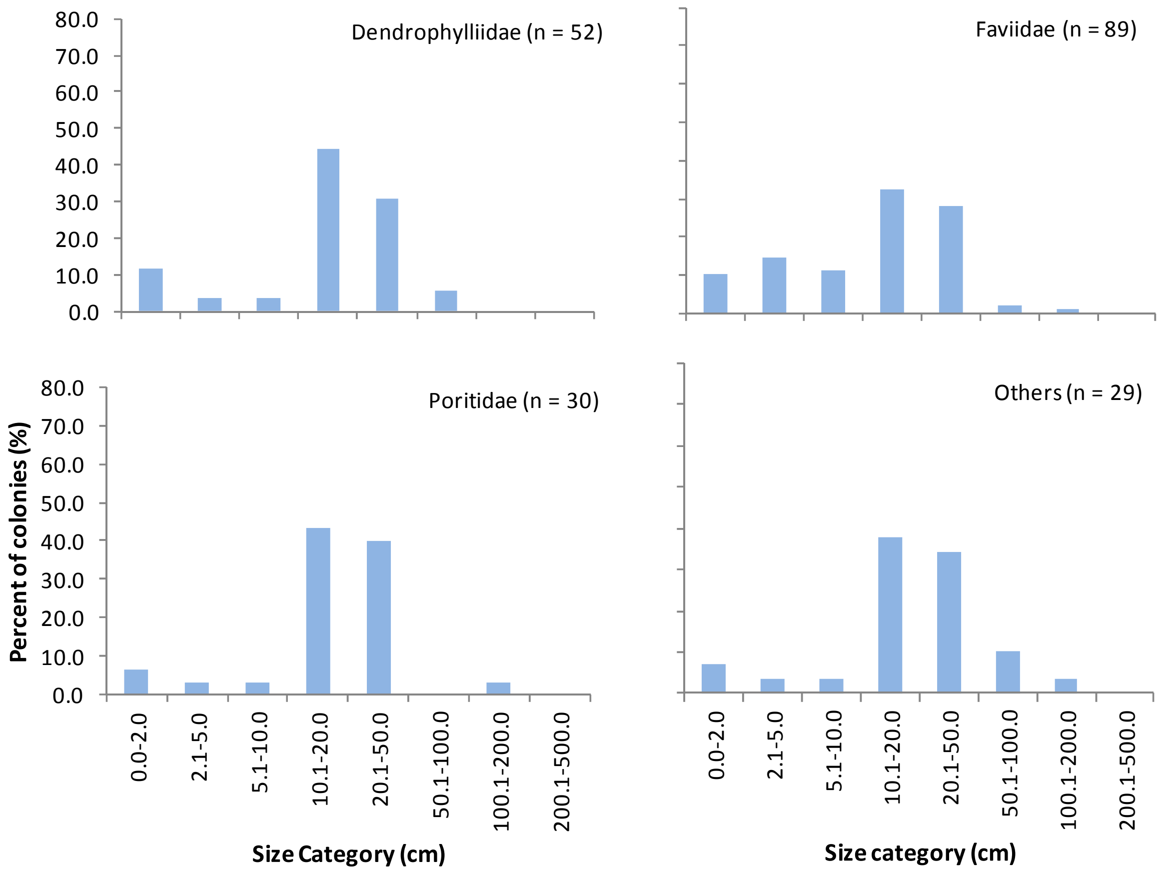



**Figure 6-13 Size-Class Frequency Distribution of Hard Corals at CI2**

### 6.4.3.3 Size-class Frequency Distribution at Reference Sites not at Risk of Material or Serious Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

#### 6.4.3.3.1 LNG3

A total of 338 hard coral colonies were measured at LNG3 (Table 6-24), with a mean number per transect of 67.6 ± 16.7 SE (Table 6-23). The most abundant colonies were massive *Porites* (23.4 per transect ± 9.3 SE) and unidentified faviids (21.2 per transect ± 6.1 SE). All other taxa were recorded at densities of <6 colonies per transect.

The mean colony size was 16 cm, which varied between a mean of 3.7 cm ± 0.3 SE for unidentified mussids and 72.5 cm ± 18.5 SE for *Hydnophora* (Table 6-23). The only colonies >200 cm in size were massive *Porites*, which numbered two colonies in total. There was a total of 82 small, <5 cm in size, colonies, in six taxonomic groups (including unidentified). The greatest in number were massive *Porites* (39 colonies), unidentified faviids (22 colonies) and *Acropora* (10 colonies). Skewness, which varied between 0.8 (acroporids) and 6.8 (poritids), was positive for all the families with the exception of the dendrophylliids, indicating that there were greater numbers of colonies in the smaller size-classes and relatively few colonies in the larger size-classes (Table 6-24). Negative skewness was recorded for the dendrophylliids (-0.2), indicating a greater proportion of larger colonies and relatively few colonies in the smaller size-classes.

There were very few large colonies, with 324 (97%) of the colonies <50 cm in diameter (Figure 6-14). The majority of acroporid and faviid colonies (80% and 87%, respectively) were 2.1–20 cm in size. The modal size-classes for the acroporids were 2.1–5.0 cm and 5.1–10.0 cm, and for the faviids was 5.1–10.0 cm (Table 6-24). The majority (93%) of poritid colonies were <50 cm in size; however, the only colonies >1 m in size at LNG3 were poritids. The modal size-class for the poritids was 2.1–5 cm. The majority (85%) of corals in the ‘Other’ families were <20 cm in size, with a modal size-class of 5.1–10.0 cm. The modal size-class for the dendrophylliids was 10.1–20.0 cm (Table 6-24). There were two colonies of *Hydnophora* (Merulinidae) that were >50 cm.

### Table 6-23 Mean (± SE) Size-Class Frequency Count and Size Statistics of Hard Corals at LNG3

| Family | Genera | Mean (± SE) number of colonies per transect (n=5) | Number of Colonies <5 cm | Mean (± SE) colony size (cm) |
|---|---|---|---|---|
| Acroporidae | *Acropora* | 5.2 ± 1.2 | 10 | 6.2 ± 0.9 |
| Acroporidae | *Montipora* | 1.8 ± 0.7 | 0 | 18.6 ± 1.6 |
| Agariciidae | *Pachyseris* | 0.4 ± 0.2 | 0 | 12.0 ± 5.0 |
| Dendrophylliidae | *Turbinaria* | 5.4 ± 1.2 | 0 | 13.4 ± 1.0 |
| Faviidae | *Unidentified* | 21.2 ± 6.1 | 22 | 9.3 ± 0.6 |
| Faviidae | *Echinopora* | 0.2 ± 0.2 | 0 | 11.0 |
| Fungiidae | *Unidentified* | 1.4 ± 0.4 | 4 | 6.9 ± 2.8 |
| Merulinidae | *Hydnophora* | 0.4 ± 0.2 | 0 | 72.5 ± 18.5 |
| Mussidae | *Lobophyllia* | 1.2 ± 0.4 | 0 | 9.0 ± 1.1 |
| Mussidae | *Unidentified* | 0.6 ± 0.2 | 3 | 3.7 ± 0.3 |
| Pectiniidae | *Echinophyllia* | 0.4 ± 0.2 | 0 | 14.0 ± 8.0 |
| Pectiniidae | *Oxypora* | 0.6 ± 0.4 | 0 | 8.7 ± 1.7 |
| Pectiniidae | *Pectinia* | 0.4 ± 0.4 | 0 | 29.0 ± 11.0 |
| Pocilloporidae | *Pocillopora* | 0.6 ± 0.2 | 0 | 22.3 ± 12.3 |
| Poritidae | *Porites* (Massive) | 23.4 ± 9.3 | 39 | 24.1 ± 6.4 |
| Poritidae | *Porites* (Branching) | 2.4 ± 1.1 | 0 | 29.1 ± 4.2 |
| Unidentified | Unidentified | 2.0 ± 1.0 | 4 | 10.4 ± 2.8 |
| **Total** | | **67.6 ± 16.7**[1] | **82** | **16.0**[2] |

*Note: n = number of transects for which mean is calculated; 1 = total value calculated by pooling counts of all taxa per transect and averaging over five transects; 2 = mean colony size (cm) across the site (the sum of all colony sizes averaged by the total number of colonies present).*

### Table 6-24 Total Count, Modal Size-class (cm), Coefficient of Variation (CoV) and Skewness for Hard Coral Size-class Frequency Data at LNG3

| Family | Count | Modal size-class (cm) | CoV | Skewness |
|---|---|---|---|---|
| Acroporidae | 35 | 2.1–5.0, 5.1–10.0 | 0.8 | 0.8 |
| Dendrophylliidae | 27 | 10.1–20.0 | 0.4 | -0.2 |
| Faviidae | 107 | 5.1–10.0 | 0.6 | 1.4 |
| Poritidae | 129 | 2.1–5.0 | 2.7 | 6.8 |
| Others | 40 | 10.1–20.0 | 1.2 | 2.9 |
| **Total** | **338** | **10.1–20.0** | **2.6** | **3.7** |

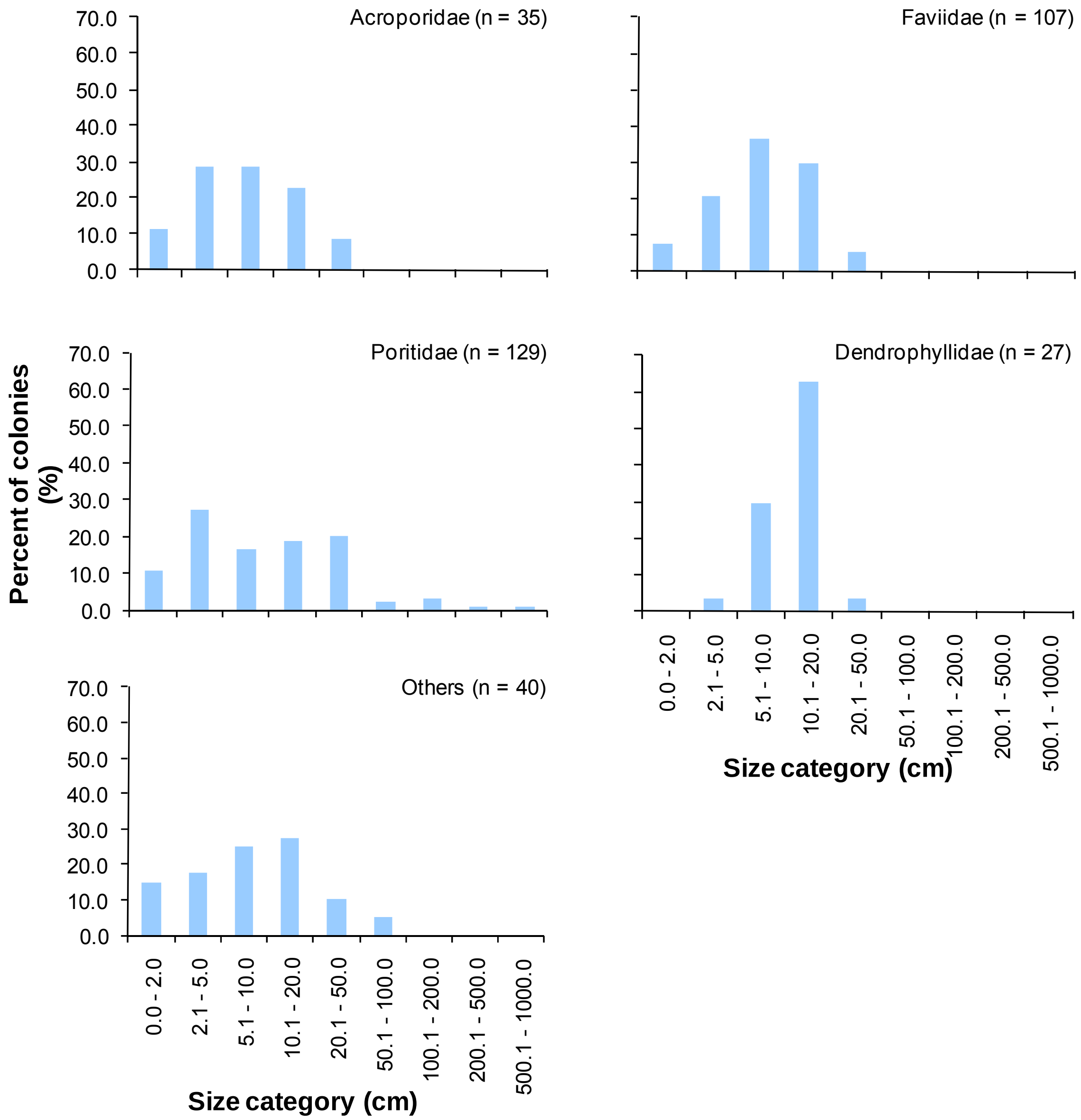



**Figure 6-14 Size-Class Frequency Distribution of Hard Corals at LNG3**

### 6.4.3.3.2 Dugong Reef [DUG]

A total of 449 colonies were measured at DUG (Table 6-26), with a mean number per transect of 89.8 ± 11.7 SE (Table 6-25). The most abundant colonies were unidentified faviids (22.4 per transect ± 3.1 SE), *Montipora* (10.4 per transect ± 2.4 SE) and *Lobophyllia* (7.6 per transect ± 1.2 SE). All other taxa were recorded at densities of ≤5 colonies per transect.

The overall mean colony size was 35.7 cm, which varied between a mean of 3.4 cm ± 0.9 SE for unidentified mussids and 120.9 cm ± 5.1 SE for massive *Porites* (Table 6-25). The only colonies >200 cm in size were massive *Porites* and *Galaxea*, with four and one colony in total respectively. There was a total of 45 small, <5 cm in size, colonies, in nine taxonomic groups (including unidentified). The greatest numbers were unidentified fungiids (12 colonies) and unidentified faviids (10 colonies) and all other taxonomic groups contained ≤7 small colonies. Skewness, which varied between 0.4 (mussids) and 4.2 (oculinids), was positive for all the families, indicating that there were greater numbers of colonies in the smaller size-classes and relatively few colonies in the larger size-classes (Table 6-26).

Colonies ranged from <2 cm to >5 m in size (the latter including a stand of the oculinid *Galaxea*) (Figure 6-15). The modal size-class across all families, with the exception of the faviids and 'Other', was 20.1–50.0 cm (Table 6-26). The modal size-class for the faviids was 10.1–20.0 and for the 'Other' was 2.1–5.0.

### Table 6-25 Mean (± SE) Size-Class Frequency Count and Size Statistics of Hard Corals at DUG

| Family | Genera | Mean (± SE) number of colonies per transect (n=5) | Number of Colonies <5 cm | Mean (± SE) colony size (cm) |
|---|---|---|---|---|
| Acroporidae | *Acropora* | 3.8 ± 1.1 | 5 | 26.1 ± 8.1 |
| Acroporidae | *Montipora* | 10.4 ± 2.4 | 0 | 32.9 ± 2.9 |
| Agariciidae | *Pachyseris* | 2.2 ± 0.7 | 0 | 60.4 ± 18.4 |
| Agariciidae | *Pavona* | 1.8 ± 0.4 | 0 | 51.6 ± 11.7 |
| Caryophylliidae | *Euphyllia* | 0.4 ± 0.2 | 0 | 12.5 ± 4.7 |
| Dendrophylliidae | *Turbinaria* | 2.2 ± 0.9 | 0 | 14.2 ± 5.3 |
| Faviidae | Unidentified | 22.4 ± 3.1 | 10 | 21.8 ± 2.2 |
| Faviidae | *Cyphastrea* | 0.2 ± 0.2 | 0 | 16.0 |
| Faviidae | *Echinopora* | 1.4 ± 1.0 | 0 | 30.7 ± 6.9 |
| Faviidae | *Goniastrea* | 1.2 ± 0.7 | 0 | 56.2 ± 29.9 |
| Faviidae | *Oulophyllia/Oulastrea* | 0.2 ± 0.2 | 0 | 37.0 |
| Fungiidae | Unidentified | 3.2 ± 1.7 | 12 | 4.7 ± 10.4 |
| Fungiidae | *Herpolitha* | 0.2 ± 0.2 | 0 | 30.0 |
| Merulinidae | *Hydnophora* | 2.6 ± 1.1 | 0 | 70.2 ± 15.3 |
| Merulinidae | *Merulina* | 3.0 ± 0.9 | 2 | 26.9 ± 6.2 |
| Mussidae | *Lobophyllia* | 7.6 ± 1.2 | 0 | 26.4 ± 2.0 |
| Mussidae | Unidentified | 2.2 ± 0.6 | 7 | 3.4 ± 0.9 |
| Oculinidae | *Galaxea* | 4.2 ± 0.6 | 1 | 80.8 ± 38.4 |
| Pectiniidae | *Echinophyllia* | 3.4 ± 0.8 | 0 | 24.8 ± 5.1 |
| Pectiniidae | *Mycedium* | 0.2 ± 0.2 | 0 | 13.0 |
| Pectiniidae | *Oxypora* | 3.4 ± 1.1 | 0 | 33.3 ± 4.7 |
| Pectiniidae | *Pectinia* | 4.0 ± 1.4 | 1 | 26.6 ± 5.3 |
| Pocilloporidae | *Pocillopora* | 0.6 ± 0.4 | 0 | 34.0 ± 10.0 |
| Poritidae | *Goniopora* | 0.2 ± 0.2 | 0 | 38.0 |
| Poritidae | *Porites* (Massive) | 5.0 ± 1.6 | 1 | 120.9 ± 5.1 |
| Poritidae | *Porites* (Branching) | 2.2 ± 0.5 | 1 | 45.3 ± 10.0 |
| Unidentified | Unidentified | 1.6 ± 0.9 | 5 | 5.9 ± 1.8 |
| **TOTAL** | | **89.8 ± 11.7**[1] | **45** | **35.7**[2] |

*Note: n = number of transects for which mean is calculated; 1 = total value calculated by pooling counts of all taxa per transect and averaging over five transects; 2 = mean colony size (cm) across the site (the sum of all colony sizes averaged by the total number of colonies present).*

**Table 6-26 Total Count, Modal Size-class (cm), Coefficient of Variation (CoV) and Skewness for Hard Coral Size-class Frequency Data at DUG**

| Family | Count | Modal size-class (cm) | CoV | Skewness |
|---|---|---|---|---|
| Acroporidae | 71 | 20.1–50.0 | 0.8 | 1.8 |
| Agariciidae | 20 | 20.1–50.0 | 0.9 | 1.7 |
| Faviidae | 127 | 10.1–20.0 | 1.1 | 4.1 |
| Merulinidae | 28 | 20.1–50.0 | 1.0 | 2.3 |
| Mussidae | 49 | 20.1–50.0 | 0.7 | 0.4 |
| Oculinidae | 21 | 20.1–50.0 | 2.1 | 4.2 |
| Pectiniidae | 55 | 20.1–50.0 | 0.8 | 1.3 |
| Poritidae | 37 | 20.1–50.0 | 1.7 | 3.1 |
| Others | 41 | 2.1–5.0 | 1.1 | 1.6 |
| **Total** | **449** | **20.1–50.0** | **1.9** | **7.9** |

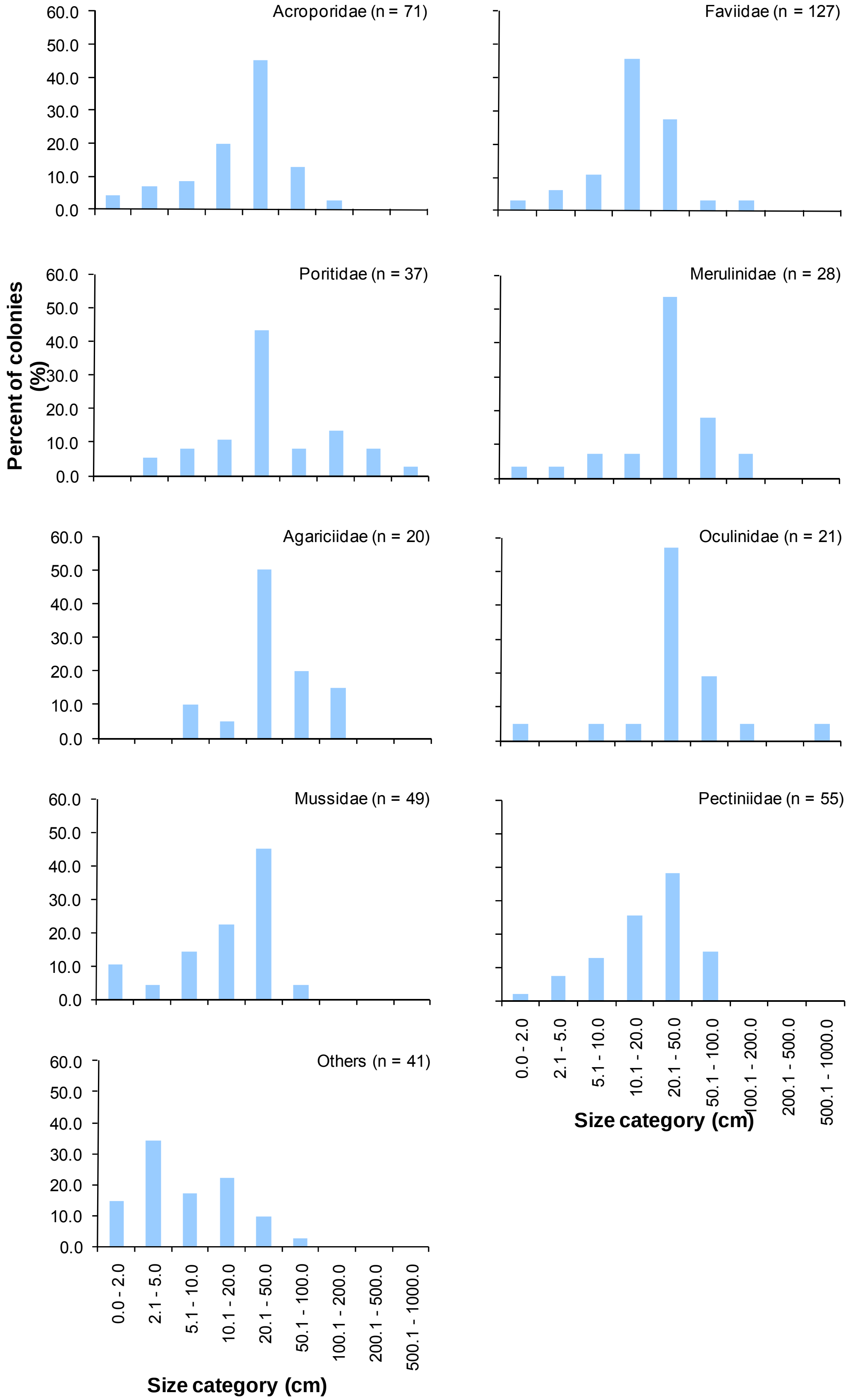



**Figure 6-15 Size-Class Frequency Distribution of Hard Corals at DUG**

#### 6.4.3.4 Size-class Frequency Distribution at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route

##### 6.4.3.4.1 CR1

A total of 666 hard coral colonies were measured at CR1 (Table 6-28), with a mean number per transect of 133.2 ± 11.4 SE (Table 6-27). The most abundant colonies were *Turbinaria* (32.2 per transect ± 7.2 SE).

The mean colony size was 19.9 cm ± 0.7 SE, which varied between a mean of 2.0 cm ± 1.0 SE for *Pseudosidastrea* and 135.0 cm ± 15.0 SE for *Oxypora* (Table 6-27**)**. There was a total of 103 small, <5 cm in size, colonies. The greatest numbers were *Goniopora* (23 colonies), *Turbinaria* (15 colonies) and *Favites* (13 colonies), and all other genera had counts of ≤11 small colonies. Small numbers of acroporids (one colony), dendrophylliids (three colonies), merulinids (one colony), and pectinids (two colonies) were >1 m in size. Skewness, which varied between 1.4 (mussids and poritids) and 2.9 (dendrophylliids), was positive for all the families, indicating that there were greater numbers of colonies in the smaller size-classes and relatively few colonies in the larger size-classes (Table 6-28).

The overall modal size-class was 20.1–50.0 cm, comprising 32.7% of the 666 colonies (Table 6-28; Figure 6-16). Faviids, dendrophylliids and poritids were the most abundant families, comprising 39.6%, 24.5% and 15.8% of the colonies, respectively. The modal size-class of the poritids was 5.1–10.0 cm. The modal size-class of the faviids and siderastreids was 10.1–20.0 cm. The modal size-class for the other families was 20.1–50.0 cm.

**Table 6-27 Mean (± SE) Size-Class Frequency Count and Size Statistics of Hard Corals at CR1**

| Family | Genera | Mean (± SE) number of colonies per transect (n=5) | Number of colonies <5 cm | Mean (± SE) colony size (cm) |
|---|---|---|---|---|
| Acroporidae | *Acropora* | 4.2 ± 2.7 | 2 | 31.5 ± 4.4 |
| Acroporidae | *Astreopora* | 0.4 ± 0.2 | 0 | 78.5 ± 71.5 |
| Acroporidae | *Montipora* | 1.6 ± 0.7 | 0 | 24.4 ± 7.2 |
| Dendrophylliidae | *Turbinaria* | 32.2 ± 7.2 | 15 | 25.9 ± 1.7 |
| Faviidae | *Cyphastrea* | 10.0 ± 1.7 | 5 | 18.4 ± 2.1 |
| Faviidae | *Favia* | 12.8 ± 0.4 | 10 | 13.2 ± 1.2 |
| Faviidae | *Favites* | 12.4 ± 2.7 | 13 | 13.7 ± 1.3 |
| Faviidae | *Goniastrea* | 6.6 ± 0.5 | 5 | 21.9 ± 2.8 |
| Faviidae | *Leptastrea* | 1.2 ± 0.4 | 1 | 15.8 ± 5.8 |
| Faviidae | *Montastrea* | 2.8 ± 1.4 | 6 | 10.1 ± 3.0 |
| Faviidae | *Moseleya* | 1.2 ± 0.5 | 2 | 8.0 ± 2.2 |
| Faviidae | *Platygyra* | 5.6 ± 1.9 | 1 | 25.1 ± 3.1 |
| Fungiidae | *Lithophyllon* | 0.4 ± 0.2 | 0 | 55.0 ± 15.0 |
| Merulinidae | *Hydnophora* | 1.4 ± 0.7 | 0 | 23.1 ± 3.8 |
| Merulinidae | *Merulina* | 1.4 ± 1.0 | 0 | 43.1 ± 17.8 |
| Mussidae | *Acanthastrea* | 2.4 ± 1.0 | 1 | 27.0 ± 6.6 |
| Mussidae | *Lobophyllia* | 3.0 ± 1.1 | 0 | 18.6 ± 4.7 |
| Mussidae | *Symphyllia* | 1.2 ± 0.5 | 0 | 22.8 ± 7.4 |
| Oculinidae | *Galaxea* | 1.4 ± 0.7 | 1 | 27.7 ± 4.5 |
| Pectiniidae | *Echinophyllia* | 0.4 ± 0.4 | 0 | 35.0 ± 2.0 |
| Pectiniidae | *Mycedium* | 3.4 ± 0.7 | 1 | 18.4 ± 3.2 |

| Family | Genera | Mean (± SE) number of colonies per transect (n=5) | Number of colonies <5 cm | Mean (± SE) colony size (cm) |
|---|---|---|---|---|
| Pectiniidae | *Oxypora* | 0.4 ± 0.4 | 0 | 135.0 ± 15.0 |
| Pocilloporidae | *Stylophora* | 0.2 ± 0.2 | 0 | 41.0 |
| Poritidae | *Goniopora* | 10.0 ± 2.0 | 23 | 11.5 ± 1.7 |
| Poritidae | *Porites* | 11.6 ± 1.0 | 11 | 12.1 ± 1.2 |
| Siderastreidae | *Psammocora* | 4.4 ± 0.6 | 4 | 12.0 ± 1.8 |
| Siderastreidae | *Pseudosidastrea* | 0.4 ± 0.2 | 2 | 2.0 ± 1.0 |
| Unidentified | Unidentified | 0.2 ± 0.2 | 0 | 8.0 |
| **Total** | | **133.2 ± 11.4[1]** | **103** | **19.9 ± 0.7[2]** |

*Note: n = number of transects for which mean is calculated; 1 = total value calculated by pooling counts of all taxa per transect and averaging over five transects; 2 = mean colony size (cm) across the site (the sum of all colony sizes averaged by the total number of colonies present).*

### Table 6-28 Total Count, Modal Size-Class (cm), Coefficient of Variation and Skewness of Coral Size-Class Frequencies Data at CR1 and CR2

| Family | CR1 | | | | CR2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Count | Modal size-class | CoV | Skew | Count | Modal size-class | CoV | Skew |
| Acroporidae | 31 | 20.1–50.0 | 0.9 | 2.4 | 37 | 20.1–50.0 | 1.0 | 2.5 |
| Dendrophylliidae | 163 | 20.1–50.0 | 0.8 | 2.9 | 51 | 10.1–20.0 | 0.8 | 1.0 |
| Faviidae | 264 | 10.1–20.0 | 0.8 | 1.7 | 229 | 10.1–20.0 | 0.8 | 1.7 |
| Merulinidae | 15 | 20.1–50.0 | 1.1 | 2.5 | 11 | 10.1–20.0 | 0.3 | 0.5 |
| Mussidae | 32 | 20.1–50.0 | 0.8 | 1.4 | 32 | 20.1–50.0 | 0.6 | 1.0 |
| Oculinidae | 8 | - | - | - | 10 | 10.1–20.0 | 0.6 | 0.3 |
| Pectiniidae | 20 | 20.1–50.0 | 1.2 | 2.4 | 18 | 20.1–50.0 | 0.5 | 0.0 |
| Poritidae | 105 | 5.1–10.0 | 0.9 | 1.4 | 51 | 20.1–50.0 | 0.7 | 0.5 |
| Siderastreidae | 24 | 10.1–20.0 | 0.8 | 1.8 | 4 | - | - | - |
| Other | 4 | - | - | - | 8 | - | - | - |
| **Total** | **666** | **20.1–50.0** | **1.0** | **3.0** | **451** | **10.1–20.0** | **0.8** | **2.6** |

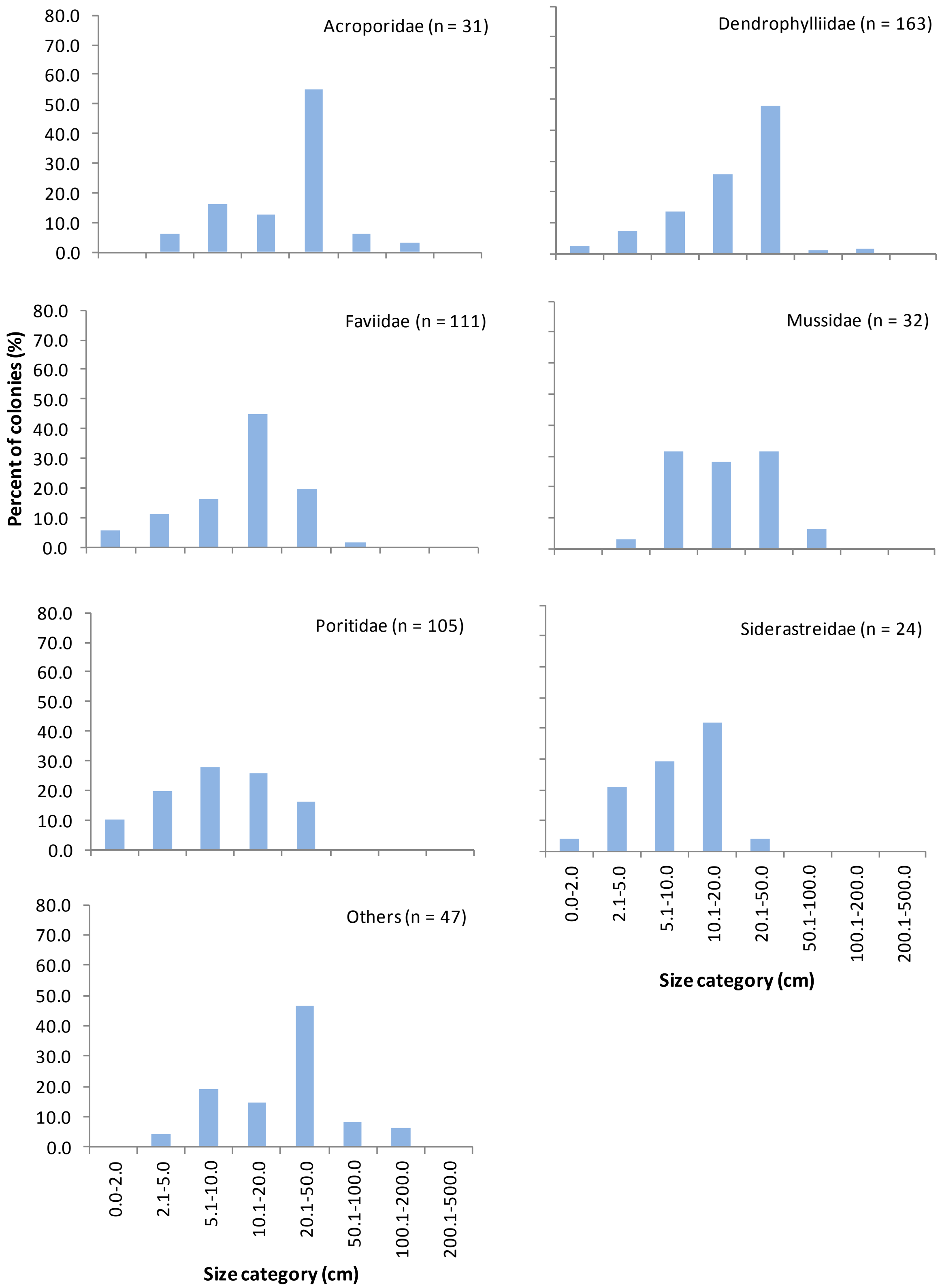



**Figure 6-16 Size-Class Frequency Distribution of Hard Corals at CR1**

#### 6.4.3.4.2 CR2

A total of 451 hard coral colonies were measured at CR2 (Table 6-28), with a mean number per transect of 90.2 ± 7.5 SE (Table 6-29). The most abundant colonies were *Favites* (18.4 per transect ± 3.5 SE).

The mean colony size was 16.8 cm ± 0.7 SE, which varied between 7.0 cm for *Caulastrea* and a mean of 35.8 cm ± 8.3 SE for *Acropora* (Table 6-29). There was a total of 79 small, <5 cm in size, colonies. The greatest in number were *Favites* (22 colonies), *Turbinaria* (16 colonies), and *Porites* (10 colonies), and all other genera had counts of ≤8 small colonies in total. There was one acroporid >1 m in size. Skewness varied between 0.0 (pectinids) and 2.5 (acroporids) (Table 6-28).

The overall modal size-class was 10.1–20.0 cm, comprising 37.7% of the 451 colonies (Table 6-28; Figure 6-17). Faviids, poritids and dendrophylliids were the most abundant families, comprising 50.8%, 11.3% and 11.3% of the colonies, respectively. The modal size-class of the dendrophylliids, faviids, merulinids and oculinids was 10.1–20.0 cm. The modal size-class for the other families was 20.1–50.0 cm. A feature of the size-class distribution at CR2 was the high proportion of small poritids and dendrophylliids.

**Table 6-29 Mean (± SE) Size-Class Frequency Count and Size Statistics of Hard Corals at CR2**

| Family | Genera | Mean (± SE) number of colonies per transect (n=5) | Number of colonies <5 cm | Mean (± SE) colony size (cm) |
|---|---|---|---|---|
| Acroporidae | *Acropora* | 1.2 ± 0.4 | 0 | 35.8 ± 8.3 |
| Acroporidae | *Astreopora* | 0.4 ± 0.2 | 0 | 20.5 ± 3.5 |
| Acroporidae | *Montipora* | 5.8 ± 1.7 | 3 | 25.4 ± 5.3 |
| Agariciidae | *Pavona* | 0.2 ± 0.2 | 0 | 20.0 |
| Dendrophylliidae | *Turbinaria* | 10.2 ± 1.1 | 16 | 13.0 ± 1.5 |
| Faviidae | *Caulastrea* | 0.2 ± 0.2 | 0 | 7.0 |
| Faviidae | *Cyphastrea* | 8.4 ± 1.2 | 8 | 13.5 ± 1.2 |
| Faviidae | *Favia* | 8.2 ± 0.4 | 2 | 16.1 ± 1.8 |
| Faviidae | *Favites* | 18.4 ± 3.5 | 22 | 14.8 ± 1.3 |
| Faviidae | *Goniastrea* | 2.0 ± 0.5 | 0 | 22.5 ± 3.5 |
| Faviidae | *Leptastrea* | 0.2 ± 0.2 | 0 | 13.0 |
| Faviidae | *Montastrea* | 1.2 ± 0.8 | 0 | 18.7 ± 5.5 |
| Faviidae | *Moseleya* | 0.4 ± 0.2 | 0 | 8.0 ± 3.0 |
| Faviidae | *Platygyra* | 6.8 ± 0.7 | 5 | 21.1 ± 2.8 |
| Fungiidae | *Fungia* | 0.2 ± 0.2 | 0 | 17.0 |
| Merulinidae | *Hydnophora* | 2.2 ± 1.0 | 0 | 20.2 ± 1.6 |
| Mussidae | *Acanthastrea* | 1.4 ± 0.4 | 2 | 16.9 ± 5.0 |
| Mussidae | *Lobophyllia* | 5.0 ± 1.3 | 2 | 26.7 ± 3.2 |
| Oculinidae | *Galaxea* | 2.0 ± 0.4 | 2 | 11.3 ± 2.0 |
| Pectiniidae | *Echinophyllia* | 1.0 ± 0.4 | 0 | 30.2 ± 2.3 |
| Pectiniidae | *Mycedium* | 2.6 ± 0.2 | 1 | 14.6 ± 2.3 |
| Pocilloporidae | *Stylophora* | 0.2 ± 0.2 | 0 | 21.0 |
| Poritidae | *Goniopora* | 3.0 ± 1.1 | 3 | 13.9 ± 2.7 |
| Poritidae | *Porites* | 7.2 ± 0.7 | 10 | 12.0 ± 1.4 |
| Siderastreidae | *Psammocora* | 0.8 ± 0.4 | 0 | 12.3 ± 6.3 |
| Unidentified | Unidentified | 1.0 ± 0.6 | 3 | 9.8 ± 7.6 |
| **Total** | | **90.2 ± 7.5[1]** | **79** | **16.8 ± 0.7[2]** |

*Note: n = number of transects for which mean is calculated; 1 = total value calculated by pooling counts of all taxa per transect and averaging over five transects; 2 = mean colony size (cm) across the site (the sum of all colony sizes averaged by the total number of colonies present).*

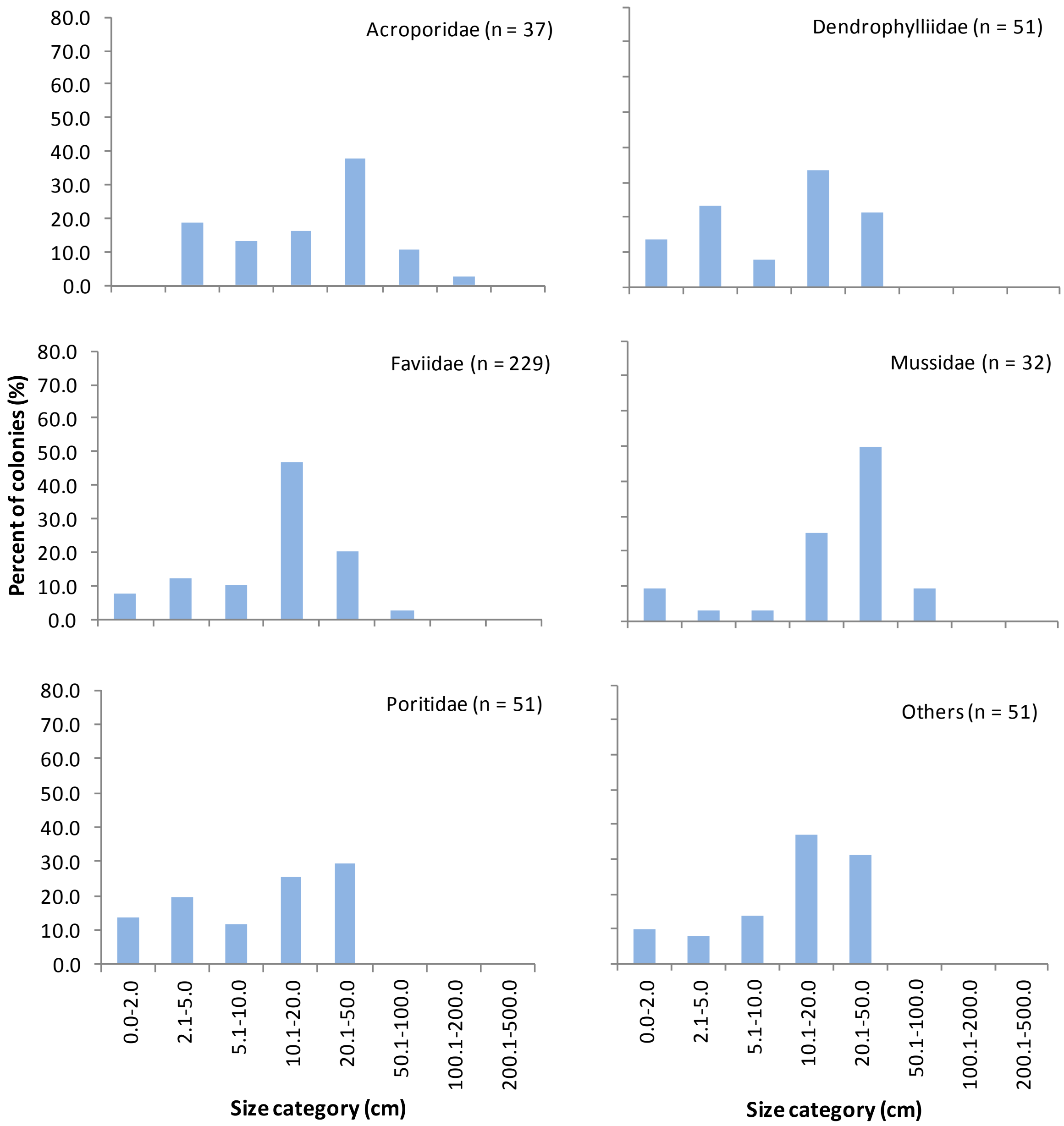



**Figure 6-17 Size-Class Frequency Distribution of Hard Corals at CR2**

The Reference Sites were characterised by a greater abundance of coral colonies than the sites at risk of Material or Serious Environmental Harm. Coral community composition was generally similar at both the Reference Sites and the sites at risk of Material or Serious Environmental Harm, with the dendrophylliids, faviids and poritids being the three most abundant families. However, CI1 and CI2 were also characterised by a higher proportion, and larger size, of soft corals (Alcyoniidae, predominantly *Sinularia*) than the Reference Sites. The modal size-class at the Reference Site CR1 was larger than at the sites at Risk of Material or Serious Environmental Harm, indicating a smaller proportion of young colonies at this site.

### 6.4.4 Survival of Dominant Hard Coral Taxa

#### 6.4.4.1 Percentage Live Coral Cover at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

##### 6.4.4.1.1 MOF1

Hard corals covered ~20% of the substratum at MOF1, with faviids representing ~50% and acroporids ~25% of the cover (Table 6-30; Figure 6-18). There was no difference in the live coral cover and percentage composition of corals over the period October 2008–October 2009. The estimates of mean turfing algae cover, which comprised ~40% of the live cover in October 2008, decreased between the two surveys, with ~25% cover recorded in April 2009; but increased again in October 2009 to ~40%. There were corresponding changes in the estimates of percentage cover of sediment.

**Table 6-30 Mean Percentage Cover (± SE) and Composition of Corals and other Benthic Ecological Elements at MOF1**

| Cover | Oct 2008 | Apr 2009 | Oct 2009 |
|---|---|---|---|
| Acroporidae | 5.3 ± 1.3 | 3.8 ± 1.1 | 53.7 ± 1.0 |
| Agariciidae | 0 | 0.1 ± 0.1 | 0.3 ± 0.2 |
| Caryophylliidae | 0 | 0 | 0 |
| Dendrophylliidae | 0 | 0 | 0 |
| Faviidae | 8.0 ± 2.1 | 7.8 ± 2.2 | 7.7 ± 1.8 |
| Fungiidae | 0 | 0 | 0.1 ± 0.1 |
| Merulinidae | 0.9 ± 0.6 | 0.4 ± 0.3 | 0.4 ± 0.3 |
| Mussidae | 0.7 ± 0.3 | 0.3 ± 0.2 | 0.1 ± 0.1 |
| Oculinidae | 0.2 ± 0.2 | 0 | 0.1 ± 0.1 |
| Pectiniidae | 1.3 ± 0.7 | 0.5 ± 0.3 | 0.3 ± 0.2 |
| Pocilloporidae | 0.1 ± 0.1 | 0.1 ± 0.1 | 0.1 ± 0.1 |
| Poritidae | 1.0 ± 0.5 | 2.1 ± 1.5 | 2.3 ± 1.0 |
| Siderastreidae | 0 | 0 | 0 |
| Bleached Coral | 0.1 ± 0.1 | 0 | 0 |
| Unidentified Coral | 1.5 ± 0.6 | 1.3 ± 0.4 | 2.1 ± 0.7 |
| Hydro Coral – Milleporidae | 0 | 0 | 0.1 ± 0.1 |
| Soft Corals – Alcyoniidae | 0 | 0 | 0 |
| Other Benthic Invertebrates | 0.9 ± 0.4 | 1.7 ± 0.8 | 2.3 ± 0.5 |
| Macroalgae | 2.1 ± 0.6 | 0 | 0.4 ± 0.2 |
| Turf Algae | 38.6 ± 3.1 | 26.1 ± 3.5 | 40.4 ± 3.5 |
| Coralline Algae | 1.4 ± 0.5 | 0.1 ± 0.1 | 0.1 ± 0.1 |
| Pavement / Rock / Rubble | 4.8 ± 1.1 | 2.7 ± 1.4 | 0.1 ± 0.1 |
| Sediment | 33.1 ± 4.2 | 53.1 ± 5.7 | 39.3 ± 4.8 |
| Seagrass | 0 | 0 | 0 |

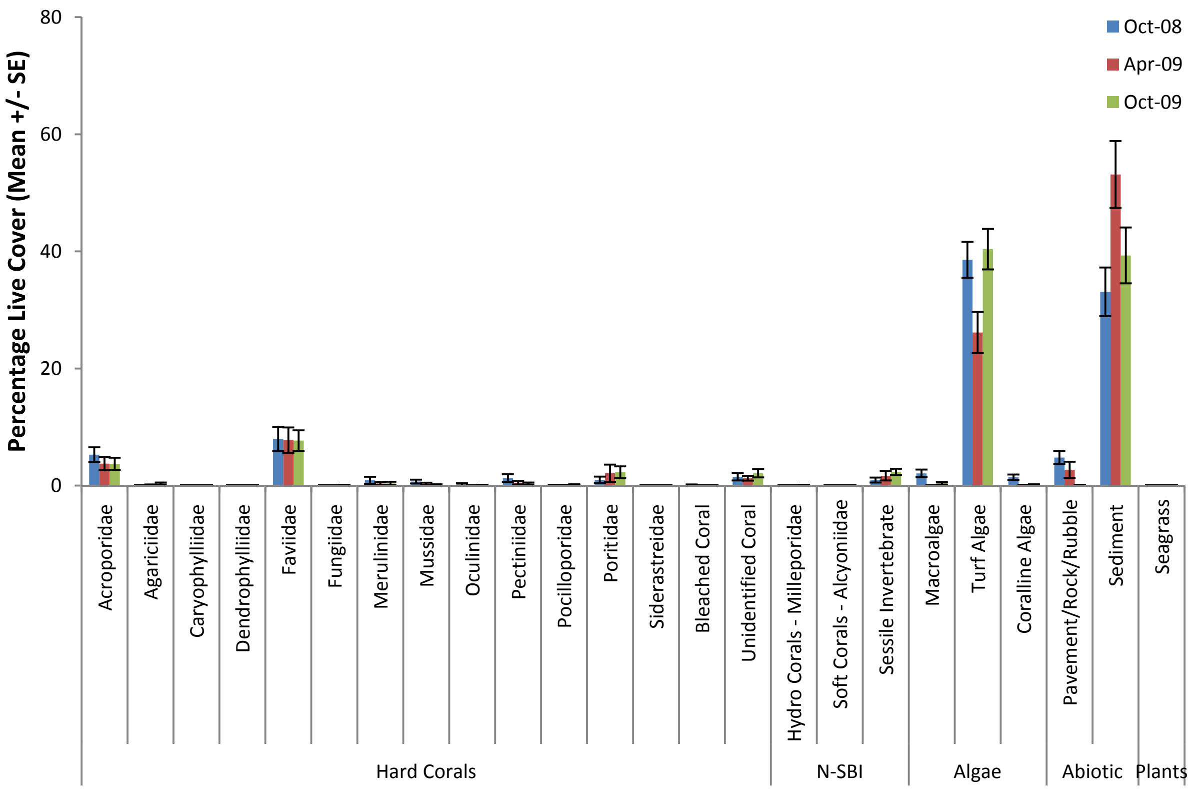



**Figure 6-18 Mean Percentage Cover (± SE) and Composition of Corals and other Benthic Ecological Elements at MOF1**

*Note: N-SBI: Non-scleractinian Benthic Invertebrates.*

### 6.4.4.2 Percentage of Live Coral Cover at Sites at the Mainland End of the DomGas Pipeline Route

The percentage cover of coral recorded in the two surveys is shown in Table 6-31 and Figure 6-19. Coral cover in both surveys was ~30% at CR1 and 15%–18% at the other three sites (CI1, CI2 and CR2). Relatively little change in coral cover was recorded between the October 2010 and April 2011 surveys, except at CR1. Coral cover decreased slightly between the October 2010 and April 2011 surveys at CI1 (-2.6%), CI2 (-0.9%) and CR2 (-0.7%); and increased by 4.8% at CR1, from 30.1% ± 2.7 SE in the October 2010 survey to 34.9% ± 3.4 SE in the April 2011 survey. An increase in coral cover of this magnitude in only five months, across a range of families rather than only the faster-growing taxa, is nevertheless unlikely to be ‘real’, and is most likely to reflect fluctuation in macroalgal cover. The greatest loss of macroalgae between surveys was recorded at CR1, with macroalgal cover declining from 41.1% ± 3.9 SE in October 2010 to 11.0% ± 2.9 SE in April 2011. Coral cover at CR1 may have decreased slightly between surveys, because several colonies were missing altogether from the quadrats.

Similarly, the decline in coral cover at CI1 and CR2 is likely to have been greater than the reported 2.6% and 0.7%, respectively. Cyclone-damaged colonies were observed at both sites, particularly at CR2, and several colonies were missing, again primarily from CR2. Macroalgal cover at CI1 and CR2 was substantially lower in the April 2011 survey than in the October 2010 survey, declining by 15.4% and 26.7%, respectively, which may have exposed some previously covered corals and partially offset the cyclone losses. Coral loss was also partially offset by dislodged colonies being deposited into the quadrats from elsewhere. However, based on field observations at CR2, it appears that most of the dislodged colonies were transported away from the transects and either washed up onto the reef flat or tumbled to the base of the reef slope. These dislodged colonies are expected to experience high mortality rates (e.g. Done 1992). The apparent constancy of coral cover at CI2 between the October 2010 and April 2011 surveys is more likely to be real, as macroalgal cover was relatively low at this site and only differed by 2.5% between the surveys.

Coral composition at all four sites was dominated by the dendrophylliids and faviids, which occurred in approximately equal proportions at all sites with the exception of CI1, where the dendrophylliids were more abundant. *Turbinaria* was the most abundant dendrophylliid genus at all sites, while the faviids were represented by a range of genera, primarily *Cyphastrea*, *Favia*, *Favites*, *Goniastrea* and *Platygyra*. These findings correspond with the RVA surveys, which classified *Turbinaria mesenterina* as the dominant species at CI1, CI2 and CR1 and a subdominant species at CR2, and a range of faviids as subdominant species at all sites. Notwithstanding these general similarities, some compositional differences were apparent between the sites. These included relatively high proportions of *Turbinaria* at CI1 (approximately 55% of the coral cover), Alcyoniidae at CI2 (approximately 15% of the coral cover), *Acropora* and poritids at CR1 (approximately 10% and 15% of the coral cover, respectively), and mussids, primarily *Lobophyllia*, at CR2 (approximately 15% of the coral cover). CI1 was also characterised by low proportions of pectiniids and merulinids relative to the other three sites (<0.1% of the coral cover for each, compared to a minimum of 2.5% and 4.4%, respectively, at the other sites).

Minor coral bleaching (maximum 1.2% of total site cover) was recorded at CI2, CR1 and CR2 in both surveys, and at CI1 in the April 2011 survey. Bleaching occurred primarily on *Turbinaria* and *Sinularia* colonies but was also observed at lower frequency on a wide range of other taxa. A small number of points were scored as ‘dead coral’ (i.e. white skeleton not yet overgrown with turf algae, indicating recent mortality).

Non-coral benthic macroinvertebrates were present in low proportions (<3%) at all four sites. Sponges were the most abundant non-coral benthic macroinvertebrates. Flora, primarily turf algae and macroalgae, were the most abundant benthic ecological element at all sites in both surveys. Macroalgal cover was higher than turf algal cover at CI1, CR1 and CR2 in the October 2010 survey, but by the April 2011 survey, the situation had reversed, with turf algae predominant at all three sites. At CI2, macroalgal cover was relatively low and did not differ between surveys. Coralline algae were recorded at <1% cover at all sites in both surveys, but were probably under-represented in the photographs as they were masked by the overlying turf and macroalgae.

A number of broken and/or dislodged colonies were observed in April 2011, particularly at CR2. The damage is likely to have been caused by wave action during Tropical Cyclone Carlos in February 2011 (Section 3.4). The cyclone may have reduced coral cover more than Figure 6-19 indicates.

**Table 6-31 Mean Percentage Cover (± SE) and Composition of Benthic Ecological Elements at Coral Survey Sites at the Mainland End of the DomGas Pipeline Route**

| Location | Site | Coral | | Other Fauna | | Flora | | Abiotic | |
|---|---|---|---|---|---|---|---|---|---|
| | | Oct 10 | Apr 11 | Oct 10 | Apr 11 | Oct 10 | Apr 11 | Oct 10 | Apr 11 |
| At risk of Material or Serious Environ-mental Harm | CI1 | 17.9 ± 2.5 | 15.3 ± 2.5 | 0.2 ± 0.1 | 1.4 ± 0.6 | 67.5 ± 3.9 | 62.7 ± 4.7 | 14.3 ± 1.9 | 20.7 ± 3.6 |
| | CI2 | 15.8 ± 2.2 | 14.9 ± 1.9 | 0.9 ± 0.5 | 0.7 ± 0.1 | 69.9 ± 4.5 | 61.2 ± 2.3 | 13.4 ± 3.1 | 23.2 ± 1.0 |
| Reference Sites | CR1 | 30.1 ± 2.7 | 34.9 ± 3.4 | 2.3 ± 0.2 | 2.1 ± 0.5 | 61.4 ± 2.3 | 56.1 ± 2.5 | 6.2 ± 1.3 | 6.9 ± 0.9 |
| | CR2 | 16.4 ± 2.8 | 15.7 ± 2.1 | 0.8 ± 0.2 | 1.0 ± 0.3 | 71.1 ± 1.5 | 71.2 ± 1.7 | 11.7 ± 2.3 | 11.1 ± 2.4 |

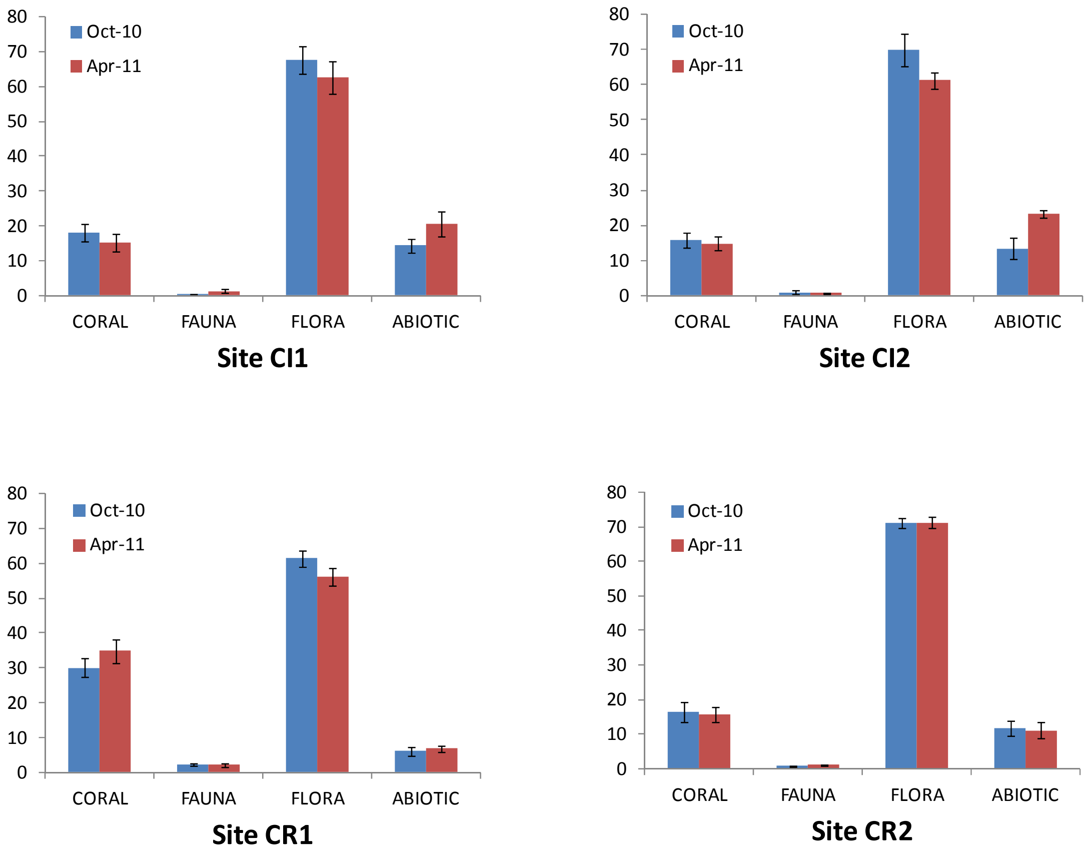



**Figure 6-19 Mean Percentage Cover (± SE) and Composition of Benthic Ecological Elements at Coral Survey Sites at the Mainland End of the DomGas Pipeline Route**

#### 6.4.4.2.1 Percentage of Live Coral Cover at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland end of the DomGas Pipeline Route

Dendrophylliids occurred at ~10% cover at CI1 and 4% at CI2 in both the October 2010 and April 2011 surveys (Table 6-32; Figure 6-20 and Figure 6-21). The dendrophylliids at both sites were almost exclusively *Turbinaria*. Faviids occurred at ~3% at CI1 and ~4% at CI2 in both surveys, and were represented primarily by *Favia*, *Favites* and *Platygyra*; and by *Cyphastrea* at CI1, and *Goniastrea* at CI2. Acroporids (predominantly *Montipora*) and Alcyoniidae were the only other families constituting more than 1% cover in both surveys at CI1. At CI2, Alcyoniidae and the poritids, predominantly *Goniopora*, were present at 1% or more in both the October 2010 and April 2011 surveys. *Sinularia* was the most abundant alcyoniid genus at both sites, generally occurring on the shallower sections of the reefs. The 2.6% reduction in coral cover recorded at CI1 between the October 2010 and April 2011 surveys occurred primarily in the dendrophylliids and faviids.

The proportions of non-coral benthic macroinvertebrates remained low and consistent between surveys at CI2 (Table 6-32; Figure 6-21). There was an increase in the abundance of crinoids at CI1 between the October 2010 and April 2011 surveys, resulting in an increase in the ‘Other Fauna’ category from 0.2% to 1.4%. Macroalgae were abundant (44% cover) and diverse at CI1 in the October 2010 survey. Common taxa included *Dictyopteris* sp., *Padina* sp. and *Zonaria* sp. By the April 2011 survey, macroalgal abundance at CI1 had decreased to 29%. This reduction may reflect a natural seasonal cycle, possibly exacerbated by Tropical Cyclone Carlos, which would have removed macroalgae such as *Asparagopsis*. Macroalgae were relatively sparse at CI2 in both surveys, covering 10% of the substrate in the October 2010 survey and 12% in the April 2011 survey.

**Table 6-32 Mean Percentage Cover (± SE) and Composition of Corals at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

| Cover | CI1 | | CI2 | |
|---|---|---|---|---|
| | Oct 2010 | Apr 2011 | Oct 2010 | Apr 2011 |
| Acroporidae | 1.5 ± 0.3 | 1.7 ± 0.4 | 0.4 ± 0.2 | 0.6 ± 0.4 |
| Agariciidae | 0 | 0 | 0 | 0 |
| Alcyoniidae | 1.6 ± 0.3 | 1.3 ± 0.3 | 2.4 ± 1.1 | 2.1 ± 1.2 |
| Caryophylliidae | 0 | 0.02 ± 0.02 | 0.02 ± 0.02 | 0.02 ± 0.02 |
| Dendrophylliidae | 10.0 ± 2.1 | 8.9 ± 2.0 | 4.1 ± 1.8 | 3.3 ± 0.7 |
| Faviidae | 2.7 ± 0.5 | 1.6 ± 0.3 | 4.0 ± 0.8 | 3.5 ± 0.6 |
| Fungiidae | 0 | 0 | 0 | 0 |
| Merulinidae | 0.02 ± 0.02 | 0.4 ± 0.2 | 1.6 ± 0.6 | 0.5 ± 0.3 |
| Mussidae | 0.03 ± 0.03 | 0.1 ± 0.1 | 0 | 0 |
| Oculinidae | 0 | 0 | 0 | 0 |
| Pectiniidae | 0 | 0.02 ± 0.02 | 0.7 ± 0.3 | 1.1 ± 0.6 |
| Pocilloporidae | 0.02 ± 0.02 | 0 | 0 | 0 |
| Poritidae | 0.7 ± 0.3 | 0.8 ± 0.3 | 1.1 ± 0.4 | 2.8 ± 1.3 |
| Siderastreidae | 0.4 ± 0.2 | 0 | 0.1 ± 0.1 | 0 |
| Unidentified Coral | 0.9 ± 0.1 | 0.5 ± 0.2 | 0.2 ± 0.1 | 1.1 ± 0.5 |
| Bleached Coral | 0 | 0.8 ± 0.3 | 1.2 ± 0.4 | 0.2 ± 0.1 |
| Dead Coral | 0 | 0.03 ± 0.02 | 0 | 0.02 ± 0.02 |
| *Millepora* | 0 | 0 | 0.3 ± 0.3 | 0 |
| Sponges | 0.2 ± 0.1 | 0.2 ± 0.1 | 0.6 ± 0.3 | 0.1 ± 0.1 |
| Other Benthic Invertebrates | 0.02 ± 0.02 | 1.2 ± 0.5 | 0 | 0.6 ± 0.1 |
| Coralline Algae | 0.1 ± 0.1 | 0.1 ± 0.1 | 0.1 ± 0.02 | 0.02 ± 0.02 |
| Macroalgae | 43.9 ± 2.5 | 28.5 ± 5.5 | 10.0 ± 1.6 | 12.5 ± 1.9 |
| Seagrass | 0.02 ± 0.02 | 0 | 0 | 0 |
| Turf Algae | 23.5 ± 2.1 | 34.1 ± 2.6 | 59.8 ± 5.0 | 48.7 ± 1.6 |
| Pavement, Rock, Rubble | 0.4 ± 0.10 | 0.1 ± 0.1 | 0.03 ± 0.02 | 0.02 ± 0.02 |
| Sand/Sediment | 14.0 ± 1.9 | 20.6 ± 3.7 | 13.4 ± 3.2 | 23.2 ± 1.0 |

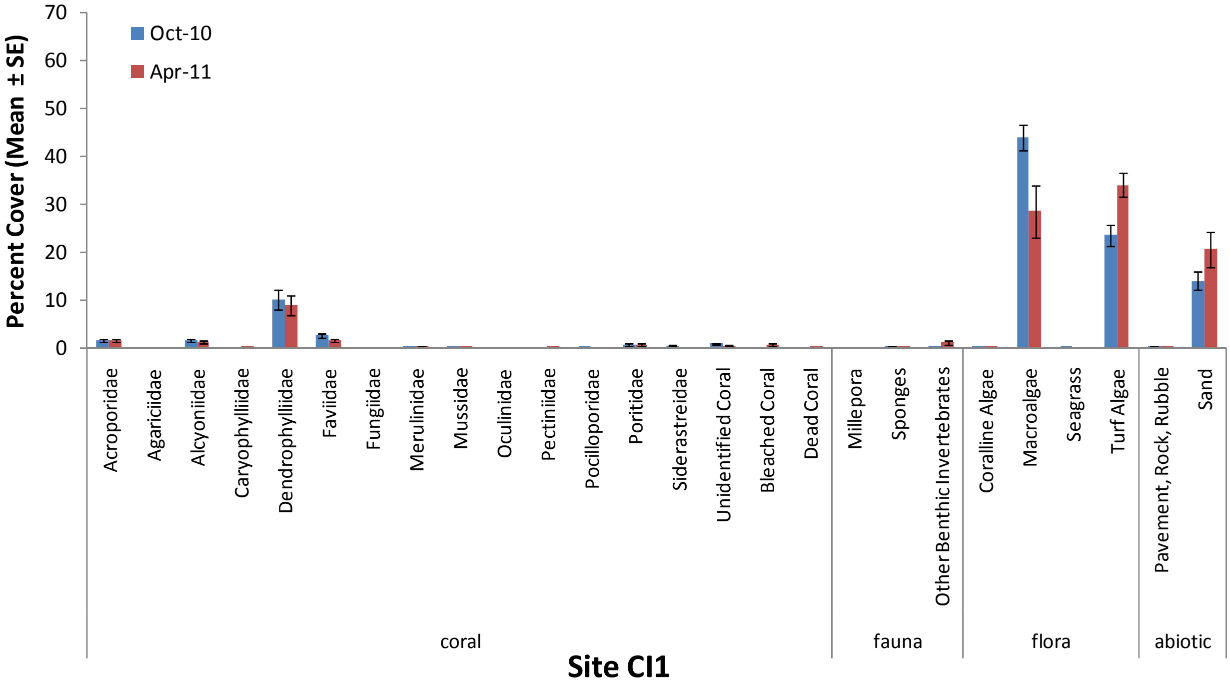



**Figure 6-20 Mean Percentage Cover (± SE) and Composition of Corals and other Benthic Ecological Elements at CI1**

*Note: The abiotic element 'sand' refers to sediment.*

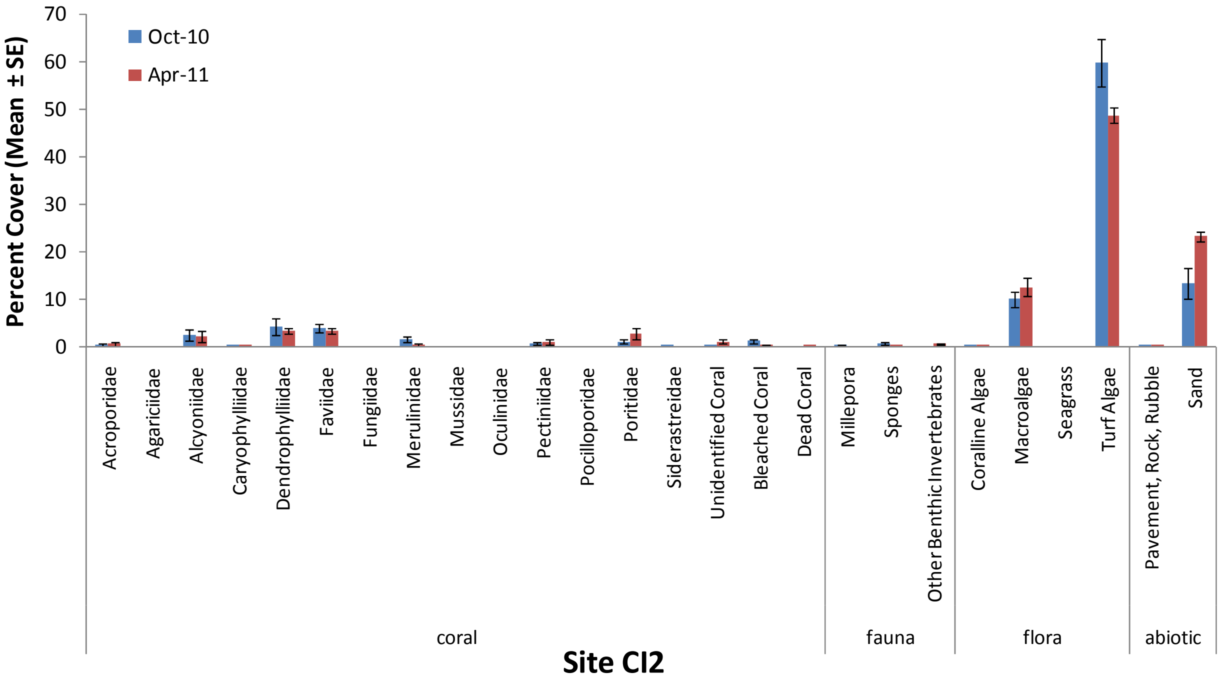



**Figure 6-21 Mean Percentage Cover (± SE) and Composition of Corals and other Benthic Ecological Elements at CI2**

*Note: The abiotic element 'sand' refers to sediment.*

#### 6.4.4.3 Percentage of Live Coral Cover at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

##### 6.4.4.3.1 LNG3

The live cover and composition of hard corals at LNG3 was generally lower (16% in September 2008) than at other coral survey sites on the east coast of Barrow Island (Table 6-33; Figure 6-22) (Chevron Australia 2013a). Poritids represented the greatest cover of hard corals (~73%) followed by unidentified coral (14%) and faviids (7%) at this time. There was no difference in the live coral cover and percentage composition of corals over the period September 2008–November 2009. The majority (>60%) of the substratum was covered by turfing algae, which remained consistently high over the survey period.

**Table 6-33 Mean Percentage Cover (± SE) and Composition of Corals and other Benthic Ecological Elements at LNG3**

| Cover | Sep 2008 | Mar 2009 | Aug 2009 | Nov 2009 |
|---|---|---|---|---|
| Acroporidae | 0.2 ± 0.1 | 0.3 ± 0.3 | 0.2 ± 0.1 | 0.1 ± 0.1 |
| Agariciidae | 0.3 ± 0.2 | 0 | 0 | 0 |
| Caryophylliidae | 0 | 0 | 0 | 0 |
| Dendrophylliidae | 0 | 0.1 ± 0.1 | 0.4 ± 0.2 | 0.2 ± 0.1 |
| Faviidae | 1.1 ± 0.4 | 1.7 ± 0.4 | 1.0 ± 0.3 | 1.7 ± 0.4 |
| Fungiidae | 0 | 0 | 0 | 0 |
| Merulinidae | 0 | 0.7 ± 0.7 | 0 | 0 |
| Mussidae | 0.1 ± 0.1 | 0 | 0.1 ± 0.1 | 0 |
| Oculinidae | 0 | 0 | 0 | 0 |
| Pectiniidae | 0 | 0 | 0 | 0.1 ± 0.1 |
| Pocilloporidae | 0 | 0.2 ± 0.2 | 0.1 ± 0.1 | 0.1 ± 0.1 |
| Poritidae | 11.6 ± 3.6 | 12.0 ± 2.9 | 5.2 ± 1.6 | 11.6 ± 3.1 |
| Siderastreidae | 0 | 0 | 0 | 0 |
| Bleached Coral | 0.1 ± 0.1 | 0 | 0.1 ± 0.1 | 0.1 ± 0.1 |
| Unidentified Coral | 2.3 ± 0.6 | 2.8 ± 1.0 | 0.2 ± 0.1 | 0.7 ± 0.3 |
| Hydro Coral – Milleporidae | 0 | 0 | 0.8 ± 0.7 | 0 |
| Soft Corals – Alcyoniidae | 0.1 ± 0.1 | 0 | 0.2 ± 0.2 | 0 |
| Other Benthic Invertebrates | 2.4 ± 1.4 | 2.0 ± 1.4 | 0.2 ± 0.1 | 0.9 ± 0.4 |
| Macroalgae | 0.4 ± 0.2 | 0 | 0.6 ± 0.4 | 1.2 ± 0.3 |
| Turf Algae | 60.6 ± 3.8 | 67.4 ± 3.2 | 75.2 ± 2.4 | 69.3 ± 3.0 |
| Coralline Algae | 0.2 ± 0.2 | 0.1 ± 0.1 | 1.8 ± 0.9 | 0.5 ± 0.2 |
| Pavement / Rock / Rubble | 15.8 ± 2.7 | 5.9 ± 1.6 | 7.3 ± 1.3 | 10.1 ± 1.7 |
| Sediment | 4.8 ± 1.0 | 6.9 ± 1.7 | 6.5 ± 1.9 | 3.5 ± 0.9 |
| Seagrass | 0 | 0 | 0 | 0 |

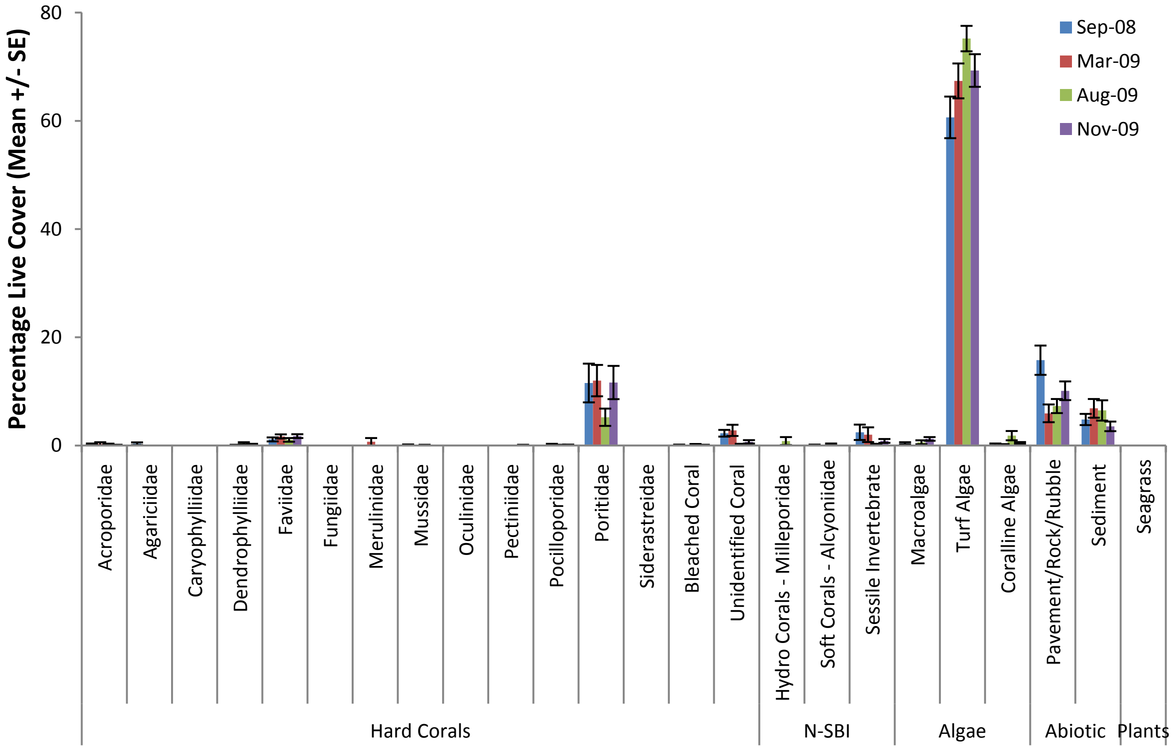



**Figure 6-22 Mean Percentage Cover (± SE) and Composition of Corals and other Ecological Elements at LNG3**

*Note: N-SBI: Non-scleractinian Benthic Invertebrates.*

#### 6.4.4.3.2 Dugong Reef [DUG]

In summary, the percentage of substratum covered by live corals was relatively high (~65–70%) at DUG compared to other sites on the east coast of Barrow Island (Table 6-34; Figure 6-23) (Chevron Australia 2013a). There was no difference in the live coral cover and percentage composition of corals over the period May 2008–June 2009. There was no one dominant family and corals from several families, including the acroporids, agariciids, faviids, oculinids, pectiniids and poritids, contributed ~5–15% to the percentage of live cover during all three surveys. Turfing algae covered ~30% of the hard substratum over the 12-month survey period.

**Table 6-34 Mean Percentage Cover (± SE) and Composition of Corals and other Benthic Ecological Elements at DUG**

| Cover | May 2008 | November 2008 | June 2009 |
|---|---|---|---|
| | Mean ± SE | Mean ± SE | Mean ± SE |
| Acroporidae | 7.6 ± 1.7 | 6.9 ± 1.6 | 10.6 ± 1.8 |
| Agariciidae | 7.5 ± 2.9 | 4.0 ± 1.2 | 7.1 ± 2.3 |
| Caryophylliidae | 0.1 ± 0.1 | 0 | 0.3 ± 0.3 |
| Dendrophylliidae | 0.1 ± 0.1 | 0 | 0 |
| Faviidae | 6.5 ± 1.3 | 11.0 ± 1.7 | 6.7 ± 1.3 |
| Fungiidae | 0.9 ± 0.4 | 0.2 ± 0.1 | 1.0 ± 0.3 |
| Merulinidae | 0.5 ± 0.3 | 1.1 ± 0.4 | 0.8 ± 0.3 |
| Mussidae | 2.8 ± 0.7 | 3.6 ± 0.9 | 1.7 ± 0.4 |

| Cover | May 2008 | November 2008 | June 2009 |
|---|---|---|---|
| | Mean ± SE | Mean ± SE | Mean ± SE |
| Oculinidae | 14.7 ± 2.8 | 10.8 ± 2.3 | 14.3 ± 2.3 |
| Pectiniidae | 9.4 ± 1.9 | 8.5 ± 2.1 | 6.3 ± 1.3 |
| Pocilloporidae | 0.4 ± 0.2 | 0.2 ± 0.2 | 0.3 ± 0.2 |
| Poritidae | 12.3 ± 2.6 | 15.2 ± 2.4 | 13.9 ± 2.5 |
| Siderastreidae | 0.1 ± 0.1 | 0 | 0 |
| Bleached Coral | 0 | 0 | 0.1 ± 0.1 |
| Unidentified Coral | 3.1 ± 0.7 | 7.3 ± 1.3 | 1.1 ± 0.3 |
| Hydro Corals – Milleporidae | 0 | 0 | 0.9 ± 0.4 |
| Soft Corals – Alcyoniidae | 0 | 0 | 0 |
| Other Benthic Invertebrates | 1.4 ± 0.8 | 0.9 ± 0.5 | 0.3 ± 0.1 |
| Macroalgae | 0.1 ± 0.1 | 0 | 0 |
| Turf Algae | 29.1 ± 2.8 | 23.9 ± 2.7 | 32.1 ± 2.6 |
| Coralline Algae | 0 | 2.1 ± 0.6 | 0.2 ± 0.1 |
| Pavement/Rock/Rubble | 2.2 ± 0.7 | 0.7 ± 0.3 | 0.1 ± 0.1 |
| Sediment | 1.2 ± 0.4 | 3.6 ± 1.2 | 2.3 ± 0.8 |
| Seagrass | 0 | 0 | 0 |

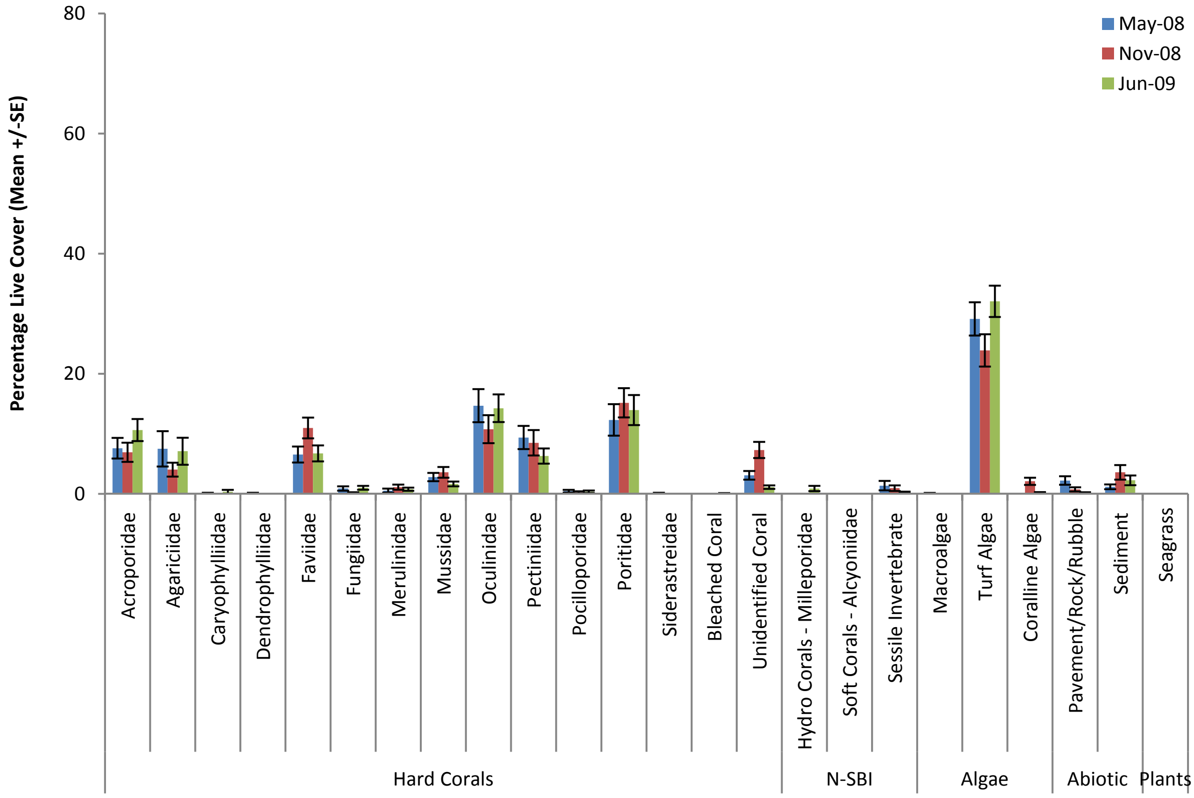



**Figure 6-23 Mean Percentage Cover (± SE) and Composition of Corals and other Benthic Ecological Elements at DUG**

#### 6.4.4.3.3 Percentage of Live Coral Cover at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland end of the DomGas Pipeline Route

Coral diversity was higher at the Reference Sites than at CI1 and CI2; families recorded at fixed transects at the Reference Sites included all those recorded at CI1 and CI2, as well as agariciids, fungiids and oculinids (Table 6-35; Figure 6-24 and Figure 6-25). Dendrophylliids and faviids were the most abundant families. The percentage cover of dendrophylliids was ~8% at CR1 and ~3% at CR2 in the October 2010 and April 2011 surveys; the cover of faviids was ~8% at CR1 and ~5% at CR2 in both surveys. Acroporids (*Acropora*, *Astreopora* and *Montipora*), merulinids (predominantly *Hydnophora*), and poritids (*Porites* and *Goniopora*) occurred at >1% cover in both the October 2010 and April 2011 surveys at both sites; similarly for mussids (including *Lobophyllia*, *Acanthastrea* and *Symphyllia*) at CR2. Soft corals, predominantly *Sarcophyton*, were present at both Reference Sites. Coral cover was relatively consistent between the October 2010 and April 2011 surveys at CR2 but increased (+4.8%) at CR1. This increase was evident in almost all coral families at CR1.

Sponges were the most abundant non-coral benthic macroinvertebrate at both sites, occurring at ~0.5% to 2% (Table 6-35; Figure 6-24). Flora were also abundant at both sites but there was a marked change in composition between the October 2010 and April 2011 surveys, from predominantly macroalgae in the October 2010 survey to turfing algae in the April 2011 survey. *Asparagopsis taxiformis* was the dominant macroalgal species at both sites in the October 2010 survey (e.g. Plate 6-4) but was present in low abundance in the April 2011 survey. The loss of macroalgae may reflect a natural seasonal cycle, possibly exacerbated by the effects of Tropical Cyclone Carlos.

**Table 6-35 Mean Percentage Cover (± SE) and Composition of Corals and other Benthic Ecological Elements at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

| Cover | CR1 | | CR2 | |
|---|---|---|---|---|
| | Oct 2010 | Apr 2011 | Oct 2010 | Apr 2011 |
| Acroporidae | 3.2 ± 1.2 | 4.7 ± 2.1 | 1.9 ± 0.6 | 1.7 ± 0.8 |
| Agariciidae | 0 | 0 | 0.2 ± 0.1 | 0.02 ± 0.02 |
| Alcyoniidae | 1.0 ± 0.7 | 2.1 ± 1.7 | 0.3 ± 0.2 | 0.2 ± 0.2 |
| Caryophylliidae | 0.1 ± 0.1 | 0.2 ± 0.1 | 0 | 0.02 ± 0.02 |
| Dendrophylliidae | 8.0 ± 1.0 | 8.4 ± 1.7 | 3.2 ± 0.6 | 2.4 ± 0.6 |
| Faviidae | 7.7 ± 1.1 | 8.0 ± 0.8 | 4.5 ± 1.2 | 5.4 ± 0.9 |
| Fungiidae | 0.9 ± 0.5 | 0.5 ± 0.3 | 0.2 ± 0.2 | 0.3 ± 0.3 |
| Merulinidae | 2.2 ± 1.1 | 2.3 ± 1.0 | 1.0 ± 0.3 | 1.0 ± 0.3 |
| Mussidae | 0.5 ± 0.2 | 0.7 ± 0.3 | 2.3 ± 0.5 | 1.5 ± 0.3 |
| Oculinidae | 0.1 ± 0.1 | 0.2 ± 0.1 | 0 | 0 |
| Pectiniidae | 1.0 ± 0.5 | 1.4 ± 0.4 | 0.6 ± 0.1 | 0.4 ± 0.1 |
| Pocilloporidae | 0.02 ± 0.02 | 0 | 0 | 0 |
| Poritidae | 4.4 ± 0.5 | 5.8 ± 0.7 | 1.5 ± 0.6 | 2.0 ± 0.8 |
| Siderastreidae | 0.1 ± 0.1 | 0.1 ± 0.1 | 0 | 0.1 ± 0.1 |
| Unidentified Coral | 0.4 ± 0. 2 | 0.7 ± 0.1 | 0.03 ± 0.02 | 0.4 ± 0.1 |
| Bleached Coral | 0.03 ± 0.02 | 0.2 ± 0.1 | 0.7 ± 0.1 | 0.1 ± 0.1 |
| Dead Coral | 0 | 0 | 0 | 0 |
| Millepora | 0 | 0 | 0 | 0 |

| Cover | CR1 | | CR2 | |
|---|---|---|---|---|
| | Oct 2010 | Apr 2011 | Oct 2010 | Apr 2011 |
| Sponges | 0.6 ± 0.3 | 1.6 ± 0.5 | 0.5 ± 0.2 | 1.0 ± 0.3 |
| Other Benthic Invertebrates | 1.7 ± 0.5 | 0.5 ± 0.1 | 0.2 ± 0.1 | 0.1 ± 0.1 |
| Coralline Algae | 0.1 ± 0.1 | 0.4 ± 0.3 | 0.1 ± 0.1 | 0.2 ± 0.1 |
| Macroalgae | 41.1 ± 3.9 | 11.0 ± 2.9 | 41.0 ± 1.5 | 14.3 ± 1.1 |
| Seagrass | 0 | 0 | 0 | 0 |
| Turf Algae | 20.3 ± 2.3 | 44.7 ± 3.7 | 30.0 ± 0.7 | 56.7 ± 2.4 |
| Pavement, Rock, Rubble | 0 | 0.02 ± 0.02 | 0.2 ± 0.1 | 0.1 ± 0.04 |
| Sand/Sediment | 6.4 ± 1.2 | 6.9 ± 0.9 | 11.5 ± 2.3 | 11.0 ± 2.4 |

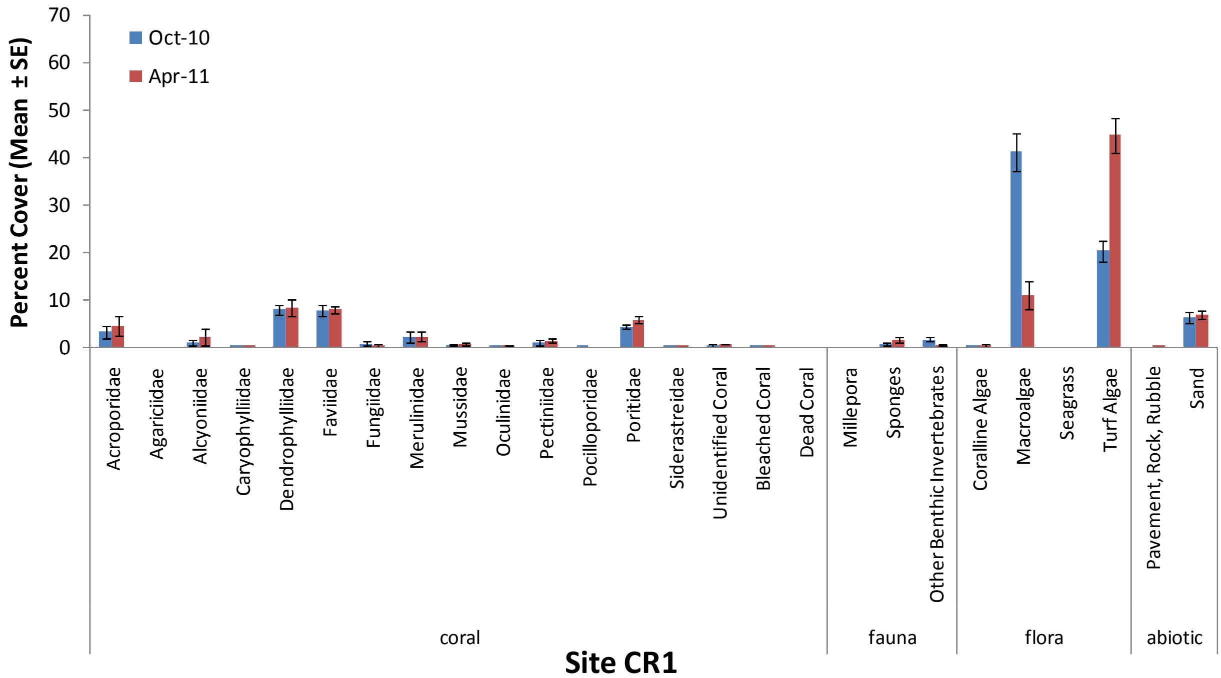



**Figure 6-24 Mean Percentage Cover (± SE) and Composition of Corals and other Benthic Ecological Elements at CR1**

*Note: The abiotic element 'sand' refers to sediment.*

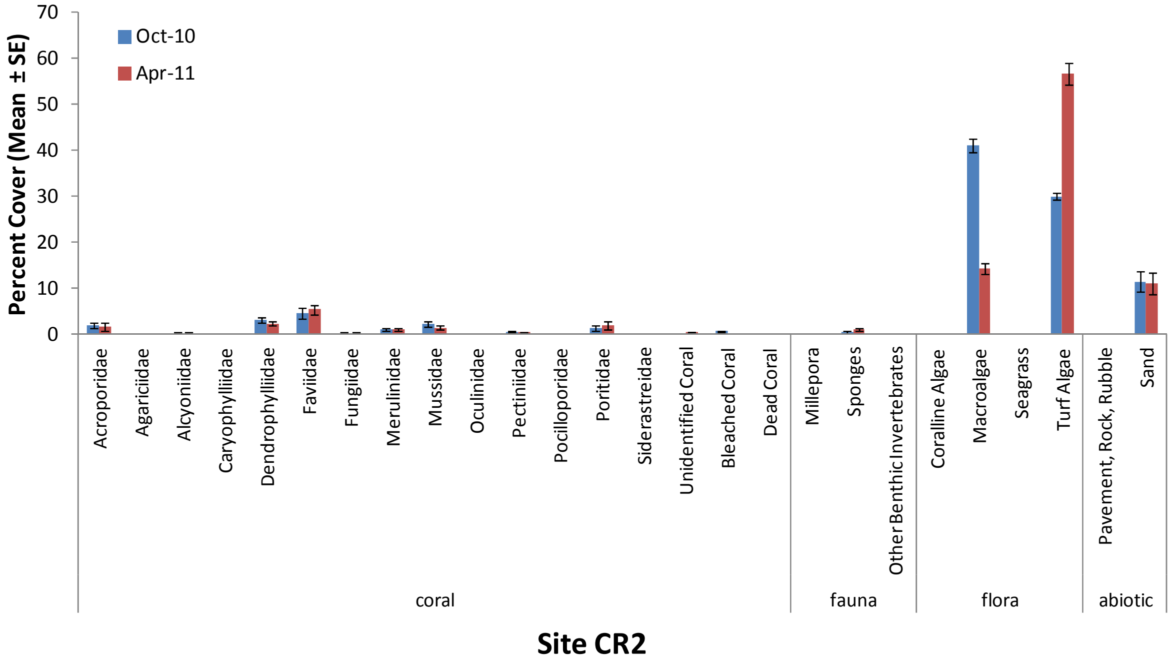
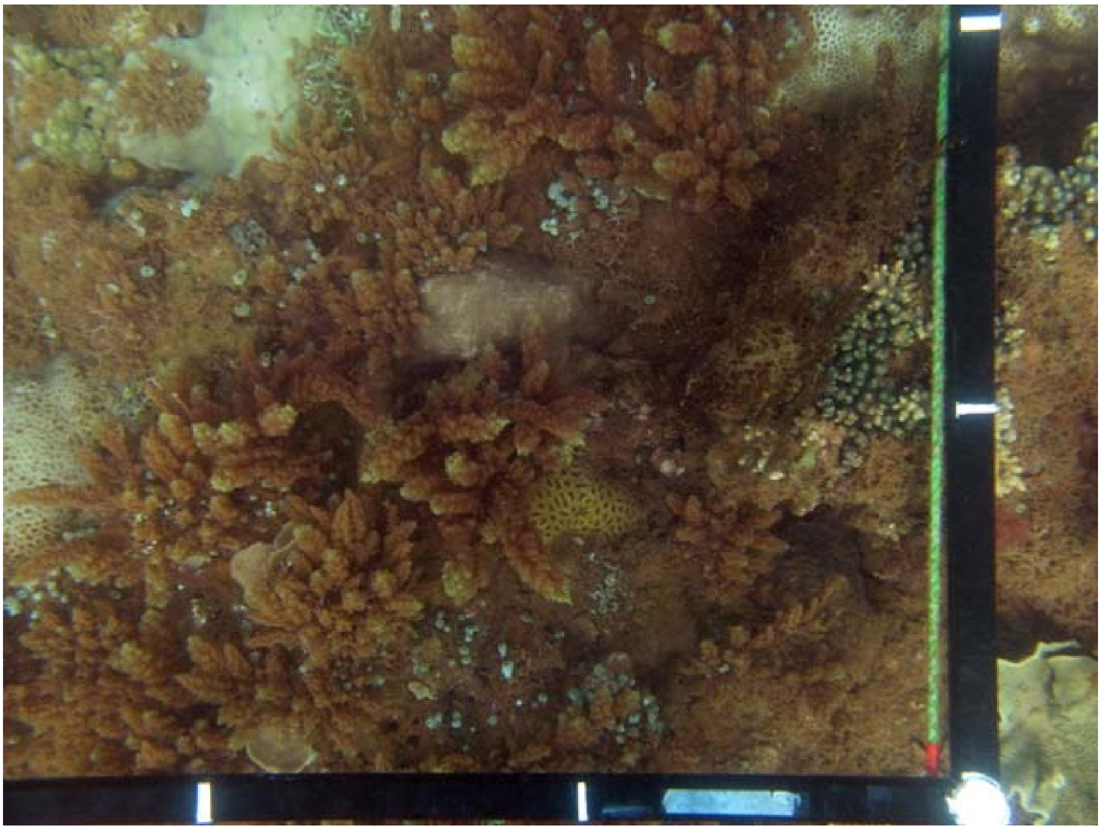



**Figure 6-25 Mean Percentage Cover (± SE) and Composition of Corals and other Benthic Ecological Elements at CR2**

*Note: The abiotic element 'sand' refers to sediment.*



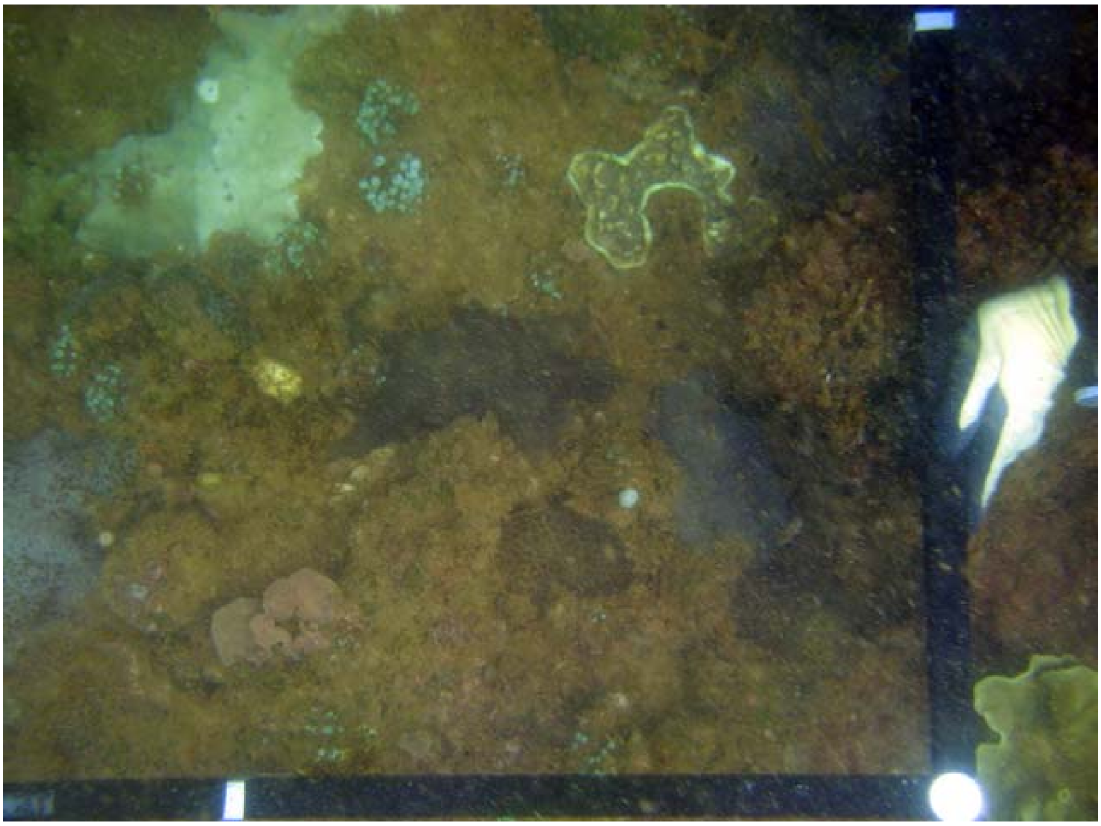


**Plate 6-4 Photo-quadrat at Passage Island (CR1) showing corals exposed by loss of macroalgae, predominantly *Asparagopsis taxiformis*, between October 2010 (above) and April 2011 (below)**

#### 6.4.4.4 Temporal Changes in Live Coral Tissue of Tagged Corals at Sites off the East Coast of Barrow Island

In summary, estimates of the mean percentage of live tissue cover of tagged colonies (genera pooled for each site) showed little to no change, or decreased between Time 0 and Time 1 and between Time 0 and Time 2 at sites around Barrow Island (Chevron Australia 2013a). At the genus/family level, faviids and *Acropora* generally showed the greatest decrease in live tissue cover of tagged colonies between both Time 0 and Time 1 (~9% and ~3%, respectively) and Time 0 and Time 2 (~15% and ~8%, respectively). Live tissue varied by <5% for both time periods in *Lobophyllia*, *Montipora* and *Pectinia*. Patterns in the change of live tissue varied among genera/families within individual sites, and among sites for different genera.

##### 6.4.4.4.1 Temporal Changes in Live Coral Tissue of Tagged Colonies at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

There was on average <3% decrease in live coral tissue cover (genera pooled) between Time 0 and Time 1, and between Time 0 and Time 2 at MOF1. The greatest decrease in the estimate of the percentage of live tissue cover of tagged colonies at MOF1 was recorded for *Lobophyllia* between Time 0 and Time 1 (Table 6-36).

**Table 6-36 Mean Change in Live Tissue Cover (% ± SE) for each Genus of Tagged Colonies at Time 1 (T1) and Time 2 (T2) at MOF1**

| Site | Genus | Mean ± SE change in live tissue (%) Time 0–Time 1 | Mean ± SE change in live tissue (%) Time 0–Time 2 |
|---|---|---|---|
| MOF1 | *Acropora* | -2.1 ± 1.4 | -0.2 ± 0.9 |
| | *Lobophyllia* | -2.9 ± 1.1 | -2.0 ± 1.1 |

#### 6.4.4.5 Temporal Changes in Live Coral Tissue of Tagged Corals at Sites at Risk of Material or Serious Environmental Harm at the Mainland End of the DomGas Pipeline Route

Mean live coral tissue cover (families pooled for each site) decreased by 5.8% ± 9.4 SE at CI1 and 4.8% ± 3.4 SE at CI2 between October 2010 and April 2011 (Table 6-37; Figure 6-26). The loss of live tissue cover at CI1 was due primarily to a single missing colony (*Psammocora*). The loss at CI2 was due primarily to fine sediment deposition (e.g. Plate 6-5). However five of the tagged colonies at CI2 were not able to be relocated in the April 2011 survey, thus the estimate of change at CI2 may not represent a real measure of the change in live tissue cover at this site.

**Table 6-37 Mean Change in Live Tissue Cover (% ± SE) for each Family of Tagged Colonies at Sites at the Mainland End of the DomGas Pipeline Route**

| Location | Site | Family | Mean ± SE Change in Live Tissue (%) Oct 10–Apr 11 |
|---|---|---|---|
| At risk of Material or Serious Environmental Harm | CI1 | Dendrophylliidae | -2.9 ± 5.0 |
| | | Faviidae | 9.5 ± 7.6 |
| | | Mussidae | -6.8 |
| | | Poritidae | 11.0 ± 11.2 |
| | | Siderastreidae | -100.0 |
| | | **Total CI1** | **-5.8 ± 9.4** |
| | CI2 | Dendrophylliidae | -2.9 ± 6.0 |
| | | Faviidae | -6.7 ± 0.6 |

| Location | Site | Family | Mean ± SE Change in Live Tissue (%) Oct 10–Apr 11 |
|---|---|---|---|
| | | Pectiniidae | -8.8 |
| | | **Total CI2** | **-4.8 ± 3.4** |
| Reference Sites | CR1 | Acroporidae | -2.9 |
| | | Dendrophylliidae | -4.5 ± 3.7 |
| | | Faviidae | 1.0 ± 1.5 |
| | | Poritidae | 11.6 ± 16.0 |
| | | **Total CR1** | **0.6 ± 3.1** |
| | CR2 | Acroporidae | -58.0 ± -24.9 |
| | | Dendrophylliidae | 10.3 ± 2.2 |
| | | Faviidae | -4.1 ± 5.6 |
| | | Mussidae | -50.0 ± 50.0 |
| | | **Total CR2** | **-29.5 ± 14.1** |

*Note: 34 of the 36 tagged colonies at CI1, CR1 and CR2 in October 2010 were accounted for in April 2011 (i.e. either found or identified as missing). However, five of the 12 tagged colonies at CI2 were not relocated.*

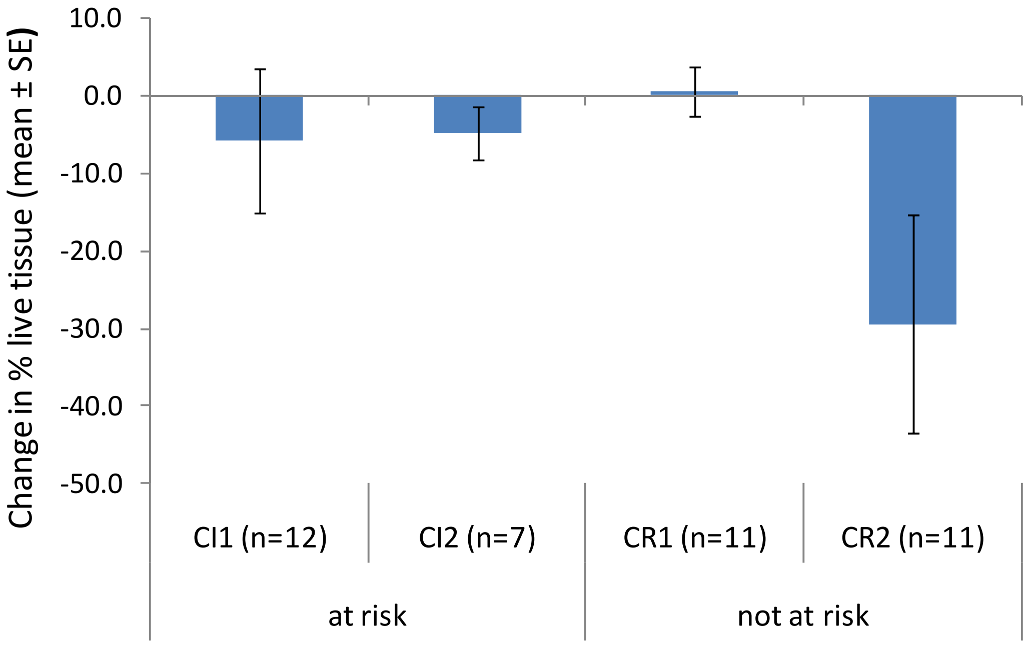



**Figure 6-26 Mean Change in Percentage Live Tissue Cover (% ± SE) of Tagged Colonies between October 2010 and April 2010 at Sites at the Mainland End of the DomGas Pipeline Route**

*Note: 'at risk' sites are those at risk of Material or Serious Environmental Harm; 'not at risk' are Reference Sites.*

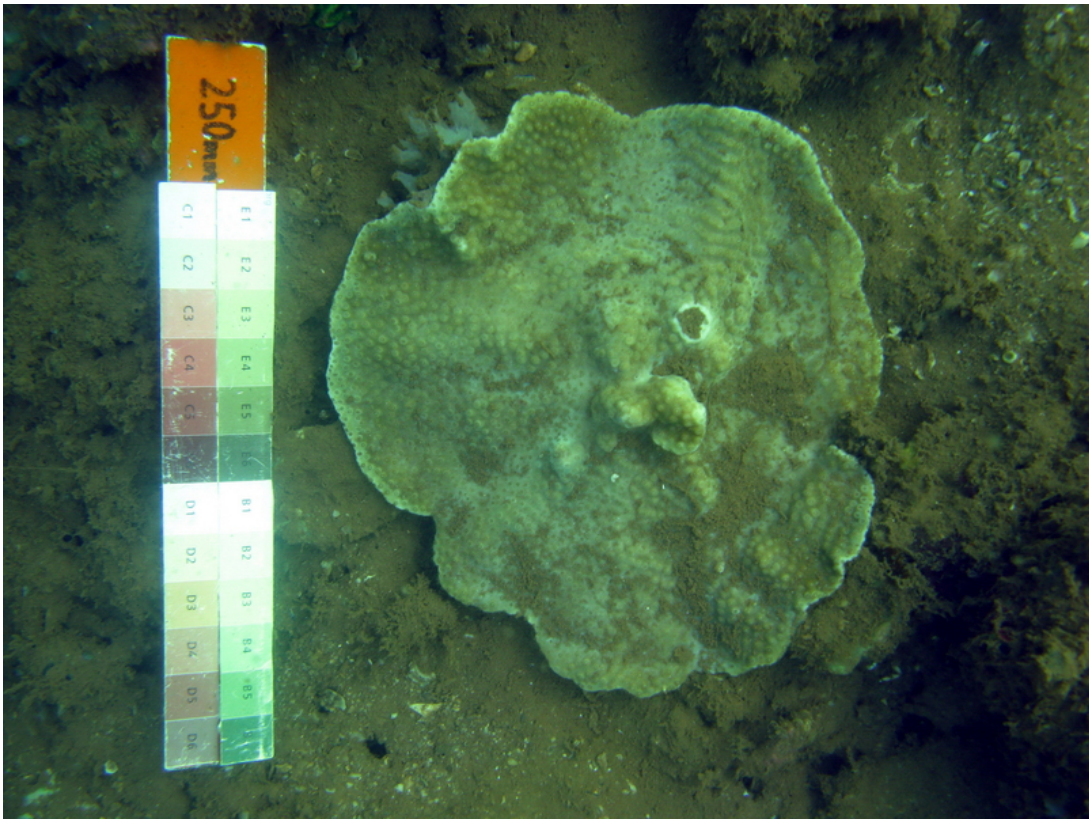


**Plate 6-5 Fine sediment deposited on tagged *Turbinaria* at Solitary Island (CI2) in April 2011**

#### 6.4.4.6 Temporal Changes in Live Coral Tissue of Tagged Colonies at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

The greatest changes between both Time 0 and Time 1 and Time 0 and Time 2 were recorded at DUG, where the average decrease in live coral tissue was <6% over both time periods, compared to a <1% change in live tissue at LNG3 over both time periods. The greatest tissue loss was observed in colonies of *Lobophyllia* between Time 0 and Time 2 at DUG (Table 6-38). In summary, the estimated changes in live tissue cover of *Acropora* colonies at LNG3 were generally lower than those recorded at other coral survey sites off the east coast of Barrow Island (Chevron Australia 2013a).

**Table 6-38 Mean Change in Live Tissue Cover (% ± SE) for each Genus of Tagged Colonies at Time 1 (T1) and Time 2 (T2) at LNG3 and DUG**

| Site | Genus | Mean ± SE change in live tissue (%) Time 0–Time 1 | Mean ± SE change in live tissue (%) Time 0–Time 2 |
|---|---|---|---|
| LNG3 | *Acropora* | 0.0 ± 0.0 | 0.0 ± 0.0 |
| | *Lobophyllia* | -0.6 ± 0.6 | -2.7 ± 1.3 |
| DUG | *Acropora* | 0.0 ± 0.0 | -0.1 ± 0.1 |
| | *Lobophyllia* | -9.4 ± 4.2 | -28.4 ± 19.8 |
| | *Montipora* | 0.0 ± 1.8 | -2.8 ± 2.9 |

| Site | Genus | Mean ± SE change in live tissue (%) Time 0–Time 1 | Mean ± SE change in live tissue (%) Time 0–Time 2 |
|---|---|---|---|
| | *Pectinia* | -0.7 ± 0.7 | -2.7 ± 1.6 |

#### 6.4.4.7 Temporal Changes in Live Coral Tissue of Tagged Colonies at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland end of the DomGas Pipeline Route

Mean live coral tissue cover increased by 0.6% ± 3.1 SE at CR1 and decreased by 29.5% ± 14.1 SE at CR2 (Table 6-37; Figure 6-26). The losses at CR2 were a combination of missing, damaged and dead colonies, with the acroporids and mussids the most affected and dendrophylliids and faviids largely unchanged. Field observations at CR2 of several fragmented *Acropora* (family Acroporidae) and *Lobophyllia* (family Mussidae) indicate that these families were disproportionately impacted by damage sustained during Tropical Cyclone Carlos. *Acropora* has previously been reported as susceptible to cyclone impacts at Dampier (LeProvost Semeniuk and Chalmer 1990), but *Lobophyllia* are usually unaffected (Fabricius *et al*. 2008). Poritids increased by 11.6% ± 16.0 SE, but this was due primarily to the loss of macroalgae that had previously obscured the colonies, rather than reflecting a real increase in coral tissue.

### 6.4.5 Growth of Non-branching Hard Coral Taxa

#### 6.4.5.1 Growth of Tagged Colonies at Sites off the East Coast of Barrow Island

In summary, coral growth was variable among genera, sites and seasons at sites around Barrow Island (Chevron Australia 2013a). At family and genus level, estimates of monthly growth rates of non-branching corals (over a 12-month period) were highest in the favids (4.5% ± 3.2 SE) and *Acropora* (3.3% ± 4.7 SE); and lowest in *Mussidae* (1.0% ± 1.9 SE). Negative growth was recorded over the 12-month period for some colonies of *Lobophyllia* and *Acropora*. This is normal in studies of growth in colonial organisms over short time periods of several months to a few years, as colony growth can be interrupted or reversed by competition, predation or injury (Hughes 1985). Coral growth among sites was often variable within genera, although 10% was the upper limit of growth per month across all genera and all sites. Growth also varied within a site between times for most of the genera

##### 6.4.5.1.1 Growth of Tagged Colonies at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

Estimates of monthly growth increments at MOF1 over the 12-month period ranged from 1.0% ± 1.3 SE for *Lobophyllia* to 2.4% ± 0.5 SE for *Acropora* (Table 6-39).

**Table 6-39 Mean Growth Increments (% ± SE) per Month for each Genus of Tagged Colonies at Time 1 (T1) and Time 2 (T2) at MOF1**

| Site | Genus | Average Growth Rate (%) ± SE per 31 days at Time 1 (first six months) | Average Growth Rate (%) ± SE per 31 days at Time 2 (second six months) | Average Growth Rate (%) ± SE per 31 days over 12 months |
|---|---|---|---|---|
| MOF1 | *Acropora* | 2.0 ± 0.7 | 1.5 ± 5.0 | 2.4 ± 0.5 |
| | *Lobophyllia* | -1.7 ± 0.8 | 4.0 ± 6.0 | 1.0 ± 1.3 |

#### 6.4.5.2 Growth of Tagged Corals at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route

Mean monthly growth increments at CI1 and CI2 were -0.4% ± 1.8 SE and 0.2% ± 0.8 SE, respectively, between October 2010 and April 2011 (Table 6-40; Figure 6-27). These low values are indicative that 'positive growth' in some colonies, primarily *Turbinaria*, was being offset by 'negative' growth as a result of mortality and/or damage of other colonies.

**Table 6-40 Mean Growth Increments (%± SE) per Month for each Family of Tagged Colonies at Coral Survey Sites at the Mainland End of the DomGas Pipeline Route**

| Location | Site | Family | Mean growth increment (% per 31 days ± SE) Oct 10 – Apr 11 |
|---|---|---|---|
| At risk of Material or Serious Environmental Harm | CI1 | Dendrophylliidae | 3.5 ± 1.0 |
| | | Faviidae | -3.5 ± 3.6 |
| | | Mussidae | 2.9 |
| | | Poritidae | -0.5 ± 2.6 |
| | | Siderastreidae | -16.4 |
| | | **Total CI1** | **-0.4 ± 1.8** |
| | CI2 | Dendrophylliidae | 0.3 ± 0.7 |
| | | Faviidae | 1.7 ± 1.2 |
| | | Pectiniidae | -2.9 |
| | | **Total CI2** | **0.2 ± 0.8** |
| Reference Sites | CR1 | Acroporidae | 1.3 |
| | | Dendrophylliidae | 0.5 ± 1.3 |
| | | Faviidae | 2.4 ± 1.2 |
| | | Poritidae | 4.7 ± 0.6 |
| | | **Total CR1** | **2.0 ± 0.8** |
| | CR2 | Acroporidae | -11.1 ± 3.9 |
| | | Dendrophylliidae | 0.5 ± 3.5 |
| | | Faviidae | 4.1 ± 1.9 |
| | | Mussidae | -8.1 ± 8.2 |
| | | **Total CR2** | **-4.3 ± 2.8** |

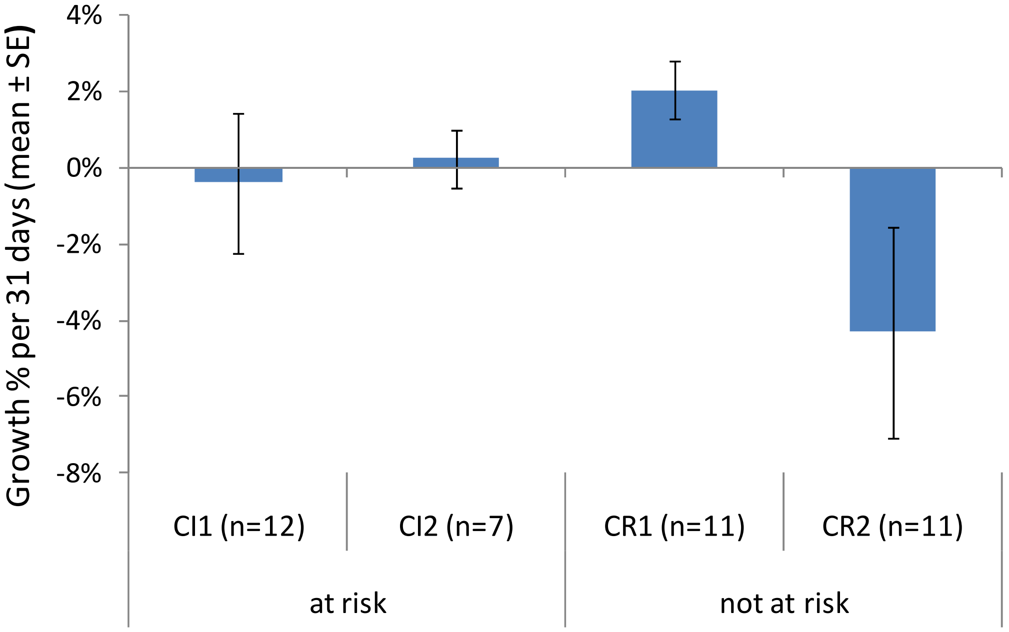



**Figure 6-27 Mean Monthly Growth Increments (% per 31 days ± SE) of all Tagged Colonies between October 2010 and April 2011**

*Note: 'at risk' sites are those at risk of Material or Serious Environmental Harm; 'not at risk' are Reference Sites.*

#### 6.4.5.3 Growth of Tagged Colonies at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

Site Dugong Reef, was excluded from analysis of coral growth as photo-quadrats did not contain a scale bar, which is required for colony growth measurements.

At LNG3, estimates of monthly growth increments over the 12-month period ranged from 1.3% ± 0.8 SE for *Lobophyllia* to 4.2% ± 1.3 SE for *Acropora* (Table 6-41).

**Table 6-41 Mean Growth Increments (% ± SE) per Month for each Genus of Tagged Colonies at Time 1 (T1) and Time 2 (T2) at LNG3 and DUG**

| Site | Genus | Average Growth Rate (%) ± SE per 31 days at Time 1 (first six months) | Average Growth Rate (%) ± SE per 31 days at Time 2 (second six months) | Average Growth Rate (%) ± SE per 31 days over 12 months |
|---|---|---|---|---|
| LNG3 | *Acropora* | 7.0 ± 2.2 | 1.9 ± 9.0 | 4.2 ± 1.3 |
| | *Lobophyllia* | 2.3 ± 1.6 | 0.8 ± 5.0 | 1.3 ± 0.8 |

#### 6.4.5.4 Growth of Tagged Colonies at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route

Mean monthly growth increments at CR1 and CR2 were 2.0% ± 0.8 SE and -4.3% ± 2.8 SE, respectively, between October 2010 and April 2011 (Table 6-40; Figure 6-27). At CR1, mean monthly growth increments were positive for all four coral families measured (acroporids, dendrophylliids, faviids and poritids). The 'negative growth' at CR2 was recorded primarily in the acroporids (-11.1% ± 3.9 SE) and mussids (-8.1% ± 8.2 SE), most likely attributable to damage sustained during Tropical Cyclone Carlos.

### 6.4.6 Coral Recruitment

#### 6.4.6.1 Coral Recruitment at Sites off the East Coast of Barrow Island

In summary, the numbers of coral recruits recorded on recruitment tiles indicated two distinct spawning periods at Barrow Island, in spring and autumn (Chevron Australia 2013a). The highest numbers of recruits were observed in autumn, with a mean number of recruits per tile of 43.5 ± 5.1 SE(~1555 per $m^2$) recorded in autumn 2009. On average, 12.1 recruits ± 1.6 SE were recorded per tile (~430 per $m^2$) in spring 2008, compared to 19.9 recruits per tile ± 2.7 SE (~710 per $m^2$) in summer 2008–2009. Recruitment was generally lower in winter, with a mean of 0.5 recruits per tile ± 0.1 SE (~18 recruits per $m^2$) in 2008 and 1.7 ± 0.3 SE (~60 recruits per $m^2$) in 2009.

In summary, recruitment was also spatially variable, with recruitment varying between the different sites, with recruitment at any site varying between different seasons and years (Chevron Australia 2013a). The composition of coral recruits was also generally variable through time, with different patterns in different seasons as well as inter-annual variation, although some clear patterns were evident. There was, however, no indication that recruits from particular families primarily recruited to a specific site.

##### 6.4.6.1.1 Coral Recruitment at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

The highest number of recruits at MOF1 were recorded in March 2008 and March 2009 (Table 6-42). In autumn 2008, recruitment at MOF1 was dominated by poritids and 'Unidentified' recruits, indicative of a multi-specific spawning event of non-acroporid species in March 2008, consistent with the results of coral gravidity assessments. The composition of the recruits in autumn 2009 was very different to the composition in autumn 2008, dominated by acroporids and lower numbers of pocilloporids, suggesting that there was very little spawning of acroporids in autumn 2008, consistent with the assessment of coral gravidity. Low numbers of recruits were recorded at MOF1 in winter 2008, spring 2008, summer 2009 and winter 2009 (with between one and 16 recruits recorded in total). Recruitment at MOF1 was generally lower than that recorded at LNG3 and DUG.

**Table 6-42 Number of Coral Recruits (± SE) per $m^2$ and Number of Days Tiles were Deployed at sites off the East Coast of Barrow Island**

| Site | | MOF1 | LNG3 | DUG |
|---|---|---|---|---|
| March 2008 | No. of recruits | 285.9 ± 64.4 | 28.6 ± 6.2 | 2663.3 ± 523.1 |
| | Days deployed | 72 | 99 | 74 |
| May 2008 | No. of recruits | - | - | 35.7 ± 11.8 |
| | Days deployed | - | - | 61 |
| June 2008 | No. of recruits | 2.4 ± 2.4 | 5.1 ± 3.5 | - |
| | Days deployed | 89 | 89 | - |
| July 2008 | No. of recruits | - | - | 2.4 ± 2.4 |
| | Days deployed | - | - | 57 |
| September 2008 | No. of recruits | 3.0 ± 3.0 | 193.6 ± 20.8 | 1393.6 ± 288.4 |
| | Days deployed | 74 | 75 | 72 |
| December 2008 | No. of recruits | 47.6 ± 14.8 | 1807.5 ± 646.8 | 711.7 ± 183.4 |
| | Days deployed | 89 | 93 | 91 |
| March 2009 | No. of recruits | 393.1 ± 104.0 | 2260.1 ± 333.6 | 704.9 ± 138.5 |
| | Days deployed | 60 | 55 | 57 |
| May 2009 | No. of recruits | 6.0 ± 4.0 | 29.8 ± 12.3 | 134.0 ± 30.2 |

| Site | | MOF1 | LNG3 | DUG |
|---|---|---|---|---|
| | Days deployed | 76 | 75 | 78 |

*Note: Where cells do not contain data, tiles were in the water, but no collection redeployment occurred during that month.*

#### 6.4.6.2 Coral Recruitment at Sites at Risk of Material or Serious Material Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route

The number of coral recruits recorded on tiles deployed at CI1 and CI2 were very low over both tile deployment periods (spring and summer), varying between 0/m$^2$ and 1.7/m$^2$ (Table 6-43; Figure 6-28). Coral recruits were nevertheless reaching these sites, as low numbers (30 recruits) of recruits were observed on the upper surface of the tiles (note that these were not scored in these surveys). These numbers were still considerably lower than the numbers recorded at the offshore sites (CR1 and CR2).

**Table 6-43 Mean Number of Coral Recruits (± SE) per m$^2$ and Number of Days Tiles were Deployed at Sites at the Mainland End of the DomGas Pipeline Route**

| Site | | CI1 | CI2 | CR1 | CR2 |
|---|---|---|---|---|---|
| Oct 2010 – Dec 2010 | No. of recruits | 1.7 ± 1.7 | 0.0 ± 0.0 | 43.6 ± 19.4 | 49.6 ± 15.2 |
| | Days deployed | 73 | 73 | 73 | 73 |
| Dec 2010 – Feb/Mar 2011 | No. of recruits | 0.0 ± 0.0 | 0.0 ± 0.0 | 17.1 ± 13.2 | 12.1 ± 6.0 |
| | Days deployed | 63 | 87 | 87 | 63 |
| Oct 2010 – Feb/Mar 2011 | No. of recruits | 0.0 ± 0.0 | 0.0 ± 0.0 | 18.0 ± 7.5 | 65.5 ± 21.2 |
| | Days deployed | 136 | 160 | 160 | 136 |

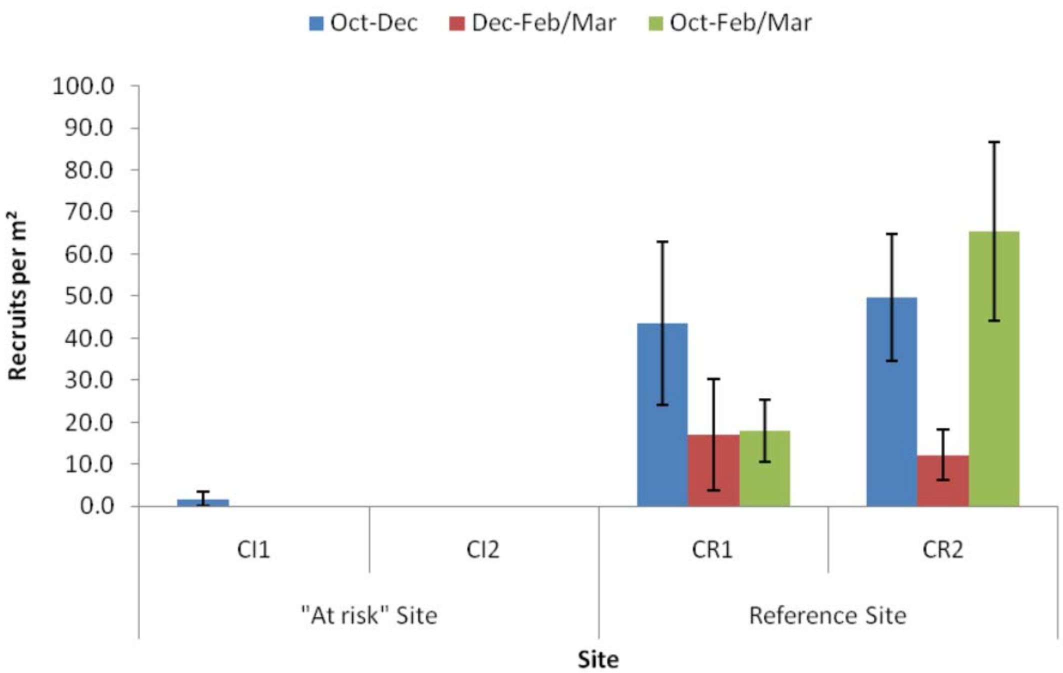



**Figure 6-28 Mean Number of Recruits (± SE) at Sites at the Mainland End of the DomGas Pipeline Route**

*Note: 'At risk' sites are those at risk of Material or Serious Environmental Harm.*

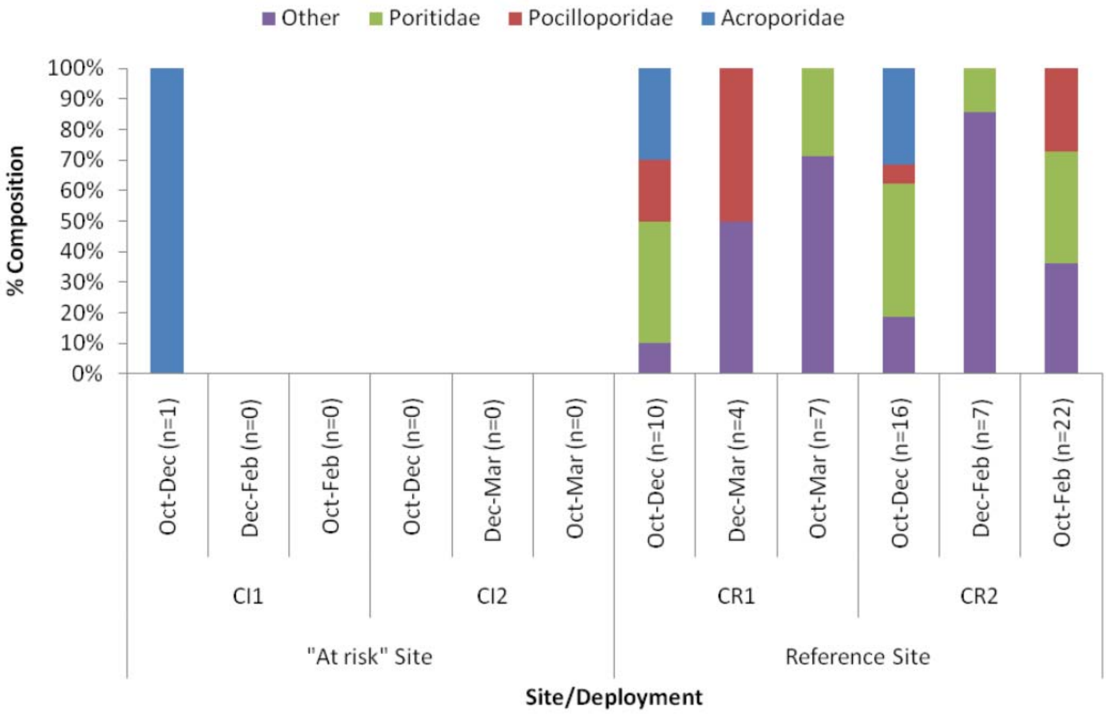



**Figure 6-29 Composition of Coral Recruits on Tiles Deployed at Sites at the Mainland End of the DomGas Pipeline Route**

*Note: Composition of recruits is the average composition of all tiles at each site, including all deployments. 'At risk' sites are those at risk of Material or Serious Environmental Harm.*

#### 6.4.6.3 Coral Recruitment at Reference Sites not at risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

In late autumn 2008, the greatest numbers of recruits were recorded at DUG (Table 6-42), made up predominantly of 'Unidentified' recruits and low numbers of acroporids and poritids. Only low numbers of recruits were recorded at LNG3, again largely made up of 'Unidentified' recruits. These results are indicative of a multi-specific spawning event of non-acroporid species in March 2008, consistent with the results from coral gravidity assessments. Low numbers of recruits, predominantly pocilloporids, were recorded at both DUG and LNG3 in winter 2008. Lower numbers of poritid and 'Unidentified' recruits were also recorded at DUG.

High numbers of recruits, predominantly pocilloporids, but in much higher numbers than in winter, indicating a seasonal peak in the reproduction for these brooding species, were recorded at DUG in spring 2008 (Table 6-42). Lower numbers of recruits were recorded at LNG3, again dominated by pocilloporids. Lower numbers of poritids and 'Unidentified' recruits were recorded at both DUG and LNG3. The presence of poritid recruits in October/November at DUG and LNG3 is indicative that some species may spawn in spring at Barrow Island. Acroporid recruits were also recorded in low numbers at LNG3. While secondary spawning events involving *Acropora* have been observed in spring in Western Australia (Stoddart and Gilmour 2005; Rosser and Gilmour 2008), the low numbers of acroporid recruits observed is indicative that this may not be an important spawning period for these species on Barrow Island.

In summer 2008–2009, the highest numbers of recruits were recorded at LNG3 (Table 6-42). The composition of recruits was predominantly acroporids. At DUG, where recruitment was lower, recruitment was dominated by poritids. This is consistent with a late spring-summer spawning of these families, supported by coral gravidity assessments. Similarly, in autumn 2009, the greatest numbers of recruits were recorded at LNG3 and recruitment at both LNG3 and DUG was dominated by acroporids. The coral communities at LNG3 are dominated by *Porites* colonies with limited numbers of *Acropora* colonies growing at this site, indicating that LNG3 was acting as a 'sink' for recruits from other source reefs in autumn 2009. The composition of recruits at both LNG3 and DUG in autumn 2009 was very different to the composition recorded on recruitment tiles in autumn 2008.

Lower numbers of recruits were recorded at both DUG and LNG3 in winter 2009 (Table 6-42). Recruitment was dominated by poritids at LNG3 and by poritids and pocilloporids at DUG. The presence of poritid recruits in winter is indicative that the poritids were spawning all year round, which may be indicative that some poritid species in Barrow Island waters are brooders. The composition of recruits recorded in winter 2009 was in contrast to winter 2008, when there were very few poritid recruits, which is consistent with inter-annual variability in the spawning of poritids.

#### 6.4.6.4 Coral Recruitment at Reference Sites not at Risk of Material or Serious Material Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route

Higher numbers of recruits were recorded at CR1 and CR2 over both the deployment periods (Table 6-43; Figure 6-28). The number of coral recruits recorded at CR1 and CR2 were significantly higher than the numbers recorded at CI1 and CI2 (Kruskall Wallis ANOVA approximation, $p = 0.000$); but there were no significant differences between the deployment periods (October–December 2010 and December 2010–February/March 2011). At CR1, the numbers of recruits recorded over the October 2010–March 2011 period was lower than the sum of the number of recruits recorded over the October–December 2010 and the December 2010–March 2011 deployment periods. This is indicative of either post-settlement mortality over that period or a decreased level of recruitment on tiles that had been deployed for more than a few months. If there was no mortality of settled corals, estimates of recruits for the October 2010–March 2011 deployment would be expected to be equivalent to the sum of the recruits settled over the October–December 2010 and the December 2010–March 2011 periods.

The composition of recruits showed little variation in the taxonomic composition between CR1 and CR2 (Figure 6-29). Combining the recruitment data across sites and surveys, counts of recruits were dominated by 'Other' (25 recruits) and poritids (22 recruits), with small numbers of pocilloporids (11 recruits) and acroporids (9 recruits). Considering the composition of recruitment over the different deployment periods, there was an increasing contribution of 'Other' across the deployment periods. Corals of the common inshore genera *Turbinaria* and *Porites* would be expected to spawn over the December–March period (Baird *et al*. 2010). This is consistent with the major contributions of the poritids and 'Other' (which includes *Turbinaria*) to recruitment at CR1 and CR2. The increase in the numbers of 'Other' recruits in the later deployment is indicative of an ongoing contribution of *Turbinaria*, which are thought to spawn monthly over the wet season (Baird *et al.* 2010).

#### 6.4.6.5 Comparison with Other Studies in North-west Australia

In summary, an average of 43.5 recruits ± 5.1 SE (or ~1554 recruits per $m^2$) was recorded on tiles deployed in autumn 2009 at sites off Barrow Island (Chevron Australia 2013a), which is comparable to the results reported from studies at other locations in Western Australia. Studies of coral recruitment at Scott Reef recorded 36.2 ± 13.7 SE (95% Confidence Interval per year) acroporid recruits per tile, equivalent to ~1273 recruits per $m^2$, in autumn 1997 and 1998, 3.4 recruits per tile ± 0.8 SE (~120 recruits per $m^2$) in spring and 0.08 ± 0.15 SE, and 0.2 ± 0.5 SE recruits per tile in winter (~3 and ~7 recruits per $m^2$) (Gilmour *et al*. 2009). At Ningaloo Reef, recruitment ranged from 2.4 to 43.4 recruits per tile pair (equivalent to ~53 to ~964 recruits per $m^2$) with acroporids contributing 73% and pocilloporids contributing 18% of recruits (Harriott and Simpson 1997). Recruitment rates of 24.7 ± 24.3 SE (or ~549 recruits per $m^2$) were recorded in autumn 1994 at Ningaloo Reef. Recruitment rates were considerably lower further south at the Houtman-Abrolhos, where mean rates of 0.77 recruits per tile pair were recorded, which equates to ~17 recruits per $m^2$. The recruitment rates recorded at Barrow Island are more similar to the tropical areas of Ningaloo Reef and Scott Reef than the subtropical Houtman-Abrolhos. The composition of recruits on tiles deployed at the Houtman-Abrolhos was similar to that at Ningaloo Reef, with acroporids contributing 83% and pocilloporids contributing 15% of recruits. The number of recruits recorded on tiles deployed at the mainland end of the DomGas Pipeline route were considerably lower than reported from other locations in Western Australia.

Direct comparisons between the different studies are not straightforward because of differences in the size of deployed tiles; differences in the types of material used for the tiles; tile orientation and position in the water column and distance above the seabed; which tile surfaces are recorded – all of which can all influence recruitment. In addition, the factors influencing spatial and temporal variability in estimates of recruitment include those affecting larval settlement and post-settlement survival: sub-lethal changes in fecundity of adult corals resulting in poor larval supply (Richmond and Hunter 1990; Hughes *et al*. 2000); local hydrodynamic effects (Hunt and Scheibling 1997; Field *et al*. 2007); variability in the supply of chemical cues from surfaces necessary to induce settlement (Morse *et al*. 1988; Keough and Raimondi 1995); the presence of specific organisms required for settlement (Keough 1998; Field *et al*. 2007); the presence of crustose coralline algae, which has been shown to provide chemical cues for several species of coral settlers (Morse *et al*. 1988; Hunt and Scheibling 1997; Heyward and Negri 1999); fish predation (Westneat and Resing 1988; Hughes *et al*. 2000); the physical environment of the settled coral (Hodgson 1990); and overgrowth by fouling organisms (Babcock *et al*. 2003).

## 6.5 Discussion and Conclusions

Benthic habitat mapping along the DomGas Pipeline route, indicates that for much of the route between nearshore Barrow Island and the Pilbara coast, the offshore seabed was ‘open bare sand with minimal biota’ including low abundances of hard and soft corals (e.g. small *Porites*, *Acropora*, faviids and coral rubble) (Section 5.3). Isolated pinnacles supporting live corals (e.g. poritids, acroporids [including *Montipora* spp.], faviids, merulinids, mussids, pectinids and dendrophylliids) and surrounded by low profile patchy reef habitat dominated by macroalgae communities or unvegetated soft sediments were identified along the pipeline route (Section 5.3). Between Passage Island and South Passage Island an area of ‘sand veneer overlying limestone with some attached biota’ occurred and the nearshore area of the mainland shore crossing consisted of soft sediments without any epifauna.

The hard and soft corals that at are risk of impacts associated with the trenching and jetting activities (the generation of turbidity and sediment deposition) at the mainland end of the DomGas Pipeline route occur on inshore reefs at Solitary Island located north-east of the pipeline route and at an unnamed reef located south-west of the pipeline route. The coral communities were classified as Mixed Coral Assemblage. These hard and soft corals are not at risk of Material or Serious Environmental Harm caused by, for example, the direct placement of infrastructure on the seabed, the permanent removal of substrates suitable for colonisation during trenching and jetting activities, or as a result of vessel movements and anchoring.

The coral composition and diversity reported in this study are typical of naturally turbid nearshore environments in the Pilbara region (Blakeway and Radford 2005) and are comparable with similar shallow turbid habitats of the Great Barrier Reef (Done 1982). The recorded coral diversity is equivalent to that recorded from Dampier Harbour (n=120; Blakeway and Radford 2005), but represents only half of the species recorded in the Dampier Archipelago (n=229; Griffith (2004). In the regional context, the corals recorded at sites in the vicinity of the mainland end of the DomGas Pipeline route are a subset of those previously recorded in the Dampier Archipelago and at Barrow Island. However, there were a number of notable differences in the coral communities within the region. In the Dampier Archipelago, Blakeway and Radford (2005) reported *Acropora*, *Porites*, *Pavona* and *Turbinaria* to be the most abundant genera. At Barrow Island, the four most abundant genera recorded were *Acropora*, *Montipora*, *Porites* and *Platygyra* (Chevron Australia 2013a). In the surveys at the mainland end of the DomGas Pipeline route, *Turbinaria, Favites, Platygyra, Goniopora* and *Lobophyllia* were the most abundant genera and there is very little representation of *Acropora* and *Pavona.* The low abundance of *Acropora* is not unusual in such turbid nearshore environments, but the low abundance of *Montipora* is unexpected, as *Montipora* is typically well represented on turbid nearshore reefs (e.g. Browne *et al*. 2010). The low abundance of the family Agariciidae, was also unusual when compared with the reefs around Barrow Island (Chevron Australia 2013a) and Dampier (Blakeway and Radford 2005). The distribution of the soft coral genus *Sinularia* also differed to that recorded in Dampier Harbour; *Sinularia* was abundant at the two inshore sites (CI1 and CI2) at the mainland end of the DomGas Pipeline route, whereas in Dampier, *Sinularia* is rare inshore and abundant offshore (Griffith 2004; Blakeway and Radford 2005).

The diversity of corals at sites at the mainland end of the DomGas Pipeline route is markedly lower (118 species of hard coral from 42 genera in the order Scleractinia, and ten species of soft coral) than the diversity of corals recorded from Barrow Island (196 species of hard coral from 48 genera in the order Scleractinia, and seven soft coral genera from the suborder Alcyonnina; Chevron Australia 2013a). The lower diversity of species recorded at the inshore mainland sites may in part reflect the comparatively low number of sites surveyed (4 sites compared to the 12 sites surveyed in Barrow Island waters). However, coral diversity generally decreases from offshore to inshore along the Western Australian coastline (Dr Barry Wilson, Naturalist and Industry Consultant, pers. comm. to Dr Zoe Richards, March 2011). The lower species diversity at the sites at the mainland end of the DomGas Pipeline route is also in part a reflection of the lack of representation of *Acropora* species (eight species compared to the 46 species recorded in Barrow Island waters). At Barrow Island, there is a high diversity of habitat types including *Acropora* thickets, which occur on the shallow reefs around the north-east and south-east of the Island. In contrast, a variety of habitat types and *Acropora* thickets were not present at the mainland end of the DomGas Pipeline route. The absence of *Acropora* from the inshore communities may be a reflection of the lack of protection from frequent cyclonic activity. Eight species (A*cropora bushyensis*, *Favites micropentagona*, *Goniopora minor*, *Goniopora somaliensis*, *Goniopora norfolkensis*, *Alveopora fenestrata*, *Turbinaria radicalis* and *Psammocora profundacella*) recorded at sites at the mainland end of the DomGas Pipeline route have not previously been recorded from Dampier (Griffith 2004; Blakeway and Radford 2005) or Barrow Island (Chevron Australia 2013a). One of these species (*Turbinaria radicalis*) was recorded as ‘rare’ at one of the sites at risk of Material or Serious Environmental Harm, noting that these results are representative of surveys undertaken at a restricted number of sites on the inshore coral reefs along this part of the Pilbara coast. Despite growing interests in the region, the differences between the coral assemblages characteristic of the inshore/offshore locations in Western Australia have not been well studied to date.

The results from the surveys of sites at risk of Material or Serious Environmental Harm associated with trenching and jetting activities at the mainland end of the DomGas Pipeline route and at Reference Sites, indicate that the sites were broadly similar in terms of coral community composition. The Faviidae, Dendrophylliidae and Poritidae consistently ranked as the most abundant coral families both in terms of percentage cover calculated from the photo-quadrats and the number of colonies recorded in the size-class frequency counts. Species of *Turbinaria*, *Porites* and Faviidae often collectively contribute the most to coral cover in naturally turbid shallow nearshore environments. There were also specific differences in generic composition identified between the sites. The most apparent patterns, such as the very high abundance of *Turbinaria* at CI1 (55% of the coral cover) indicate strong links between sites and coral taxa; e.g. the reef habitat at CI1 clearly favours recruitment, survival, and growth of *Turbinaria*. The significance of some of the weaker patterns is difficult to assess, as they could potentially arise randomly.

Based on the generic similarity of the coral communities at sites at the mainland end of the DomGas Pipeline route to those characteristic of Dampier Harbour (Blakeway and Radford 2005) and the inshore Great Barrier Reef (Done 1982), it is inferred that the coral assemblages in the vicinity of the DomGas Pipeline route are likely to be reasonably tolerant to turbidity and sedimentation. The surveys undertaken in September–October 2010 and February–April 2011 indicate that turbid conditions prevail year-round at the inshore sites (CI1 and CI2), and primarily during the wet season (or during periods of above average wind and/or swell during the dry season) at the sites further offshore (CR1 and CR2). The lower coral diversity recorded at the inshore sites may be related to differences in the prevailing environmental conditions. The species pool at these inshore sites also probably represents a more sediment-tolerant subset of the species occurring at the offshore sites. While corals have generally been considered to require clear water conditions because light penetration benefits photosynthesis, recent studies have found that at high particle loads, corals gain energy by increasing their heterotrophic feeding (Anthony and Fabricius 2000). Thus, corals growing in the vicinity of the DomGas Pipeline may offset the stress that accompanies high turbidity by changing their trophic mode, thereby sustaining a positive energy balance in turbid conditions (Dr Zoe Richards, Australian Museum, per. comm. June 2011).

The major differences between the October 2010 dry season and the February–April 2011 wet season surveys were the damage and dislodgement of coral colonies attributed to Tropical Cyclone Carlos, and the reduction in macroalgal cover. Cyclones are a recurring seasonal phenomenon in the Pilbara region (Section 3.4), and are associated with high winds, large swells and extreme turbidity. On the basis of field observations during the wet season survey, the effect of Tropical Cyclone Carlos was greatest at CR2 (where broken and dislodged colonies were common), and moderate at CI1, CI2 and CR1 (occasional broken, dislodged and overturned colonies). The differences in the extent of coral damage may partly be attributable to differences in site depth and orientation relative to the north-north-west direction of the strongest winds associated with the cyclone. It was probably also related to the type of corals present at each site; e.g. no damage to the large (up to several metres diameter) encrusting and massive (solid, dome-shaped) coral colonies was observed at CI2. These forms of coral can withstand substantial wave impact (Done 1992; Fabricius *et al*. 2008). Smaller specimens of these robust corals are prevalent throughout the study area. Their prevalence, together with the absence of the more delicate branching colonies, suggests that wave impacts are important in defining the coral communities, as would be expected in such a cyclone-prone area.

# 7.0 Non-Coral Benthic Macroinvertebrates

## 7.1 Introduction

While the knowledge of the benthic macroinvertebrate assemblages in the Montebello/Barrow Islands region is generally limited to species lists and distributions of taxa, the available information suggests that the assemblages are species-rich (Marsh 1993; Wells *et al.* 1993; Chevron Australia 2005, 2013a, 2011b; DEC 2007; RPS Bowman Bishaw Gorham 2007). Invertebrate species richness is considered high in the Montebello Islands region in particular, with 633 species of molluscs and 170 species of echinoderms recorded (Wells *et al.* 1993; Marsh *et al.* 1993b cited in DEC 2007). Deeper limestone reef areas in the region may support benthic macroinvertebrate communities that contain diverse assemblages of tubular, digitate, laminar, branching, globose and encrusting sponges; hydroids; gorgonians (sea fans); sea whips; soft corals; colonial and solitary ascidians; bryozoans and small scleractinian corals (such as *Turbinaria* spp.) (Chevron Australia 2005).

The habitats on the east and west coasts of Barrow Island support different benthic macroinvertebrate assemblages (Chevron Australia 2005). Of the 316 species of molluscs recorded from Barrow Island, less than one third occur on both coasts. The muddier habitats on the east coast support a greater proportion of bivalve species, whilst the west coast supports a greater proportion of coral reef gastropod species (Chevron Australia 2005). The gastropod *Amoria macandrewi,* is endemic to sandbars within the Montebello/Barrow Islands region (Chevron Australia 2005). The macroinvertebrate fauna of the rocky shores and intertidal mudflats on the leeward sides of the offshore islands in the Montebello/Barrow Islands region also have strong affinities with the fauna of the nearshore intertidal areas on the mainland (Chevron Australia 2005).

Non-coral benthic macroinvertebrate assemblages characteristic of the western shores of Barrow Island are typical of the Pilbara Offshore (PIO) Marine Bioregion and have affinities with assemblages of the west coast of the Montebello Islands (Chevron Australia 2005). Previous surveys have recorded 32 species of echinoderm and 75 species of molluscs on the intertidal reef at Biggada Reef on the west coast of Barrow Island (Bowman Bishaw Gorham 1996; Chevron Australia 2005). Sessile benthic macroinvertebrates (sponges, hydroids, sea pens, sea whips, gorgonians, ascidians and *Turbinaria* spp.) were present in relatively low abundances (0–3.1/$m^2$, with the majority of sites recording <1/$m^2$) in west coast Barrow Island waters near the Horizontal Directional Drilling (HDD) exit alignment (Chevron Australia 2011b). The abundances and taxonomic diversity of the sessile benthic macroinvertebrate assemblages were spatially and temporally variable, both between and within sites. There were no significant benthic macroinvertebrate assemblages observed in the vicinity of the Offshore Feed Gas Pipeline System in State waters and the marine component of the shore crossing.

Surveys along the Domestic Gas Pipeline route were undertaken in 2002–2004 and 2008 (Chevron Australia 2005; URS 2009). Both studies reported very sparse abundances of biota and isolated organisms such as sea whips, gorgonians, hydroids and sponges. Some medium density assemblages of crinoids and soft corals were identified in shallow sediments (<7 m) near the mainland coast (Chevron Australia 2005). Accumulations of mostly dead bivalve molluscs, which are likely to provide locally significant habitat for small invertebrates, were identified in both surveys (Chevron Australia 2005).

A survey of the broad intertidal sand flat seaward of the mangroves at the mainland shore crossing identified a number of sparse faunal assemblages of echinoderms, molluscs, crustaceans and other invertebrates, including nemerteans, gastropods (*Nassarius, Polinices, Syrinx*), digitate sponges and small sand dollars (*Echinodiscus*) (Chevron Australia 2005). Drainage channels included areas of soft corals (*Dendronephthya* sp.), while lower intertidal areas included abundant small feather stars (crinoids) and large asteroids (*Protoreaster*), which appeared to migrate tidally (Chevron Australia 2005). A subsequent survey also reported gastropods (*Cerithidea cingulata, Haminoea* sp., *Nassarius dorsatus, Littoraria* sp. and *Nassarius* sp.) on the mudflat seaward of the mangroves (URS 2009). Within the mangroves, the fauna included red fiddler crabs (*Uca*), occasional portunid crabs including mud crabs

(*Scylla serrata*), mud skippers (*Periopthalmus vulgaris*), mud lobsters (*Thalassina anomala*), crawling gastropods, and rock oysters (*Saccostrea*) (Chevron Australia 2005).

## 7.2 Scope

This Section records the existing dominant species of non-coral benthic macroinvertebrates (Condition 14.8.iii, Statement No. 800; Condition 11.8.III, EPBC Reference: 2003/1294 and 2008/4178) and describes and maps the non-coral benthic macroinvertebrates:

- that are at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iii, Statement No. 800; Condition 11.6.III EPBC Reference: 2003/1294 and 2008/4178)
- at Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iv, Statement No. 800; Condition 11.6.IV, EPBC Reference: 2003/1294 and 2008/4178).

Baseline surveys have been undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800 and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178.

Non-coral benthic macroinvertebrates (hereafter referred to as ‘benthic macroinvertebrates’) are a broad category of fauna that include sessile, filter-feeding taxa such as sponges, gorgonians, bryozoans and ascidians, as well as mobile taxa such as asteroids (starfish), echinoids (sea urchins) and holothurians (sea cucumbers). The Marine Baseline Program has focused on the dominant (most common) benthic macroinvertebrate species among the sessile, habitat-forming groups that characterise the benthic macroinvertebrate assemblages around Barrow Island and at the mainland end of the Domestic Gas Pipeline (Condition 14.8.iii, Statement No. 800; Condition 11.8.III, EPBC Reference: 2003/1294 and 2008/4178).

While the baseline surveys focused on these groups, hard corals (mainly *Turbinaria* spp.) and soft corals (e.g. *Sarcophyton* sp.), were also recorded as they are commonly observed in benthic macroinvertebrate dominated habitats in Barrow Island waters and at the mainland end of the Domestic Gas Pipeline route (outside of coral reef habitats) and represent an important part of the sessile benthic macroinvertebrate assemblages.

## 7.3 Methods

### 7.3.1 Site Locations: East Coast of Barrow Island

Thirteen benthic macroinvertebrate survey sites were selected within areas where benthic macroinvertebrates were identified as being present through broadscale benthic habitat mapping and ground-truthing of the east coast of Barrow Island (Section 5.1). Nine sites were located in areas of soft sediment. Two of these (TPC3 and DGI0) were located within the DomGas Pipeline Marine Disturbance Footprint; i.e. in areas at risk of Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline (Table 7-1; Figure 7-1). Two sites (TPCI1 and TPCI2) were located within the Zone of High Impact Dredge Management Area associated with the generation of turbidity and sediment deposition from dredging and spoil disposal activities on the east coast of Barrow Island (Section 2.3.4). Two other sites (TP5 and TP6) were located on limestone pavement within the Zone of High Impact. One site (TPC1) was located in the indicative anchoring area. Six Reference Sites (LC4, DSR5, DSR6, DSS1, TP9 and TP10) were located in the surrounding waters and are not at risk of Material or Serious Environmental Harm due to the construction or operation of the Marine Facilities. The sites DSR6 and TP10 were located on limestone pavement. For information on other benthic macroinvertebrate survey sites on the east coast of Barrow Island, refer to Chevron Australia (2013a). Note that some benthic macroinvertebrate survey sites were also macroalgal and/or seagrass survey sites as these ecological elements commonly occurred together. Macroalgae and benthic macroinvertebrates co-occurred on the inshore limestone pavement, while seagrass and benthic macroinvertebrates often co-occurred in soft sediments.

**Table 7-1 Non-coral Benthic Macroinvertebrate Survey Sites in Waters off the East Coast of Barrow Island**

| Location | Site Code | Easting | Northing | Latitude | Longitude | Habitat[1] | Survey Date | | |
|---|---|---|---|---|---|---|---|---|---|
| | | (GDA94, MGA Zone 50) | | (GDA94) | | | Nov 08 | Jan 09 | Jul 09 |
| At risk of Material or Serious Environmental Harm | TPC3* | 342101 | 7694972 | 20° 50.315'S | 115° 28.947'E | SS | | X | |
| | DGI0 | 342795 | 7690816 | 20° 52.571' S | 115° 29.325' E | SS | | X | X |
| | TPCI1 * | 342952 | 7697366 | 20° 49.022' S | 115° 29.451' E | SS | | X | |
| | TPCI2 * | 343537 | 7697097 | 20° 49.171' S | 115° 29.787' E | SS | | X | |
| | TP5* | 342085 | 7699098 | 20° 48.079' S | 115° 28.961' E | LP | | | X |
| | TP6* | 342238 | 7699286 | 20° 47.978' S | 115° 29.050' E | LP | X[2] | | X |
| Indicative Anchoring Area | TPC1* | 342628 | 7694475 | 20° 50.587' S | 115° 29.249' E | SS | | X | |
| Reference Sites | LC4* | 344832 | 7698996 | 20° 48.148' S | 115° 30.543' E | SS | | X | X |
| | DSR5 | 346075 | 7694125 | 20° 50.794' S | 115° 31.234' E | SS | | X | X |
| | DSR6 | 350774 | 7693683 | 20° 51.057' S | 115° 33.941' E | LP | | X[3] | |
| | DSS1* | 347316 | 7687119 | 20° 54.598' S | 115 31.913' E | SS | | X | X[3] |
| | TP9* | 341069 | 7695737 | 20° 49.895' S | 115° 28.357' E | SS | X | | |
| | TP10* | 337826 | 7694122 | 20° 50.754' S | 115° 26.478' E | LP | X[3] | | |

** Denotes a sampling site located in a Dredge Management Area. Source: Chevron Australia (2013a).*

*[1] = SS: Soft Sediment Habitat, LP: Limestone Pavement. [2] = habitat classified as Soft Sediment at this survey date. [3] = Transects fall on both Soft Sediment and Limestone habitat.*

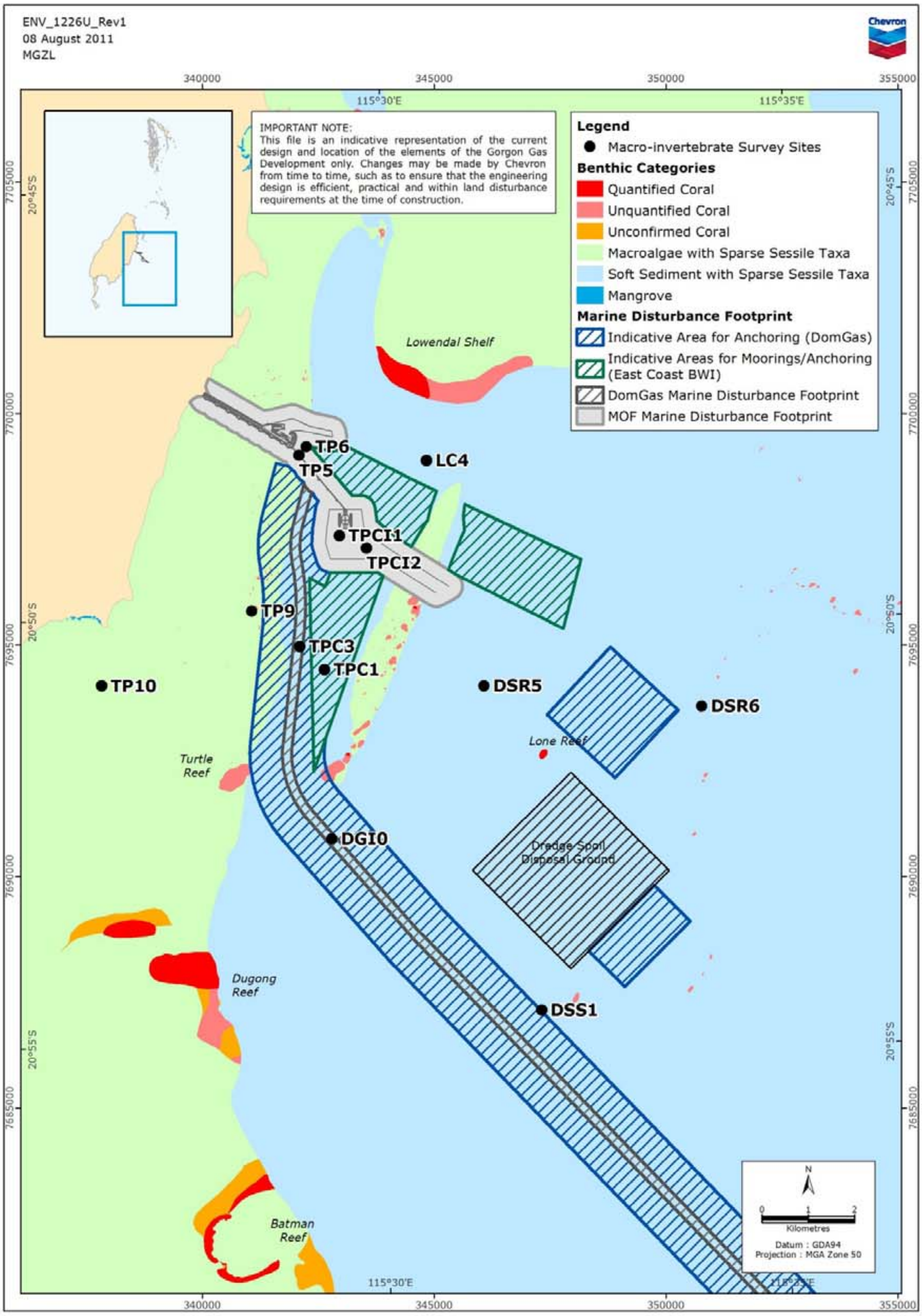



**Figure 7-1 Non-coral Benthic Macroinvertebrate Survey Sites in Waters off the East Coast of Barrow Island**

### 7.3.2 Site Locations: Mainland End of the DomGas Pipeline Route

Six benthic macroinvertebrate survey sites were located within areas where benthic macroinvertebrates were identified as being present through broadscale mapping and ground-truthing (Section 5.4) at the mainland end of the DomGas Pipeline route (Table 7-2; Figure 7-2). Three sites (BI1, BI2, BI3) were located in areas at risk of Material or Serious Environmental Harm within the trenching and jetting Marine Disturbance Footprint; and three Reference Sites (BR1, BR2, BR3) were located in areas not at risk of Material or Serious Environmental Harm, outside the trenching and jetting Marine Disturbance Footprint (Section 2.3.3.2). The sites were located in depths of <1 m to approximately 8 m, with the offshore sites typically located in deeper water than the inshore sites.

Sessile benthic macroinvertebrates were generally associated with the offshore extremities of reef systems around the offshore islands in the study area (e.g. Angle Island, Passage Island, South Passage Island, Solitary Island, and Cowle Island). The sessile benthic macroinvertebrates were attached to reef that was typically covered by a veneer of soft sediment (the sediment depth varied and was typically <15 cm). Sessile benthic macroinvertebrate abundance was the primary factor determining the selection of survey sites, with sites selected to ensure that sessile benthic macroinvertebrates were the dominant ecological element, on the basis of the Barrow Island Habitat Classification Scheme (Section 5.2.2; Appendix 2).

Soft sediment habitats were occasionally dominated by mobile benthic macroinvertebrates (e.g. crinoids). However, establishing survey sites on the basis of the temporary abundance of transient mobile organisms was not considered suitable.

**Table 7-2 Non-coral Benthic Macroinvertebrate Survey Sites at the Mainland End of the DomGas Pipeline Route**

| Location | Site | Easting | Northing | Latitude | Longitude | Survey Date | |
|---|---|---|---|---|---|---|---|
| | | (GDA94, MGA Zone 50) | | (GDA94) | | Sept–Oct 10 | Apr 11 |
| At risk of Material or Serious Environmental Harm | BI1 | 374493 | 7656021 | 21° 11.576' S | 115° 47.453' E | X | X |
| | BI2 | 374934 | 7665393 | 21° 06.498' S | 115° 47.749' E | X | X |
| | BI3 | 378284 | 7661654 | 21° 08.538' S | 115° 49.668' E | - | X |
| Reference Sites | BR1 | 372921 | 7651675 | 21° 13.925' S | 115° 46.525' E | X | X |
| | BR2 | 378928 | 7669621 | 21° 04.223' S | 115° 50.074' E | X | X |
| | BR3 | 369955 | 7662521 | 21° 08.034' S | 115° 44.860' E | - | X |

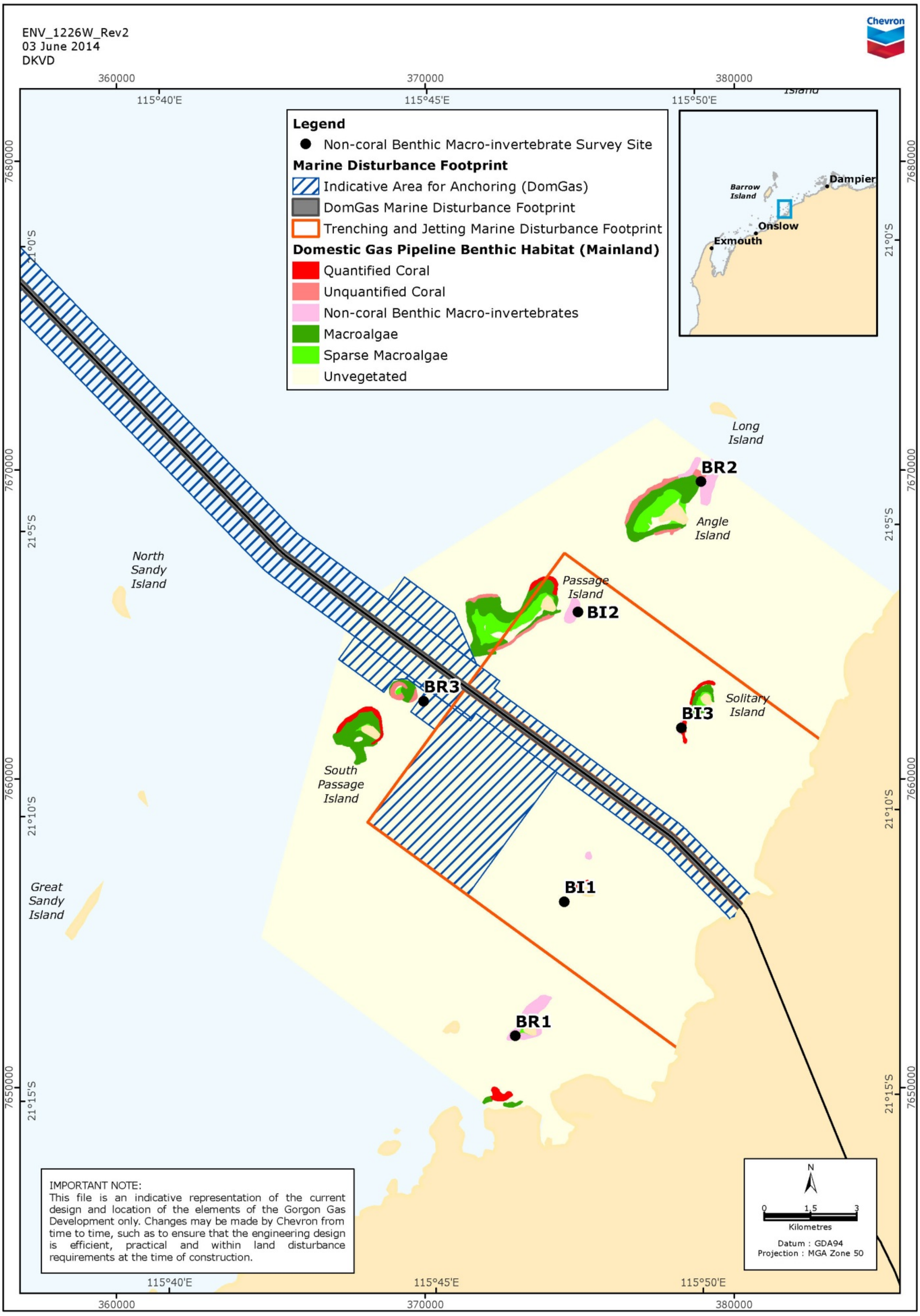



**Figure 7-2 Non-coral Benthic Macroinvertebrate Survey Sites at the Mainland End of the DomGas Pipeline Route**

### 7.3.3 Survey Methods

At each site, three 30 m long and 0.5 m wide belt transects were filmed using a diver-operated high definition video camera (e.g. Sony HDR-CX110) in a waterproof housing (e.g. Amphibico EVO HD Elite 2), with the lens maintained at a fixed distance of 50 cm from the substratum. Each transect covered an area of approximately 15 $m^2$. The first transect was orientated parallel to the anchor line and the two others at 90° to the first. The coordinates of the start point of each transect were recorded using GPS.

The dominant benthic macroinvertebrates along each transect were photographed with a digital camera in a waterproof housing (e.g. Panasonic FT2) and voucher specimens were collected, preserved (frozen or in 70% ethanol), and catalogued. Samples of common taxa collected from sites at the mainland end of the DomGas Pipeline route were provided to relevant taxonomic experts for identification (sponges, Dr Jane Fromont, Museum of Western Australia; octocorals, Dr Philip Alderslade, CSIRO Marine Research; bryozoans, Dr Philip Bock, independent specialist consultant).

### 7.3.4 Timing and Frequency of Surveys

Sampling was undertaken in waters off the east coast of Barrow Island during November 2008, January 2009, and July 2009. At sites at the mainland end of the DomGas Pipeline route, sampling was undertaken during the dry season (September–October 2010) and wet season (April 2011). Four sites (BI1, BI2, BR1 and BR2) were surveyed in the dry season, with an additional two sites (BI3 and BR3) surveyed in the wet season (Table 7-2). The wet season survey was originally scheduled to be undertaken in February 2011; however, some field activities in the wet season were delayed until April 2011 due to the passage of tropical cyclones, adverse weather conditions or logistical constraints.

### 7.3.5 Treatment of Survey Data

The benthic macroinvertebrate assemblages were described at a broad taxonomic level. Video footage of each of the transects was reviewed to:

- identify growth form of the sessile benthic macroinvertebrates
- identify family (where possible) of the sessile benthic macroinvertebrates
- estimate the abundance of the sessile benthic macroinvertebrates (i.e. numbers of individuals, or colonies of each of the major benthic macroinvertebrates taxon along each transect).

Sponges were classified according to a morphological classification scheme adapted from Bell and Barnes (2001). Sponges were classified as barrel-shaped (*Xestospongia*), flabellate, arborescent, cup-shaped, tubular, globular, or with variable (irregular) morphologies. Additional taxonomic resources and guides were used to identify growth forms of other taxa recorded on video transects (Gosliner *et al*. 1996; Fabricius and Alderslade 2001).

Within sites, abundance data were averaged (± Standard Error [SE]) across the replicate transects for each taxonomic group. To describe relative dominance of individual taxa, the numbers of each taxon were divided by the total number of observations and expressed as a percentage (i.e. 'Percentage contribution').

## 7.4 Results

### 7.4.1 Distribution of Benthic Macroinvertebrates in Waters Surrounding the DomGas Pipeline Route

#### 7.4.1.1 Distribution of Benthic Macroinvertebrates in Barrow Island Waters

Figure 7-3 shows the spatial distribution of benthic macroinvertebrates in Barrow Island waters as point (presence/absence) observations derived from broadscale mapping and ground-truthing. 'Null observations' were recorded where benthic macroinvertebrates were not observed during ground-truthing.

In summary, benthic macroinvertebrate assemblage composition was relatively homogenous across broad areas of similar substrate, and while benthic macroinvertebrates were generally sparsely distributed, the abundance of the different taxa was variable (Chevron Australia 2013a). Distinct benthic macroinvertebrate assemblages were observed on the different substrate types (sand or soft sediment and limestone pavement). Benthic macroinvertebrates were relatively common on the inshore limestone pavement areas, growing in mixed assemblages with macroalgae and occasionally seagrass. The most abundant benthic macroinvertebrate associated with hard limestone pavement were ascidians, sea whips, and variable sponges. Macroalgae were generally the most common biota on shallow limestone pavements in Barrow Island waters.

Benthic macroinvertebrates often occurred with macroalgae and the only areas where benthic macroinvertebrates were the most common or abundant benthic biota were in the deeper (>10 m) soft sediment habitats. The macroinvertebrate assemblages associated with soft sediment habitats were generally sparse in most areas, but nevertheless represented the dominant benthic ecological element. The distribution and density of macroinvertebrates in soft sediment habitats is generally limited by the availability of hard substrates for attachment (Fromont 2004). The substrate of those areas mapped as 'Soft Sediment with Sparse Sessile Taxa' (Figure 7-3) comprised a sediment veneer of varying depths overlaying a hard limestone pavement. Rocks and outcrops of limestone pavement in these soft sediment habitats often served as attachment points for sponges, sea whips and other macroinvertebrate taxa. In summary, the most abundant benthic macroinvertebrates on soft sediments were sea whips, sponges, and Turbinaria, predominantly arborescent and variable sponges (Chevron Australia 2013a).

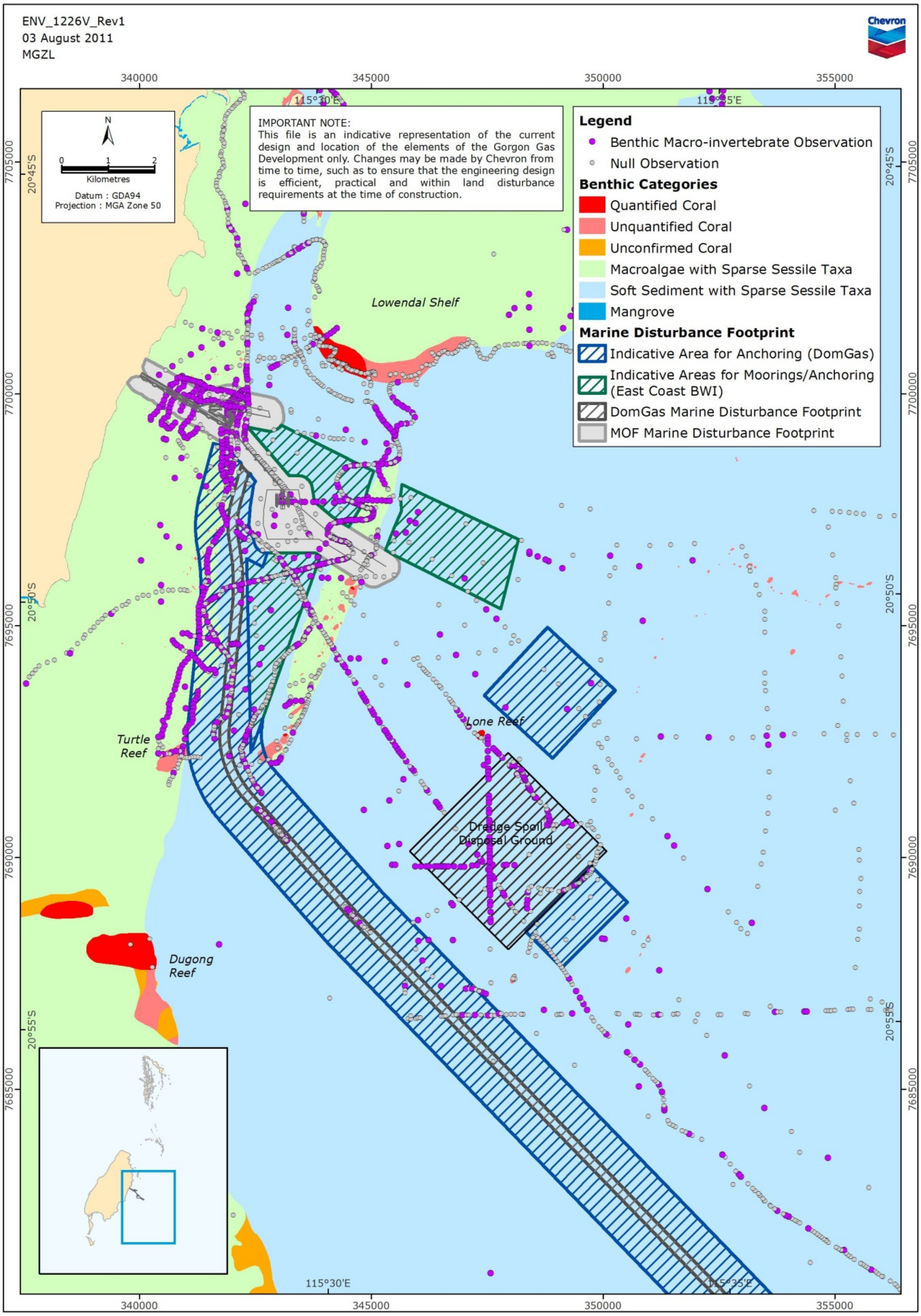



**Figure 7-3 Observations of Benthic Macroinvertebrates in Waters around Barrow Island**

#### 7.4.1.2 Distribution of Benthic Macroinvertebrates at the Mainland End of the DomGas Pipeline Route

The spatial distribution of benthic macroinvertebrates at the mainland end of the DomGas Pipeline route is shown in Figure 7-4. The map is based primarily on benthic macroinvertebrate presence/absence derived from observations made during broadscale surveys (towed video) and in-water ground-truthing (Section 5.4). 'Null observations' were recorded where benthic macroinvertebrates were not observed during ground-truthing.

Sessile benthic macroinvertebrates assemblages were generally associated with the outer extremities of reef systems surrounding the offshore islands in the study area. In these areas the benthic macroinvertebrates formed diverse sponge/octocoral 'gardens' typically on deeper sections of reef covered by a veneer of soft sediment. The assemblages dominated by benthic macroinvertebrates were generally in high current locations (based on field observations) and their distribution in the study area probably reflects localised patterns of accelerated tidal water movement.

Sessile benthic macroinvertebrates were also recorded in the soft sediment habitats that dominated the study area (Section 5.4). These included occasional sea pens or sea whips (estimated density <0.1/$m^2$). Mobile benthic macroinvertebrates (typically crinoids) were also observed in low densities on unvegetated soft sediments (estimated density ranging from <1–5/$m^2$).

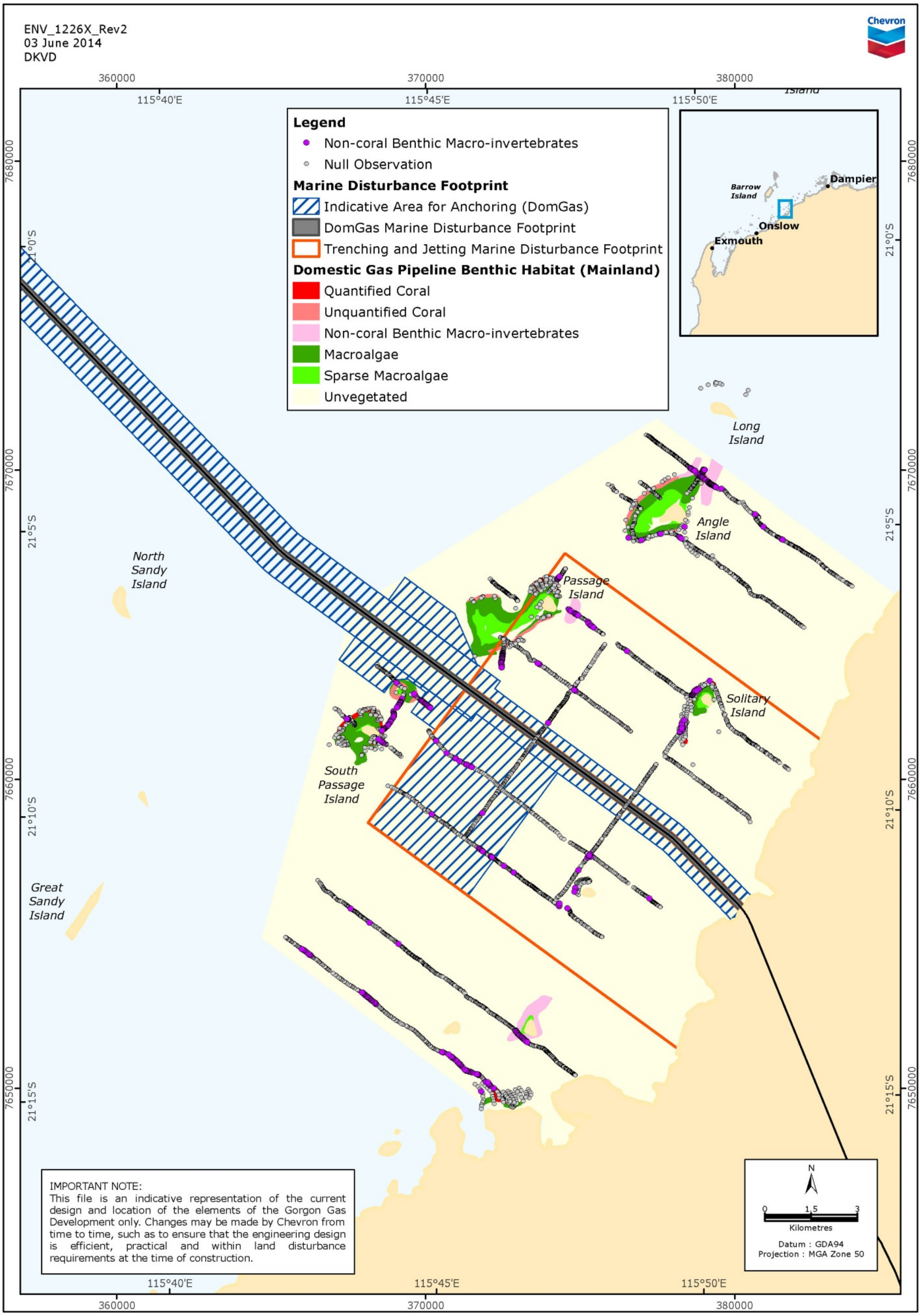



**Figure 7-4 Observations of Benthic Macroinvertebrates at the Mainland End of the DomGas Pipeline Route**

### 7.4.2 Dominant Benthic Macroinvertebrates

#### 7.4.2.1 Barrow Island waters

In summary, the dominant (or most common) benthic macroinvertebrate taxa in Barrow Island waters (Chevron Australia 2013a), were:

- Sponges: Sponges of varying morphology were relatively common on both limestone pavement and soft sediments (Plate 7-1).
- Soft corals (Alcyoniidae): Soft corals were relatively common in Barrow Island waters. The fleshy, massive soft corals in the genus *Sarcophyton* and *Lobophytum* were observed in soft sediment and occasionally on limestone pavement habitats.
- Sea whips: Including the fleshy branching and non-branching soft corals such as *Juncella* spp. and *Rumphella* spp. The non-branching, elongated sea whip, *Juncella* spp., was commonly observed in soft sediments and less commonly observed on limestone pavements, with unidentified branching sea whips also relatively common (Plate 7-1).
- Gorgonians: Densely reticulated sea fans growing in a single plane and with a rigid exoskeleton (Plate 7-1) were relatively common in Barrow Island waters.
- Sea pens: Pennatulids occurred at few sites and in low abundances in soft sediment habitats in Barrow Island waters.
- Hydroids: Hydroids were commonly observed on hard substrates, occasionally with ascidians attached.
- Hard corals: *Turbinaria* spp. were common on both limestone pavement and soft sediment substrates.
- Crinoids: Crinoids were often attached to other benthic macroinvertebrates on limestone pavement and soft sediment habitats (Plate 7-1).
- Ascidians: *Atriolum robustum* (family Didemnidae) was the most commonly observed ascidian in waters off the east coast of Barrow Island, occurring on hard substrates such as limestone pavements (Plate 7-1) and the calcified stalks of hydroids.

Barrel Sponge

Flabellate Sponge

Ascidians (*Atriolum robustum)*

Gorgonian (Sea Fan)

Sea Whip

Crinoid attached to Sea Whip

**Plate 7-1 Benthic Macroinvertebrates found in Waters around Barrow Island**

### 7.4.2.2 Mainland End of the DomGas Pipeline Route

The dominant (or most common) benthic macroinvertebrate taxa at the mainland end of the DomGas Pipeline, were:

- sponges (of varying morphologies, in particular flabellate, arborescent and irregular)
- holothurians (e.g. *Pentacta* cf. *ancepes*)
- hard coral (*Turbinaria* spp.)
- sea whips (e.g. *Juncella, Rumphella*)
- gorgonians (sea fans).

Other taxa recorded included other morphologies of sponges (e.g. barrel, cup, globular and tubular), hydroids, other hard corals (e.g. *Favia*-type and flat corals), bivalve molluscs, Alcyoniidae, bryozoans, colonial and solitary ascidians, and crinoids (Table 7-3; Plate 7-2)

Sponges were the most abundant benthic macroinvertebrates recorded at sites at the mainland end of the DomGas Pipeline route. Flabellate growth forms (12.9% of total observations) and arborescent growth forms (12.7%) were the most common sponge growth forms recorded in the September–October 2010 and April 2011 surveys (Table 7-3). The relative abundance patterns of flabellate forms were comparable between the two surveys; however, arborescent forms were more abundant in the September–October 2010 surveys. The contribution of holothurians to overall benthic macroinvertebrate abundance was also high (12.8%), with high abundances recorded in the April 2011 survey. Colonies of the hard coral, *Turbinaria* spp., were common in both surveys and occurred at all sites (10.1%).

Sea whips (8.6%) and gorgonians (5.6%) were also relatively abundant (Table 7-3). When considered across both surveys, the relative abundance of Alcyoniidae, hydroids, and bryozoans (all groups) was low (1–5%), while abundance of other groups (e.g. ascidians, molluscs) was very low (<1%). Mobile benthic macroinvertebrates (e.g. sea stars, sea urchins) were rarely observed in either survey, with the notable exception of holothurians in the April 2011 survey, when they represented 20% of all individuals observed (Table 7-3). Holothurians were not recorded at all the sites; however, at two sites in the April 2011 survey they were recorded in high abundances (88.7/15 $m^2$ ± 38.8 SE at BR3 and 33.0/15 $m^2$ ± 21.5 SE at BI2).

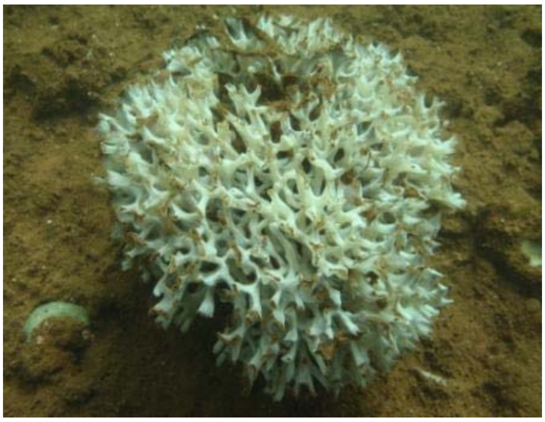
**Table 7-3 Percentage Contribution of each Taxa (total number) to the Total Number of Individuals Recorded at Benthic Macroinvertebrate Survey Sites**

| Taxa | % contribution combined seasons | % contribution dry season | % contribution wet season |
|---|---|---|---|
| Sponge – Flabellate (e.g. *Ectyoplasia vannus*) | 12.9 | 12.1 | 13.4 |
| Echinoderm – Holothurian | 12.8 | 0.4 | 20.0 |
| Sponge – Arborescent (e.g. *Ectyoplasia tabula*) | 12.7 | 18.9 | 9.2 |
| Hard Coral – *Turbinaria* spp. | 10.1 | 10.8 | 9.7 |
| Sponge – Irregular | 8.9 | 8.1 | 9.3 |
| Sea whips (e.g. *Juncella , Rumphella*) | 8.6 | 5.6 | 10.3 |
| Gorgonians (sea fans) | 5.6 | 8.6 | 3.8 |
| Hydroids | 3.9 | 3.0 | 4.4 |
| Hard Coral – Other | 3.8 | 4.4 | 3.4 |
| Alyconiidae (*Lobophytum, Sinularia, Sarcophyton*) | 3.7 | 2.9 | 4.2 |
| Hard Coral – *Favia*-type | 3.4 | 5.3 | 2.2 |
| Bryozoan – Cheilostome | 3.3 | 7.8 | 0.7 |
| Sponge – Assemblage | 2.8 | 5.3 | 1.4 |
| Unidentified sessile invertebrates | 1.8 | 0.0 | 2.8 |
| Bryozoans – Lace | 1.2 | 1.7 | 0.9 |
| Sponge – Barrel (e.g. *Spheciospongia*) | 1.1 | 1.2 | 1.0 |
| Coral – Flat | 0.7 | 0.9 | 0.7 |
| Echinoderm – Crinoids | 0.7 | 0.0 | 1.1 |
| Sponge – Cup | 0.7 | 0.9 | 0.5 |
| Ascidian – Colonial | 0.4 | 0.5 | 0.3 |
| Alyconacea (e.g. tree-like - *Litophyton*) | 0.3 | 0.3 | 0.3 |
| Mollusc – Bivalve | 0.3 | 0.5 | 0.2 |
| Echinoderm – Asteroids | 0.2 | 0.3 | 0.2 |
| Sponge – Globular | 0.1 | 0.4 | 0.0 |
| Sponge – Tubular | 0.1 | 0.2 | 0.0 |
| Ascidian – Solitary | 0.1 | 0.2 | 0.0 |
| Unidentified polychaetes | 0.0 | 0.0 | 0.1 |

Arborescent sponge

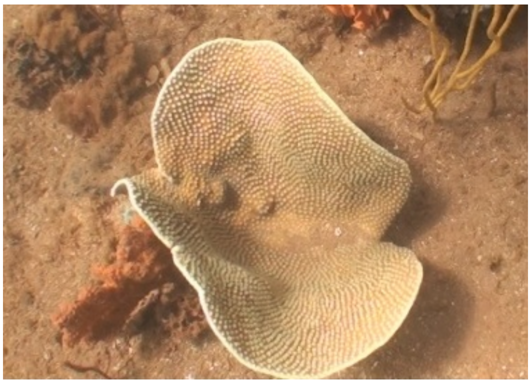
Gorgonian

Flabellate sponge



Cheilostome Bryozoan

Irregular sponge



Hard coral *Turbinaria* sp.

**Plate 7-2 Benthic Macroinvertebrates found at the Mainland End of the DomGas Pipeline Route**

### 7.4.3 Description of Benthic Macroinvertebrates at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

#### 7.4.3.1 East Coast of Barrow Island

DGI0 and TPC3 were located in soft sediments off the east coast of Barrow Island. The total mean abundance of benthic macroinvertebrates was similar at both sites in the January 2009 survey (DGI0: 17.3/15m$^2$ ± 2.3 SE, which equates to ~1.2/m$^2$; TPC3: 18.3/15m$^2$ ± 1.2 SE [~1.2/m$^2$]) (Table 7-4; Figure 7-5). Lower mean abundance of all taxa was recorded in the July 2009 survey at DGI0 (8.0/15m$^2$ ± 2.5 SE [~0.5/m$^2$]). Sponges of variable morphologies were the most abundant benthic macroinvertebrates at sites located in soft sediments. Variable sponges were the most abundant sponge at DGI0 in the January 2009 survey (4.7/15 m$^2$ ± 0.3 SE [~0.3/m$^2$]) and were also common at TPC3 (4.3/15 m$^2$ ± 0.3 SE [~0.3/m$^2$]) at this time. Arborescent and digitate sponges were common at DGI0 in the January 2009 survey (4.3/15 m$^2$ ± 1.2 SE [~0.3/m$^2$] and 2.7/15 m$^2$ ± 1.8 SE [~0.2/m$^2$] respectively), and fan/flabellate sponges were common at TPC3 (3.0/15m$^2$ ± 0.6 SE [~0.2/m$^2$]) in the January 2009 survey. Sea whips were also one of the abundant taxa at TPC3 in the January 2009 survey (2.3/15m$^2$ ± 0.3 SE [~0.2/m$^2$]). A high diversity of benthic macroinvertebrate taxa was recorded at both TPC3 and DGI0 in the January 2009 survey (12 and 10 respectively [including taxonomic group 'unknown']).

Sea whips and sponges of various morphologies were the most abundant benthic macroinvertebrates in the soft sediment habitats between the inshore limestone pavement and the East Barrow Ridge (TPCI1, TPCI2 and TPC1; Table 7-4). Mean abundances of sea whips varied between 3.0/15 m$^2$ ± 1.5 SE [~0.2/m$^2$] at TPC1 and 5.3/15 m$^{2\,\pm}$ 0.9 SE [~0.4/m$^2$] at TPCI1. The highest total mean abundance was recorded at TPC1 in the January 2009 survey (15.7/15 m$^2$ ± 6.9 SE [~1.0/m$^2$]), which also recorded the highest diversity of benthic macroinvertebrates (12 taxa) of these three sites (Figure 7-5). Only four taxa were recorded at TPCI2 in the January 2009 survey, and the total mean abundance was also low at this site (6.7/15 m$^2$ ± 2.9 SE [~0.4/m$^2$]).

The highest total mean abundance of benthic macroinvertebrates on limestone pavement was recorded in the November 2008 survey at TP6 (27.3/15 m$^2$ ± 6.2 SE [~1.8/m$^2$]) (Table 7-4; Figure 7-5). Lower total mean abundances were recorded at TP6 (10.3/15 m$^2$ ± 0.3 SE [~0.7/m$^2$]) and at TP5 (5.3/15 m$^2$ ± 0.9 SE [~0.4/m$^2$]) in the July 2009 survey. Turbinaria were the most abundant benthic macroinvertebrates at TP6 in the November 2008 survey (5.3/15 m$^2$ ± 1.7 SE [~0.4/m$^2$]), as well as sea whips in both November 2008 (5.0/15 m$^2$ ± 2.1 SE [~0.3/m$^2$]) and July 2009 (4.0/15 m$^2$ ± 1.2 SE [~0.3/m$^2$]). Ascidians (November 2008: 2.3/15 m$^2$ ± 0.9 SE [~0.2/m$^2$]; July 2009: 2.7/15 m$^2$ ± 0.9 SE [0.2/m$^2$]) and sponges (arborescent: 4.0/15 m$^2$ ± 1.5 SE [~0.3/m$^2$]; and variable: 3.0/15 m$^2$ ± 1.2 SE [~0.2/m$^2$]) were also recorded at this site. Variable sponges were the most abundant benthic macroinvertebrates at TP5 (2.3/15 m$^2$ ± 0.7 SE [~0.2/m$^2$]) in the July 2009 survey. The highest diversity of benthic macroinvertebrate taxa recorded at sites on limestone pavement was 14 (including taxonomic group 'unknown') taxa at TP6 in the November 2008 survey. Lower taxonomic diversity was recorded in the July 2009 survey at TP6 (eight taxa), while seven benthic macroinvertebrate taxa were recorded at TP5 in the July 2009 survey.

**Table 7-4 Mean Benthic Macroinvertebrate Abundance (± SE) per 30 m Transect (approximately 15 $m^2$) at Sites and Sampling Occasions at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities**

| Benthic Macroinvertebrate | Mean Abundance (± SE) per 30 m Transect (approximately 15 $m^2$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | TPC3 | DGI0 | | TPCI1 | TPCI2 | TP5 | TP6 | | TPC1 |
| | Jan 09 | Jan 09 | Jul 09 | Jan 09 | Jan 09 | Jul 09 | Nov 08 | Jul 09 | Jan 09 |
| Ascidian colonial | 0.3 ± 0.3 | - | - | - | - | - | 2.3 ± 0.9 | 2.7 ± 0.9 | 0.7 ± 0.3 |
| Ascidian solitary | - | - | - | - | - | - | - | - | - |
| Crinoid | 1.7 ± 1.2 | 0.3 ± 0.3 | - | 0.7 ± 0.7 | 0.7 ± 0.7 | 0.7 ± 0.7 | 0.7 ± 0.7 | - | 0.7 ± 0.3 |
| Gastropod | - | - | - | - | - | - | - | - | - |
| Gorgonian | - | - | - | 0.3 ± 0.3 | - | - | 0.3 ± 0.3 | - | 0.3 ± 0.3 |
| Hydroid | - | 0.3 ± 0.3 | - | - | - | - | 1.3 ± 1.3 | 1.0 ± 0.0 | - |
| Nudibranch | - | - | - | - | - | - | - | - | - |
| Other soft coral (e.g. Alcyoniidae) | 1.0 ± 1.0 | 1.3 ± 0.9 | 0.3 ± 0.3 | - | - | 0.3 ± 0.3 | 1.7 ± 1.2 | 0.7 ± 0.3 | - |
| Sea cucumber | 0.7 ± 0.3 | 0.7 ± 0.7 | 3.0 ± 1.7 | - | - | - | 0.7 ± 0.3 | - | - |
| Sea star | - | - | - | - | 0.3 ± 0.3 | - | - | - | 0.3 ± 0.3 |
| Sea urchin | - | - | - | 0.3 ± 0.3 | 2.0 ± 2.0 | - | - | - | - |
| Sea whip | 2.3 ± 0.3 | 0.7 ± 0.3 | - | 5.3 ± 0.9 | 3.7 ± 1.5 | 0.7 ± 0.7 | 5.0 ± 2.1 | 4.0 ± 1.2 | 3.0 ± 1.5 |
| Sponge barrel | 0.3 ± 0.3 | - | 0.3 ± 0.3 | - | - | - | 0.3 ± 0.3 | - | 0.3 ± 0.3 |
| Sponge branching/ arborescent | 2.3 ± 0.9 | 4.3 ± 1.2 | - | - | - | - | 4.0 ± 1.5 | 0.3 ± 0.3 | 2.7 ± 1.5 |
| Sponge cup | - | - | - | - | - | 0.3 ± 0.3 | - | 0.3 ± 0.3 | - |
| Sponge digitate | 0.7 ± 0.3 | 2.7 ± 1.8 | 0.7 ± 0.7 | - | - | - | - | - | 0.7 ± 0.3 |
| Sponge fan/flabellate | 3.0 ± 0.6 | - | 1.7 ± 0.3 | - | - | - | 1.3 ± 0.9 | - | 1.3 ± 1.3 |
| Sponge globular | 1.0 ± 1.0 | - | 0.3 ± 0.3 | - | - | 0.3 ± 0.3 | - | - | - |
| Sponge tubular | - | - | 0.3 ± 0.3 | 1.0 ± 0.6 | - | - | 0.7 ± 0.7 | - | 0.3 ± 0.3 |
| Sponge variable | 4.3 ± 0.3 | 4.7 ± 0.3 | 1.0 ± 0.0 | 0.7 ± 0.3 | - | 2.3 ± 0.7 | 3.0 ± 1.2 | 1.0 ± 0.0 | 4.0 ± 1.2 |
| Turbinaria | 0.7 ± 0.3 | 1.0 ± 0.6 | 0.3 ± 0.3 | - | - | 0.7 ± 0.3 | 5.3 ± 1.7 | 0.3 ± 0.3 | 1.3 ± 0.9 |
| Unknown | - | 1.3 ± 0.3 | - | 1.3 ± 0.3 | - | - | 0.7 ± 0.3 | - | - |
| **Mean total abundance per transect** | **18.3 ± 1.2** | **17.3 ± 2.3** | **8.0 ± 2.5** | **9.7 ± 1.2** | **6.7 ± 2.9** | **5.3 ± 0.9** | **27.3 ± 6.2** | **10.3 ± 0.3** | **15.7 ± 6.9** |

*Note: '-' indicates no invertebrates from that taxa were observed.*

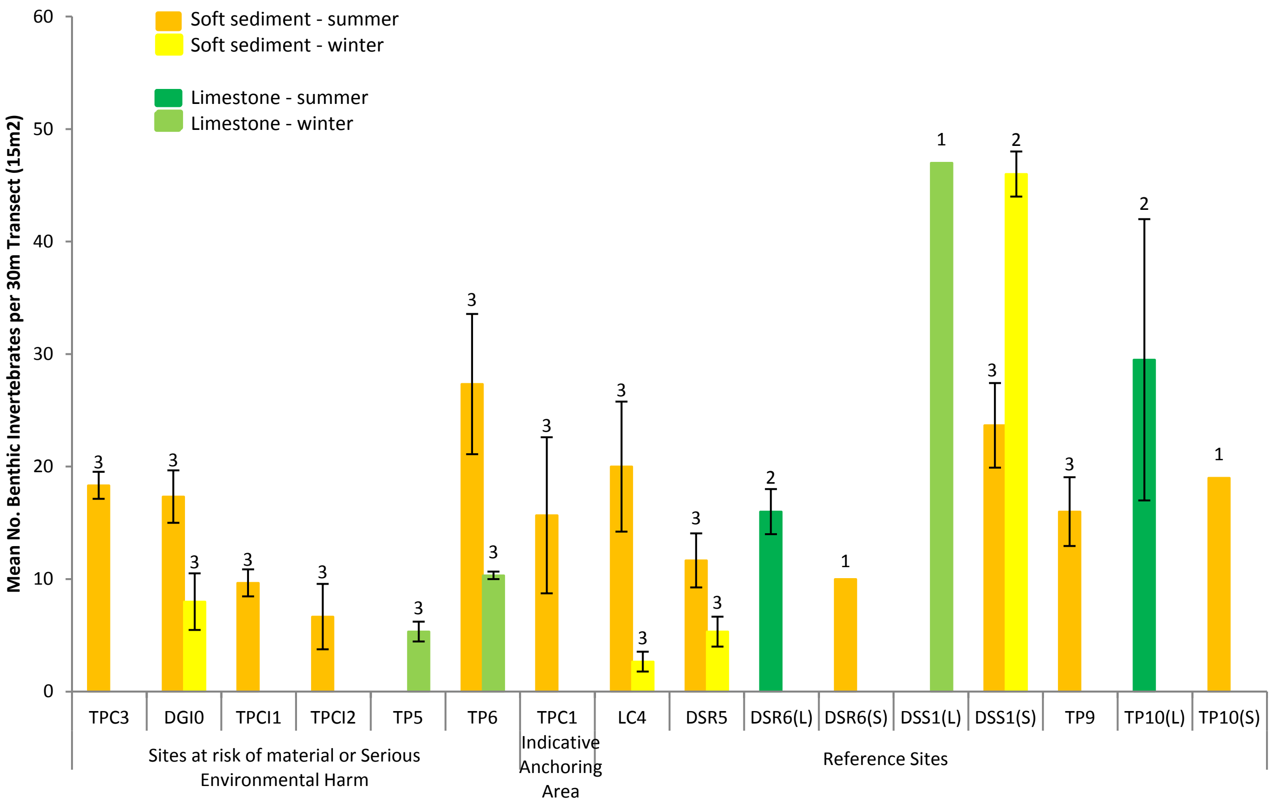



**Figure 7-5 Mean Abundance (± SE) of Sessile Benthic Macroinvertebrates per 30 m Transect (15 m$^2$) at Survey Sites in Waters off the East Coast of Barrow Island**

*Note: Numbers above error bars indicate the number of transects at the site. Summer = Nov 08/Jan 09 Surveys; Winter = July 09 survey. Sites with transects falling on both soft sediment and limestone have been separated by habitat type and are further identified by L (limestone) and S (soft sediment) after the site name.*

#### 7.4.3.2 Mainland End of the DomGas Pipeline Route

Benthic macroinvertebrate assemblage composition and abundance varied between the sites at risk of Material or Serious Environmental Harm (Table 7-5; Figure 7-6). Differences between the sites were evident in both the September–October 2010 and April 2011 surveys. Total mean abundance at the inshore site, BI1, was high in both surveys, averaging 161.0/15 m$^2$ ± 8.1 SE (which equates to ~10.7/m$^2$) in the September–October 2010 survey and 144.0/15 m$^2$ ± 7.5 SE [~9.6/m$^2$] in the April 2011 survey. In contrast, total mean benthic macroinvertebrate abundance was lower at the offshore site, BI2, ranging between 36.7/15 m$^2$ ± 5.8 SE (~2.4/m$^2$) in the September–October 2010 survey and 68.3/15 m$^2$ ± 31.5 SE (~4.6/m$^2$) in the April 2011 survey. Seasonal differences evident at BI2 were largely attributable to an increase in the numbers of holothurians recorded at this site in the April 2011 survey. Total mean benthic macroinvertebrate abundance at the inshore site, BI3, averaged 115.0/15 m$^2$ ± 28.6 SE (~7.7/m$^2$) in the April 2011 survey.

Arborescent sponges were abundant at BI1 in both surveys (September–October 2010: 38.0/15 m$^2$ ± 1.2 SE [~2.5/m$^2$]; April 2011: 24.7/15 m$^2$ ± 1.3 SE [~1.6/m$^2$]); as were flabellate sponges (September–October 2010: 30.3/15 m$^2$ ± 3.2 SE [~2.0/m$^2$]; April 2011: 33.0/15 m$^2$ ± 5.5 SE [2.2/m$^2$]) (Table 7-5). *Turbinaria* spp. were abundant at BI1 in both surveys (September–October 2010: 26.3/15 m$^2$ ± 2.6 SE [~1.8/m$^2$]; April 2011: 23.0/15 m$^2$ ± 2.5 SE [~1.5/m$^2$]) and at BI3 (23.7/15 m$^2$ ± 11.6 SE [~1.6/m$^2$]) in the April 2011 survey. Holothurians were abundant in the April 2011 survey at BI2 (33.0/15 m$^2$ ± 21.5 SE [2.2/m$^2$]), were recorded in lower numbers at the site in the September–October 2010 survey (1.3/15 $m^2$ ± 1.3 SE [~0.1/$m^2$]), and were rarely recorded at the other sites.

The diversity of taxonomic groups was relatively high at the inshore BI1 and BI3 sites, with 17 to 19 taxa recorded at BI1 and 18 at BI3 (Table 7-5). Diversity was lower at BI2, with 13 taxa recorded in the September–October 2010 survey and 12 taxa in the April 2011 survey. Arborescent, flabellate and irregular sponges, along with gorgonians, sea whips (e.g. *Juncella*, *Rumphella*) and Alyconiidae (e.g. *Sacrophyton*, *Lobophytum*, *Sinularia*), were the most abundant benthic macroinvertebrate taxa recorded at BI1 and BI3 in both surveys. The hard coral *Turbinaria* spp. was also common at both sites, averaging >20 colonies per transect. At BI2 gorgonians and sea whips and arborescent sponges were the most abundant taxa.

**Table 7-5 Mean Benthic Macroinvertebrate Abundance (± SE) per 30 m Transect (approximately 15 $m^2$) at Sites at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

| Taxonomic Group | Mean Abundance ± SE per 15 $m^2$ | | | | |
|---|---|---|---|---|---|
| | BI1 | | BI2 | | BI3* |
| | Sept–Oct 10 | Apr 11 | Sept–Oct 10 | Apr 11 | Apr 11 |
| Alyconacea (e.g. tree-like - *Litophyton*) | - | 0.3 ± 0.3 | 0.3 ± 0.3 | - | - |
| Alcyoniidae | 6.3 ± 0.7 | 2.3 ± 1.2 | - | - | 8.0 ± 4.0 |
| Arborescent sponge | 38.0 ± 1.2 | 24.7 ± 1.3 | 6.7 ± 3.8 | 6.7 ± 2.3 | 7.7 ± 1.2 |
| Ascidian | 0.7 ± 0.3 | - | - | - | - |
| 'Assemblage' sponge | 3.0 ± 0.0 | - | 4.0 ± 1.0 | 2.7 ± 0.9 | 0.7 ± 0.3 |
| Asteroid (starfish) | 0.7 ± 0.3 | - | - | 0.3 ± 0.3 | - |
| Barrel sponge | 2.7 ± 0.3 | 2.7 ± 0.7 | - | - | 0.7 ± 0.7 |
| Bivalve mollusc | - | - | - | - | - |
| Cheilostome bryozoan | 3.3 ± 0.9 | - | 1.7 ± 0.9 | - | 1.3 ± 0.9 |
| Crinoid | - | 2.3 ± 1.5 | - | - | 4.0 ± 2.5 |
| Cup sponge | 1.0 ± 1.0 | 0.7 ±0.7 | - | - | 1.7 ± 0.9 |
| *Favia*-type coral | 8.0 ± 2.1 | 2.0 ± 0.6 | 0.3 ± 0.3 | - | 1.0 ± 0.6 |
| Flabellate sponge | 30.3 ± 3.2 | 33.0 ± 5.5 | 2.0 ± 1.0 | 0.7 ± 0.3 | 27.7 ± 11.8 |
| Flat coral (hard) | 0.7 ± 0.7 | - | - | - | 1.3 ± 0.7 |
| Globular sponge | 1.0 ± 0.6 | - | - | - | - |
| Gorgonians (sea fans) | 9.0 ± 0.6 | 6.7 ± 1.3 | 9.7 ± 6.5 | 8.0 ± 4.6 | 2.0 ± 0.6 |
| Holothurian | - | 0.3 ± 0.3 | 1.3 ± 1.3 | 33.0 ± 21.5 | - |
| Hydroids | 3.7 ± 0.9 | 5.0 ± 1.0 | - | 3.3 ± 2.0 | 6.0 ± 1.0 |
| Irregular sponge | 6.7 ± 0.9 | 20.3 ± 3.5 | 4.0 ± 0.6 | 3.3 ± 0.7 | 12.7 ± 3.3 |
| Lace bryozoan | 5.0 ± 1.7 | 2.0 ± 2.0 | - | - | 3.3 ± 1.2 |
| 'Other' hard coral | 3.7 ± 0.7 | 1.7 ± 1.2 | 0.3 ± 0.3 | - | 5.0 ± 1.0 |
| Sea whip | 11.0 ± 3.5 | 13.3 ± 3.2 | 4.7 ± 1.5 | 8.7 ± 2.8 | 5.3 ± 0.7 |
| Tubular sponge | - | - | 0.7 ± 0.7 | - | - |
| *Turbinaria* spp. | 26.3 ± 2.6 | 23.0 ± 2.5 | 1.0 ± 1.0 | 1.0 ± 0.0 | 23.7 ± 11.6 |
| Unidentified polychaetes | - | - | - | 0.3 ± 0.3 | - |
| Unidentified sessile invertebrates | - | 3.7 ± 2.0 | - | 0.3 ± 0.3 | 3.0 ± 1.0 |
| **Mean total abundance per transect** | **161.0 ± 8.1** | **144.0 ± 7.5** | **36.7 ± 5.8** | **68.3 ± 31.5** | **115.0 ± 28.6** |
| **Total number of taxa** | **19** | **17** | **13** | **12** | **18** |

*Note: * Due to poor visibility, video footage quality at BI3 was of low quality on the April 2011 survey.*

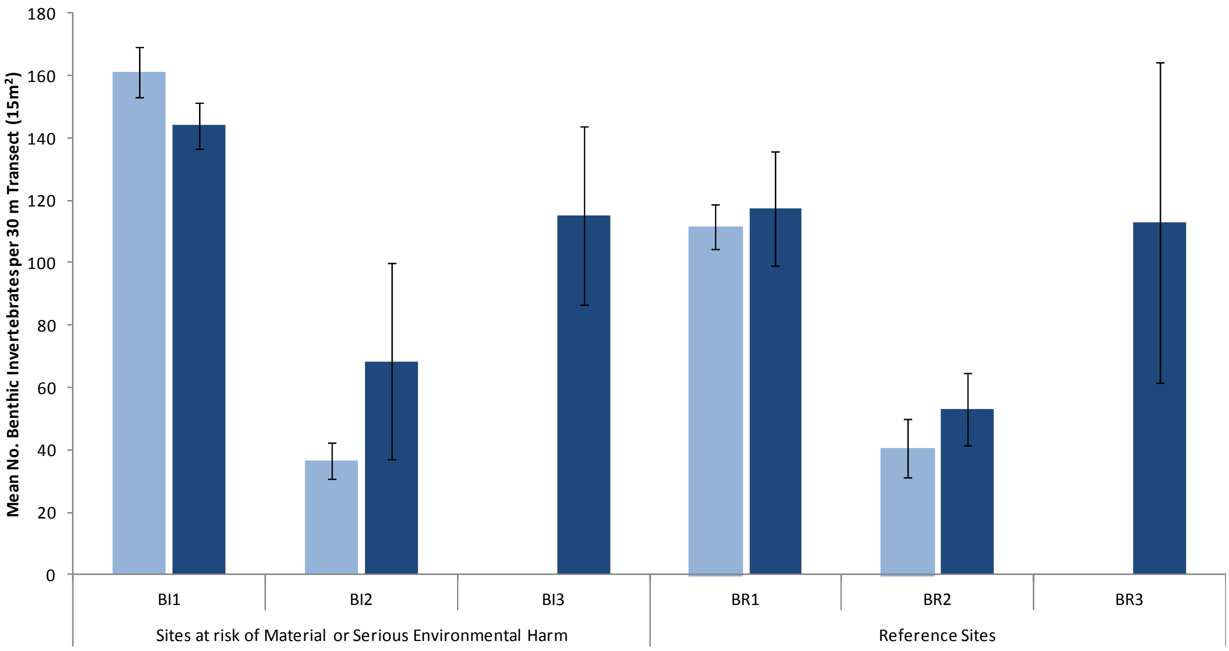



**Figure 7-6 Mean Abundance (± SE) of Sessile Benthic Macroinvertebrates per 30 m Transect (15 m$^2$) at Survey Sites at the Mainland End of the DomGas Pipeline Route**

*Note: light colour = dry season survey; dark colour = wet season survey.*

## 7.4.4 Description of Benthic Macroinvertebrate Assemblages at Reference Sites not at Risk Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

### 7.4.4.1 East Coast of Barrow Island

The highest total mean abundance of benthic macroinvertebrates was recorded at DSS1 (July 2009: 46.3/15 m$^2$ ± 1.2 SE, which equates to ~3.1/m$^2$), and equal highest taxonomic diversity was recorded at DSS1 and TP10 (14 taxa, [including taxonomic group 'unknown'] in July 2009 and November 2008 respectively) (Table 7-6; Figure 7-5). Site TP10 is located on the inshore limestone pavement whilst DSS1 is located further offshore from Barrow Island along the DomGas Pipeline route. Relatively high numbers of sea whips (January 2009: 10.0/15 m$^2$ ± 2.5 SE [~0.7/m$^2$]; July 2009: 12.3/15 m$^2$ ± 0.9 SE [~0.8/m$^2$]) and sponges of various morphologies (e.g. variable sponges in January 2009: 4.3/15 m$^2$ ± 2.0 SE [~0.3/m$^2$]; and flabellate sponges in July 2009: 10.7/15 m$^2$ ± 2.8 SE [~0.7/m$^2$]) were recorded at this site.

Total mean abundance and taxonomic diversity in the November 2008 survey varied between (26.0/15 m$^2$ ± 8.0 SE [~1.7/m$^2$]; 14 taxa) at TP10 and (16.0/15 m$^2$ ± 3.1 SE [~1.1/m$^2$]; ten taxa [including taxonomic group 'unknown']) at TP9, located on the inshore limestone pavement (Table 7-6; Figure 7-5). Ascidians (colonial) were the most abundant benthic macroinvertebrate at TP9 (7.3/15 m$^2$ ± 2.3 SE [0.5/m$^2$]) and variable sponges were the most abundant macroinvertebrate at TP10 (8.7/15 m$^2$ ± 5.2 SE [~0.6/m$^2$]). Sea whips and colonial ascidians were also relatively abundant at TP10 (3.0/15 m$^2$ ± 1.5 SE [~0.2/m$^2$], and 3.3/15 m$^2$ ± 0.3 SE [~0.2/m$^2$] respectively). There were lower abundances of sponges of various morphologies at these sites, and TP10 had the highest abundance of soft corals (from the Alcyoniidae) recorded at any site (4.0/15 m$^2$ ± 0.6 SE [~0.3/m$^2$]).

Total mean abundance (20.0/15 m$^2$ ± 5.8 SE [~1.3/m$^2$]) and taxonomic diversity (12 taxa, including taxonomic group 'unknown') were also relatively high in the January 2009 survey at

LC4, located in the north of the sandy channel east of the inshore limestone pavement (Table 7-6; Figure 7-5). The most abundant benthic macroinvertebrates were sea urchins (6.0/15 $m^2$ ± 3.2 SE [~0.4/$m^2$]), sea whips (3.3/15 $m^2$ ± 1.9 SE [~0.2/$m^2$]), and sponges of various morphologies. Taxonomic diversity declined (five taxa) in the July 2009 survey, and total mean abundance declined substantially to 2.7/15 $m^2$ ± 0.9 SE (~0.2/$m^2$).

Slightly lower total mean abundances and taxonomic diversity were recorded at the two sites DSR5 and DSR6 in the deep soft sediments east of the East Barrow Ridge (Table 7-6; Figure 7-5). Mean total abundances of 11.7/15 $m^2$ ± 2.4 SE [~0.8/$m^2$] were recorded in the January 2009 survey at DSR5, declining to 5.3/15 $m^2$ ± 1.3 SE [~0.4/$m^2$] in the July 2009 survey. At DSR5 the most abundant benthic macroinvertebrates were sea whips (3.0/15 $m^2$ ± 1.0 SE [~0.2/$m^2$]) and variable sponges (3.0/15 $m^2$ ± 1.2 SE [~0.2/$m^2$]) in the January 2009 survey. At DSR6 the most abundant macroinvertebrates were Turbinaria (4.7/15 $m^2$ ± 1.3 SE [~0.3/$m^2$]). Between seven and ten taxa were recorded at both sites during the survey periods (including taxonomic group ‘unknown’).

**Table 7-6 Mean Benthic Macroinvertebrate Abundance (± SE) per 30 m Transect (approximately 15 m²) at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities**

| Benthic Macroinvertebrate | Mean Abundance (± SE) per 30 m Transect (approximately 15 m²) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | LC4 | | DSR5 | | DSR6 | DSS1 | | TP9 | TP10 |
| | Jan 09 | Jul 09 | Jan 09 | Jul 09 | Jan 09 | Jan 09 | Jul 09 | Nov 08 | Nov 08 |
| Ascidian colonial | 0.3 ± 0.3 | - | - | - | 1.7 ± 1.2 | 0.3 ± 0.3 | 4.0 ± 0.6 | 7.3 ± 2.3 | 3.3 ± 0.3 |
| Ascidian solitary | - | 0.3 ± 0.3 | - | - | - | - | 0.7 ± 0.7 | 0.7 ± 0.7 | 1.7 ± 1.2 |
| Crinoid | 2.0 ± 1.0 | - | - | - | - | - | - | - | - |
| Gastropod | 0.3 ± 0.3 | - | - | - | - | - | - | - | - |
| Gorgonian | 1.3 ± 0.3 | - | - | - | - | - | 0.3 ± 0.3 | - | - |
| Hydroid | - | - | 0.3 ± 0.3 | - | 2.3 ± 0.9 | 1.3 ± 1.3 | 0.3 ± 0.3 | 1.0 ± 1.0 | 0.3 ± 0.3 |
| Nudibranch | - | - | - | - | - | - | - | - | - |
| Other soft coral (e.g. Alcyoniidae) | 1.3 ± 0.7 | 0.3 ± 0.3 | - | 1.3 ± 0.7 | 2.3 ± 1.5 | - | 2.0 ± 0.6 | 1.0 ± 1.0 | 4.0 ± 0.6 |
| Sea cucumber | - | - | 1.0 ± 0.6 | 0.3 ± 0.3 | 0.3 ± 0.3 | - | 0.7 ± 0.3 | - | 0.3 ± 0.3 |
| Sea star | - | - | - | - | - | - | - | - | - |
| Sea urchin | 6.0 ± 3.2 | - | 0.7 ± 0.7 | - | - | - | - | - | - |
| Sea whip | 3.3 ± 1.9 | 0.7 ± 0.3 | 3.0 ± 1.0 | 0.7 ± 0.3 | - | 10.0 ± 2.5 | 12.3 ± 0.9 | 1.0 ± 0.6 | 3.0 ± 1.5 |
| Sponge barrel | - | - | - | - | 0.3 ± 0.3 | - | - | 1.7 ± 0.7 | 0.3 ± 0.3 |
| Sponge branching/ arborescent | 1.0 ± 0.6 | 1.0 ± 0.6 | 1.3 ± 0.9 | 0.3 ± 0.3 | - | 2.3 ± 1.5 | 3.7 ± 0.3 | 1.0 ± 0.6 | 1.3 ± 0.9 |
| Sponge cup | - | - | - | - | - | 1.0 ± 0.6 | 2.7 ± 0.3 | - | 0.3 ± 0.3 |
| Sponge digitate | - | - | - | - | - | - | 5.7 ± 2.6 | - | 0.7 ± 0.7 |
| Sponge fan/flabellate | - | - | 0.3 ± 0.3 | 1.3 ± 0.3 | 0.7 ± 0.7 | 3.3 ± 0.9 | 10.7 ± 2.8 | - | 1.0 ± 1.0 |
| Sponge globular | - | - | - | - | 0.3 ± 0.3 | - | - | - | - |
| Sponge tubular | 0.3 ± 0.3 | - | - | - | - | - | 0.3 ± 0.3 | - | - |
| Sponge variable | 3.0 ± 1.5 | - | 3.0 ± 1.2 | - | 1.0 ± 1.0 | 4.3 ± 2.0 | 2.7 ± 1.2 | 0.3 ± 0.3 | 8.7 ± 5.2 |
| Turbinaria | 0.3 ± 0.3 | 0.3 ± 0.3 | 1.3 ± 0.3 | 1.0 ± 0.6 | 4.7 ± 1.3 | 1.0 ± 0.6 | - | 1.7 ± 1.2 | 0.3 ± 0.3 |
| Unknown | 0.7 ± 0.3 | - | 0.7 ± 0.3 | 0.3 ± 0.3 | 0.3 ± 0.3 | - | 0.3 ± 0.3 | 0.3 ± 0.3 | 0.7 ± 0.3 |
| **Mean total abundance per transect** | **20.0 ± 5.8** | **2.7 ± 0.9** | **11.7 ± 2.4** | **5.3 ± 1.3** | **14.0 ± 2.3** | **23.7 ± 3.8** | **46.3 ± 1.2** | **16.0 ± 3.1** | **26.0 ± 8.0** |

*Note: '-' indicates no invertebrates from that taxa were observed*

#### 7.4.4.2 Mainland End of the DomGas Pipeline Route

Benthic macroinvertebrate assemblage composition and abundance varied between the Reference Sites not at risk of Material or Serious Environmental Harm (Table 7-7; Figure 7-6). Differences between the sites were evident in both the September–October 2010 and April 2011 surveys. At the inshore site, BR1, total mean abundance was high, averaging 111.7/15 $m^2$ ± 7.2 SE (which equates to ~7.4/$m^2$) in the September–October 2010 survey and 117.3/15 $m^2$ ± 18.2 SE (~7.8/$m^2$) in the April 2011 survey. At the offshore site, BR2, mean total abundance was low, averaging 40.7/15 $m^2$ ± 9.3 SE (~2.7/$m^2$) in the September–October 2010 survey and 53.0/15 $m^2$ ± 11.5 SE (~3.5/$m^2$) in the April 2011 survey, which was approximately half the abundance of benthic macroinvertebrates recorded at the other two sites. Total mean abundance in the April 2011 survey at the offshore site, BR3, 113.0/15 $m^2$ ± 51.4 SE (~7.5/$m^2$) was largely driven by holothurians, which averaged 88.7/15 $m^2$ ± 38.8 SE (~5.9/$m^2$). Holothurians were not recorded at any other Reference Site in either the September–October 2010 or the April 2011 surveys. Sea whips (9.0/15 $m^2$ ± 3.1 SE [~0.6/$m^2$]) and other taxa were also recorded at BR3 in the April 2011 survey, although in lower numbers.

Cheilostome bryozoans were the most abundant taxa at BR1 in the September–October 2010 survey (21.0/15 $m^2$ ± 4.7 SE [~1.4/$m^2$]), followed by arborescent sponges (14.3/15 $m^2$ ± 2.7 SE [~1.0/$m^2$]), irregular sponges (13.0/15 $m^2$ ± 5.0 SE [~0.9/$m^2$]) and gorgonians (10.0/15 $m^2$ ± 2.0 SE [~0.7/$m^2$]) (Table 7-7). Seasonal differences were evident at BRI, with lower abundance of cheilostome bryozoan and gorgonians recorded in the April 2011 survey. Sea whips (e.g. *Juncella*, *Rumphella*; 19.3/15 $m^2$ ± 4.3 SE [~1.3/$m^2$]), flabellate sponges (15.7/15 $m^2$ ± 2.8 SE [~1.0/$m^2$]) and Alcyoniidae (e.g. *Sacrophyton*, *Lobophytum*, *Sinularia*; 13.3/15 $m^2$ ± 1.5 SE [~0.9/$m^2$]) were the most abundant taxa recorded at BR1 in the April 2011 survey. Seasonal differences were also evident at BR2. Hydroids were the most abundant taxa recorded at BR2 (9.7/15 $m^2$ ± 2.6 SE [~0.6/$m^2$]) in the April 2011 survey. Other taxa recorded at BR2 included irregular sponges (7.3/15 $m^2$ ± 2.7 SE [~0.5/$m^2$]) in the April 2011 survey and arborescent sponges (7.0/15 $m^2$ ± 0.6 SE [~0.5/$m^2$]) in the September–October 2010 survey. While not observed on the video transect footage, the occasional dislodged gorgonian was observed by divers during the April 2011 survey, potentially indicative of cyclone-mediated wave disturbance.

Benthic macroinvertebrate diversity was highest at BR1, with 21 and 19 taxa recorded in the September–October 2010 and April 2011 surveys, respectively (Table 7-7). The number of taxa recorded at BR2 ranged from 14 in the September–October 2010 survey to 15 in the April 2011 survey, while 13 taxa were recorded in the April 2011 survey at BR3.

**Table 7-7 Mean Benthic Macroinvertebrate Abundance (± SE) per 30 m Transect (approximately 15 $m^2$) at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

| Taxonomic Group | Mean Abundance ± SE per 15 $m^2$ | | | | |
|---|---|---|---|---|---|
| | BR1 | | BR2 | | BR3 |
| | Sept–Oct 10 | Apr 11 | Sept–Oct 10 | Apr 11 | Apr 11 |
| Alyconacea (e.g. tree-like - *Litophyton*) | 0.7 ± 0.7 | 1.7 ± 0.7 | - | - | - |
| Alcyoniidae | 1.7 ± 0.9 | 13.3 ± 1.5 | 2.0 ± 0.6 | 1.7 ± 0.7 | 0.3 ± 0.3 |
| Arborescent sponge | 14.3 ± 2.7 | 10.7 ± 4.1 | 7.0 ± 0.6 | 1.0 ± 0.0 | 5.3 ± 5.3 |
| Ascidian | 1.7 ± 0.7 | - | - | 2.0 ± 0.6 | - |
| ‘Assemblage’ sponge | 9.0 ± 1.2 | 1.0 ± 1.0 | 2.7 ± 0.7 | 2.3 ± 1.2 | 1.7 ± 0.9 |
| Asteroid (starfish) | 0.3 ± 0.3 | 0.7 ± 0.3 | - | - | - |
| Barrel sponge | 1.7 ± 0.3 | 1.0 ± 1.0 | - | 0.7 ± 0.3 | 1.0 ± 0.6 |

| Taxonomic Group | Mean Abundance ± SE per 15 m$^2$ | | | | |
|---|---|---|---|---|---|
| | BR1 | | BR2 | | BR3 |
| | Sept–Oct 10 | Apr 11 | Sept–Oct 10 | Apr 11 | Apr 11 |
| Bivalve mollusc | 1.7 ± 0.7 | 1.0 ± 0.6 | - | - | - |
| Cheilostome bryozoan | 21.0 ± 4.7 | 2.7 ± 0.3 | 1.3 ± 0.7 | - | - |
| Crinoid | - | - | - | - | 0.3 ± 0.3 |
| Cup sponge | 1.3 ± 0.3 | 0.3 ± 0.3 | 0.7 ± 0.3 | 0.3 ± 0.3 | 0.3 ± 0.3 |
| *Favia*-type coral | 6.0 ± 1.5 | 5.7 ± 0.3 | 4.3 ± 3.0 | 5.0 ± 2.6 | - |
| Flabellate sponge | 8.7 ± 0.9 | 15.7 ± 2.8 | 1.3 ± 0.7 | 3.3 ± 1.2 | 1.3 ± 0.7 |
| Flat coral (hard) | 1.0 ± 1.0 | 2.0 ± 1.2 | 1.3 ± 0.3 | 0.7 ± 0.7 | - |
| Globular sponge | 0.3 ± 0.3 | - | - | - | - |
| Gorgonian (sea fans) | 10.0 ± 2.0 | 5.3 ± 1.5 | 1.3 ± 0.9 | - | 1.3 ± 0.9 |
| Holothurian | - | - | - | - | 88.7 ± 38.8 |
| Hydroids | 2.3 ± 1.9 | 2.3 ± 1.5 | 4.3 ± 1.3 | 9.7 ± 2.6 | 0.7 ± 0.3 |
| Irregular sponge | 13.0 ± 5.0 | 10.7 ± 2.7 | 4.7 ± 1.9 | 7.3 ± 2.7 | 2.7 ± 1.2 |
| Lace bryozoan | 1.0 ± 0.0 | - | - | - | - |
| ‘Other’ hard coral | 8.0 ± 1.7 | 11.0 ± 1.0 | 3.3 ± 0.9 | 3.3 ± 1.3 | - |
| Sea whip | 2.0 ± 0.0 | 19.3 ± 4.3 | 2.0 ± 0.6 | 7.3 ± 0.9 | 9.0 ± 3.1 |
| Tubular sponge | - | - | - | - | - |
| *Turbinaria* spp. | 6.0 ± 1.5 | 6.0 ± 1.2 | 4.3 ± 3.8 | 5.0 ± 1.2 | 0.3 ± 0.3 |
| Unidentified polychaetes | - | - | - | - | - |
| Unidentified sessile invertebrates | - | 7.0 ± 1.7 | - | 3.3 ± 1.8 | - |
| **Mean total abundance per transect** | **111.7 ± 7.2** | **117.3 ± 18.2** | **40.7 ± 9.3** | **53.0 ± 11.5** | **113.0 ± 51.4** |
| **Total number of taxa** | **21** | **19** | **14** | **15** | **13** |

## 7.5 Discussion and Conclusions

Benthic habitat mapping along the DomGas Pipeline route, indicates that for much of the route between nearshore Barrow Island and the Pilbara coast, the offshore seabed was ‘open bare sand with minimal biota’ with a small offshore area of an ephemeral macroalgae assemblage (*Caulerpa*) some 20 km from Barrow Island (Section 5.3). Between Passage Island and South Passage Island, an area of ‘sand veneer overlying limestone with some attached biota’ occurred, and the nearshore area of the mainland shore crossing consisted of soft sediments without any epifauna.

Benthic macroinvertebrates were generally sparsely distributed and relatively homogenous across broad areas of similar substratum in the waters off the east coast of Barrow Island (Chevron Australia 2013a). Distinct assemblages were observed on the different substrate types (sand or soft sediment and limestone pavement). Benthic macroinvertebrates often occurred with macroalgae, and the only areas where benthic macroinvertebrates were the most common or abundant benthic biota were in the deeper (>10 m) sand habitats, even though they were generally in lower abundances than on limestone pavements. In the waters off the east coast of Barrow Island where the DomGas will tie-in with the LNG Jetty, the DomGas Pipeline overlies habitat categorised as ‘Soft Sediments with Sparse Sessile Taxa’, including sparse sessile benthic macroinvertebrate taxa at subdominant levels of cover. Sea whips, sponges, and Turbinaria were the most abundant of the benthic macroinvertebrates on the sandy substratum in this area. All the benthic macroinvertebrate taxa (including Alyconiidae, ascidians, a variety of different morphological types of sponges, gorgonians, hydroids, sea whips, and *Turbinaria*) at risk of Serious or Material Environmental Harm associated with construction activities, dredging and spoil disposal activities on the east coast of Barrow Island, were also found outside these areas and were well represented elsewhere.

At the mainland end of the DomGas Pipeline route, sessile benthic macroinvertebrate assemblages were generally associated with the outer extremities of reef systems surrounding the offshore islands, in particular in areas with high currents. The sessile benthic macroinvertebrate assemblages were characterised by diverse sponge/octocoral (including sea fans and sea whips) 'gardens' and mainly occurred on sections of reef covered by a veneer of soft sediment. Sessile and mobile benthic macroinvertebrates were also recorded at very low densities on unvegetated soft sediments, which was the dominant habitat type within the study area.

The taxonomic composition of the observed benthic macroinvertebrate fauna at the mainland end of the DomGas Pipeline route was generally comparable to that observed in the waters surrounding Barrow Island, with a dominance of sponges, gorgonians and sea whips, and bryozoans, interspersed with occasional *Turbinaria* spp. and faviid corals. One difference relates to ascidians, which were rarely encountered in the DomGas Pipeline study area at the mainland end, but were common at some Barrow Island survey sites. This may be reflective of higher abundances of fine suspended particles in the inshore areas, which may adversely affect filter feeding by ascidians (e.g. Riisgard 1988). While species composition was comparable with the waters surrounding Barrow Island, overall abundance was generally higher at the mainland end of the DomGas Pipeline route. Mean benthic macroinvertebrate abundances reported from Barrow Island were <50 organisms per 15 $m^2$, whereas at the mainland end of the DomGas Pipeline mean abundances were often >100 organisms per 15 $m^2$. These differences between Barrow Island waters and waters at the mainland end of the DomGas Pipeline are also likely to reflect the relatively high turbidity that prevails in the inshore areas, compared to the offshore oceanic waters surrounding Barrow Island (Section 13.0).

Although the numerical abundance of some groups such as holothurians differed markedly between the dry season and wet season surveys, the overall diversity of benthic macroinvertebrates at sites at the mainland end of the DomGas Pipeline was largely consistent between surveys. However, there was some indication that some differences may be linked to natural disturbance events. The Pilbara coast experiences more cyclones than any other part of Australia, averaging about one every two years (BOM 2011b). Weather patterns in the period preceding the wet season survey were particularly severe, with three cyclones passing close to the study area. Such weather events are likely to have influenced benthic macroinvertebrate assemblages as a result of elevated turbidities and increased wave action. Broken and dislodged gorgonians were evident at some sites in the wet season survey, and were likely to have been dislodged during periods of cyclonic activity. An increased coverage of sediment on sessile benthic macroinvertebrates was also observed during the wet season. While this apparent change was not quantified in these surveys, it is likely to be linked to high rainfall and wave events associated with cyclones. The apparent increase in detritus feeding holothurians (Hopkins 2009), may also reflect a build-up of detritus on the reef edge, potentially related to an increase in detritus following high wave energy events. Alternatively, the apparent differences in holothurian abundance may reflect seasonal differences in their burying behaviour in response to seasonal environmental factors (e.g. Mercier *et al.* 2000; Wolkenhauer 2008), rather than real changes in abundance.

The quantitative baseline surveys undertaken in the Marine Baseline Program indicate there were differences in sessile benthic macroinvertebrate assemblage structure between inshore and offshore sites at the mainland end of the DomGas Pipeline route, a pattern consistent between sites at risk of Material or Serious Environmental Harm and Reference Sites. Inshore/offshore variation persisted between the dry season and wet season surveys, with benthic macroinvertebrate abundance and diversity higher at inshore sites (BI1, BI3 and BR1) than at sites further offshore (BI2, BR2 and BR3). Differences in light regime, sedimentation levels, levels of nutrient matter and/or physical disturbance, which are key determinants of benthic macroinvertebrate assemblage structure (e.g. Dinesen 1983; Palumbi 1984; Wilkinson and Cheshire 1989; Wilkinson and Evans 1989; Carballo 2006) may all have contributed to the observed differences. Inshore sites would be expected to be subject to higher turbidity due to shallower water depths with associated wave-driven turbulence reaching the seabed and closer proximity to inputs of turbid freshwater.

There was no evidence of differences in the mean abundance or assemblage composition of benthic macroinvertebrates between sites at risk of Material or Serious Environmental Harm and Reference Sites at the mainland end of the DomGas Pipeline route. Patterns of broad equivalence between sites at risk of Material or Serious Environmental Harm and Reference Sites were maintained in both the dry and wet season surveys.

# 8.0 Macroalgae

## 8.1 Introduction

The macroalgal flora of tropical northern Australia are relatively poorly known compared to temperate regions and there have been few systematic collections undertaken to date (Huisman and Borowitzka 2003) There is a marine flora checklist for the Dampier Archipelago, which identifies some 210 species (Huisman and Borowitzka 2003). This includes 114 species of red algae (Rhodophyta), 50 species of green algae (Chlorophyta), 32 species of brown algae (Heterokontophyta, Phaeophyceae), and five species of blue-green algae (Cyanophyta). Fifty-seven species were new records for Western Australia and five were new records for Australia. More than 90 species of macroalgae have been identified in Barrow Island waters during the Marine Baseline Program, including some 40 species of red algae, 29 species of green algae, 24 species of brown algae, and one blue-green species (Cyanophyta) (Chevron Australia 2013a, 2011b).

The macroalgal assemblages are typically dominated by species of brown algae, particularly of the genera *Sargassum*, *Dictyopteris, Turbinaria* and *Padina* (Chevron Australia 2005, 2013a, 2011b; DEC 2007). Other common taxa include *Halimeda*, *Dictyopteris*, *Dictyota*, *Cystoseira*, *Codium*, and *Laurencia*. Green algae from the genera *Caulerpa, Cladophora* and *Halimeda* and red algae from the genera *Centroceras*, *Ceramium*, *Champia*, *Chondria*, *Gelidiopsis*, and *Hypnea* are dominant or widespread off the east coast of Barrow Island (Chevron Australia 2005, 2011b, 2013a; DEC 2007; RPS Bowman Bishaw Gorham 2007). Some species, such as *Avrainvillea* sp. and *Halimeda macroloba*, appear to be restricted to the east coast of Barrow Island (Chevron Australia 2005). One species—*Gracilaria urvillei*—is known only from Barrow Island (Chevron Australia 2005).

Macroalgal-dominated limestone reef and subtidal reef platform/sand mosaic are the most extensive habitat types in the Montebello/Barrow Islands region (DEC 2007), including in the waters around Barrow Island (Chevron Australia 2011b, 2013a). The extensive subtidal macroalgae communities are major benthic primary producers, significantly contributing to the productivity of the region, as well as providing refuge areas for fish and invertebrates (DEC 2007). Macroalgal assemblages were commonly recorded on limestone pavement in depths of 5 to 10 m and were the most common ecological element along the shallow shelf of the east coast of Barrow Island and on the East Barrow Ridge (DEC 2007; Chevron Australia 2013a). Macroalgal assemblages were also common across the shallow limestone pavement of the Southern Lowendal Shelf that extends north towards the Montebello Islands. Macroalgae often co-occurred in lower abundance with seagrass and non-coral benthic macroinvertebrates. Macroalgae were not common on soft sediments, and low percentage cover was recorded on substrate comprising thick sand veneer over limestone pavement and on sand on the east coast of Barrow Island, with little-to-no macroalgae recorded in the deeper sand areas, e.g. between the broad, shallow limestone platform adjacent to the east coast of Barrow Island and the East Barrow Ridge (Chevron Australia 2013a). Macroalgal habitats in the Montebello/Barrow Islands region vary seasonally in response to water temperature, day length, reproductive cycles, physical disturbance and regrowth (DEC 2007; Chevron Australia 2013a).

At North Whites Beach on the west coast of Barrow Island, macroalgae species grow on the shallow subtidal pavement reef at varying densities (Chevron Australia 2005). Macroalgae species are particularly dense in reef fissures and holes. Macroalgal beds were also reported on the high profile reefs that stand up to three metres above the seabed in nearshore waters of approximately 5 to 10 m water depth (Chevron Australia 2005). The macroalgae assemblages found on the limestone reef off North Whites Beach include *Sargassum* spp., *Dictyopteris* spp. and *Halimeda* spp. (Chevron Australia 2005). Seventy-eight species of macroalgae (42 red algae, 19 green algae, 17 brown algae) and one cyanobacterium, have been recorded in the intertidal area on the west coast of Barrow Island (RPS 2009a). Common species at all sites included *Sargassum* spp., *Sirophysalis trinodis,* and *Cystoseira* sp.; the majority of the other species were recorded in low densities. Subtidal macroalgal assemblages were recorded on the shallow limestone pavement, with overlying sand veneer, near North Whites Beach, where the brown algae (*Sargassum* and *Dictyopteris* spp.) and the green alga (*Halimeda* spp.) were dominant in terms of percentage cover (Chevron Australia 2011b). Macroalgae were also recorded in deeper State waters off the west coast of Barrow Island, although average percentage cover was low (Chevron Australia 2011b).

Macroalgal habitat along the DomGas Pipeline route between Barrow Island and the mainland is sparse, limited by sediment type and increasing turbidity with proximity to the coast (Chevron Australia 2005). A survey of benthic habitats along the Domestic Gas Pipeline route recorded substantial amounts of the macroalga *Caulerpa* (estimated 75% coverage) at a location approximately 18 km off the south-east coast of Barrow Island (URS 2009). Elsewhere, *Caulerpa* was recorded only in isolated small patches. Small patches of *Sargassum* (<5% total cover) were observed near South Passage Island, which appeared to be associated with an area of shallow sand overlying a flat platform. Sparse *Halimeda*, *Caulerpa*, and *Penicillus* were observed in the shallow subtidal zone, probably exposed on extremely low tides (Chevron Australia 2005).

## 8.2 Scope

This Section records the existing dominant species of macroalgae (Condition 14.8.iii, Statement No. 800; Condition 11.8.III, EPBC Reference: 2003/1294 and 2008/4178) and describes and maps the macroalgae:

- that are at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iii, Statement No. 800; Condition 11.6.III EPBC Reference: 2003/1294 and 2008/4178)
- at Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iv, Statement No. 800; Condition 11.6.IV, EPBC Reference: 2003/1294 and 2008/4178).

Baseline surveys have been undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800 and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178.

## 8.3 Methods

### 8.3.1 Site Locations: East Coast of Barrow Island

Ten macroalgal survey sites were selected within areas where macroalgae were identified as being present through broadscale habitat mapping and ground-truthing off the east coast of Barrow Island (Section 5.1). Two sites (TP4 and TPC3) were located within the DomGas Pipeline Marine Disturbance Footprint; i.e. in areas at risk of Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline (Table 8-1; Figure 8-1). Three sites (TP5, TP6 and TP2) were located in the Dredge Management Areas (Zone of High Impact and Zone of Moderate Impact) associated with the generation of turbidity and sediment deposition from dredging and spoil disposal activities on the east coast of Barrow Island (Section 2.3.4). One site (TPC1) was located in the indicative anchoring area. Four Reference Sites (LC4, DSS1, TP9 and TP10) were located in the surrounding waters and are not at risk of Material or Serious Environmental Harm due to the construction or operation of the Marine Facilities. For information on other macroalgae survey sites on the east coast of Barrow Island, refer to Chevron Australia (2013a). Note that macroalgae survey sites were also seagrass and non-coral benthic macroinvertebrate survey sites where these ecological elements co-occurred in the same area.

### Table 8-1 Macroalgal Survey Sites in Waters off the East Coast of Barrow Island

| Location | Site Code | Easting | Northing | Latitude | Longitude | Survey Date | | |
|---|---|---|---|---|---|---|---|---|
| | | (GDA94, MGA Zone 50) | | (GDA94) | | Nov 08 | Jan 09 | Jul 09 |
| At risk of Material or Serious Environmental Harm | TP4* | 342407 | 7698457 | 20° 48.428' S | 115° 29.143' E | X | | X |
| | TPC3* | 342101 | 7694972 | 20° 50.315' S | 115° 28.947' E | | X | |
| | TP5* | 342085 | 7699098 | 20° 48.079' S | 115° 28.961' E | X | | X |
| | TP6* | 342238 | 7699286 | 20° 47.978' S | 115° 29.050' E | | | X |
| | TP2* | 342235 | 7700923 | 20° 47.091' S | 115° 29.057' E | X | | X |
| Indicative Anchoring Area | TPC1* | 342628 | 7694475 | 20° 50.587' S | 115° 29.249' E | | X | |
| Reference Sites | LC4* | 344832 | 7698996 | 20° 48.148' S | 115° 30.543' E | | X | X |
| | DSS1* | 347316 | 7687119 | 20° 54.598' S | 115° 31.913' E | | X | X |
| | TP9* | 341069 | 7695738 | 20° 49.895' S | 115° 28.357' E | X | | X |
| | TP10* | 337827 | 7694122 | 20° 50.754' S | 115° 26.479' E | X | | |

** Denotes a sampling site located in a Dredge Management Area. Source: Chevron Australia (2013a).*

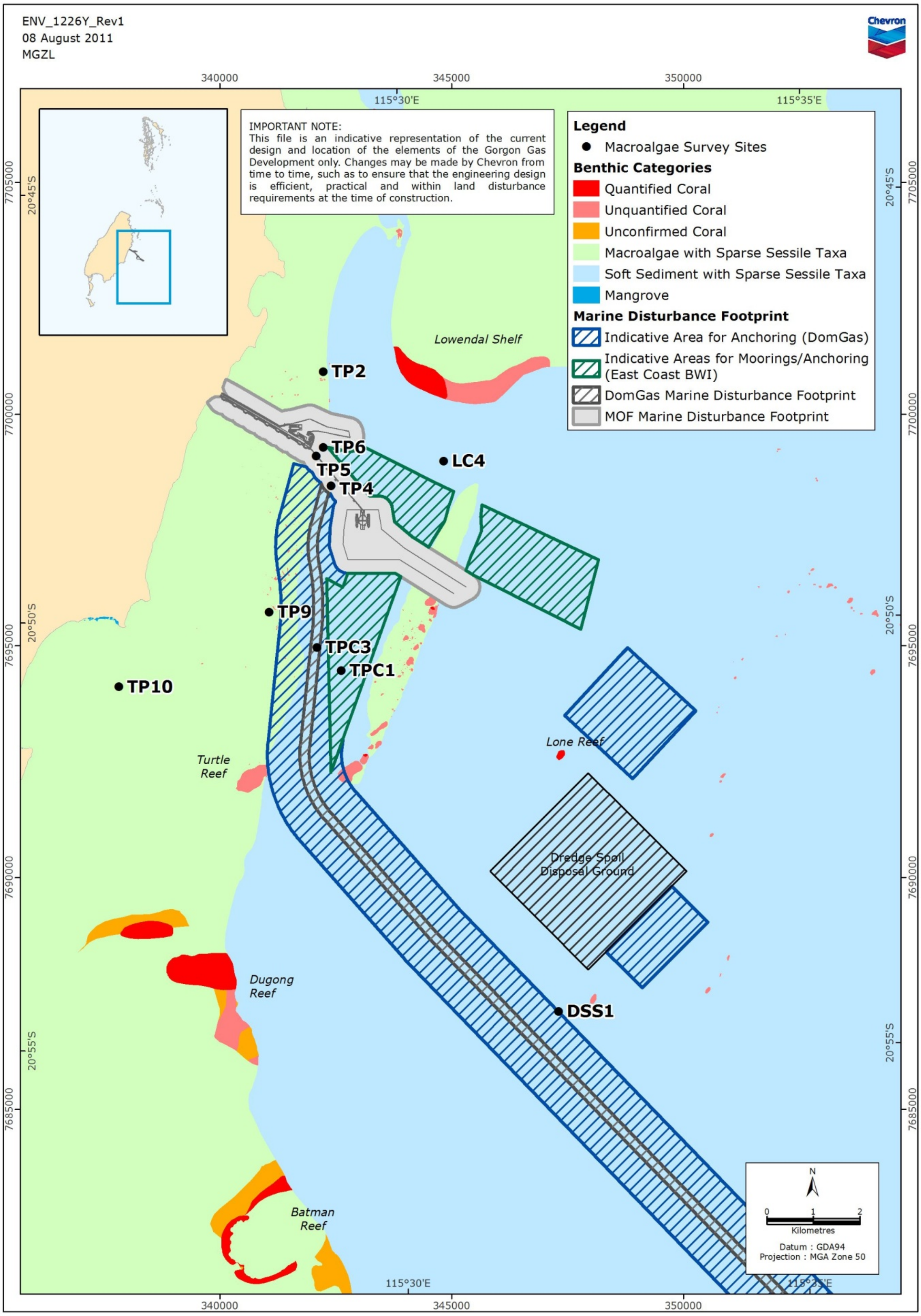



**Figure 8-1 Macroalgae Survey Sites in Waters off the East Coast of Barrow Island**

### 8.3.2 Site Locations: Mainland End of the DomGas Pipeline Route

Four macroalgae survey sites were located within areas where macroalgae were identified as being present through broadscale habitat mapping and ground-truthing (Section 5.4) at the mainland end of the DomGas Pipeline route (Table 8-2; Figure 8-2). Two sites (MAI1, MAI2) were located in areas at risk of Material or Serious Environmental Harm within the trenching and jetting Marine Disturbance Footprint; and two Reference Sites (MAR1, MAR2) were located in areas not at risk of Material or Serious Environmental Harm, outside the trenching and jetting Marine Disturbance Footprint (Section 2.3.3.2). Macroalgal abundance was the primary factor determining the selection of survey sites. Macroalgae were generally associated with the outer edges of the intertidal reef flats around the offshore islands in the study area (e.g. Angle Island, Passage Island, South Passage Island, Solitary Island and Cowle Island). Sites were selected to ensure that macroalgae were the dominant ecological element, based on the Barrow Island Habitat Classification Scheme (Section 5.2.2; Appendix 2). The sites were located in depths of <0.5 m to 2.5 m.

**Table 8-2 Macroalgal Survey Sites at the Mainland End of the DomGas Pipeline Route**

| Location | Site Code | Easting | Northing | Latitude | Longitude | Survey Date | |
|---|---|---|---|---|---|---|---|
| | | (GDA94, MGA Zone 50) | | (GDA94) | | Sept–Oct 10 | Apr 11 |
| At risk of Material or Serious Environmental Harm | MAI1 | 374984 | 7656623 | 21° 11.252' S | 115° 47.739' E | X | X |
| | MAI2 | 374122 | 7666175 | 21° 06.071' S | 115° 47.283' E | X | X |
| Reference Sites | MAR1 | 376512 | 7668193 | 21° 04.987' S | 115° 48.672' E | X | X |
| | MAR2 | 367236 | 7661459 | 21° 08.598' S | 115° 43.284' E | X | X |

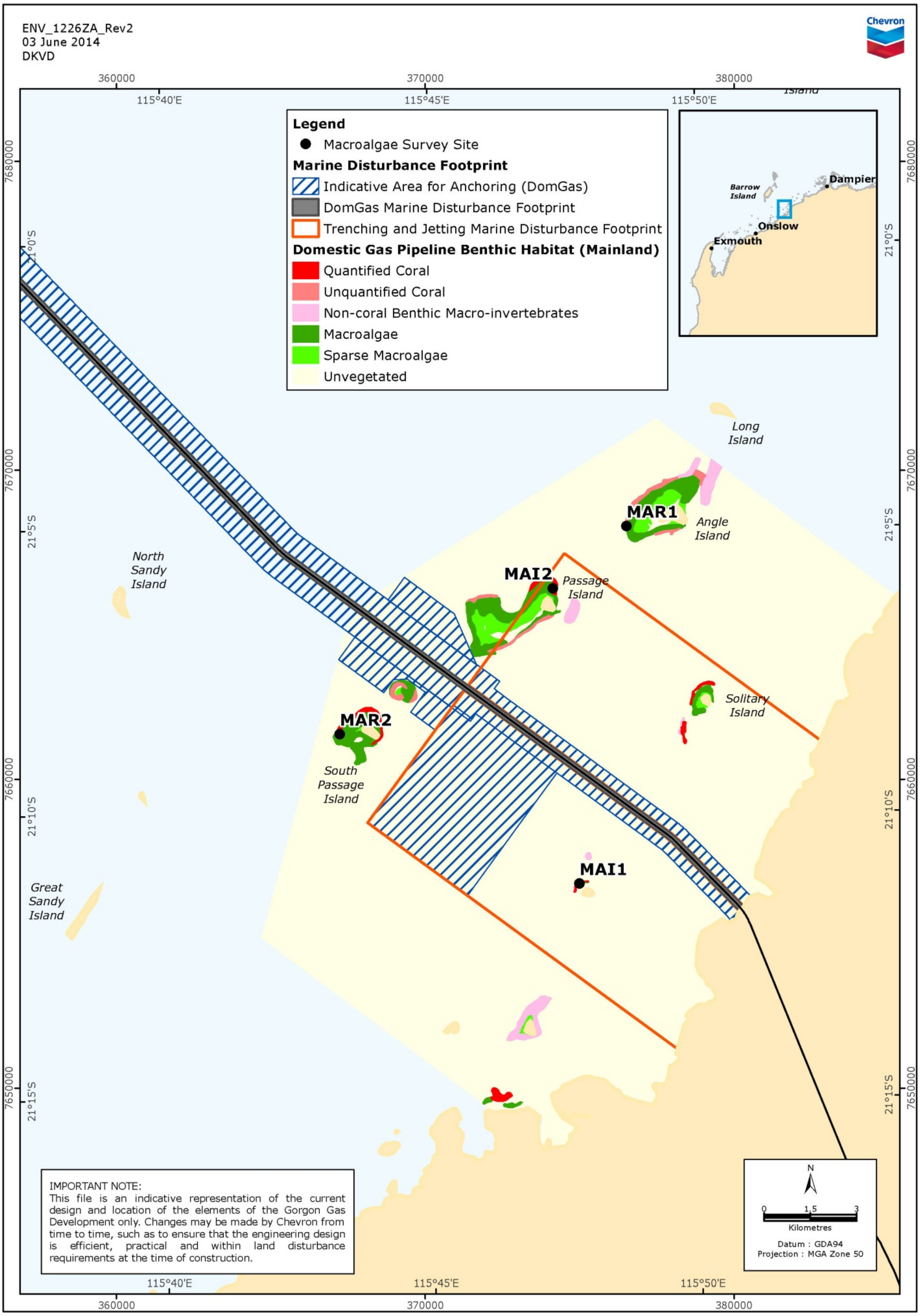



**Figure 8-2 Macroalgae Survey Sites at the Mainland End of the DomGas Pipeline Route**

### 8.3.3 Methods

At each site, three 30 m length transects were laid out from a central point. The first transect was orientated parallel to the vessel's anchor line and the other two orientated at approximately ± 90° to the first transect. The coordinates of the start point of each transect were recorded using GPS.

A total area of 1 $m^2$ (either 1 $m^2$ or, in conditions of poor visibility, four 0.25 $m^2$ sub-quadrats positioned adjacent to each other to form 1 $m^2$) was photographed at 5 m intervals along the right side of each transect (i.e. a total of seven locations along each transect). The macroalgae species present in the quadrat (or sub-quadrat) were recorded, and the percentage cover was estimated in situ by divers. The macroalgae species present in each quadrat (or sub-quadrat) were identified to the lowest reliable taxonomic level (to genus and species level where possible). Voucher samples of those species that could not be reliably identified in the field were collected, preserved, and catalogued for identification by Dr John Huisman (Western Australian Herbarium/Murdoch University).

In the November 2008 and January 2009 surveys, the macroalgae in two 0.25 $m^2$ sub-quadrats along each transect were collected for total biomass measurement (i.e. a total of six samples per site). A quadrat was located at 10 m and 20 m intervals along the left side of each transect. In the July 2009, October 2010, and April 2011 surveys, the macroalgae in two 0.25 $m^2$ sub-quadrats were collected from each of 10 m and 20 m intervals (Barrow Island), or 10 m and 25 m intervals (mainland), along each transect (i.e. a total of 12 samples per site). If a quadrat was located on bare sand, no biomass sample was collected. Samples were blot-dried and total wet weight recorded. On those occasions where the biomass samples of macroalgae and seagrass could not be easily separated, combined wet weight results have been presented.

### 8.3.4 Timing and Frequency of Surveys

Sampling was undertaken in the waters off the east coast of Barrow Island during November 2008, January 2009, and July 2009. At sites at the mainland end of the DomGas Pipeline route, sampling was undertaken during the dry season (September–October 2010) and the wet season (April 2011). The wet season survey was originally scheduled to be undertaken in February 2011; however, some field activities in the wet season were delayed until April 2011 due to the passage of tropical cyclones, adverse weather conditions or logistical constraints.

### 8.3.5 Treatment of Survey Data

Digital images were analysed using Coral Point Count with Excel extensions (CPCe; Kohler and Gill 2006). Thirty random points were overlaid over each 1 $m^2$ image and each point visually classified by a trained scorer into the broad categories of benthic cover (macroalgae, seagrass, coral, non-coral benthic macroinvertebrates, sand, pavement, rubble and 'unidentified'). Where 0.25 $m^2$ sub-quadrats were photographed, the thirty points were spread across the four images. The percentage of all points scored for each broad category of benthic cover was calculated and the mean (± Standard Error [SE]) percentage cover was determined.

## 8.4 Results

### 8.4.1 Distribution of Macroalgae in Waters Surrounding the DomGas Pipeline Route

#### 8.4.1.1 Distribution of Macroalgae in Barrow Island Waters

Figure 8-3 shows the spatial distribution of macroalgae in Barrow Island waters as point (presence/absence) observations derived from broadscale mapping and ground-truthing. 'Null observations' were recorded where macroalgae were not observed during ground-truthing.

In summary, macroalgal assemblages were commonly recorded on limestone pavement in depths of 5 to 10 m and were the most common ecological element along the shallow shelf off the east coast of Barrow Island and on the East Barrow Ridge (Chevron Australia 2013a).

Macroalgae often co-occurred in lower abundance with seagrass and non-coral benthic macroinvertebrates. Macroalgal assemblages were also common across the shallow limestone pavement of the Southern Lowendal Shelf that extends north towards the Montebello Islands. Macroalgae were not common on soft sediments and low percentage covers were recorded on substrata comprising a thick sand veneer over limestone pavement and on sand. There were little-to-no macroalgae observed in the deeper sand area between the broad, shallow limestone platform adjacent to the east coast of Barrow Island and the East Barrow Ridge.

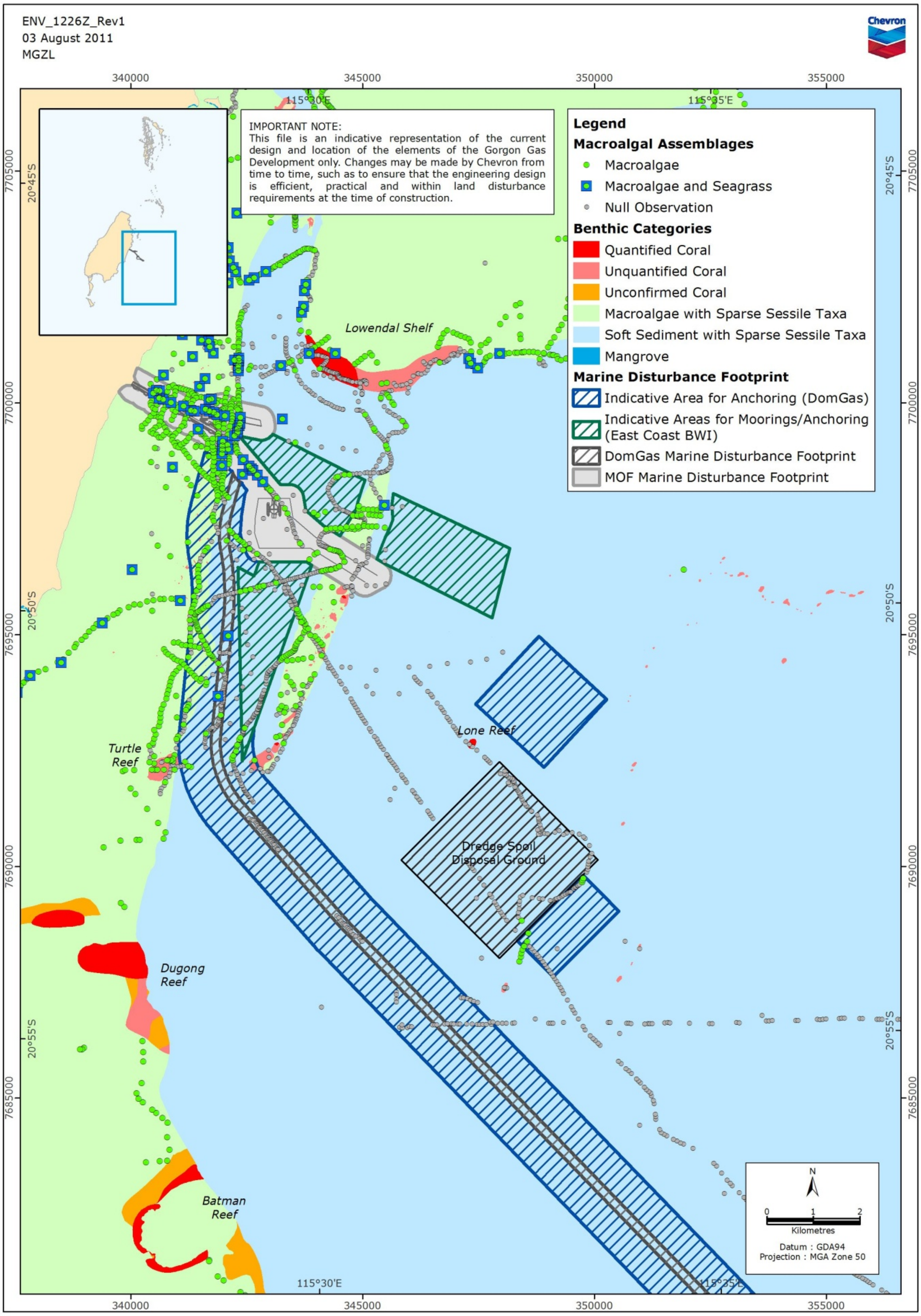



**Figure 8-3 Observations of Macroalgae in the Waters around Barrow Island**

#### 8.4.1.2 Distribution of Macroalgae at the Mainland End of the DomGas Pipeline Route

The spatial distribution of macroalgae at the mainland end of the DomGas Pipeline route is shown in Figure 8-4. The map is based primarily on macroalgae presence/absence derived from observations made during broadscale surveys (towed video) and in-water ground-truthing (Section 5.4). 'Null observations' were recorded where macroalgae were not observed during ground-truthing.

Macroalgal assemblages were generally associated with fringing reefs surrounding the islands in the study area, where they were observed in shallow depths (0.5 to 4 m) (Section 5.4.4). A general pattern for these fringing reefs was the occurrence of coral-dominated habitats on the outer reef edge (Section 6.3.3.1.3), with macroalgal assemblages the dominant ecological element on the inside margin of the coral assemblages and the adjacent reef flats (Figure 8-4).

Macroalgae, mainly *Caulerpa cupressoides*, were also observed on the soft sediments that dominated the study area (Section 5.4.4). *Caulerpa cupressoides* was recorded at a low percentage cover (<1%) amongst sparse seagrass assemblages (Section 9.4.1.2).

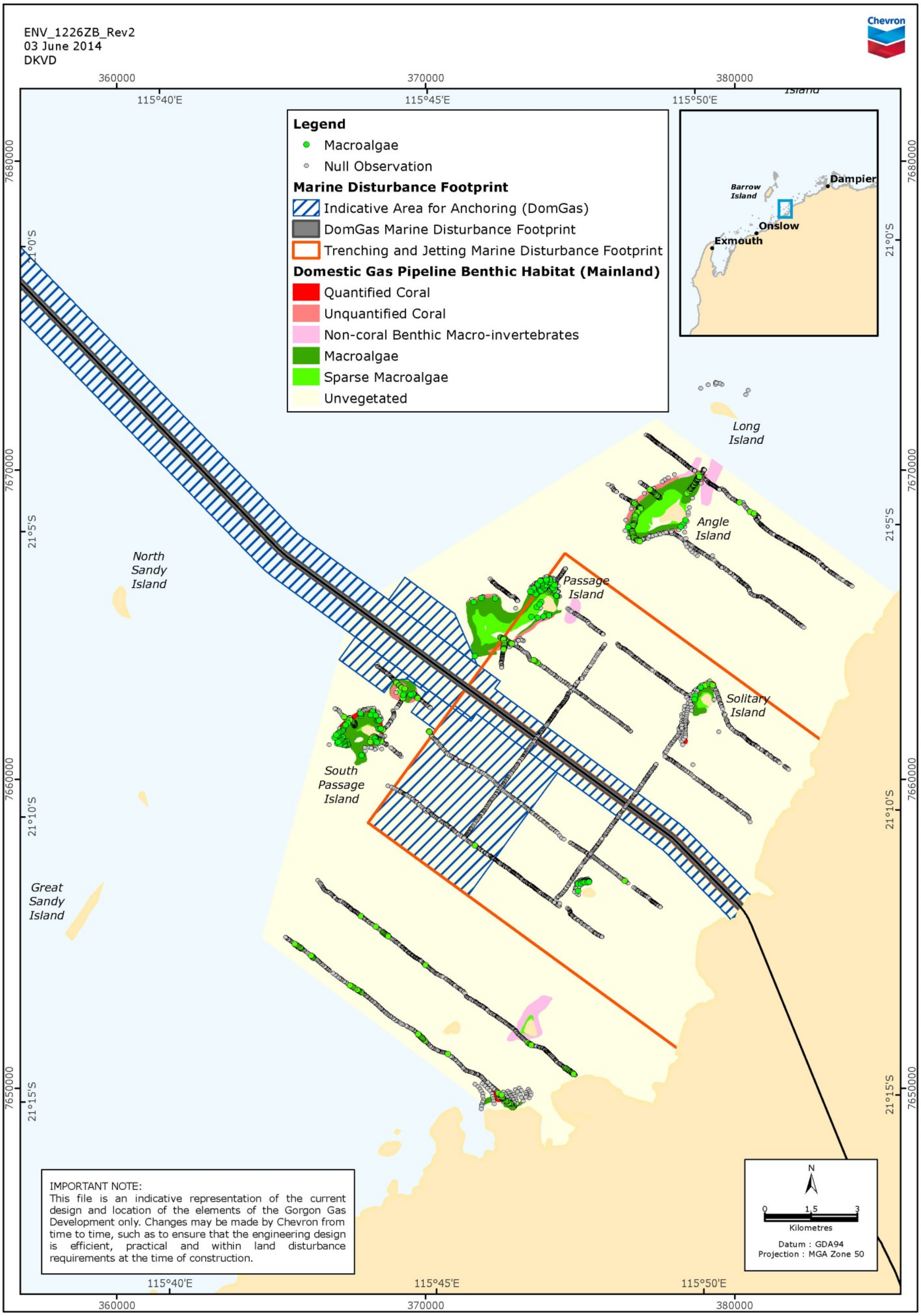



**Figure 8-4 Observations of Macroalgae at the Mainland End of the DomGas Pipeline Route**

### 8.4.2 Dominant Macroalgae Species

#### 8.4.2.1 Barrow Island waters

In summary, the dominant (or most common) macroalgae in terms of percentage cover recorded in Barrow Island waters were the brown algae and green algae (Chevron Australia 2013a). The dominant brown algae were *Dictyopteris* spp., including *D. australis*, *D. serrata* and *D. woodwardii*; *Padina* spp., including *P. australis*, *P. boryana* and an unidentified *Padina* sp.; *Sargassum* spp., including *S. oligocystum*, as well as two unidentified *Sargassum* species (*Sargassum* sp.1 and *Sargassum* sp.2) and *Sargassopsis decurrens* (formerly *Sargassum decurrens*) (Plate 8-1). The dominant green algae were *Halimeda* cf. *cuneata*, *Caulerpa corynephora*, and *C. cupressoides* (Plate 8-1). The red algae were numerically dominant but, due to their generally small growth morphology and epiphytic habit, occupied a smaller percentage of the substratum than the other algal divisions. The less abundant species by percentage cover and occurrence were the brown alga *Encyothalia cliftoni* and the green alga *Udotea argentea*.

Different survey techniques were used for the various components of the Marine Baseline Program, and these all contributed to the systematic compilation of the macroalgae reported in Barrow Island waters. In summary, ninety-one species of macroalgae were identified in Barrow Island waters during the Marine Baseline Program (Table 8-3), including 35 species of red algae (Rhodophyta), 27 species of brown algae (Phaeophyta), 28 species of green algae (Chlorophyta), and one blue-green species (Cyanophyta) (Chevron Australia 2013a). Many of these species were epiphytic on macroalgae.

**Table 8-3 Macroalgae Species Identified in Barrow Island Waters**

| Rhodophyta | Phaeophyta | Chlorophyta | Cyanophyta |
|---|---|---|---|
| *Acrochaetium* sp. | *Dictyopteris australis* | *Avrainvillea obscura* | *Calothrix* sp. |
| *Aglaothamnion cordatum* | *Dictyopteris serrata* | *Bornetella oligospora* | |
| *Amphiroa fragilissima* | *Dictyopteris* sp. | *Caulerpa brachypus* | |
| *Anotrichium tenue* | *Dictyopteris woodwardii* | *Caulerpa cactoides* | |
| *Asparagopsis taxiformis* | *Dictyota* sp. | *Caulerpa corynephora* | |
| *Centroceras clavulatum* | *Encyothalia cliftoni* | *Caulerpa cupressoides* | |
| *Champia parvula* | *Feldmannia* sp. | *Caulerpa cupressoides* var. *mamillosa* | |
| *Champia* sp. | *Hincksia mitchelliae* | *Caulerpa lentillifera* | |
| *Chondria* sp. | *Hormophysa cuneiformis* | *Caulerpa racemosa* var. *lamourouxii* | |
| *Chondrophycus* sp. | *Hydroclathrus clathratus* | *Caulerpa serrulata* | |
| *Coelarthrum cliftonii* | *Lobophora variegata* | *Cualerpa* sp. | |
| *Coelothrix irregularis* | *Padina australis* | *Cladophora catenata* | |
| *Cottoniella filamentosa* | *Padina boryana* | *Cladophora vagabunda* | |
| Crustose coralline algae sp. | *Padina* sp. | *Codium dwarkense* | |
| *Dasya* sp. | Phaeophyceae sp. (turf) | *Halimeda cuneata* | |
| *Desikacharyella indica* | *Sargassum carpophyllum* | *Halimeda discoidea* | |
| *Galaxaura rugosa* | *Sargassopsis decurrens*[1] | *Halimeda* cf. *cuneata* | |
| *Galaxaura* sp. | *Sargassum oligocystum* | *Halimeda* cf. *discoidea* | |
| *Gayliella flaccida* | *Sargassum peronii* | *Halimeda lacunalis* | |
| *Griffithsia* sp. | *Sargassum* sp. | *Halimeda macroloba* | |
| *Haliptilon roseum* | *Sargassum* sp. 1 | *Halimeda* sp. | |
| *Herposiphonia secunda* | *Sargassum* sp. 2 | *Penicillus nodulosus* | |
| *Heterosiphonia callithamnion* | *Sargassum* sp. 3 | *Penicillus* sp. | |

| Rhodophyta | Phaeophyta | Chlorophyta | Cyanophyta |
|---|---|---|---|
| *Heterosiphonia crassipes* | *Sirophysalis trinodis*[2] | *Udotea argentea* | |
| *Hypnea pannosa* | *Spatoglossum macrodontum* | *Udotea flabellum* | |
| *Jania rosea* | *Sphacelaria rigidula* | *Udotea glaucescens* | |
| *Jania* sp. | *Sporochnus comosus* | *Udotea orientalis* | |
| *Laurencia* sp. | | *Udotea* sp. | |
| *Leveillea jungermannoides* | | | |
| *Lophocladia* sp. | | | |
| *Placophora binderi* | | | |
| *Platysiphonia delicata* | | | |
| *Polysiphonia* sp. | | | |
| *Spyridia filamentosa* | | | |
| *Tolypiocladia glomerulata* | | | |

*Notes:*

1. *This species has had a recent change of taxonomic identity, formerly* Sargassum decurrens *(Dr J. Huisman).*
2. *This species has had a recent change of taxonomic identity, formerly* Cystoseira trinodis *(Dr J. Huisman).*

*Dictyopteris* sp.

*Padina* sp.

*Sargassopsis decurrens**

*Halimeda* cf. *cuneata*

*Caulerpa corynephora*

*Caulerpa cupressoides*

**Plate 8-1 Brown and Green Macroalgae in Waters Around Barrow Island**

*Note: * This species has had a recent change of taxonomic identity, formerly* Sargassum decurrens.

#### 8.4.2.2 Mainland End of the DomGas Pipeline Route

Brown macroalgae were the most abundant macroalgae observed at the survey sites in terms of percentage cover and biomass. *Sargassum* spp. were generally the dominant taxa observed in both surveys, often exceeding 70% cover (Plate 8-2). *Sargassum* species could not be identified to species level in the September–October 2010 survey since fertile reproductive structures required for identification were not present. In the April 2011 survey, *Sargassum* species could be separated into separate taxonomic groupings and two species were observed (*Sargassum illicifolium* and *S. aquifolium*), along with the closely related *Sargassopsis decurrens*. Another species with a morphological resemblance to *Sargassum*, *Sirophysalis trinodis* (formerly *Cystoseira trinodis*), was also common in the April 2011 survey (in situ percentage cover estimates up to 40% were recorded in quadrats). Other subdominant brown algal taxa commonly observed in both surveys included *Padina australis* and *Lobophora variegata*. Drift plants of the brown alga *Turbinaria* sp. were frequently observed in the study area in the September–October 2010, but not in the April 2011 survey. Attached *Turbinaria* sp. plants were not recorded during either survey.

Green algae were rarely observed in the study area. Of the green algae identified, *Halimeda* cf. *cuneata* and *Caulerpa* sp. were the most frequently observed taxa. Abundance of red algae was also generally very low within the study area during both survey periods (CPCe analysis: mean cover <1%).

There were some distinct seasonal differences in terms of the macroalgal species observed during site surveys. The ephemeral brown algae *Sporochnus comosus* was abundant on some reefs in the September–October 2010 survey (in situ percentage cover estimates up to 40% were recorded in quadrats), but declined dramatically between the September–October 2010 and April 2011 surveys. The seasonal nature of *S. comosus* was evident in the April 2011 survey, with only the occasional degraded plant observed with correspondingly low levels of cover (maximum in situ percentage cover estimate 1%). Similarly, *Dictyopteris* spp. (*D. australis* and *D. woodwardi*) were relatively common in the September–October 2010 survey (in situ percentage cover estimate 3.5%, averaged across all sites), but were not recorded in the April 2011 survey. Epiphytic algae were also observed on *Sargassum* plants. While differences between seasons could not be quantified, epiphytic species (particularly red algal species) appeared more prominent in the September–October 2010 survey (Plate 8-2).

Macroalgal assemblage composition varied slightly depending on the distance offshore in the dry season survey. *Sargassum* spp. were the most common species at offshore sites (e.g. Passage Island, South Passage Island), while on an unnamed reef located south-west of the pipeline route and north-east of Cowle Island, macroalgal community structure tended to be dominated by smaller species such as *Dictyopteris* spp. and *Padina australis*. Whilst a notable pattern in the dry season survey, these differences were not as distinct in the wet season survey due to the increased abundance of *Sargassum illicifolium* at the unnamed reef. Macroalgae at other inshore locations were not quantified in the September–October 2010 or April 2011 surveys, so the generality of this pattern remains unclear.

Different survey techniques were used for the various components of the Marine Baseline Program, and these all contributed to the systematic compilation of the macroalgae reported at the mainland end of the DomGas Pipeline route. Thirty species of macroalgae were identified in waters at the mainland end of the DomGas Pipeline route during the Marine Baseline Program, including sixteen species of brown algae (Phaeophyta), nine species of red algae (Rhodophyta), and five species of green algae (Chlorophyta) (Table 8-4). Epiphytic macroalgae were recorded, in particular in the dry season when red algal epiphytes were common (e.g. *Champia* sp., *Hypnea spinella*, *Jania adhaerens*).

## Table 8-4 Macroalgae Species Identified at the Mainland End of the DomGas Pipeline Route

| Rhodophyta | Phaeophyta | Chlorophyta |
|---|---|---|
| *Amphiroa foliacea* | *Canistrocarpus cervicornis* | *Caulerpa* sp. |
| *Amphiroa* sp. | *Colpomenia* sp. | *Caulerpa cupressoides* |
| *Asparagopsis taxiformis* | *Dictyopteris australis* | *Halimeda cuneata* |
| *Champia* sp.* | *Dictyopteris woodwardi* | *Neomeris* sp. |
| *Galaxaura rugosa* | *Hincksia mitchelliae** | *Udotea* sp. |
| *Hypnea spinella** | *Hormophysa cuneiformis* | |
| *Jania adhaerens** | *Lobophora variegata* | |
| *Laurencia brongniartii* | *Padina australis* | |
| *Laurencia* sp. | *Sporochnus comosus* | |
| | *Sporochnus* cf. *bolleanus* | |
| | *Sargassum aquifolium* | |
| | *Sargassum ilicifolium* | |
| | *Sargassopsis decurrens*[1] | |
| | *Sirophysalis trinodis*[1] | |
| | *Sphacelaria rigidula* | |
| | *Turbinaria* sp.[2] | |

*Notes: * are epiphytic algae.*

1. Sargassopsis decurrens *(formerly* Sargassum decurrens*) and* Sirophysalis trinodis *(formerly* Cystoseira trinodis*) have had recent changes to taxonomic identity (Dr J. Huisman).*
2. Turbinaria *sp. was observed as a drift plant in the September–October 2010 survey and was not observed during the April 2011 survey or as an attached specimen.*

*Sirophysalis trinodis*

Macroalgal assemblage dominated by *Dictyopteris* spp.

Epiphytic cover on *Sargassum* sp.

*Sargassum ilicifolium*

**Plate 8-2 Brown Macroalgae and Epiphytic Cover at the Mainland End of the DomGas Pipeline Route**

### 8.4.3 Description of the Macroalgae at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

#### 8.4.3.1 East Coast of Barrow Island

Estimates of mean macroalgal percentage cover (0.2% ± 0.2 SE in November 2008; 0.3% ± 0.2 SE in July 2009), biomass and total number of species (four) recorded at TP4 (Table 8-5), were generally lower than at sites located on the adjacent limestone pavements. TP4 was located in the deeper sand substrates in the channel between the limestone pavement adjacent to Town Point and East Barrow Ridge. Occasional *Udotea* spp. and *Caulerpa* spp. were identified from towed video camera footage of the sandy substrate located between the limestone pavement adjacent to Town Point and East Barrow Ridge, and occasionally further east in deeper water (Figure 8-3). Other taxa observed at TP4 included Corallinaceae, *Galaxaura* sp., *Dictyopteris* sp., *Sargassum* sp. and *Penicillus* sp.

*Sargassum* spp., *Caulerpa* spp. and *Halimeda* spp. were recorded at TPC3, located south of Town Point on the slope between the limestone pavement and the deeper sand channel (Table 8-5). All 12 species recorded at this site were sparse in cover, with no species estimated as covering more than 1%.

Mean macroalgal percentage cover and biomass were highest at the three sites located on the inshore limestone pavement (TP5, TP6 and TP2) in both the November 2008 and July 2009 surveys (Table 8-5). Mean macroalgal biomass in the November 2008 survey was 528.0 g wet weight/$m^2$ ± 179.1 SE at TP5, where eight species were recorded. Estimates of mean biomass were lower in the July 2009 survey, varying between ~115–240 g wet weight/$m^2$, with between six and eight species recorded. Percentage cover varied between ~5–12% in the November 2008 survey and ~4–11% in the July 2009 survey. *Padina australis*/*Padina boryana* and *Sargassum oligocystum* were the most abundant species recorded at TP5 in the November 2008 survey (diver visual estimate ~15% and 10% cover respectively); and *Dictyopteris australis* was the only species recorded at TP2 in the November 2008 survey (diver visual estimate ~10% cover). Other taxa observed at TP5 include *Anotrichium tenue*, *Gayliella flaccida*, *Hypnea pannosa*, *Polysiphonia* sp., *Dictyota* sp., Phaeophycea sp., *Sphacelaria rigidula*, *Caulerpa lentillifera*, *Caulerpa serrulata*, *Penicillus* sp., and *Coelothrix irregularis*. Other taxa observed at TP6 include *Dictyota* sp., *Padina* sp., Phaeophyceae sp., and *Penicillus* sp.; and at TP2, include *Dictyota* sp., *Padina* sp., *Halimeda* sp., and *Udotea* sp.

In the January 2009 survey, sparse percentage cover (diver visual estimate <1%) of three macroalgae species was recorded at TPC1, located in the sandy channel between the inshore limestone pavement on the east coast of Barrow Island and the East Barrow Ridge (Table 8-5). No macroalgae were recorded in the biomass quadrats sampled at this site.

### Table 8-5 Mean Macroalgal Percentage Cover (± SE), Mean Total Biomass (± SE) and Dominant Species at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

<table>
<tr><th rowspan="2">Site</th><th colspan="2">Mean % Cover ± SE</th><th colspan="2">Mean Biomass ($g/m^2$) ± SE</th><th colspan="2">No. Dominant Species</th><th colspan="2">Dominant Species</th></tr>
<tr><th>Nov 08/ Jan 09</th><th>Jul 09</th><th>Nov 08/ Jan 09</th><th>Jul 09</th><th>Nov 08/ Jan 09</th><th>Jul 09</th><th>Nov 08/ Jan 09</th><th>Jul 09</th></tr>
<tr><td rowspan="4">TP4</td><td rowspan="4">0.2 ± 0.2 (22)</td><td rowspan="4">0.3 ± 0.2 (21)</td><td rowspan="4">No samples in quadrats</td><td rowspan="4">No samples in quadrats</td><td rowspan="4">2</td><td rowspan="4">3</td><td>*Udotea argentea*</td><td>Not recorded</td></tr>
<tr><td>Not recorded</td><td>*Caulerpa cactoides*</td></tr>
<tr><td>Not recorded</td><td>Phaeophyceae spp.</td></tr>
<tr><td colspan="2">*Tolypiocladia glomerulata*</td></tr>
<tr><td rowspan="12">TPC3</td><td rowspan="12">Photographs could not be analysed by CPCe</td><td rowspan="12">Not surveyed</td><td rowspan="12">Macroalgae and Seagrass combined wet weight only</td><td rowspan="12">Not surveyed</td><td rowspan="12">12</td><td rowspan="12">Not surveyed</td><td>*Avrainvillea obscura*</td><td rowspan="12">Not surveyed</td></tr>
<tr><td>*Bornetella oligospora / Codium dwarkense*</td></tr>
<tr><td>*Caulerpa cupressoides*</td></tr>
<tr><td>*Caulerpa lentillifera*</td></tr>
<tr><td>*Codium dwarkense*</td></tr>
<tr><td>*Galaxaura rugosa*</td></tr>
<tr><td>*Halimeda discoidea*</td></tr>
<tr><td>*Halimeda macroloba*</td></tr>
<tr><td>*Penicillus nodulosus*</td></tr>
<tr><td>Phaeophyceae sp.</td></tr>
<tr><td>*Sargassum* sp.3</td></tr>
<tr><td>*Udotea flabellum / U. orientalis*</td></tr>
<tr><td rowspan="9">TP5</td><td rowspan="9">12.0 ± 2.56 (18)</td><td rowspan="9">10.5 ± 2.7 (19)</td><td rowspan="9">528.0 ± 179.1 (5)</td><td rowspan="9">241.9 ± 49.0 (10)</td><td rowspan="9">8</td><td rowspan="9">8</td><td colspan="2">*Caulerpa cactoides*</td></tr>
<tr><td>*Chondrophycus* sp.</td><td>Not recorded</td></tr>
<tr><td>*Dictyopteris australis*</td><td>*Dictyopteris* sp.</td></tr>
<tr><td colspan="2">*Galaxaura rugosa*</td></tr>
<tr><td colspan="2">*Padina australis / Padina boryana*</td></tr>
<tr><td>Not recorded</td><td>*Sargassum carpophyllum*</td></tr>
<tr><td colspan="2">*Sargassopsis decurrens*</td></tr>
<tr><td colspan="2">*Sargassum oligocystum*</td></tr>
<tr><td colspan="2">*Udotea orientalis*</td></tr>
</table>

| Site | Mean % Cover ± SE | | Mean Biomass (g/m²) ± SE | | No. Dominant Species | | Dominant Species | |
|---|---|---|---|---|---|---|---|---|
| | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 |
| TP6 | Not surveyed | 4.3 ± 0.9 (21) | Not surveyed | 127.0 ± 19.0 (9) | Not surveyed | 6 | Not surveyed | *Caulerpa lentillifera* |
| | | | | | | | | *Dictyopteris* sp. |
| | | | | | | | | *Halimeda discoidea* |
| | | | | | | | | *Jania* sp. |
| | | | | | | | | *Sargassum* sp. |
| | | | | | | | | *Udotea argentea* |
| TP2 | 5.1 ± 1.6 (21) | 10.0 ± 1.9 (21) | No samples collected | 115.4 ± 64.5 (12) | 1 | 7 | *Dictyopteris australis* | *Dictyopteris australis* |
| | | | | | | | Not recorded | *Asparagopsis taxiformis* |
| | | | | | | | Not recorded | *Caulerpa brachypus* |
| | | | | | | | Not recorded | *Caulerpa cactoides* |
| | | | | | | | Not recorded | *Galaxaura rugosa* |
| | | | | | | | Not recorded | Phaeophyceae spp. |
| | | | | | | | Not recorded | *Sargassum* sp. |
| TPC1 | Photographs could not be analysed by CPCe | Not surveyed | No samples in quadrats | Not surveyed | 3 | Not surveyed | *Halimeda macroloba* | Not surveyed |
| | | | | | | | *Penicillus* sp. | |
| | | | | | | | *Udotea* sp. | |

*Note: n = number of photo-quadrats sampled*.

#### 8.4.3.2 Mainland End of the DomGas Pipeline Route

Macroalgal assemblage composition and abundance varied between sites at risk of Material or Serious Environmental Harm, and between the September–October 2010 and April 2011 surveys, with the differences most pronounced in the September–October 2010 survey (Table 8-6; Figure 8-5). At MAI1, mean macroalgal percentage cover increased from 22.0% ± 2.3 SE during the September–October 2010 survey to 53.4% ± 3.8 SE in the April 2011 survey, with a corresponding increase in biomass from 188.3 g wet weight/$m^2$ ± 86.3 SE in the September–October 2010 survey to 1586.7 g wet weight/$m^2$ ± 347.9 SE in the April 2011 survey. Ten macroalgal species were recorded at MAI1 in the September–October 2010 survey, including *Dictyopteris* spp., *Padina australis*, and *Lobophora variegata*. *Sargassum* spp. were recorded at very low levels (in situ visual estimate, mean cover per quadrat <2%). There were seasonal differences in species composition at MAI1, which were reflected in the lower number of taxa recorded in the April 2011 survey. Only four taxa were recorded in the April 2011 survey, Halimeda *cuneata, Lobophora variegata*, encrusting coralline algae and *Sargassum illicifolium*; Dictyopteris spp., and *Padina australis* were not recorded. *Sargassum* spp. increased, with mean in situ estimates of *Sargassum illicifolium* cover per quadrat >30% in the April 2011 survey.

At MAI2, mean percentage cover (September–October 2010: 88.5% ± 5.2 SE; April 2011: 77.0% ± 8.3 SE) and biomass (September–October 2010: 2125.7 g wet weight/$m^2$ ± 299.1 SE; April 2011: 1616.7 g wet weight/$m^2$ ± 673.6 SE) were high in both surveys, corresponding with high cover of brown macroalgae. *Sargassum* spp. were the dominant taxa observed in both surveys. The relative abundance of *Sporochnus comosus* was also very high in some quadrats in the September–October 2010 survey (in situ visual estimates up to 40%). Twelve taxa were recorded at MAI2 in the April 2011 survey, compared to seven in the September–October 2010 survey. This difference can partly be attributed to improved taxonomic information in relation to *Sargassum* species, which could be identified to separate species in the April 2011 survey. Whilst overall diversity was comparable between the surveys at MAI2, differences in species composition were apparent, with several taxa only recorded from one survey. Other notable differences between the surveys were the declines in *Dictyopteris* spp., *Sporochnus comosus* and epiphytic red algae that occurred at MAI2 between the September–October 2010 and April 2011 surveys.

**Table 8-6 Mean Macroalgal Percentage Cover (± SE) and Mean Total Biomass (± SE) at Sites at Risk of Material and Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

<table>
<tr><th rowspan="2">Site</th><th colspan="2">Mean % Cover ± SE</th><th colspan="2">Mean Biomass (g/m²) ± SE</th><th colspan="2">No. Species</th><th colspan="2">Species</th></tr>
<tr><th>Sept–Oct 10</th><th>Apr 11</th><th>Sept–Oct 10</th><th>Apr 11</th><th>Sept–Oct 10</th><th>Apr 11</th><th>Sept–Oct 10</th><th>Apr 11</th></tr>
<tr><td rowspan="10">MAI1</td><td rowspan="10">22.0 ± 2.3</td><td rowspan="10">53.4 ± 3.8</td><td rowspan="10">188.3 ± 86.3</td><td rowspan="10">1586.7 ± 347.9</td><td rowspan="10">10</td><td rowspan="10">4</td><td>*Caulerpa* sp.</td><td>Not recorded</td></tr>
<tr><td>*Colpomenia* sp.</td><td>Not recorded</td></tr>
<tr><td>*Dictyopteris* spp. (*D. australis/ D. woodwardii*)</td><td>Not recorded</td></tr>
<tr><td colspan="2">Encrusting coralline algae spp.</td></tr>
<tr><td>Epiphytic red algae (*Champia* sp./ *Hypnea spinella/ Jania adhaerens)*</td><td>Not recorded</td></tr>
<tr><td>*Galaxaura rugosa*</td><td>Not recorded</td></tr>
<tr><td colspan="2">*Halimeda cuneata*</td></tr>
<tr><td colspan="2">*Lobophora variegata*</td></tr>
<tr><td>*Padina australis*</td><td>Not recorded</td></tr>
<tr><td>*Sargassum* spp.[1]</td><td>*Sargassum illicifolium*</td></tr>
<tr><td rowspan="15">MAI2</td><td rowspan="15">88.5 ± 5.2</td><td rowspan="15">77.0 ± 8.3</td><td rowspan="15">2125.7 ± 299.1</td><td rowspan="15">1616.7 ± 673.6</td><td rowspan="15">7</td><td rowspan="15">12</td><td>Not recorded</td><td>*Amphiroa* sp.</td></tr>
<tr><td>*Caulerpa* sp.</td><td>Not recorded</td></tr>
<tr><td>*Dictyopteris* spp. (*D. australis/ D. woodwardia*)</td><td>Not recorded</td></tr>
<tr><td>Not recorded</td><td>Encrusting coralline algae spp.</td></tr>
<tr><td>Epiphytic red algae (*Champia* sp./ *Hypnea spinella/ Jania adhaerens)*</td><td>Not recorded</td></tr>
<tr><td colspan="2">*Halimeda cuneata*</td></tr>
<tr><td>Not recorded</td><td>*Galaxaura rugosa*</td></tr>
<tr><td>Not recorded</td><td>*Laurencia brongniartii*</td></tr>
<tr><td colspan="2">*Lobophora variegata*</td></tr>
<tr><td>Not recorded</td><td>*Padina australis*</td></tr>
<tr><td rowspan="3">*Sargassum* spp.[1]</td><td>*Sargassum aquifolium*</td></tr>
<tr><td>*Sargassum illicifolium*</td></tr>
<tr><td>*Sargassopsis decurrens*</td></tr>
<tr><td>Not recorded</td><td>*Sirophysalis trinodis*</td></tr>
<tr><td colspan="2">*Sporochnus comosus*</td></tr>
</table>

*Note:* Sargassum *spp. could not be identified in the dry season due to the lack of reproductive structures. Combined visual estimate of* Sargassum *spp. in the dry season may have included* Sargassopsis decurrens.

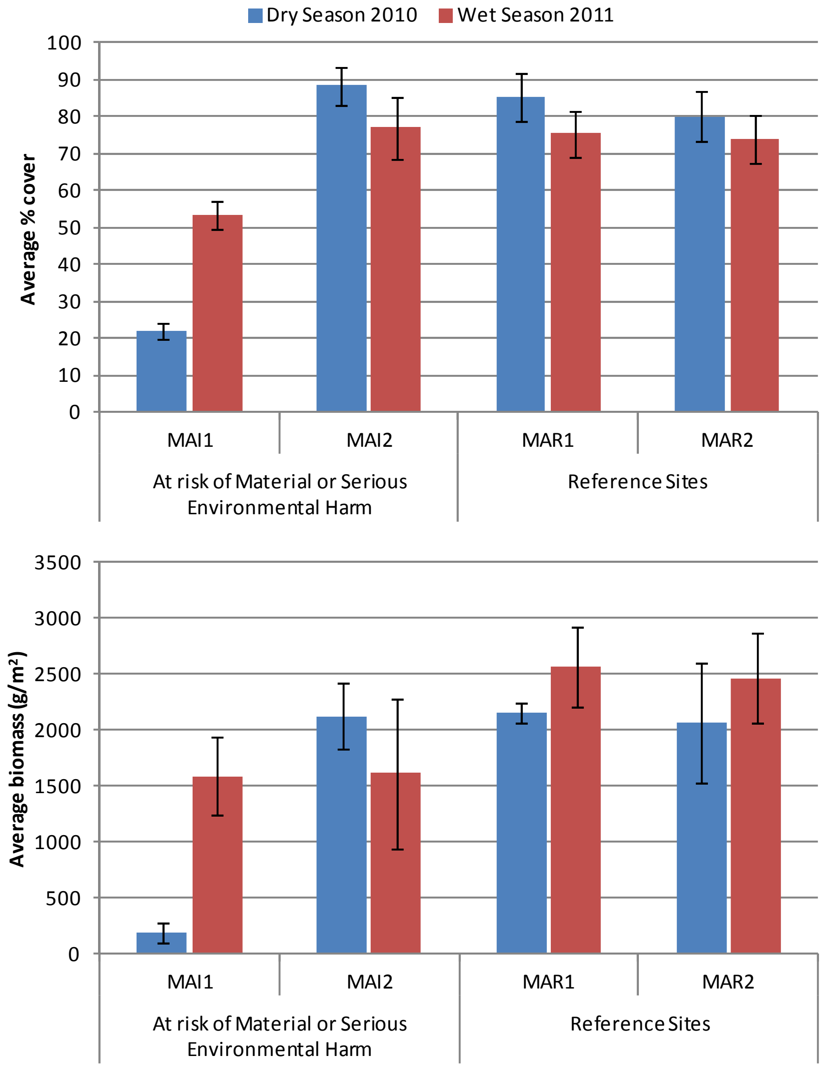



**Figure 8-5 Macroalgal Abundance as estimated by (a) % Cover (± SE) and (b) Biomass (± SE)**

## 8.4.4 Description of the Macroalgae at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

### 8.4.4.1 East Coast of Barrow Island

Mean macroalgal percentage cover at the two sites on the inshore limestone pavement south of Town Point (TP9 and TP10) varied between ~8–12% in the November 2008 survey (Table 8-7). At both sites, mean macroalgal biomass was >900 g wet weight/$m^2$. *Dictyopteris australis* was the most abundant species (diver visual estimate 15% cover) at TP9 and *Halimeda* cf. *cuneata* (diver visual estimate ~25% cover) at TP10 in the November 2008 survey. *Halimeda* cf. *cuneata* also occurred at TP9 and *Udotea argentea* at TP10, but both were much sparser in cover (diver visual estimate 1% at each site). *Padina* sp. was also recorded at both sites (diver visual estimate ~1% cover at each site). Estimates of mean percentage cover, biomass and species diversity were markedly lower in the July 2009 survey at TP9. Other taxa observed at TP9 included Corallinaceae, *Galaxaura* sp., *Dictyopteris* sp., *Dictyota* sp., and *Caulerpa* sp.; and at TP10 included *Centroceras clavulatum*.

At DSS1, mean percentage macroalgal cover was not recorded in the January 2009 survey and was nil in the July 2009 survey (Table 8-7). No macroalgae were recorded in the biomass quadrats in either of the surveys. The two dominant species observed on the transects at this site in the January 2009 survey (*Halimeda macroloba* and *Udotea glaucescens*) had very sparse cover (diver visual estimate <1%). Other taxa observed at DSS1 included, Corallinaceae, *Galaxaura* sp. and *Udotea* sp.

Sparse cover (visual estimate <1%) of one macroalgae species (*Halimeda cuneata*) was recorded on the transects at LC4, located in the sandy channel east of the inshore limestone pavement, in January 2009 (Table 8-7). No macroalgae were recorded in the biomass quadrats sampled at this site.

## Table 8-7 Mean Macroalgal Percentage Cover (± SE), Mean Total Biomass (± SE) and Dominant Species at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities

<table>
<tr><th rowspan="2">Site</th><th colspan="2">Mean % Cover ± SE</th><th colspan="2">Mean Biomass ($g/m^2$) ± SE</th><th colspan="2">No. Dominant Species</th><th colspan="2">Dominant Species</th></tr>
<tr><th>Nov 08/ Jan 09</th><th>Jul 09</th><th>Nov 08/ Jan 09</th><th>Jul 09</th><th>Nov 08/ Jan 09</th><th>Jul 09</th><th>Nov 08/ Jan 09</th><th>Jul 09</th></tr>
<tr><td>LC4</td><td>Photographs could not be analysed by CPCe</td><td>Photographs could not be analysed by CPCe</td><td>No samples in quadrats</td><td>No samples in quadrats</td><td>1</td><td>0</td><td>Halimeda cuneata</td><td>No sample</td></tr>
<tr><td rowspan="3">DSS1</td><td rowspan="3">Photographs could not be analysed by CPCe</td><td rowspan="3">0.0 ± 0.0<br>(19)</td><td rowspan="3">No samples in quadrats</td><td rowspan="3">No samples in quadrats</td><td rowspan="3">2</td><td rowspan="3">1</td><td>Halimeda macroloba</td><td>. Not recorded</td></tr>
<tr><td>Udotea glaucescens</td><td>Not recorded</td></tr>
<tr><td>Not recorded</td><td>Phaeophyceae spp.</td></tr>
<tr><td rowspan="4">TP9</td><td rowspan="4">11.6 ± 2.4<br>(20)</td><td rowspan="4">0.6 ± 0.6<br>(20)</td><td rowspan="4">1306.7 ± 275.<br>3<br>(6)</td><td rowspan="4">149.2 ± 110.4<br>(2)</td><td rowspan="4">4</td><td rowspan="4">2</td><td>Dictyopteris australis</td><td>Not recorded</td></tr>
<tr><td>Halimeda cf. cuneata</td><td>Not recorded</td></tr>
<tr><td colspan="2">Padina sp.</td></tr>
<tr><td colspan="2">Sargassum sp.</td></tr>
<tr><td rowspan="5">TP10</td><td rowspan="5">7.9 ± 1.0<br>(21)</td><td rowspan="5">Not surveyed</td><td rowspan="5">933.3 ± 161.9<br>(6)</td><td rowspan="5">Not surveyed</td><td rowspan="5">5</td><td rowspan="5">Not surveyed</td><td>Caulerpa cupressoides var. mamillosa</td><td rowspan="5">Not surveyed</td></tr>
<tr><td>Halimeda cf. cuneata</td></tr>
<tr><td>Padina sp.</td></tr>
<tr><td>Spyridia filamentosa</td></tr>
<tr><td>Udotea argentea</td></tr>
</table>

*Note: n = number of photo-quadrats sampled*.

#### 8.4.4.2 Mainland End of the DomGas Pipeline Route

Macroalgal assemblage composition and abundance were similar at the Reference Sites MAR1 and MAR2 and in the September–October 2010 and April 2011 surveys (Table 8-8; Figure 8-5). Seasonal differences in total macroalgal cover and biomass were not evident at the Reference Sites. Mean macroalgal percentage cover and biomass were high at both sites in the September–October 2010 and April 2011 surveys, exceeding mean percentage cover of 70% and 2000 g wet weight/m$^2$. *Sargassum* spp. were consistently the dominant taxa observed in both surveys. In the April 2011 survey, the dominant species was *Sargassum illicifolium*, with mean in situ estimates per quadrat >55% cover across both sites.

Macroalgal diversity ranged from three species at MAR1 in the September–October 2010 survey, to nine species at the same site in the April 2011 survey. Although overall diversity and community structure at the level of broad taxonomic groupings were relatively consistent, some differences in species composition were apparent between the two surveys. Consistent with the patterns recorded for sites at risk of Material or Serious Environmental Harm, *Dictyopteris* spp. and epiphytic red algae were recorded in the September–October 2010 survey, but not in the April 2011 survey. The brown macroalga *Sirophysalis trinodis* was recorded at both sites in the April 2011 survey (in situ visual estimate, mean cover per quadrat 6% across both sites), but was not recorded in the September–October 2010 survey. Other differences in species composition were driven by relatively small species and were not consistent between the sites (e.g. *Amphiroa foliacea* and *Galaxaura rugosa* recorded in the April 2011 survey at MAR1; *Caulerpa* sp. recorded in the September–October 2010 survey at MAR2).

**Table 8-8 Mean Macroalgal Percentage Cover (± SE) and Mean Total Biomass (± SE) at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

<table>
<tr><th rowspan="2">Site</th><th colspan="2">Mean % Cover ± SE</th><th colspan="2">Mean Biomass (g/m$^2$) ± SE</th><th colspan="2">No. Species</th><th colspan="2">Species</th></tr>
<tr><th>Sept–Oct 10</th><th>Apr 11</th><th>Sept–Oct 10</th><th>Apr 11</th><th>Sept–Oct 10</th><th>Apr 11</th><th>Sept–Oct 10</th><th>Apr 11</th></tr>
<tr><td rowspan="11">MAR1</td><td rowspan="11">85.6 ± 6.6[1]</td><td rowspan="11">75.4 ± 6.0</td><td rowspan="11">2153.7 ± 93.3</td><td rowspan="11">2570.0 ± 360.7</td><td rowspan="11">3</td><td rowspan="11">9</td><td>Not recorded</td><td>Amphiroa foliacea</td></tr>
<tr><td>Dictyopteris spp. (D. Australis / D. woodwardia)</td><td>Not recorded</td></tr>
<tr><td>Not recorded</td><td>Encrusting coralline algae sp.</td></tr>
<tr><td>Epiphytic red algae (Champia sp. / Hypnea spinella / Jania adhaerens)</td><td>Not recorded</td></tr>
<tr><td>Not recorded</td><td>Galaxaura rugosa</td></tr>
<tr><td>Not recorded</td><td>Halimeda cuneata</td></tr>
<tr><td>Not recorded</td><td>Lobophora variegata</td></tr>
<tr><td>Not recorded</td><td>Padina australis</td></tr>
<tr><td rowspan="2">Sargassum spp.[2]</td><td>Sargassum illicifolium</td></tr>
<tr><td>Sargassopsis decurrens</td></tr>
<tr><td>Not recorded</td><td>Sirophysalis trinodis</td></tr>
<tr><td rowspan="13">MAR2</td><td rowspan="13">80.1 ± .9</td><td rowspan="13">73.8 ± 6.5</td><td rowspan="13">2066.7 ± 529.7</td><td rowspan="13">2465.0 ± 400.8</td><td rowspan="13">8</td><td rowspan="13">7</td><td>Caulerpa sp.</td><td>Not recorded</td></tr>
<tr><td>Dictyopteris spp. (D. australis / D. woodwardia)</td><td>Not recorded</td></tr>
<tr><td>Encrusting coralline algae spp.</td><td>Not recorded</td></tr>
<tr><td>Epiphytic red algae (Champia sp. / Hypnea spinella / Jania adhaerens)</td><td>Not recorded</td></tr>
<tr><td colspan="2">Lobophora variegata</td></tr>
<tr><td>Not recorded</td><td>Neomeris sp.</td></tr>
<tr><td colspan="2">Padina australis</td></tr>
<tr><td rowspan="3">Sargassum spp.[2]</td><td>Sargassum aquifolium</td></tr>
<tr><td>Sargassum illicifolium</td></tr>
<tr><td>Sargassopsis decurrens</td></tr>
<tr><td>Not recorded</td><td>Sirophysalis trinodis</td></tr>
<tr><td>Sporochnus comosus</td><td>Not recorded</td></tr>
</table>

*Notes:*

1. *Due to poor visibility, images used for CPCe analysis for MAR1 were of low quality.*
2. Sargassum *spp. could not be identified in the dry season due to the lack of reproductive structures. Combined visual estimate of* Sargassum *spp. in the dry season could have included* Sargassopsis decurrens*.*

## 8.5 Discussion and Conclusions

Benthic habitat mapping along the DomGas Pipeline route, indicates that for much of the route between nearshore Barrow Island and the Pilbara coast, the offshore seabed was 'open bare sand with minimal biota' with a small offshore area of an ephemeral macroalgae assemblage (*Caulerpa*) some 20 km from Barrow Island (Section 5.3). Elsewhere, macroalgae (*Caulerpa*) were only observed in isolated small patches. Between Passage Island and South Passage Island, an area of 'sand veneer overlying limestone with some attached biota' occurred, and the nearshore area of the mainland shore crossing consisted of soft sediments without any epifauna.

In summary, macroalgal assemblages represent the most extensive ecological element in the waters off the east coast of Barrow Island (Chevron Australia 2013a). Percentage cover, biomass and species richness (excluding turfing and crustose coralline algae) of macroalgae assemblages were spatially variable, both between and within sites; however, percentage cover and biomass were generally highest on the areas of shallow limestone pavements and lowest on soft sediments. The limestone platform off the east coast of Barrow Island was dominated by macroalgal assemblages with sparse sessile taxa. The macroalgal assemblage was dominated by mixed Phaeophyceae (including *Sargassum* spp. [*S. oligocystum* and *Sargassum* sp.], *Sargassopsis decurrens*, *Dictyopteris* spp., *Padina* spp. [*P. australis* and *P. boryana*]) and mixed Chlorophyta (particularly, *Halimeda cuneata* and *Udotea* spp. [*Udotea* sp., *U. argentea*, *U. orientalise*]). Offshore from the limestone platform, where the DomGas Pipeline will tie-in with the LNG Jetty, the dominant benthic habitat is soft sediment with sparse sessile taxa at subdominant levels of cover, including sparse cover of macroalgae. All macroalgae taxa at risk of Serious or Material Environmental Harm associated with construction activities, dredging and spoil disposal activities on the east coast of Barrow Island, were also found outside these areas and were common within the local area and region.

At the mainland end of the DomGas Pipeline route, macroalgal assemblages were associated with fringing reefs surrounding the offshore islands, where they formed dense beds with >70% macroalgal cover. Seasonal trends in macroalgal percentage cover and biomass were generally minor and comparable between surveys for most of the sites. The greatest seasonal changes were observed at a site on an inshore reef within the area at risk of Material or Serious Environmental Harm. Macroalgal cover and biomass increased markedly at this site between the dry and wet season surveys, driven by *Sargassum illicifolium*. Seasonal trends in macroalgal abundance are commonly observed on tropical shallow reef systems, and have been recorded at Barrow Island (e.g. Chevron Australia 2013a) and elsewhere, including at Cape Lambert located 150 km north-east of the mainland shore crossing (SKM 2009) and the Great Barrier Reef (e.g. Martin-Smith 1993; Vuki and Price 1994; Schaffelke and Klumpp 1997). *Sargassum* species, in particular, are well known to undergo strong intra-annual fluctuations, typically displaying lowest cover in winter and seasonal peaks in spring/summer (Martin-Smith 1993; Vuki and Price 1994; Schaffelke and Klumpp 1997). There were some other distinct seasonal differences with respect to species composition, including the decline in abundance of *Sporochnus comosus* and *Dictyopteris* spp., taxa that were abundant in the dry season survey. Similarly, red epiphytic algae were commonly observed in the dry season survey but declined dramatically in the wet season survey. Whilst there were some seasonal differences in species composition, most sites were dominated by *Sargassum* spp., which were abundant on both survey occasions. In some instances, differences in species composition between the dry and wet season surveys were not consistent between the sites and were not necessarily indicative of season patterns. Such differences are likely to be a reflection of spatial variability in sampling, rather than temporal changes. This is particularly likely to be the case for small, inconspicuous species that had low cover values (<1%) (e.g. *Galaxaura rugosa* and *Amphiroa* sp.).

Macroalgal abundance and assemblage composition may also have been influenced by severe weather events. The Pilbara coast experiences more cyclones than any other part of Australia, averaging about one every two years (BOM 2011b). Weather patterns in the period preceding the wet season survey were particularly severe, with three cyclones passing close to the study area (Section 3.4). Elevated turbidities and increased wave action associated with such weather events are likely to have the potential to impact on macroalgal assemblages. However, despite the likely disturbance from such weather events, there was no widespread loss in macroalgae recorded at the macroalgae survey sites, potentially indicating resilience to cyclonic disturbance. This contrasts with observations at the coral survey sites (Section 6.4.4.2), where a decline in macroalgal cover was recorded between the dry season and wet season surveys. This apparent difference is potentially a reflection of the decline in abundance of the red alga, *Asparagopsis taxiformis*, at the coral survey sites, a species that was not recorded at the macroalgae survey sites. The decline in *A. taxiformis* may be due to this species having a weaker holdfast compared to the brown algae that dominated at the macroalgae survey sites, and thus this species may be more susceptible to cyclone damage. The effect of the cyclone activity may have exacerbated natural seasonal changes in macroalgal abundance as have been observed at Cape Lambert (SKM 2009).

The quantitative baseline surveys undertaken in the Marine Baseline Program indicate that macroalgal percentage cover, biomass, and species diversity were generally comparable between macroalgal assemblages at risk of Material or Serious Environmental Harm and at Reference Sites at the mainland end of the DomGas Pipeline route. The number and composition of macroalgal taxa recorded at sites at risk of Material or Serious Environmental Harm was also comparable with those observed at Reference Sites. Most of the macroalgal species recorded at sites at risk of Material or Serious Environmental Harm have also been recorded in nearby offshore waters at Barrow Island (Chevron Australia 2013a, 2011b). Some species not recorded at Barrow Island, but observed in the study area at the mainland end of the DomGas Pipeline route, include *Amphiroa foliacea*, *Hypnea spinella*, *Laurencia brongniartii*, *Canistrocarpus cervicornis*, *Colpomenia* sp., *Sporochnus* cf. *bolleanus*, *Sargassum aquifolium* and *Sargassum illicifolium*, most likely a reflection of the different inshore environment.

# 9.0 Seagrass

## 9.1 Introduction

The diversity and distribution of seagrass species on the North West Shelf are not well documented. Huisman and Borowitzka (2003) identified nine species of seagrass in the Dampier Archipelago, from the families Hydrocharitaceae and Cymodoceaceae. Seven species have been recorded to date from the Montebello/Barrow Islands region: *Cymodocea angustata, Halophila ovalis, H. spinulosa, Halodule uninervis*, *Thalassia hemprichii*, *Thalassodendron ciliatum* and *Syringodium isoetifolium* (DEC 2007). Of these, *Halophila* spp. are the most common on shallow soft substrates and sand veneers throughout the region (DEC 2007). Seagrass do not appear to form extensive beds in the area, but rather are sparsely interspersed between macroalgae, extending from the intertidal zone to approximately 15 m water depth (DEC 2007).

Seagrass distribution in the waters surrounding Barrow Island is even less well-known. Six species of seagrass have been identified during the Marine Baseline Program: *Cymodocea serrulata*, *Syringodium isoetifolium*, *Halodule* sp., *Halophila decipiens*, *Halophila ovalis* and *Halophila spinulosa* (Chevron Australia 2013a, 2011b). The dominant (or most common) species, in terms of percentage cover, on the east coast of Barrow Island were *H*. *ovalis* and *H*. *spinulosa* (Chevron Australia 2013a); *Syringodium isoetifolium* was the dominant species in terms of percentage cover in the waters off the west coast of Barrow Island (Chevron Australia 2011b). Seagrass were observed across a range of benthic substrates, including soft sediments at depths of 14 to 18 m, and on veneers of sand covering limestone pavement at depths of 5 to 10 m. Seagrass were observed as both mono-specific assemblages of *Halophila* spp., or, more rarely, mixed assemblages of *Halophila* spp. and *Syringodium* spp. Non-coral benthic macroinvertebrates and coral were occasionally recorded co-occurring with seagrass in the macroalgal-dominated assemblages on the shallow limestone pavement off the east coast of Barrow Island. Seagrass were also occasionally recorded co-occurring within non-coral benthic macroinvertebrates in deeper soft sediment habitats.

Between Barrow Island and the Pilbara coast along the Domestic Gas Pipeline route, small, isolated patches of *Halophila* have been reported in some areas, but no seagrass beds have been recorded (URS 2009). The benthic habitats that support these ephemeral seagrasses are very widespread along the Pilbara coast, and the seagrass are adapted to the dynamic environment with constant cycles of colonisation and burial or erosion (Chevron Australia 2005). Intertidal seagrass assemblages were dominated by *Halophila* with lesser *Halodule*; these formed patches in shallow, water holding depressions (Chevron Australia 2005).

Seagrass beds in the Montebello/Barrow Islands region make an important contribution to the local productivity, as well as representing an important direct food source for some animals (e.g. Dugong [*Dugong dugon*] and Green Turtles [*Chelonia mydas*]), and providing refuge for fish and invertebrates (Chevron Australia 2005; DEC 2007). Seagrass habitats in the Montebello/Barrow Islands region vary seasonally in response to water temperature, day length, reproductive cycles, physical disturbance, and regrowth (DEC 2007; Chevron Australia 2013a).

## 9.2 Scope

This Section records the existing dominant species of seagrass (Condition 14.8.iii, Statement No. 800; Condition 11.8.III, EPBC Reference: 2003/1294 and 2008/4178) and describes and maps the seagrass:

- that are at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iii, Statement No. 800; Condition 11.6.III, EPBC Reference: 2003/1294 and 2008/4178)

- at Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iv, Statement No. 800; Condition 11.6.IV, EPBC Reference: 2003/1294 and 2008/4178).

Baseline surveys have been undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800 and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178.

## 9.3 Methods

### 9.3.1 Site Locations: East Coast of Barrow Island

Twelve seagrass survey sites were selected within areas where seagrass were identified as being present through broadscale habitat mapping and ground-truthing off the east coast of Barrow Island (Section 5.1). Four sites (TP4, TPC2, TPC3, DGI0) were located within the DomGas Pipeline Marine Disturbance Footprint; i.e. in areas at risk of Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline (Table 9-1; Figure 9-1). Two sites (TP5 and TP2) were located in the Dredge Management Areas (Zone of High Impact and Zone of Moderate Impact, respectively) associated with the generation of turbidity and sediment deposition from dredging and spoil disposal activities on the east coast of Barrow Island (Section 2.3.4). Two sites (TPC1 and DSR1) were located in the indicative anchoring area. Four Reference Sites (TP9, TP10, DSS1 and DSR5) were located in the surrounding waters and are not at risk of Material or Serious Environmental Harm due to the construction or operation of the Marine Facilities. For information on other seagrass survey sites on the east coast of Barrow Island, refer to Chevron Australia (2013a). Note that seagrass survey sites were also macroalgae and benthic macroinvertebrate survey sites where these ecological elements co-occurred in the same area.

**Table 9-1 Seagrass Survey Sites in Waters off the East Coast of Barrow Island**

| Location | Site Code | Easting | Northing | Latitude | Longitude | Survey Date | | |
|---|---|---|---|---|---|---|---|---|
| | | (GDA94, MGA Zone 50) | | (GDA94) | | Nov 08 | Jan 09 | Jul 09 |
| At risk of Material or Serious Environmental Harm | TP4* | 342407 | 7698457 | 20° 48.428' S | 115° 29.143' E | X | | X |
| | TPC2* | 342071 | 7694176 | 20° 50.747' S | 115° 28.926' E | | X | |
| | TPC3* | 342101 | 7694972 | 20° 50.315' S | 115° 28.947' E | | X | |
| | DGI0 | 342795 | 7690816 | 20° 52.571' S | 115° 29.325' E | | X | X |
| | TP5* | 342085 | 7699098 | 20° 48.079' S | 115° 28.961' E | X | | X |
| | TP2* | 342235 | 7700923 | 20° 47.091' S | 115° 29.057' E | X | | X |
| Indicative Anchoring Area | TPC1* | 342628 | 7694475 | 20° 50.587' S | 115° 29.249' E | | X | |
| | DSR1 | 347711 | 7684857 | 20° 55.826' S | 115° 32.129' E | | X | X |
| Reference Sites | DSS1* | 347316 | 7687119 | 20° 54.598' S | 115° 31.913' E | | X | X |
| | DSR5 | 346075 | 7694125 | 20° 50.794' S | 115° 31.234' E | | X | X |
| | TP9* | 341069 | 7695738 | 20° 49.895' S | 115° 28.357' E | X | | X |
| | TP10* | 337827 | 7694122 | 20° 50.754' S | 115° 26.479' E | X | | |

** Denotes a sampling site located in a Dredge Management Area. Source: Chevron Australia (2013a).*

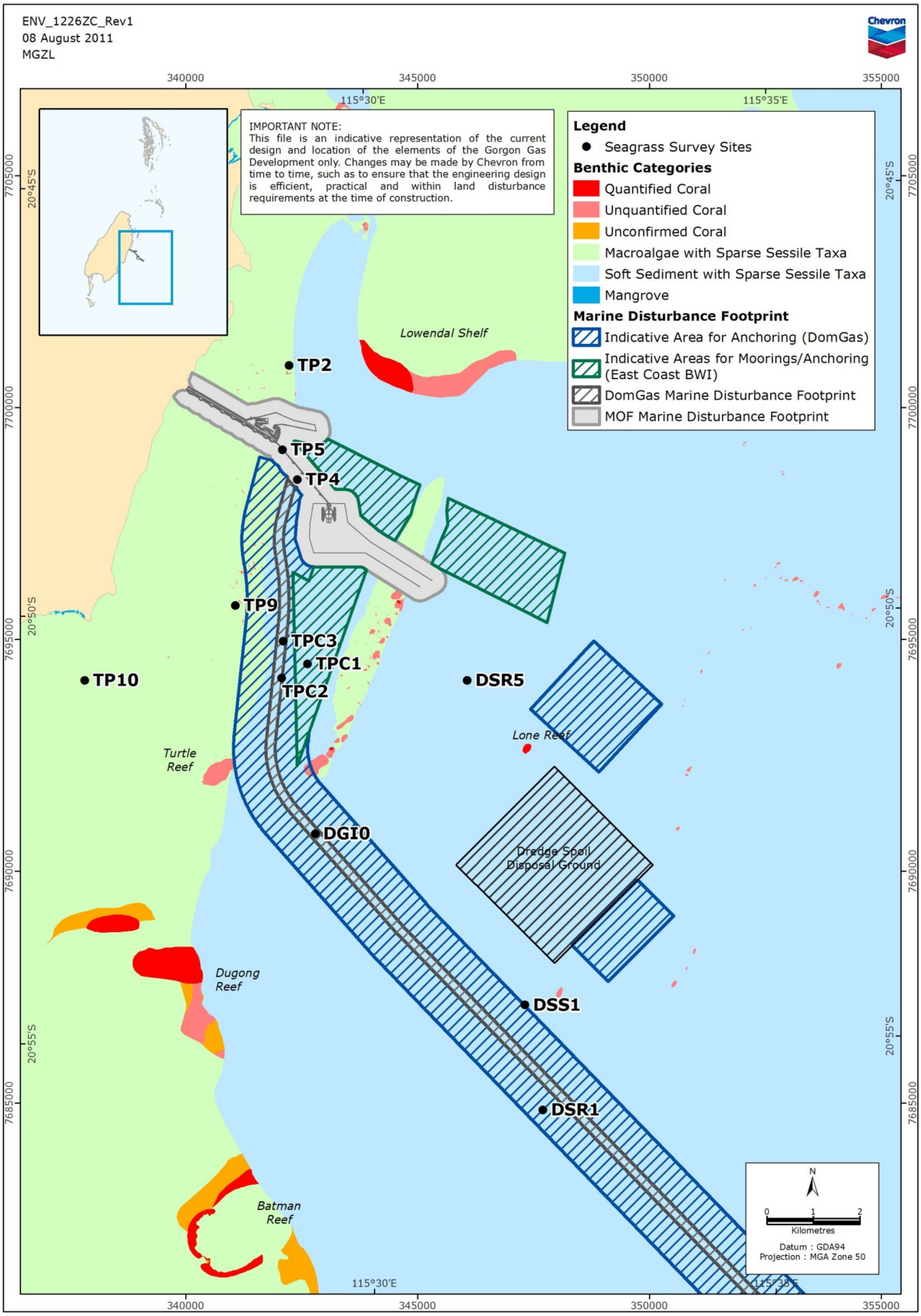



Figure 9-1 Seagrass Survey Sites in Waters off the East Coast of Barrow Island

### 9.3.2 Site Locations: Mainland End of the DomGas Pipeline Route

Seagrass survey sites at the mainland end of the DomGas Pipeline route were selected within areas where seagrass were identified as being present through broadscale habitat mapping and ground-truthing (Section 5.4). However, seagrass cover was generally very low (<2–5%) and patchy (typical patch size estimated to be <10m$^2$), which limited the availability of suitable sites for seagrass surveys (Section 5.4.4). Two sites were surveyed in the dry season, with an additional two sites surveyed in the wet season (Table 9-2; Figure 9-2). The four seagrass survey sites are considered to be representative of the most abundant seagrass assemblages and dominant species within the study area. Two sites (SGI1, SGI2) were located in areas at risk of Material or Serious Environmental Harm within the trenching and jetting Marine Disturbance Footprint; and two sites (SGR1, SGR2) were located in areas not at risk of Material or Serious Environmental Harm, outside the trenching and jetting Marine Disturbance Footprint (Section 2.3.3.2). The sites were located in water depths of 2 to 4.5 m.

**Table 9-2 Seagrass Survey Sites at the Mainland End of the DomGas Pipeline Route**

| Location | Site Code | Easting | Northing | Latitude | Longitude | Survey Date | |
|---|---|---|---|---|---|---|---|
| | | (GDA94, MGA Zone 50) | | (GDA94) | | Oct 10 | Apr 11 |
| At risk of Material or Serious Environmental Harm | SGI1 | 371993 | 7657550 | 21 °10.737’ S | 115° 46.014’ E | X | X |
| | SGI2 | 372830 | 7664333 | 21° 07.064’ S | 115° 46.529’ E | - | X |
| Reference Sites | SGR1 | 372638 | 7652067 | 21° 13.711’ S | 115° 46.363’ E | X | X |
| | SGR2 | 368515 | 7661176 | 21° 08.757’ S | 115° 44.022’ E | - | X |

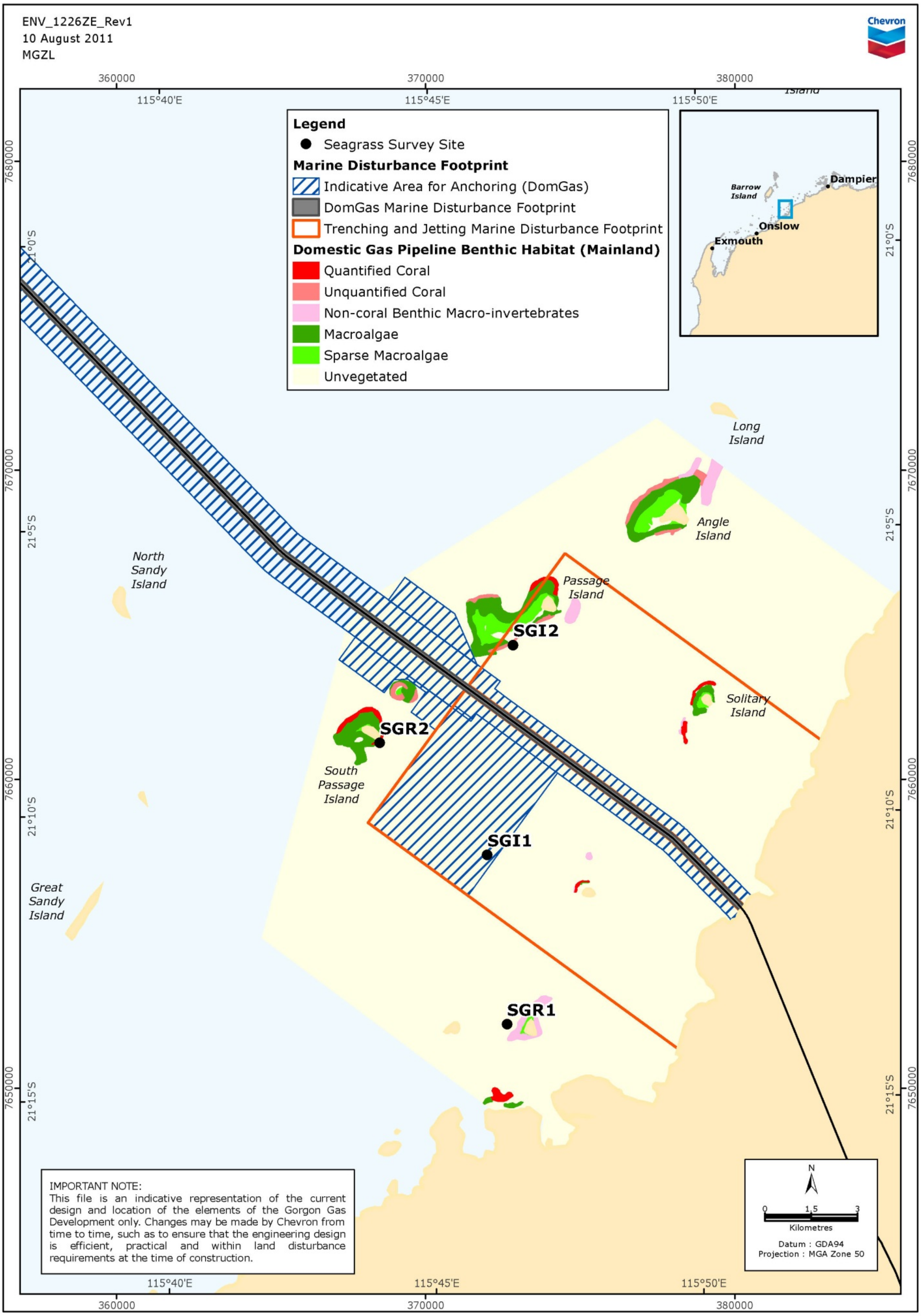



**Figure 9-2 Seagrass Survey Sites at the Mainland End of the DomGas Pipeline Route**

### 9.3.3 Methods

At each site, three 30 m length transects were laid out from a central point. The first transect was oriented parallel to the vessel's anchor line and the other two oriented at approximately ± 90° to the first transect. The coordinates of the start point of each transect were recorded using GPS.

A total area of 1 $m^2$ (either 1 $m^2$ or, in conditions of poor visibility, four 0.25 $m^2$ sub-quadrats positioned adjacent to each other to form 1 $m^2$) was photographed at 5 m intervals along the right side of each transect (i.e. a total of seven locations along each transect). The seagrass species present in the quadrat (or sub-quadrat) were recorded and the percentage cover was estimated in situ by divers. Where no seagrass were present in a quadrat, this was recorded as 'absent'. The seagrass species present in each quadrat (or sub-quadrat) were identified to the lowest reliable taxonomic level (to genus and species level where possible).

In the dry season surveys, species identifications were confirmed in the field by Dr Kirkman (independent specialist consultant). In the wet season surveys, voucher samples of those species that could not be reliably identified in the field were collected, preserved, and catalogued for identification by Dr John Huisman (Western Australian Herbarium/Murdoch University).

In the November 2008 and January 2009 surveys, the seagrass in two 0.25 $m^2$ sub-quadrats along each transect were collected for total biomass measurement (i.e. a total of six samples per site). A quadrat was located at 10 m and 20 m intervals along the left side of each transect. In the July 2009, October 2010, and April 2011 surveys, the seagrass in two 0.25 $m^2$ sub-quadrats were collected from each of 10 m and 20 m intervals (Barrow Island), or 10 m and 25 m intervals (mainland), along each transect (i.e. a total of 12 samples per site). If a quadrat was located on bare sand, no biomass sample was collected. Samples were blot-dried and total wet weight recorded. Because of the very small sample sizes, the April 2011 samples were frozen and weighed in the laboratory. On those occasions where the biomass samples of macroalgae and seagrass could not be easily separated, combined wet weight results have been presented.

### 9.3.4 Timing and Frequency of Surveys

Sampling was undertaken in the waters off the east coast of Barrow Island during November 2008, January 2009 and July 2009. At sites at the mainland end of the DomGas Pipeline route, sampling was undertaken during the dry season (October 2010) and the wet season (April 2011). Two sites were surveyed in the dry season (SGI1 and SGR1), with an additional two sites (SGI2 and SGR2) surveyed in the wet season (Table 9-2). The wet season survey was originally scheduled to be undertaken in February 2011; however, some field activities in the wet season were delayed until April 2011 due to the passage of tropical cyclones, adverse weather conditions or logistical constraints.

### 9.3.5 Treatment of Survey Data

Digital images were analysed using Coral Point Count with Excel extensions (CPCe; Kohler and Gill 2006). Thirty random points were overlaid over each 1 $m^2$ image and each point visually classified by a trained scorer into the broad categories of benthic cover (macroalgae, seagrass, coral, non-coral benthic macroinvertebrates, sand, pavement, rubble and 'unidentified'). Where 0.25 $m^2$ sub-quadrats were photographed, the thirty points were spread across the four images. The percentage of all points scored for each broad category of benthic cover was calculated and the mean (± Standard Error [SE]) percentage cover was determined.

## 9.4 Results

### 9.4.1 Distribution of Seagrass in Waters Surrounding the DomGas Pipeline Route

#### 9.4.1.1 Distribution of Seagrass in Barrow Island Waters

Figure 9-3 shows the spatial distribution of seagrass in Barrow Island waters as point (presence/absence) observations derived from broadscale mapping and ground-truthing. 'Null observations' were recorded where seagrass were not observed during ground-truthing.

In summary, seagrass were observed across a range of benthic substrates, including soft sediments at depths of 14 to 18 m, and on veneers of sand covering limestone pavement at depths of 5 to 10 m (Chevron Australia 2013a). Seagrass were observed as both mono-specific assemblages of *Halophila* spp. or, more rarely, mixed assemblages of *Halophila* spp. and *Syringodium* spp. Non-coral benthic macroinvertebrates and coral were occasionally recorded co-occurring with seagrass in the macroalgal-dominated assemblages. These mixed communities were most common along the shallow limestone pavement off the east coast of Barrow Island. Seagrass were occasionally observed co-occurring with non-coral benthic macroinvertebrates in deeper soft sediment habitats.

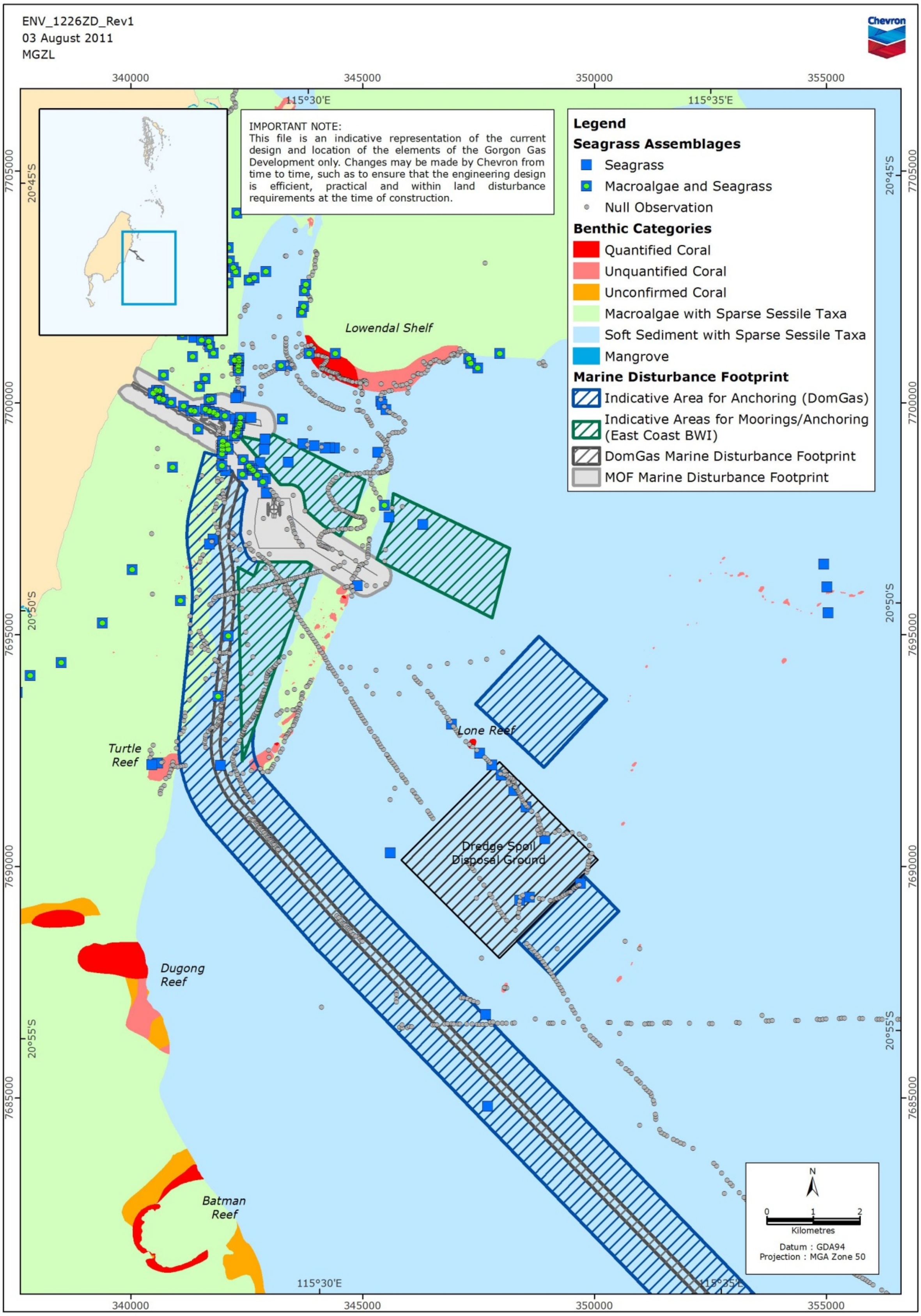



**Figure 9-3 Observations of Seagrass in the Waters around Barrow Island**

#### 9.4.1.2 Distribution of Seagrass at the Mainland End of the DomGas Pipeline Route

The spatial distribution of seagrass at the mainland end of the DomGas Pipeline route is shown in Figure 9-4. The map is based primarily on seagrass presence/absence derived from observations made during broadscale surveys (towed video) and in-water ground-truthing undertaken during the dry season (Section 5.4). 'Null observations' were recorded where seagrass were not observed during ground-truthing. Some additional in-water ground-truthing was undertaken during the wet season to identify additional seagrass survey sites.

Seagrass were mainly observed on the soft sediments that dominated the study area (Section 5.4.4). Towed video surveys indicated that the overall area occupied by sparse seagrass within the study area was extensive. However, seagrass cover was typically very low (<5%). In-water surveys indicated that the seagrass cover was not only sparse, but also very patchy in nature (typical patch size estimated to be <10 $m^2$) (Plate 9-1).

Identification of the seagrass species from the dry season towed video surveys across the study area was sometimes difficult due to the small size of seagrass in the study area. In some instances, it was also difficult to distinguish *Halophila spinulosa* from the green macroalga *Caulerpa cupressoides*. Similarly, the small fine blades of *Halophila decipiens* were difficult to detect from towed video footage alone. Nevertheless, *H. spinulosa* and *C. cupressoides* typically co-occurred, thus the recorded point observations are considered a reliable depiction of seagrass extent in the study area.

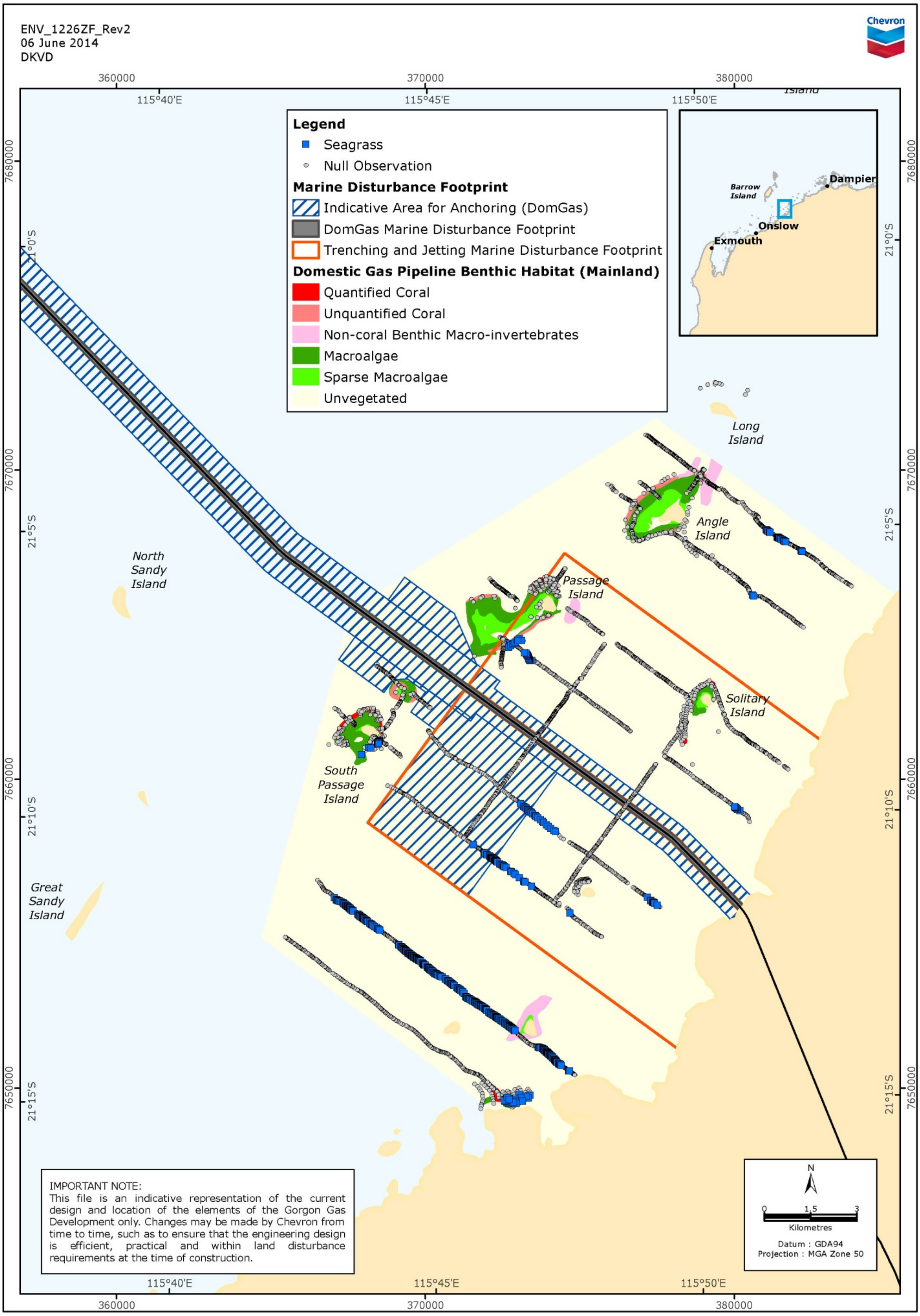



**Figure 9-4 Observations of Seagrass at the Mainland End of the DomGas Pipeline Route**

*Halophila spinulosa*

*Halophila decipiens*

**Plate 9-1 Sparse Seagrass at Sites at the Mainland End of the DomGas Pipeline Route**

## 9.4.2 Dominant Seagrass Species

### 9.4.2.1 Barrow Island waters

In summary, the dominant (or most common) seagrass in terms of percentage cover recorded in Barrow Island waters were *Halophila ovalis* and *Halophila spinulosa* (Plate 9-2) (Chevron Australia 2013a). *Cymodocea serrulata*, *Syringodium isoetifolium*, *Halodule* sp. and *Halophila decipiens* were less common.

*Halophila ovalis*

*Halophila spinulosa*

**Plate 9-2 Seagrass Recorded in Waters Around Barrow Island**

### 9.4.2.2 Mainland End of the DomGas Pipeline Route

Two species, *Halophila decipiens* and *Halophila spinulosa* (Plate 9-1) were observed in the October 2010 survey at SGI1 and SGR1. These species were considered to be co-dominants, since either could occur as the dominant species depending on the site and its associated sediment characteristics.

In the wet season, *Halophila decipiens* was observed in most quadrats (recorded from 33 of 42 quadrats at SGI2 and SGR2) at very low levels (<1%). In contrast to the dry season, neither *H. decipiens* or *Halophila spinulosa* were observed at SGI1 or SGR1. A third species, *Halodule* *uninervis*, was recorded at SGI1 and SGI2 in the wet season, with low abundance (<1% cover) recorded in a small number of quadrats (recorded from two of 42 quadrats at the two sites).

### 9.4.3 Description of the Seagrass at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

#### 9.4.3.1 East Coast of Barrow Island

Mean seagrass percentage cover and biomass at sites on the limestone pavement adjacent to Town Point (TP2, TP4 and TP5) varied between <1–8% in the November 2008 survey and <1–25% in the July 2009 survey (Table 9-3). Mean biomass was 60 g wet weight/m$^2$ in November 2008 at site TP4 (no samples were collected/insufficient data were available in November 2008 to calculate the biomass of TP2 and TP5 respectively), and varied between 27 and 128 g wet weight/m$^2$ in July 2009 (TP4, TP2), with no seagrass recorded at TP5. Estimates of percentage cover and biomass were generally highest at TP4 in both the November 2008 and July 2009 surveys; and *Halophila ovalis* and *Halophila spinulosa* were the most abundant species in November 2009 (diver visual estimate ~10% cover each). *Halophila ovalis* and *H. spinulosa* were recorded at TP4 in both the November 2008 and July 2009 surveys; *Halophila decipiens* and *Syringodium isoetifolium* were also observed at TP4. *Halophila ovalis* percentage coverage was very low (diver visual estimate <1%) at TP5 in November 2008. The highest percentage cover (diver visual estimate ~40%) of *H. ovalis* in November 2008 was recorded at TP2, located north of Town Point. *Halophila spinulosa* and *S. isoetifolium* were also observed at TP2.

TPC1, TPC2, and TPC3 were located in the sandy channel east of the inshore limestone pavement on the east coast of Barrow Island. In the January 2009 survey, seagrass at TPC3 co-occurred in small patches amongst macroalgae and benthic macroinvertebrates; no other benthic assemblages were recorded co-occurring with seagrass at TPC1 and TPC2. In the January 2009 survey, mean biomass was ~49 g wet weight/m$^2$ at TPC2 whilst seagrass biomass was only recorded in combination with macroalgae at TPC3 (Table 9-3). There were no seagrass in the quadrats for biomass measurement at TPC1 in the January 2009 survey. *Halophila ovalis* was the only species recorded at TPC1 and TPC2 in the January 2009 survey; and three species were recorded in sparse abundance (diver visual estimate <1–2% cover) at TPC3 (*H. ovalis*, *H. spinulosa* and *H. decipiens*) in the January 2009 survey.

DGI0 and DSR1 were located in the deeper (<18 m water depth) soft sediments east of the East Barrow Ridge (Table 9-3). There were no seagrass in the biomass quadrats at DG10 in either the January 2009 or July 2009 surveys and no seagrass was recorded at this site in July 2009. *Halophila ovalis* was the only species recorded at DGI0. Mean seagrass biomass at DSR1 varied from ~19–90 g wet weight/m$^2$ between the two surveys. *Halophila spinulosa* was the only species recorded at DSR1 with sparse cover in the January 2009 survey (diver visual estimate <5%). *Halophila ovalis* was also observed at DSR1.

**Table 9-3 Mean Seagrass Percentage Cover (± SE), Mean Total Biomass (± SE), and Dominant Species at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities**

| Site | Mean % Cover ± SE | | Mean Biomass (g/m$^2$) ± SE | | No. Dominant Species | | Dominant Species | |
|---|---|---|---|---|---|---|---|---|
| | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 |
| TP4 | 8.0 ± 2.3 (22) | 24.5 ± 3.4 (21) | 60.0 ± 20.0 (4) | 127.5 ± 27.1 (11) | 2 | 2 | *Halophila ovalis*<br>*Halophila spinulosa* | |
| TPC2 | Photographs | Not | 48.6 ± 21.4 | Not surveyed | 1 | Not | *Halophila* | Not |

<table>
<tr><th rowspan="2">Site</th><th colspan="2">Mean % Cover ± SE</th><th colspan="2">Mean Biomass (g/m²) ± SE</th><th colspan="2">No. Dominant Species</th><th colspan="2">Dominant Species</th></tr>
<tr><th>Nov 08/ Jan 09</th><th>Jul 09</th><th>Nov 08/ Jan 09</th><th>Jul 09</th><th>Nov 08/ Jan 09</th><th>Jul 09</th><th>Nov 08/ Jan 09</th><th>Jul 09</th></tr>
<tr><td></td><td>could not be analysed by CPCe</td><td>surveyed</td><td>(6)</td><td></td><td></td><td>surveyed</td><td>ovalis</td><td>surveyed</td></tr>
<tr><td rowspan="3">TPC3</td><td rowspan="3">Photographs could not be analysed by CPCe</td><td rowspan="3">Not surveyed</td><td rowspan="3">Macroalgae and Seagrass combined weight only</td><td rowspan="3">Not surveyed</td><td rowspan="3">3</td><td rowspan="3">Not surveyed</td><td>Halophila ovalis</td><td rowspan="3">Not surveyed</td></tr>
<tr><td>Halophila spinulosa</td></tr>
<tr><td>Halophila decipiens</td></tr>
<tr><td>DGI0</td><td>Photographs could not be analysed by CPCe</td><td>0.0 ± 0.0 (21)</td><td>No samples in quadrats</td><td>No samples in quadrats</td><td>1</td><td>1</td><td colspan="2">Halophila ovalis</td></tr>
<tr><td>TP5</td><td>0.2 ± 0.2 (18)</td><td>0.2 ± 0.2 (19)</td><td>Insufficient data</td><td>No samples in quadrats</td><td>1</td><td>1</td><td colspan="2">Halophila ovalis</td></tr>
<tr><td rowspan="2">TP2</td><td rowspan="2">7.3 ± 1.3 (21)</td><td rowspan="2">12.0 ± 2.2 (21)</td><td rowspan="2">No samples collected</td><td rowspan="2">27.1 ± 7.9 (12)</td><td rowspan="2">1</td><td rowspan="2">2</td><td colspan="2">Halophila ovalis</td></tr>
<tr><td>Not recorded</td><td>Halophila decipiens</td></tr>
<tr><td>TPC1</td><td>Photographs could not be analysed by CPCe</td><td>Not surveyed</td><td>No samples in quadrats</td><td>Not surveyed</td><td>1</td><td>Not surveyed</td><td>Halophila ovalis</td><td>Not surveyed</td></tr>
<tr><td>DSR1</td><td>Photographs could not be analysed by CPCe</td><td>1.0 ± 0.5 (21)</td><td>89.7 ± 23.1 (4)</td><td>18.8 ± 2.7 (4)</td><td>1</td><td>1</td><td colspan="2">Halophila spinulosa</td></tr>
</table>

*Note: n = number of photo-quadrats sampled*.

### 9.4.3.2 Mainland End of the DomGas Pipeline Route

The mean percentage cover and mean biomass recorded at SGI1 in the October 2010 survey were 5.4% ± 0.5 SE and 16.9 g wet weight/m$^2$ ± 8.5 SE, respectively (Table 9-4). *Halophila spinulosa* was the only seagrass species recorded at this site in the October 2010 survey, although the green alga *Caulerpa cupressoides* was also occasionally observed. There was a marked decline in seagrass abundance recorded at SGI1 in the April 2011 survey. No seagrass was observed in the 1 m$^2$ quadrats. A single rhizome of *Halodule uninervis* was collected from within a biomass quadrat; this was the only observation of seagrass across the survey site (i.e. encompassing survey quadrats and general observations of surrounding areas).

*Halophila decipiens* and *Halodule uninervis* were observed at SGI2 in the April 2011 survey (Table 9-4). The highest percentage cover estimated from in situ visual assessments was 2%, with most quadrats estimated at <1% cover. No seagrass was scored in the CPCe analysis of photographs (i.e. seagrass cover was 0%). Biomass was correspondingly low, averaging 3.4 g wet weight/m$^2$ ± 1.2 SE.

**Table 9-4 Mean Seagrass Percentage Cover (± SE) and Mean Total Biomass (± SE) at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

| Site | Mean % Cover ± SE | | Mean Biomass (g/m$^2$) ± SE | | No. Species | | Species | |
|---|---|---|---|---|---|---|---|---|
| | Oct 10 | Apr 11 | Oct 10 | Apr 11 | Oct 10 | Apr 11 | Oct 10 | Apr 11 |
| SGI1 | 5.4 ± 0.5 | 0.0 ± 0.0 | 16.9 ± 8.5 | 0.0 ± 0.0 | 1 | 1 | *Halophila spinulosa* | Not recorded |
| | | | | | | | Not recorded | *Halodule uninervis* |
| SGI2 | Not surveyed | 0.0 ± 0.0 | Not surveyed | 3.4 ± 1.2 | Not surveyed | 2 | Not surveyed | *Halophila decipiens* |
| | | | | | | | | *Halodule uninervis* |

### 9.4.4 Description of the Seagrass at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

#### 9.4.4.1 East Coast of Barrow Island

Estimates of mean seagrass percentage cover at the two sites on the inshore limestone pavement south of Town Point (TP9 and TP10) varied between ~2% and ~4% in the November 2008 survey (Table 9-5). *Halophila ovalis* was the only species of seagrass recorded at these sites, occurring in sparse patches in November 2008 (diver visual estimates ~20% and 5% cover at TP9 and TP10, respectively). *Cymodocea serrulata* was also observed at TP9.

DSS1 and DSR5 were located in the deeper (<18 m water depth) soft sediments south-east of the East Barrow Ridge. Mean seagrass biomass at DSS1 was 13.2 g wet weight/m$^2$ ± 4.0 SE in the January 2009 survey, and 4.0 g wet weight/m$^2$ ± 0.8 SE in the July 2009 survey (Table 9-5). Two *Halophila* species were recorded in sparse abundance (diver visual estimates <1–2%) at DSS1 in the January 2009 survey, with only one of these species (*H. ovalis*) recorded in the July 2009 survey. *Halophila ovalis* was the only species observed at DSR5. No seagrass was recorded in quadrats for percentage cover or biomass at DSR5.

**Table 9-5 Mean Seagrass Percentage Cover (± SE), Mean Total Biomass (± SE) and Dominant Species at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the East Coast Barrow Island Marine Facilities**

| Site | Mean % Cover ± SE | | Mean Biomass (g/m$^2$) ± SE | | No. Dominant Species | | Dominant Species | |
|---|---|---|---|---|---|---|---|---|
| | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 |
| DSS1 | Photographs could not be analysed by CPCe | 0.0 ± 0.0 (19) | 13.2 ± 4.0 (2) | 4.0 ± 0.8 (2) | 2 | 1 | *Halophila ovalis* | |
| | | | | | | | *Halophila spinulosa* | Not recorded |
| DSR5 | Photographs could not be analysed by CPCe | 0.0 ± 0.0 (21) | No samples in quadrats | No samples in quadrats | 1 | 1 | *Halophila ovalis* | |
| TP9 | 4.0 ± 1.5 | 0.0 ± 0.0 | No | No | 1 | 1 | *Halophila ovalis* | |

| Site | Mean % Cover ± SE | | Mean Biomass (g/m²) ± SE | | No. Dominant Species | | Dominant Species | |
|---|---|---|---|---|---|---|---|---|
| | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 | Nov 08/ Jan 09 | Jul 09 |
| | (20) | (20) | samples in quadrats | samples in quadrats | | | | |
| TP10 | 2.0 ± 1.0 (21) | Not surveyed | No samples in quadrats | Not surveyed | 1 | Not surveyed | *Halophila ovalis* | Not surveyed |

*Note: n = number of photo-quadrats sampled*.

#### 9.4.4.2 Mainland End of the DomGas Pipeline Route

The mean percentage cover and mean biomass recorded at SGR1 in the October 2010 survey were 4.9% ± 2.0 SE and 20.2 g wet weight/m$^2$ ± 5.6 SE (Table 9-6). Both *Halophila decipiens* and *Halophila spinulosa* were recorded at this site in the October 2010 survey, with *H. decipiens* being the dominant species present (mean cover 4.8%) and accounting for the majority of seagrass observed (*H. spinulosa* mean cover 0.2%). In the April 2011 survey, no seagrass species were observed in any transect quadrats at SGR1, nor were they observed anywhere across the broader survey site.

*Halophila decipiens* was recorded at SGR2 in the April 2011 survey; however, percentage cover was estimated at ≤1% from in situ visual assessment. Seagrass cover estimates derived from CPCe analysis averaged only 0.3% ± 0.2 SE (Table 9-6). Similarly, mean biomass values were very low at SGR2, averaging 0.3 g wet weight/m$^2$ ± 0.1 SE.

**Table 9-6 Mean Seagrass Percentage Cover (± SE) and Mean Total Biomass (± SE) at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

| Site | Mean % Cover ± SE | | Mean Biomass (g/m²) ± SE | | No. Species | | Species | |
|---|---|---|---|---|---|---|---|---|
| | Oct 10 | Apr 11 | Oct 10 | Apr 11 | Oct 10 | Apr 11 | Oct 10 | Apr 11 |
| SGR1 | 4.9 ± 2.0 | 0.0 ± 0.0 | 20.2 ± 5.6 | 0.0 ± 0.0 | 2 | 0 | *Halophila decipiens*<br>*Halophila spinulosa* | Not recorded |
| SGR2 | Not surveyed | 0.3 ± 0.2 | Not surveyed | 0.3 ± 0.1 | Not surveyed | 0 | Not surveyed | *Halophila decipiens* |

## 9.5 Discussion and Conclusions

Benthic habitat mapping along the DomGas Pipeline route, indicates that for much of the route between nearshore Barrow Island and the Pilbara coast, the offshore seabed was ‘open bare sand with minimal biota’ with a small offshore area of an ephemeral macroalgae assemblage (*Caulerpa*) some 20 km from Barrow Island (Section 5.3). Between Passage Island and South Passage Island, an area of ‘sand veneer overlying limestone with some attached biota’ occurred, and the nearshore area of the mainland shore crossing consisted of soft sediments without any epifauna. Small isolated patches of seagrass (*Halophila*) were observed, but no continuous or extensive seagrass beds.

In summary, seagrass assemblages were recorded in soft sediment habitats and on veneers of sand overlying limestone pavement, generally as small sparse (≤5% cover) patches rather than distinct beds in the waters off the east coast of Barrow Island (Chevron Australia 2013a). *Halophila spinulosa* was the most common species recorded in soft sediments, although abundance was generally low with the seagrass occurring in small (<5 $m^2$) patches. The seagrass on the limestone pavement with sand veneers off the east coast of Barrow Island was most commonly small patches of *Halophila ovalis*, mixed with macroalgae and benthic macroinvertebrates. Seagrass assemblages were spatially variable in terms of their percentage cover, biomass and species richness. All seagrass taxa (*Halophila decipiens*, *H. ovalis*, *H. spinulosa* and *Syringodium isoetifolium*) at risk of Serious or Material Environmental Harm associated with construction activities, dredging and spoil disposal activities on the east coast of Barrow Island were also found outside these areas and were common within the local area and region.

At the mainland end of the DomGas Pipeline route, while seagrass assemblages were present over a broad area within the study area, percentage cover was low, with seagrass typically present as small (<10 $m^2$) sparse (<5% cover) patches rather than continuous extensive seagrass beds. The low percentage cover and small-scale patchy nature of seagrass in the study area limited the availability of suitable sites for baseline surveys. There was also an indication of marked temporal variability between the dry season and the wet season surveys, with a pronounced decline in seagrass abundance in the wet season survey. Whether the observed decline in seagrass abundance at the mainland end of the DomGas Pipeline route in the wet season survey reflects seasonal variability typical of these communities is unknown. The above-ground portions of tropical seagrass communities is often ephemeral and highly variable with changing environmental conditions (e.g. Birch and Birch 1984; Carruthers *et al.* 2002).

Seagrass abundance and assemblage composition may have been influenced by severe weather events. The Pilbara coast experiences more cyclones than any other part of Australia, averaging about one every two years (BOM 2011b). Weather patterns in the period preceding the wet season survey were particularly severe, with three cyclones passing close to the study area (Section 3.4). Periods of increased turbidity and wave activity are often associated with cyclone activity, both of which may influence seagrass distribution and abundance. Turbidity is an important factor determining seagrass distribution and abundance, as it decreases light levels available to seagrass; decreased light levels affect seagrass by reducing photosynthetic rates, survival and recruitment (de Boer 2007). Periods of elevated turbidities associated with, for example, flooding rivers, have the potential to significantly impact on tropical seagrass communities (e.g. Longstaff and Dennison 1999; Teeter *et al*. 2001). Gradients in turbidity across the study area, with higher turbidity recorded at inshore locations and decreasing offshore (Section 13), may also explain the occurrence of seagrass at offshore locations rather than inshore locations in the wet season survey. Declines in seagrass may have been more significant in the inshore areas (SGI1 and SGR1) due to higher turbidity levels during the wet season; but it is important to note that the survey sites located further offshore (SGI2 and SGR2) were not surveyed in the 2010 dry season.

Extreme wave events during cyclonic events are also likely to directly influence seagrass distribution and abundance. Erosion of seagrass beds through sheer stress or catastrophic events is an important process affecting seagrass assemblages (e.g. Teeter *et al*. 2001; de Boer 2007) and it is likely that wave and current events experienced during cyclonic conditions would have had negative impacts on seagrasses in the study area. Whether or not the observed differences in seagrass distribution and abundance reflect typical seasonal variability, seasonal fluctuations in seagrass abundance would be expected in the study area. The shallow and naturally turbid nature of the study area, particularly the inshore region, combined with the high frequency of cyclone events, is likely to result in periodic disturbances to seagrass assemblages. Such variability in tropical seagrass abundance is well known from north-eastern

Australia (Carruthers *et al.* 2002). It should also be noted that one of the seagrass species recorded in the area, *Halophila decipiens*, is unusual amongst seagrass in that it is an annual species, at least in some areas, and is reliant on seed set and the development of new plants each year (Edgar 2008). Thus, the observed decline in seagrass cover between the dry and wet season surveys may be a consequence of seasonal phenology.

Overall, the quantitative baseline surveys undertaken in the Marine Baseline Program indicate that seagrass percentage cover, biomass, species composition and diversity were generally comparable between seagrass communities at risk of Material or Serious Environmental Harm and at Reference Sites. Importantly, the apparent seasonal decline in seagrass abundance from dry to wet season was consistent between the sites at risk of Material or Serious Environmental Harm and the Reference Sites.

# 10.0 Mangroves

## 10.1 Introduction

Mangroves along the northern coastline of Western Australia increase in species richness and diversity from the arid subtropics in the south, which has relatively small tides, to the tropical and humid Kimberley coast, which has a tidal range of >11 m (Alongi *et al.* 2005). The mangroves in the Pilbara region exhibit lower productivity than mangrove communities of the wet tropics due to extreme water and salinity stresses in the Pilbara intertidal zone (EPA 2001). The mangroves in the Pilbara region form relatively diverse fringing stands (Alongi *et al.* 2000), with trees often stunted but forming extensive forests (EPA 2001, Duke 2006). *Avicennia marina* (Grey Mangrove) and *Rhizophora stylosa* (Long-style Stilt Mangrove) are the most commonly occurring species along the coastal plain, along with *Ceriops australis*[14] (Smooth Fruited Yellow Mangrove) (Gordon *et al.* 1995; Alongi *et al.* 2000). Other species that occur in the region are *Aegialitis annulata* (Club Mangrove), *Aegiceras corniculatum* (River Mangrove) and *Bruguiera exaristata* (Ribbed-fruit Orange Mangrove) (Chevron Australia 2005; DEC 2007). Six species of mangrove are found in the Montebello/Barrow Islands region, including *Avicennia marina*, *Bruguiera exaristata*, *Ceriops australis*, *Rhizophora stylosa*, *Aegialitis annulata* and *Aegiceras corniculatum* (DEC 2007). The majority of mangrove forests in the area occur in the Montebello Islands (DEC 2007).

*Avicennia marina* is the only species found around Barrow Island. This species is the most widespread mangrove species in Australia, found in coastal areas from Leschenault Estuary, Bunbury, Western Australia (33° 16' S; 115° 42' E), throughout northern Australia, to Corner Inlet, Victoria (38° 45' S; 146° 29' E) (Duke 2006). *Avicennia marina* is a tree or shrub that can grow to 10 m high and is categorised by its smooth bark that appears green when wet and chalky white when dry. The leaves are ovate-elliptical in shape and are 37–84 mm in length and 18–27 mm in width (Duke 2006). Flowering and maturation of *A. marina* propagules varies with latitude (Duke 2006). In the Barrow Island region, flowering often occurs between December and January, while propagules mature mostly in March (Duke 2006). The pneumatophores of *A. marina* are often tall and slender and can reach heights of 30 cm. It grows in both soft sediments and on rock, as well as where sediment accumulates in the intertidal zone (KJVG 2008).

Mangroves dominate the upper intertidal zone of the mainland shore crossing of the Domestic Gas Pipeline (Chevron Australia 2005). The seaward trees of the mangrove zone are *Avicennia marina*, with trees reaching heights of approximately 5 m, decreasing in size (maximum height 1.5 m) and increasing in density further shoreward (URS 2009). On the seaward side of the mangroves is an extensive pneumatophore zone. The broader mangrove zone is regularly dissected by muddy tidal creeks with very turbid water, the longest of which extend several kilometres inland. In addition to *A. marina*, isolated stands of *Rhizophora stylosa* and *Ceriops australis* have also been recorded in a small tidal creek to the south-west of the shore crossing (URS 2009). *Rhizophora stylosa* formed taller canopies in the midst of the mangrove community (Chevron Australia 2005). Tidal flats were located on the landward side of the mangroves (Astron Environmental Services 2009).

The nearest Mangrove Management Area (Section 3.2.1) to the Domestic Gas Pipeline route is located approximately 6 km to the south, and represents regionally significant mangroves around the Robe River Delta.

## 10.2 Scope

This Section records the dominant species of mangroves (Condition 14.8.iii, Statement No. 800; Condition 11.8.iii, EPBC Reference: 2003/1294 and 2008/4178) and describes and maps the mangroves:

[14] *Ceriops australis* is synonymous with *Ceriops tagal* and reflect differences by naming authorities only.

- that are at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iii, Statement No. 800; Condition 11.6.III, EPBC Reference: 2003/1294 and 2008/4178)
- at Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iv, Statement No. 800; Condition 11.6.IV, EPBC Reference: 2003/1294 and 2008/4178).

Baseline surveys have been undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800 and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178.

On Barrow Island, *Avicennia marina* grows as a narrow fringe in the sheltered embayments on the southern and eastern coasts from Bandicoot Bay to Shark Point, with small communities further north at Mattress Point (Chevron Australia 2013a). There are no stands of *A. marina* on the east coast of Barrow Island that are at risk of Material or Serious Environmental Harm due to the construction or operation of the Domestic Gas Pipeline. Therefore, no further field surveys of either the mangrove communities or the demersal fish assemblages that characterise these communities, have been undertaken on the east coast of Barrow Island as part of the Marine Baseline Program for the Domestic Gas Pipeline. Field surveys of both the mangroves and the demersal fish assemblages that characterise these communities have been undertaken at sites on the east coast of Barrow Island as part of the Marine Baseline Program for the MOF, LNG Jetty and Dredge Spoil Disposal Ground (Chevron Australia 2013a).

## 10.3 Method

### 10.3.1 Site Locations

Eight mangrove survey locations were selected in the mangrove community along the Pilbara coast, in areas at risk of Material or Serious Environmental Harm within the trenching and jetting Marine Disturbance Footprint; and at Reference Sites not at risk of Material or Serious Environmental Harm (Table 10-1; Figure 10-1). Reference Sites were located within two Reference Areas, one located to the south of the DomGas Pipeline route and one to the north of the pipeline route. These sites were identified based on an interpretation of available aerial imagery (1:5000). Sites were located in areas of *Avicennia marina*, which is widely distributed on the mainland coast and thus considered a suitable target community representative of the mangroves in the area. Sites were also selected to be representative of both the open coast (wave-exposed) and the creeks and tributaries (sheltered). Logistical constraints, include safe site access, were also considered in the selection of survey sites.

**Table 10-1 Mangrove Survey Sites at the Mainland End of the DomGas Pipeline Route**

| Location | Site Code | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|---|
| | | (GDA94, MGA Zone 50) | | (GDA94) | |
| At risk of Material or Serious Environmental Harm | MI1 | 381217 | 7655802 | 21° 11.722´ S | 115° 51.339´ E |
| | MI2 | 381562 | 7655798 | 21° 11.725´ S | 115° 51.537´ E |
| | MI3 | 380484 | 7656060 | 21° 11.579´ S | 115° 50.916´ E |
| | MI4 | 380075 | 7655282 | 21° 11.999´ S | 115° 50.676´ E |
| Reference Sites | MR1 | 382777 | 7660320 | 21° 09.279´ S | 115° 52.258´ E |
| | MR2 | 383281 | 7660136 | 21° 09.281´ S | 115° 52.549´ E |
| | MR3 | 379259 | 7652747 | 21° 13.370´ S | 115° 50.193´ E |

| Location | Site Code | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|---|
| | | (GDA94, MGA Zone 50) | | (GDA94) | |
| | MR4 | 379777 | 7652573 | 21° 13.466´ S | 115° 50.492´ E |

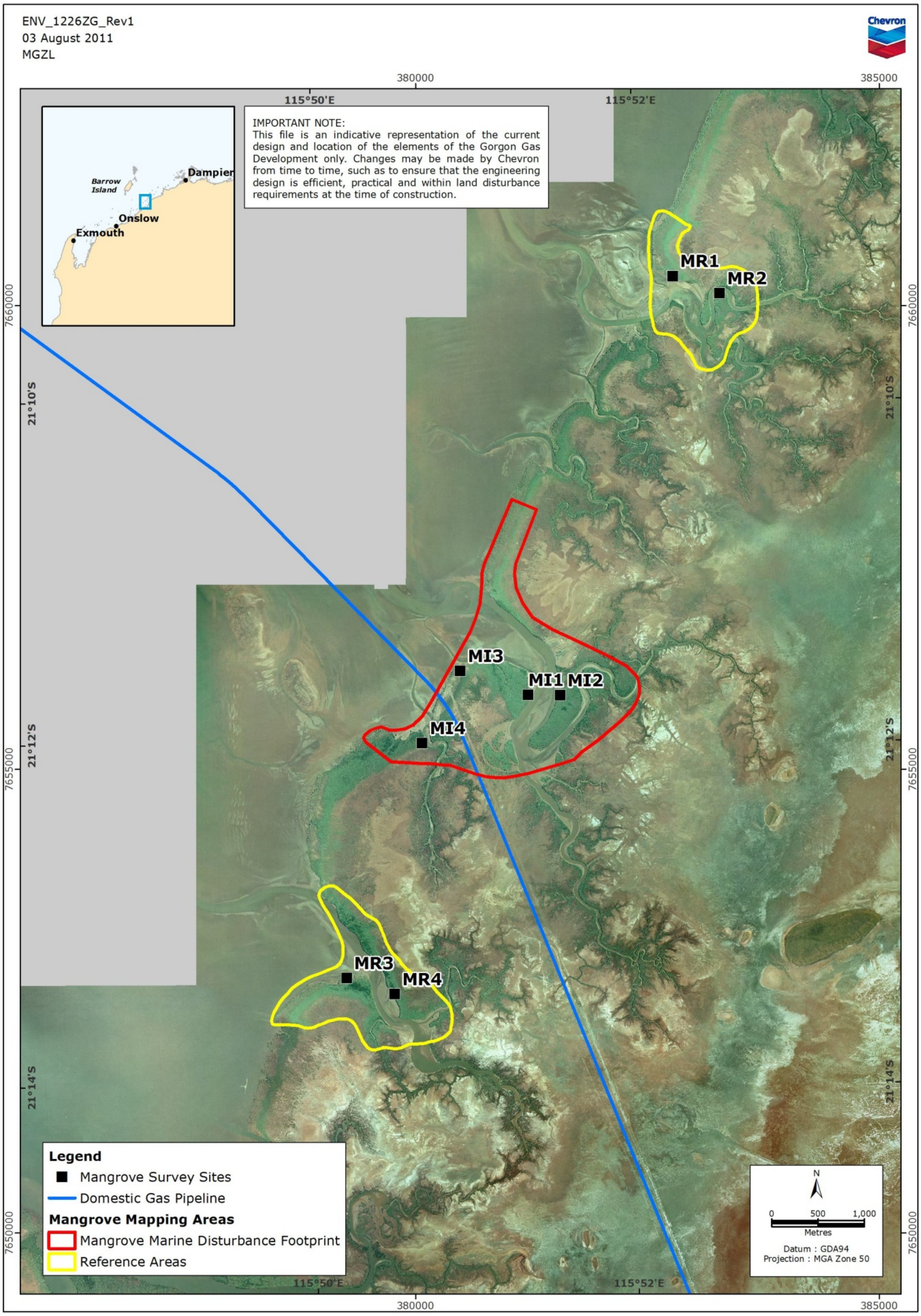



**Figure 10-1 Mangrove Survey Sites at the Mainland End of the DomGas Pipeline Route**

### 10.3.2 Vegetation Surveys

At each site, three permanent 50 × 1 m wide belt transects were established ~50 m apart extending inland from the seaward side of the mangrove community. As far as practicable, the transects at each site were aligned parallel to each other and were orientated perpendicular to the local shoreline.

#### 10.3.2.1 Quantitative Assessments

##### 10.3.2.1.1 Light Infiltration and Canopy Cover

Light infiltration was measured under five randomly selected mature mangrove trees at each site. Light infiltration readings were collected over the period between 10:00 and 14:00 WST under clear sky conditions as light intensity is usually at a maximum during these hours, using a DS N19Q1367 Lux meter (dry season survey) or a Yokogawa 510-01 Digital Illuminance meter (wet season survey). Incident light measurements were made at 40 randomly selected points beneath the canopy of each selected tree (i.e. a total of 200 under-canopy measurements per site) at a fixed distance of 30 cm above the sediment surface. Ten additional light measurements were taken in direct unobstructed sunlight; five before and five after the measurements were recorded under each tree (i.e. a total of 50 unobstructed sunlight sample points per site).

##### 10.3.2.1.2 Pneumatophore Density

Pneumatophore density was recorded at 15 locations at each site. In the dry season survey, pneumatophore density was recorded at five randomly selected points along each transect. In the wet season survey, pneumatophore density was recorded next to 15 randomly sampled trees, including those used for light measurements and leaf pathology, at each site. At each sampling location, a 1 $m^2$ quadrat was positioned, where practicable, in areas free of human disturbance and exposed lateral roots, and its location recorded using GPS. The total number of exposed pneumatophores in each quadrat was recorded and a digital photograph of each quadrat was taken to support field counts (if required), and to provide a visual record of the pneumatophore density.

##### 10.3.2.1.3 Leaf Pathology

Leaf pathology was assessed for five randomly selected mature mangrove trees at each site.[15] The same trees used for light infiltration measurements were assessed for leaf pathology. Six leaf pathogen indicators were assessed on each tree: leaf yellowing/discolouration, sooty mould, leaf galls, scaling, spotting (yellow or white spots) and ‘Nil Leaf Pathology’ (i.e. no pathogen present) (Plate 10-1). To ensure an even distribution of sampling, the canopy of each tree was ‘visually’ divided into four equal sections: ocean-facing upper half, ocean-facing lower half, land-facing upper half and land-facing lower half. Within each section, 25 leaves were randomly selected, totalling 100 leaves per tree and 500 leaf assessments per site. In the dry season survey, the dominant pathogen (i.e. the pathogen which affected the greatest area of the leaf surface) present on each sampled leaf was identified; in the wet season survey, each sampled leaf was scored for the presence or absence of the six leaf pathogen indicators.

[15] Note that leaf pathology was not assessed on one tree at MI1 in the wet season survey due to the tidal conditions restricting site access.

Leaf Spotting

Leaf Yellowing

Leaf Gall

**Plate 10-1 Examples of Leaf Pathology Indicators Observed in October 2010**

#### 10.3.2.2 Qualitative Assessments

##### 10.3.2.2.1 General Site Assessment

The total number of mangrove trees within each of the 1 m wide belt transects (dry season survey) or the total number of trees that intersected the tape used to delineate the transect (wet season survey), the mangrove species composition (including the presence of other species either within or adjacent to the transect), the estimated total canopy cover (% or $m^2$ [16]), and the presence and number of mangrove seedlings, were recorded along each transect.

##### 10.3.2.2.2 Mangrove Tree Health

Qualitative Visual Health Assessments were recorded for five randomly selected mature mangrove trees on each transect (i.e. 15 trees per site). In the dry season survey, the selected trees included those selected for light infiltration measurements and leaf pathology assessment; in the wet season survey, the randomly selected trees for assessment of pneumatophore density were used. Each tree was visually assessed and allocated a health score for each of six individual parameters based on the modified health score system adapted from Eldridge *et al.* (1993) and Astron Environmental Services (2009) (Table 10-2). The intent of this qualitative

[16] Estimated as the canopy spread of dominant and subdominant mangrove species covering the 1 m-wide × 50 m-long transect at each site.

assessment of tree health was to complement and assist with the interpretation of the quantitative assessment (Section 10.3.2.1).

**Table 10-2 Qualitative Mangrove Health Scoring System**

| Canopy Cover | |
|---|---|
| **Total Canopy Cover (%)** | **Health Score** |
| 100 - 90% | 6 |
| 90 - 70% | 5 |
| 70 - 50% | 4 |
| 50 - 30% | 3 |
| 30 - 10% | 2 |
| 10 - 1% | 1 |
| < 1% | 0 |
| **Reproductive Parts (flowers/fruits)** | |
| **Crypto-viviparous Fruit (Rounded)/Flowers** | **Health Score** |
| Absent | 0 |
| Present | 1 |
| **Lateral Roots** | |
| **Exposed Lateral Roots from Tree Base** | **Health Score** |
| Absent (Covered) | 1 |
| Present (Exposed) | 0 |
| **TOTAL HEALTH SCORE (sum of scores above)** | |
| **Qualitative Description** | **Health Score** |
| Heavily Defoliated/Dead | < 6 |
| Degraded | 6 - 10 |
| Poor | 10 - 14 |
| Moderate | 14 – 18 |
| Good | 18 – 22 |
| Excellent | 22 - 26 |

| Qualitative Mangrove Health Scoring System | |
|---|---|
| **Damaged Leaves** | |
| **Total Percentage Cover of Damaged Leaves (%)** | **Health Score** |
| 100 - 90% | 0 |
| 90 - 70% | 1 |
| 70 - 50% | 2 |
| 50 - 30% | 3 |
| 30 - 10% | 4 |
| 10 - 1% | 5 |
| < 1% | 6 |
| **Defoliated Branches** | |
| **Total Percentage Cover of Completely Defoliated Branches (%)** | **Health Score** |
| 100 - 90% | 0 |
| 90 - 70% | 1 |
| 70 - 50% | 2 |
| 50 - 30% | 3 |
| 30 - 10% | 4 |
| 10 - 1% | 5 |
| < 1% | 6 |
| **New Foliage** | |
| **Total Percentage Cover of New Leaves (%)** | **Health Score** |
| 100 - 90% | 6 |
| 90 - 70% | 5 |
| 70 - 50% | 4 |
| 50 - 30% | 3 |
| 30 - 10% | 2 |
| 10 - 1% | 1 |
| < 1% | 0 |

## 10.3.3 Timing and Frequency of Surveys

Mangrove surveys were undertaken during the dry season in October 2010 and the wet season in March 2011.

## 10.3.4 Treatment of Survey Data

### 10.3.4.1 Light Infiltration and Canopy Cover

The canopy cover (%) for each tree was calculated as the mean of the following calculations of each light measurement:

100 – (light reading under tree/mean of ambient light readings in unobstructed position * 100).

#### 10.3.4.2 General Site Assessment

Data are presented as the total of the three transects at each site, with the exception of estimated total canopy cover, which is presented as the mean (± Standard Error [SE]) of the three transects at each site.

#### 10.3.4.3 Mangrove Tree Health

A total health score, the sum of each of the six component scores for each tree, was calculated to provide an overall estimate of mangrove health (Tree Health Score).

#### 10.3.4.4 Statistical Analysis

Permutational multivariate analysis of variance (PERMANOVA; Anderson *et al.* 2008) was used to assess the statistical significance of differences in the various measures of mangrove health between sites at risk of Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline and Reference Sites. A nested mixed-model design was applied using the categorical fixed factor ‘Area’ (two levels: at risk of Material or Serious Environmental Harm, Reference Site not at risk of Material or Serious Environmental Harm) with the random factor ‘Site’ nested hierarchically within each of the two levels for ‘Area’. The similarity matrix was calculated using Euclidean Distance without data transformation (which was unnecessary because of homogeneous variance structure), residuals were permutated under a reduced model, and a Type III (partial) PERMANOVA model was used (Anderson *et al*. 2008). The same model design was used for both univariate (canopy cover, pneumatophore density, total Qualitative Health Assessment Score) and multivariate (leaf pathology indicators) tests.

## 10.4 Results

### 10.4.1 Distribution of Mangroves at the Mainland End of the DomGas Pipeline Route

Mangroves dominate the upper intertidal along the Pilbara coast at the mainland end of the DomGas Pipeline (Figure 5-9; Figure 5-10; Figure 5-11).

### 10.4.2 Dominant Mangrove Species at the Mainland End of the DomGas Pipeline Route

The dominant (or most common) mangrove in terms of canopy cover and number of trees at the mainland end of the DomGas Pipeline route in areas at risk of Material or Serious Environmental Harm and at Reference Sites, was *Avicennia marina* (Table 10-3; Table 10-5; Plate 10-2). Observations of mono-specific stands of *Avicennia marina* were less common than those with two to three species, which included *Rhizophora stylosa, Ceriops australis, Aegialitis annulata* or *Aegiceras corniculatum.* These species were less common (subdominant) and did not occur at all survey sites. *Suaeda arbusculoides* and *Tecticornia* spp. (samphire) were recorded in association with the mangroves.

*Avicennia marina* at MI2

*Rhizophora stylosa* at MI4

*Ceriops australis* at MI2

*Aegialitis annulata* at MI3

*Tecticornia* spp.

*Suaeda arbusculoides* at MI1

**Plate 10-2 Examples of Mangrove Species and Understorey Vegetation Observed at the Mainland End of the DomGas Pipeline Route**

### 10.4.3 Description of Mangroves at Risk of Material or Serious Environmental Harm due to the Construction and Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route

#### 10.4.3.1 General Site Description

A general description of each site, based on field observations, is provided in Table 10-3. *Avicennia marina* was the dominant species at all four sites (Table 10-4). Mangrove species richness and composition varied, with between two and four species recorded at each site.

In total, 302 trees were counted along transects at the four sites during the dry season survey (Table 10-4). The overall estimated canopy cover along the transects at these sites was 283 $m^2$, covering 47% of the area surveyed (total area surveyed was 600 $m^2$) and with a site-average spread per tree of 0.9 $m^2$. Seedlings were present at all sites in the dry season survey.

In total, 377 trees were recorded along the transects at the four sites during the wet season survey (Table 10-4). The estimated canopy cover at the four sites ranged from 25% to 85%. Mangrove seedlings were present at each site but in low numbers.

**Table 10-3 General Site Description for Mangrove Survey Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

| Site | Mangrove Community Description |
|---|---|
| MI1<br>Western bank of the northern creek within the area at risk of Material or Serious Environmental Harm. | • Moderate-to-dense mangroves with a samphire understorey.<br>• Mangrove species composition:<br>  • Dominant: *Avicennia marina*<br>  • Subdominant: *Rhizophora stylosa*, *Aegiceras corniculatum*, *Aegialitis annulata*.<br>• Associated Species: *Suaeda arbusculoides*, *Tecticornia* spp. |
| MI2<br>Eastern bank of the northern creek within the area at risk of Material or Serious Environmental Harm. | • Moderate-to-dense mangroves.<br>• Mangrove species composition:<br>  • Dominant: *Avicennia marina*<br>  • Subdominant: *Rhizophora stylosa*, *Ceriops australis*.<br>• Associated Species: *Suaeda arbusculoides*, *Tecticornia* spp. |
| MI3<br>South-eastern bank at the shoreline entrance to the northern creek within the area at risk of Material or Serious Environmental Harm. | • Open mangroves with trees up to 2 m tall. Exposed lateral roots.<br>• Mangrove species composition:<br>  • Dominant: *Avicennia marina*<br>  • Subdominant: *Aegialitis annulata*.<br>• Associated Species: None. |
| MI4<br>South-western bank of the southern creek within the area at risk of Material or Serious Environmental Harm. | • Dense mangroves with trees 2–3 m tall. Exposed lateral roots.<br>• Mangrove species composition:<br>  • Dominant: *Avicennia marina*<br>  • Subdominant: *Rhizophora stylosa* (and *Ceriops australis* outside the transects).<br>• Associated Species: *Suaeda arbusculoides*, *Tecticornia* spp. |

**Table 10-4 Summary of the General Assessment of Mangroves at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

| Attribute | | Visual Estimate Average % Cover | Number of Trees (total count) | | | | | | Mangrove Species Richness | Number of Seedlings (total count) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Avicennia marina* | *Rhizophora stylosa* | *Aegiceras corniculatum* | *Aegialitis annulata* | *Ceriops australis* | Total | | *Avicennia marina* | *Rhizophora stylosa* | *Ceriops australis* | *Aegialitis annulata* |
| MI1 | Oct 2010 | 37% | 41 | 1 | 1 | 5 | - | 48 | 4 | 7 | - | - | - |
| | Mar 2011 | 40% | 63 | 2 | 1 | 18 | - | 84 | 4 | 4 | - | - | - |
| MI2 | Oct 2010 | 55% | 97 | 2 | - | - | 9 | 108 | 3 | 5 | - | 6 | - |
| | Mar 2011 | 60% | 98 | 2 | - | - | 5 | 105 | 3 | 3 | 2 | - | - |
| MI3 | Oct 2010 | 10% | 25 | - | - | 2 | - | 27 | 2 | 2 | - | - | 2 |
| | Mar 2011 | 25% | 44 | - | - | 6 | - | 50 | 2 | 2 | - | - | - |
| MI4 | Oct 2010 | 87% | 111 | 8 | - | - | - | 119 | 2 | - | 13 | - | - |
| | Mar 2011 | 85% | 125 | 11 | - | - | - | 138 | 2 | 2 | 3 | - | - |

*Note: Data represent totals for all three transects at each site, with the exception of estimated percentage cover, which represents the mean of the three transects.*

#### 10.4.3.2 Light Infiltration and Canopy Cover

The highest mean canopy cover, as measured by the percentage of light attenuated by the canopy, was recorded at MI1 (78.8% ± 2.8 SE) during the dry season survey, whilst the lowest was recorded at MI3 (56.3% ± 6.9 SE) (Figure 10-2). The overall mean canopy cover for mangroves at risk of Material or Serious Environmental Harm during the dry season survey was 70.9% ± 0.9 SE. In contrast, during the wet season survey the overall mean canopy cover was 60.0% ± 4.2 SE across the four sites. In the wet season survey, mangroves at MI3 had the lowest mean canopy density (48.5% ± 6.5 SE), whereas trees at MI4 had the highest (68.2% ± 3.5 SE).

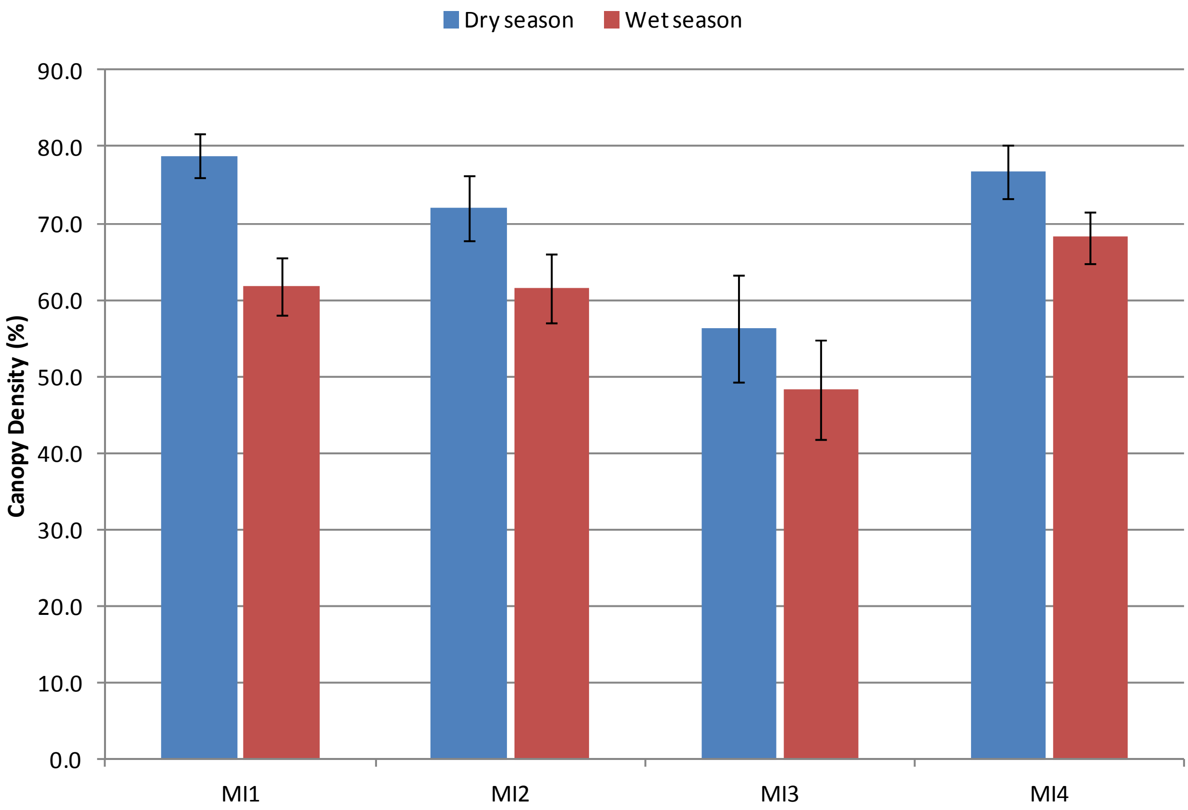



**Figure 10-2 Mean Canopy Density (± SE) per 5 Sample Trees at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

#### 10.4.3.3 Pneumatophore Density

The mean pneumatophore density recorded at each site ranged between 48.6 per $m^2$ ± 16.4 SE at MI2 and 109.1 per $m^2$ ± 3.8 SE at MI4 during the dry season survey, and between 98.2 per $m^2$ ± 40.3 SE at MI2 and 143.8 per $m^2$ ± 17.2 SE at MI4 during the wet season survey. There was considerable variation in pneumatophore density between transects at each site in both the dry season and wet season surveys (Figure 10-3). In the dry season survey, mean pneumatophore density ranged from 20.2 per $m^2$ ± 5.4 SE for Transect 2 at MI2, to 125.6 per $m^2$ ± 24.8 SE for Transect 3 at MI3. In the wet season survey, mean pneumatophore density ranged from 46.2 per $m^2$ ± 22.6 SE for Transect 2 at MI2, to 203.2 per $m^2$ ± 31.7 SE for Transect 3 at MI3.

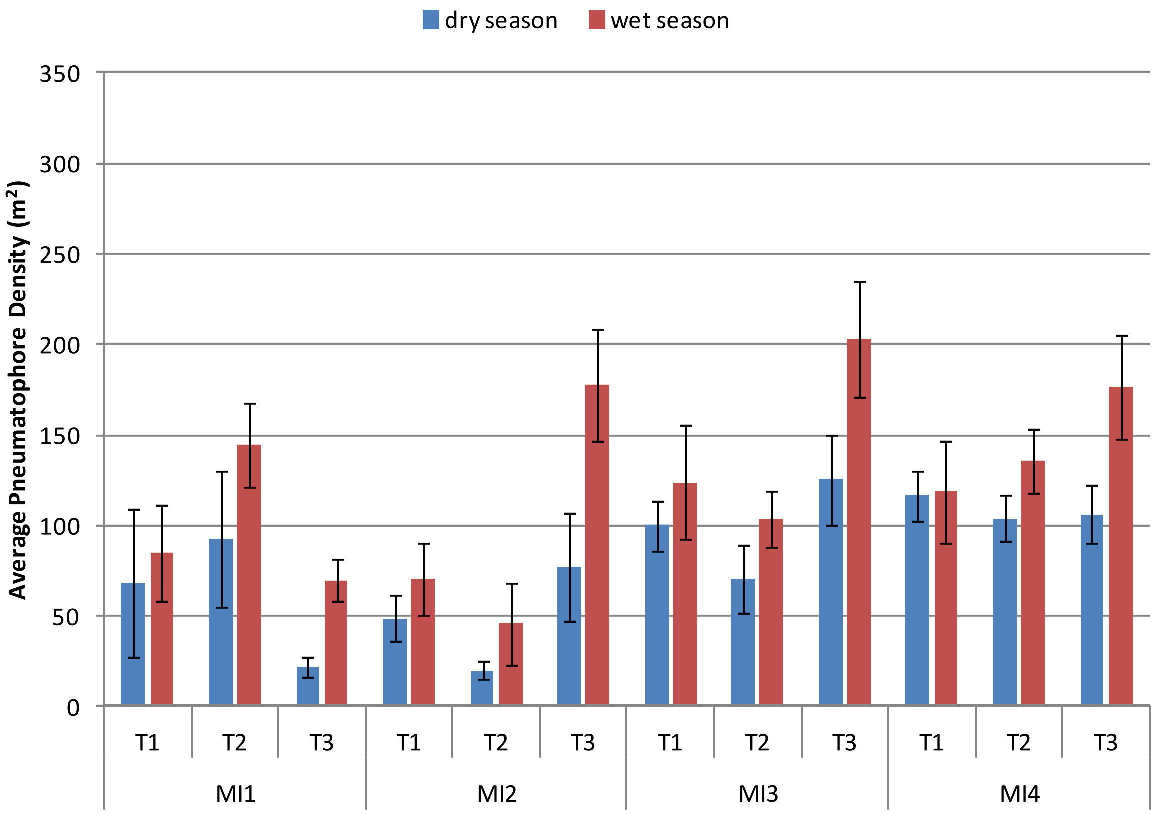



**Figure 10-3 Mean Pneumatophore Density (± SE) at Transects at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

#### 10.4.3.4 Leaf Pathology

The most prevalent leaf pathogen on mangroves during the dry season survey was leaf spotting (Figure 10-4). The highest incidence of leaf spotting was recorded at MI2 (63.8 affected leaves per 100 leaves assessed ± 2.6 SE), and the lowest at MI4 (46.8 affected leaves per 100 leaves assessed ± 2.8 SE). The highest incidence of unaffected leaves with no leaf pathogens (32.0 leaves per 100 leaves assessed ± 2.9 SE) was also recorded at MI4. In comparison to leaf spotting, the incidences of scale and sooty mould were very low, occurring on 0.8 leaves ± 0.3 SE and 0.2 leaves ± 0.1 SE, respectively, per 100 leaves assessed. The incidences of yellowing and leaf galls were also low, recorded on 7.0 leaves ± 1.2 SE and 13.1 leaves ± 2.1 SE, respectively, per 100 leaves assessed.

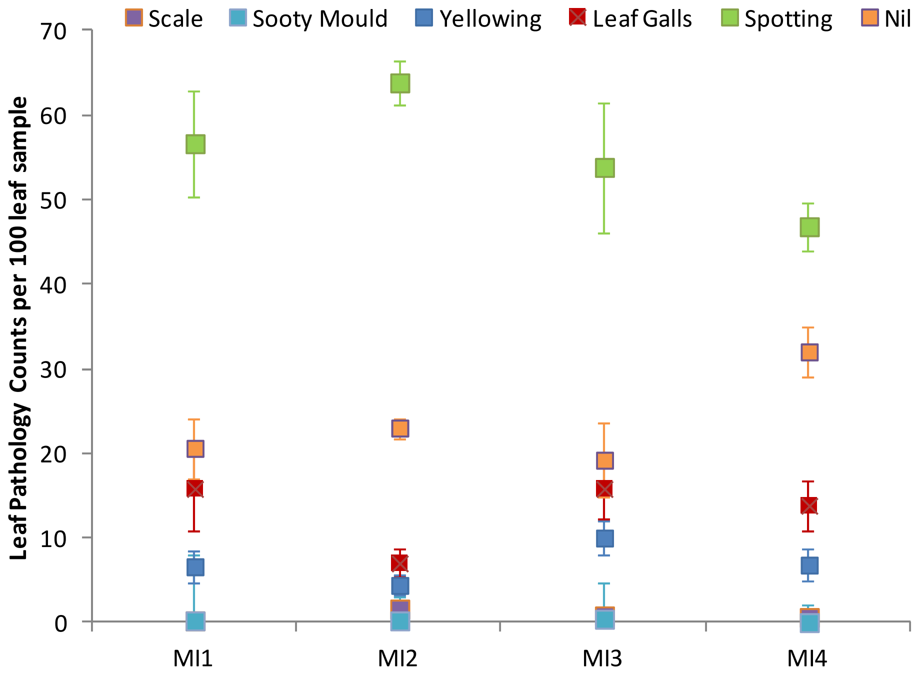



**Figure 10-4 Mean Dominant Leaf Pathology Indicator (± SE) in the Dry Season Survey at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland end of the DomGas Pipeline Route**

*Note: Where leaves presented more than one leaf pathology indicator, the indicator scored was the one that affected most of the leaf surface. Where no leaf pathology indicator was observed on any particular leaf, the assessment was recorded as 'Nil'.*

During the wet season survey, the incidence of spotting and galls was much greater than yellowing (Figure 10-5). The mean incidence of spotting ranged from 25.4 leaves per 100 leaves assessed ± 2.1 SE at MI4, to 42.2 leaves ± 4.4 SE at MI3. The incidence of galls ranged from 17.6 leaves ± 1.5 SE at MI2, to 29.0 leaves ± 7.6 SE at MI1. The incidence of yellowing was greatest at MI3 (5.0 leaves ± 0.5 SE) and lowest at MI4 (0.8 leaves ± 0.6 SE). There was no incidence of sooty mould or scale recorded during the wet season survey.

A comparison of the number of leaves with no pathology indicators recorded in the dry season and wet season surveys is presented in Figure 10-6. The highest incidence of absence of leaf pathogens (i.e. the 'Nil' condition score) was recorded in the wet season survey, when a large number of leaves were observed with the 'Nil' condition, ranging between 41.6 leaves ± 5.9 SE at MI3 to 58.8 leaves ± 3.3 SE at MI4.

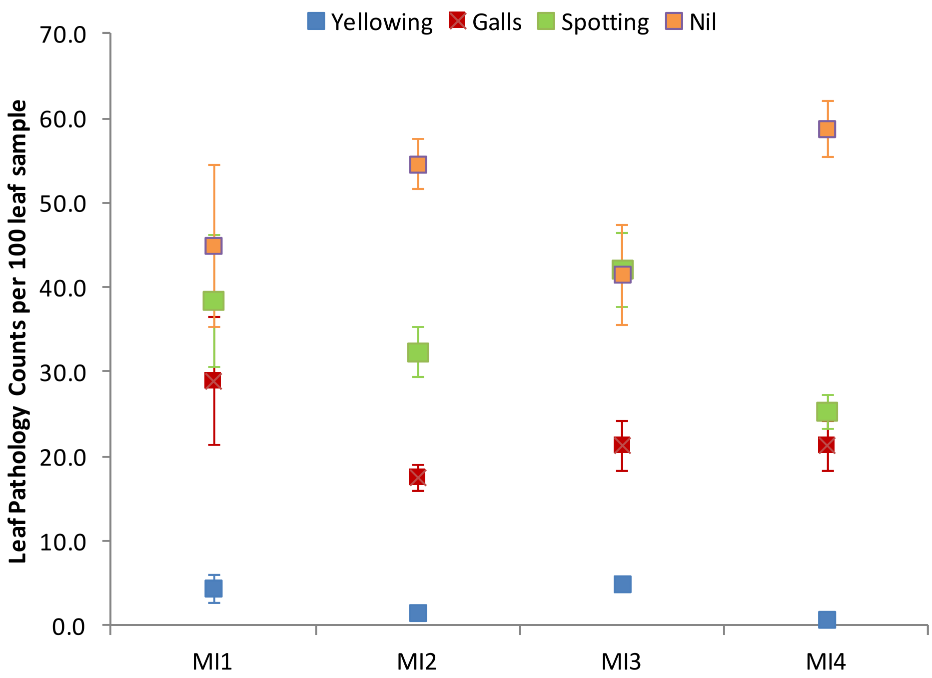



**Figure 10-5 Mean Leaf Pathology Indicators (± SE) in the Wet Season Survey at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

*Note: Scale and Sooty Mould were not recorded during the April 2011 survey.*

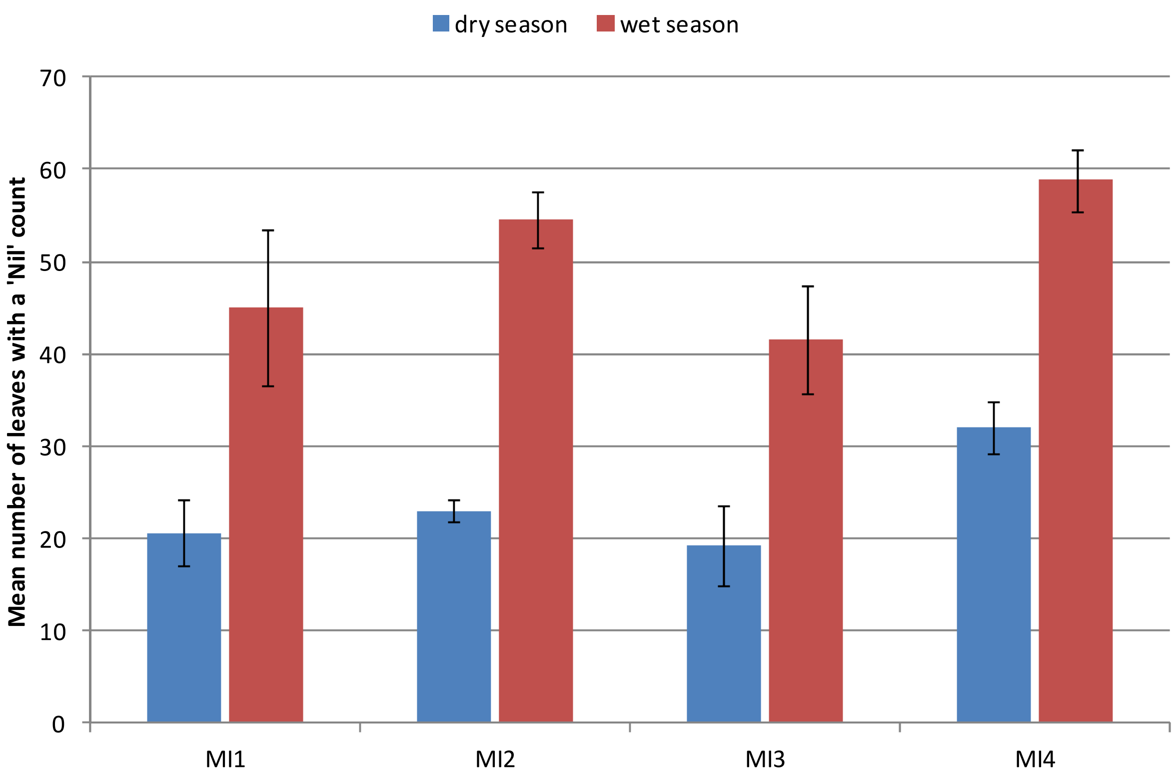



**Figure 10-6 Mean Leaf Pathology 'Nil' Counts (± SE) in the Dry Season and Wet Season Surveys at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

*Note: n=5 (trees per site), n=4 for MI1 wet season survey.*

#### 10.4.3.5 Qualitative Visual Health Assessment

Results for the Qualitative Visual Health Assessments from the dry and wet season surveys are presented in Figure 10-7. During the dry season survey, one site (MI4) was scored as within the 'Moderate' category, while the other sites rated as 'Poor'. The mean Tree Health Score for mangroves at all sites was 13.5 ± 0.6 SE. In contrast, the mean Tree Health Score for mangroves at all sites during the wet season survey was 15.5 ± 0.2 SE. This score falls within the 'Moderate' category. There was little variation between mean Tree Health Scores during the wet season survey and all were within the 'Moderate' category.

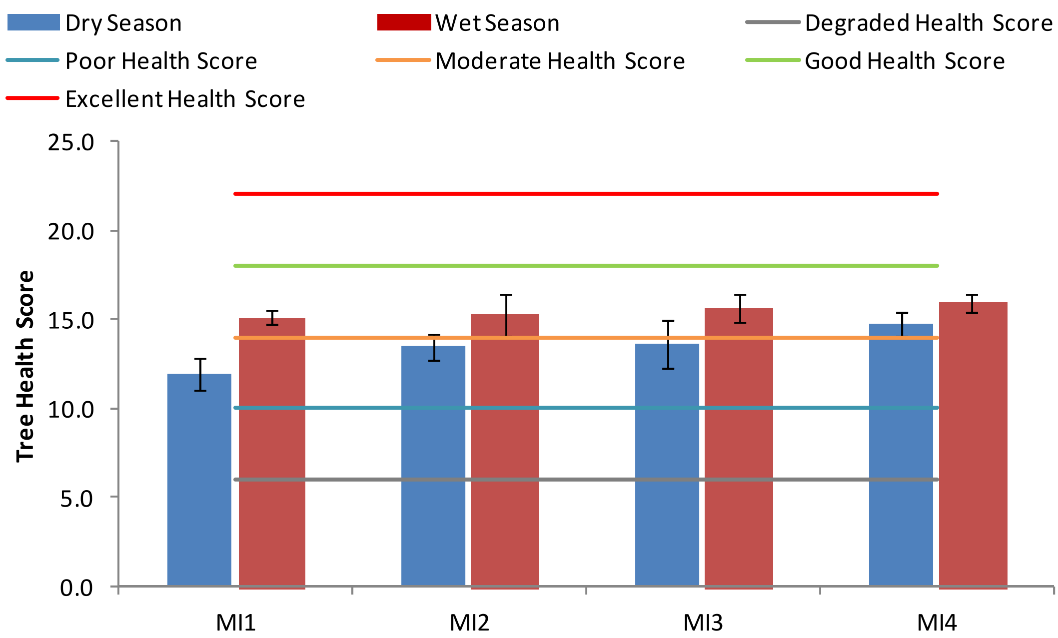



**Figure 10-7 Mean (± SE) Qualitative Visual Health Assessment for Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

### 10.4.4 Description of Mangroves at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route

#### 10.4.4.1 General Site Description

A general description of each site, based on field observations, is provided in Table 10-5. *Avicennia marina* was the dominant species at all four sites (Table 10-6). Mangrove richness and species composition varied, with between one and three species recorded at each site.

In total, 278 trees were counted along transects at the four sites during the dry season survey (Table 10-6). The overall estimated canopy cover along the transects at these sites was 229 $m^2$, covering 38% of the area surveyed (total area surveyed was 600 $m^2$) and with a site-average spread per tree of 0.8 $m^2$. Seedlings were present at only one (MR2) of the four sites, where 160 *A. marina* seedlings were recorded on the first 25 m of the transect across a sandbank adjacent to the creek bank, an area clear of mature trees.

In total, 276 trees were recorded along the transects at the four sites during the wet season survey (Table 10-6). The estimated canopy cover at the four sites ranged from 25% to 90%. Mangrove seedlings were relatively abundant at MR2 (31 *A. marina* seedlings) and were not present at MR1 or MR4.

### Table 10-5 General Site Description for Mangrove Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route

| Site | Mangrove Community Description |
|---|---|
| MR1<br>North-western bank of the northern reference creek | • Sparse population of 3.5–4 m tall trees each with a dense canopy, extensive area of sediment with no mangroves.<br>• Mangrove species composition:<br>  • Dominant: *Avicennia marina*<br>  • Subdominant: None.<br>• Associated Species: None. |
| MR2<br>Eastern bank of a tributary within the northern reference creek | • The creek ends of transects at this site traversed approximately 25 m of sandbank. The intermediate section of transects at this site (~25–40 m) comprised a dense canopy of 3–4 m tall mangroves transitioning to 1.2–2 m tall trees towards the inland ends of the transects.<br>• Mangrove species composition:<br>  • Dominant: *Avicennia marina*<br>  • Subdominant: *Ceriops australis*.<br>• Associated Species: *Suaeda arbusculoides*, *Tecticornia* spp. |
| MR3<br>Southern bank of the southern reference creek | • Site situated at the mouth of the southern reference creek with all transects comprising sparse mangrove vegetation with a moderately dense canopy of 3–4 m tall trees.<br>• Mangrove species composition:<br>  • Dominant: *Avicennia marina* (codominant)<br>  • Subdominant: *Rhizophora stylosa* (codominant), *Ceriops australis*.<br>• Associated Species: None. |
| MR4<br>North-eastern bank of the southern reference creek | • Transects 1 and 2 comprised dense *Rhizophora stylosa* trees to 3 m in height, transitioning after ~30 m to *Avicennia marina* inland. Transect 3 comprised *A. marina* with *Ceriops australis* dominating inland.<br>• Mangrove species composition:<br>  • Dominant: *Avicennia marina*<br>  • Codominant to Subdominant: *Rhizophora stylosa*, *Ceriops australis*.<br>• Associated Species: None. |

**Table 10-6 Summary of the General Assessment of Mangroves at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

| Attribute | | Visual Estimate Average % Cover | Number of Trees (total count) | | | | | | Mangrove Species Richness | Number of Seedlings (total count) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Avicennia marina* | *Rhizophora stylosa* | *Aegiceras corniculatum* | *Aegialitis annulata* | *Ceriops australis* | Total | | *Avicennia marina* | *Rhizophora stylosa* |
| MR1 | Oct 2010 | 21% | 25 | - | - | - | -- | 25 | 1 | - | - |
| | Mar 2011 | 30% | 42 | - | - | - | - | 42 | 1 | - | - |
| MR2 | Oct 2010 | 31% | 27 | - | - | - | 6 | 33 | 2 | 160 | - |
| | Mar 2011 | 40% | 87 | - | - | - | 3 | 73 | 2 | 31 | - |
| MR3 | Oct 2010 | 33% | 22 | - | - | - | - | 22 | 1 | - | - |
| | Mar 2011 | 25% | 38 | - | - | - | - | 38 | 1 | 1 | 1 |
| MR4 | Oct 2010 | 68% | 109 | 43 | - | - | 46 | 198 | 3 | - | - |
| | Mar 2011 | 90% | 112 | Thicket | - | - | 11 | 123 | 3 | - | - |

*Note: Data represents totals for all three transects at each site, with the exception of estimated percentage cover, which represents the mean of the three transects.*

#### 10.4.4.2 Light Infiltration and Canopy Density

The highest mean canopy cover was recorded at MR1 (78.8% ± 3.0 SE) during the dry season survey, whilst the lowest was recorded at MR3 (70.4% ± 2.8 SE) (Figure 10-8). The overall mean canopy density for mangroves at Reference Sites during the dry season survey was 74.6% ± 1.3 SE. In contrast, during the wet season survey, the overall mean canopy cover was 67.9% ± 2.2 SE during the wet season survey. Mangroves at MR3 have the lowest mean canopy density (62.9% ± 5.7 SE), whereas trees at MR2 had the highest canopy density during the wet season survey (73.4% ± 1.8 SE).

Canopy cover was not significantly different between sites within the area at risk of Material or Serious Environmental Harm and Reference Sites, in either the dry season or wet season surveys. There were also no significant differences in canopy cover amongst the different sites at risk of Material or Serious Environmental Harm or amongst the different Reference Sites.

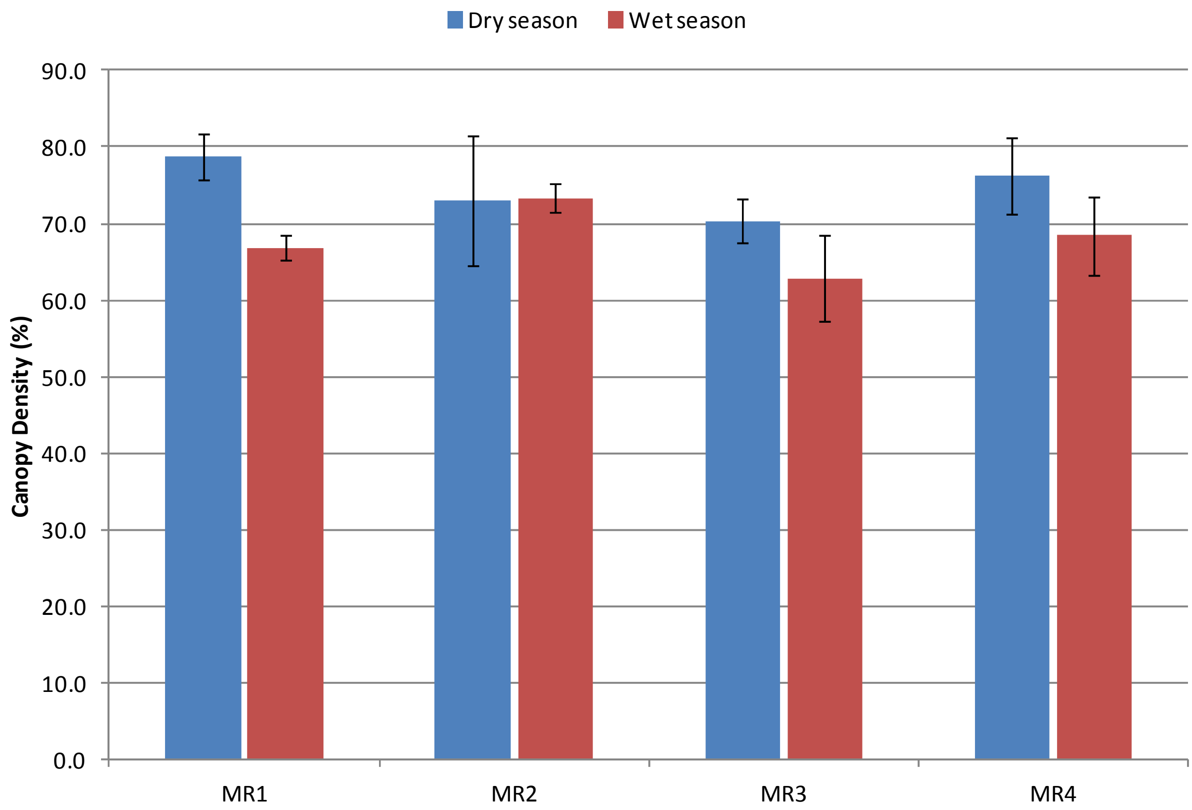



**Figure 10-8 Mean Canopy Density (± SE) per 5 Sample Trees at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

#### 10.4.4.3 Pneumatophore Density

The mean pneumatophore density recorded at each Reference Site ranged between 35.7 per $m^2$ ± 15.5 SE at MR2 and 143.9 per $m^2$ ± 13.9 SE at MR1 during the dry season survey, and between 78.8 per $m^2$ ± 21.1 SE at MR2 and 217.9 per $m^2$ ± 15.6 SE at MR1 during the wet season survey. There was considerable variation in pneumatophore density between transects at each site in both the dry season and wet season surveys (Figure 10-9). The highest mean pneumatophore density during the dry season survey was recorded on Transect 2 at MR4 (256.0 per $m^2$ ± 82.4 SE), whilst the lowest was recorded on Transect 3 at MR2 (17.8 per $m^2$ ± 7.5 SE). The greatest variability in mean pneumatophore density per transect during the dry season survey was recorded at MR4. Variation between transects was also large during the wet season survey, ranging from 40.4 per $m^2$ ± 13.5 SE on Transect 2 at MR2, to 249.2 per $m^2$ ± 37.9 SE for Transect 1 at MR1.

Pneumatophore density was not significantly different between sites within the area at risk of Material or Serious Environmental Harm and Reference Sites, in either the dry season or wet season surveys. There were no significant differences in pneumatophore density amongst the different sites at risk of Material or Serious Environmental Harm or amongst the Reference Sites in the dry season survey; however, in the wet season survey, there was a significant difference in pneumatophore density amongst the sites (PERMANOVA, $F_{1,6}$ = 4.090, $p$ = 0.016).

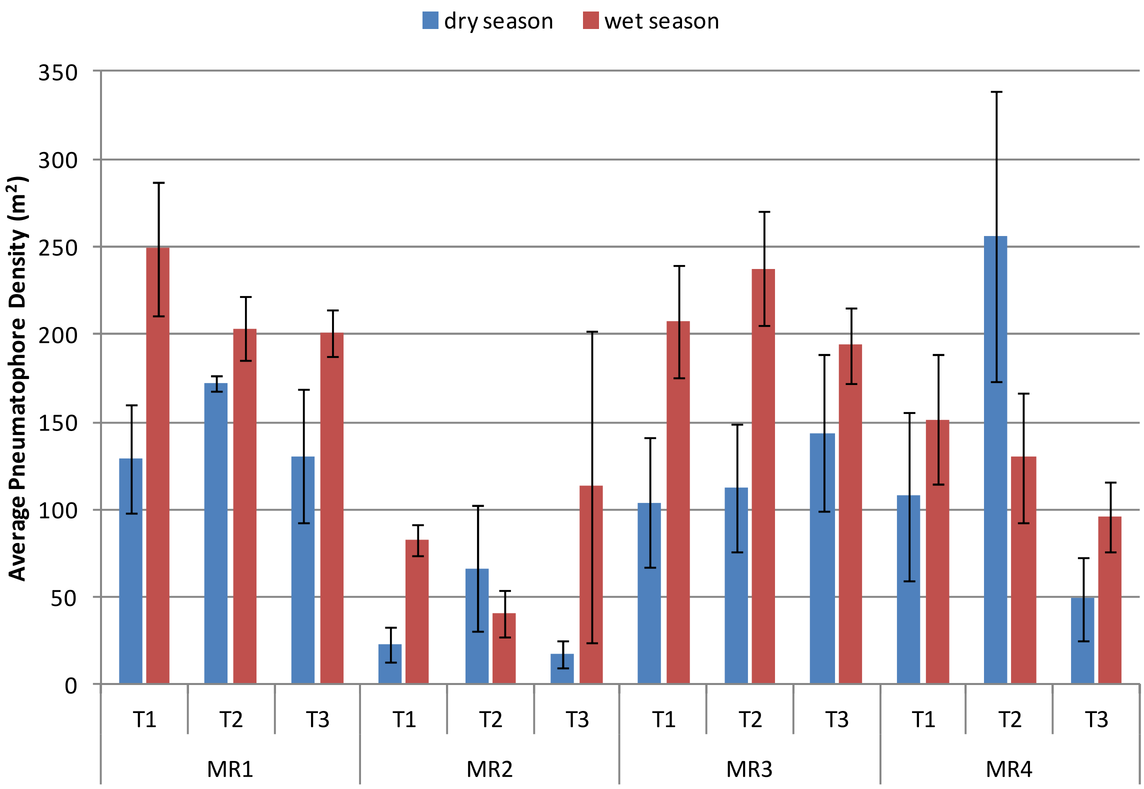



**Figure 10-9 Mean Pneumatophore Density (± SE) at Transects at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

### 10.4.4.4 Leaf Pathology

The most prevalent leaf pathogen on mangroves at Reference Sites during the dry season survey was leaf spotting followed by the absence of leaf pathogens (i.e. the 'Nil' condition score) (Figure 10-10). The highest incidence of leaf spotting was recorded at MR4 (57.8 affected leaves per 100 leaves assessed ± 5.3 SE), and the lowest at MR1 (40.4 affected leaves per 100 leaves assessed ± 4.4 SE). The highest incidence of unaffected leaves with no leaf pathogens (41.2 unaffected leaves per 100 leaves assessed ± 8.8 SE) was recorded at MR3, while MR2 had the lowest incidence of unaffected leaves, with a mean of 23.2 unaffected leaves per 100 leaves assessed ± 7.1 SE. In comparison to leaf spotting, the incidences of scale and sooty mould were low during the dry season survey, occurring on 1.0 leaves ± 0.4 SE and 0.6 leaves ± 0.3 SE, respectively, per 100 leaves assessed. The incidences of yellowing and leaf galls were also low, recorded on 6.6 leaves ± 0.7 SE and 11.3 leaves ± 3.9 SE, respectively, per 100 leaves assessed.

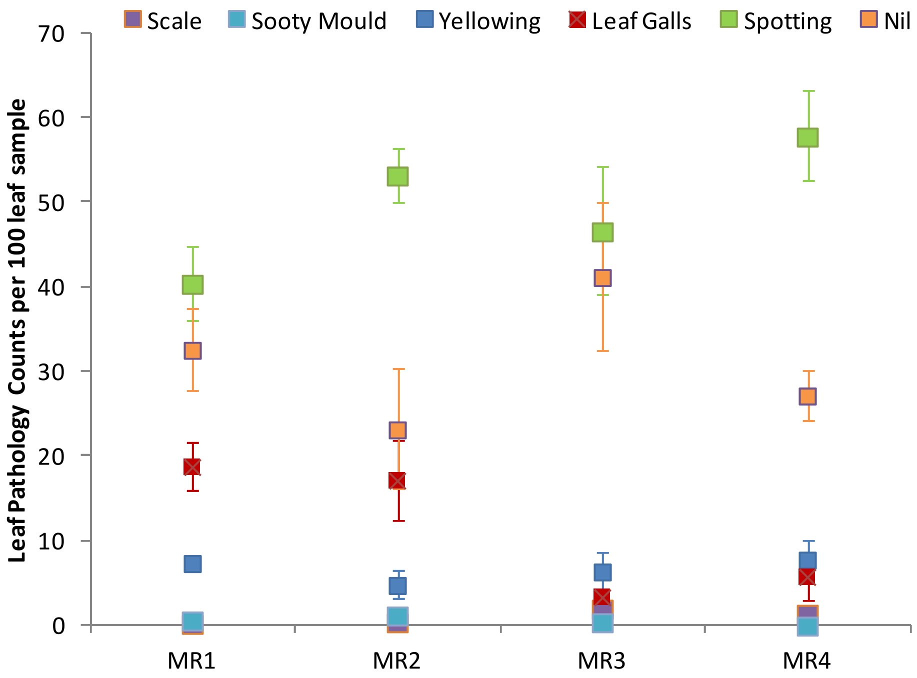



**Figure 10-10 Mean Dominant Leaf Pathology Indicator (± SE) in the Wet Season Survey at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

*Note: Where leaves presented more than one leaf pathology indicator, the indicator scored was the one that affected most of the leaf surface. Where no leaf pathology indicator was observed on any particular leaf, the assessment was recorded as 'Nil'.*

At all the Reference Sites, the majority of leaves were recorded as having no leaf pathogens (i.e. the 'Nil' condition score) during the wet season survey (Figure 10-11). The 'Nil' condition ranged from 49.6 leaves ± 1.2 SE at MR2, to 63.6 leaves ± 2.8 SE at MR3. The incidence of leaf spotting was higher than galls, which in turn was higher than yellowing. The incidence of spotting ranged from 22.6 leaves ± 2.7 SE at MR3, to 33.6 leaves ± 2.0 SE at MR2; the incidence of galls ranged from 14.8 leaves ± 3.7 SE at MR3, to 20.2 leaves ± 1.4 SE at MR1; and the incidence of yellowing ranged from 1.0 leaves ± 0.4 SE at MR4, to 3.6 leaves ± 0.8 SE at MR1. No leaves with sooty mould or scale were recorded during the wet season survey.

A comparison of the number of leaves with no pathology indicators is presented in Figure 10-12. The highest incidence of absence of leaf pathogens (i.e. the 'Nil' condition score) was recorded in the wet season survey.

The incidence of leaf pathogens was not significantly different between sites within the area at risk of Material or Serious Environmental Harm and Reference Sites, in either the dry season or wet season survey. There were no significant differences in the incidence of leaf pathogens amongst the different sites at risk of Material or Serious Environmental Harm or amongst the Reference Sites in the wet season survey; however, in the dry season survey, there was a significant difference in the incidence of leaf pathogens amongst the sites (PERMANOVA, $F_{1,6} = 2.151$, $p = 0.015$).

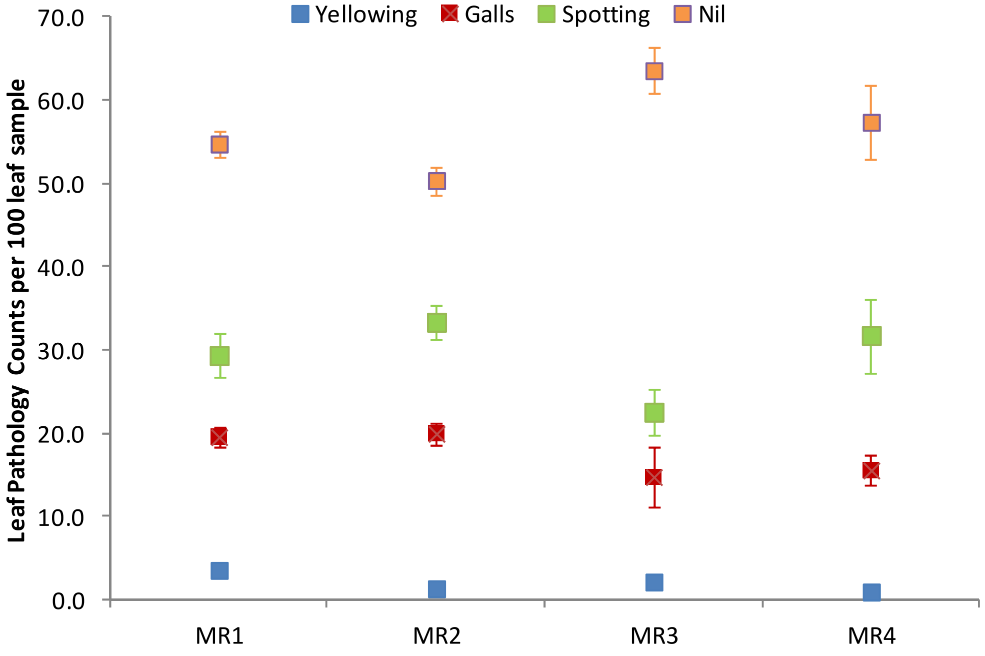



**Figure 10-11 Mean Leaf Pathology Indicators (± SE) in the Wet Season Survey at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

*Note: Scale and Sooty Mould were not recorded during the April 2011 survey.*

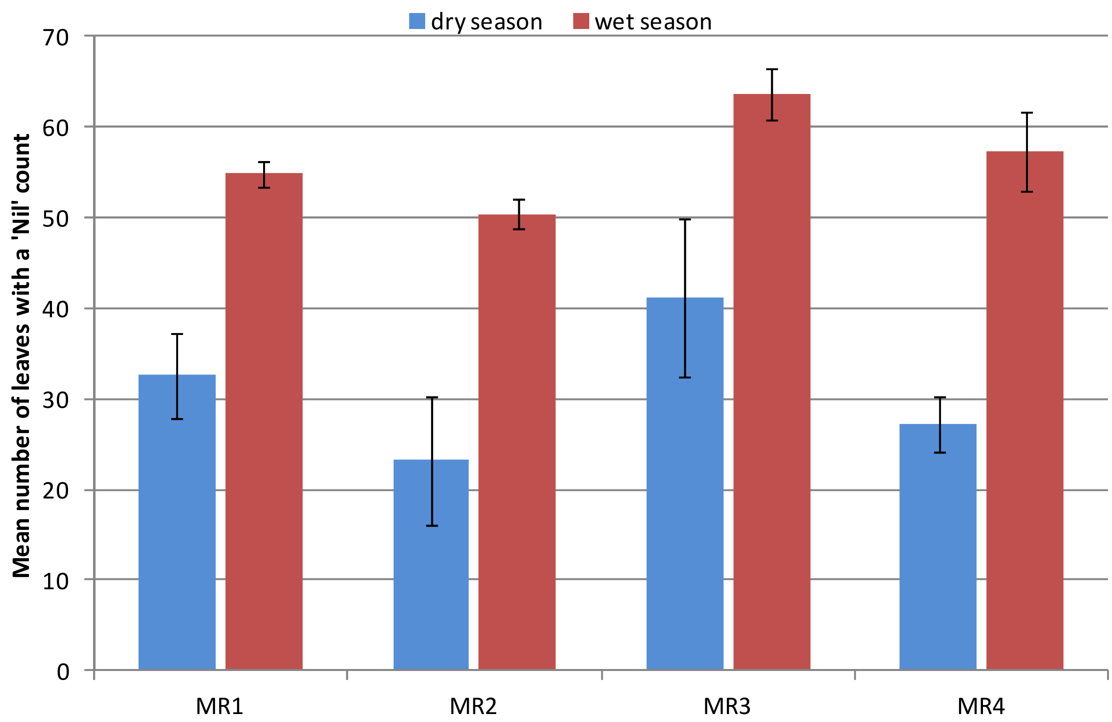



**Figure 10-12 Mean Leaf Pathology 'Nil' Counts (± SE) in the Dry Season and Wet Season Surveys at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

#### 10.4.4.5 Qualitative Visual Health Assessment

All the Reference Sites were rated as 'Poor' during the dry season survey. The mean Tree Health Score for mangroves at all four Reference Sites was 12.2 ± 0.3 SE, ranging from 11.5 ± 0.9 SE at MR3 to 12.7 ± 0.7 SE at MR2 and 12.7 ± 0.5 SE at MR4 (Figure 10-13). The mean Tree Health Score at all the Reference Sites during the wet season survey was 15.8 ± 0.3 SE. This score falls in the 'Moderate' category. Mean health scores for all four sites were within the 'Moderate' category, and ranged from 15.1 ± 0.7 SE at MR3 to 16.4 ± 0.5 SE at MR1.

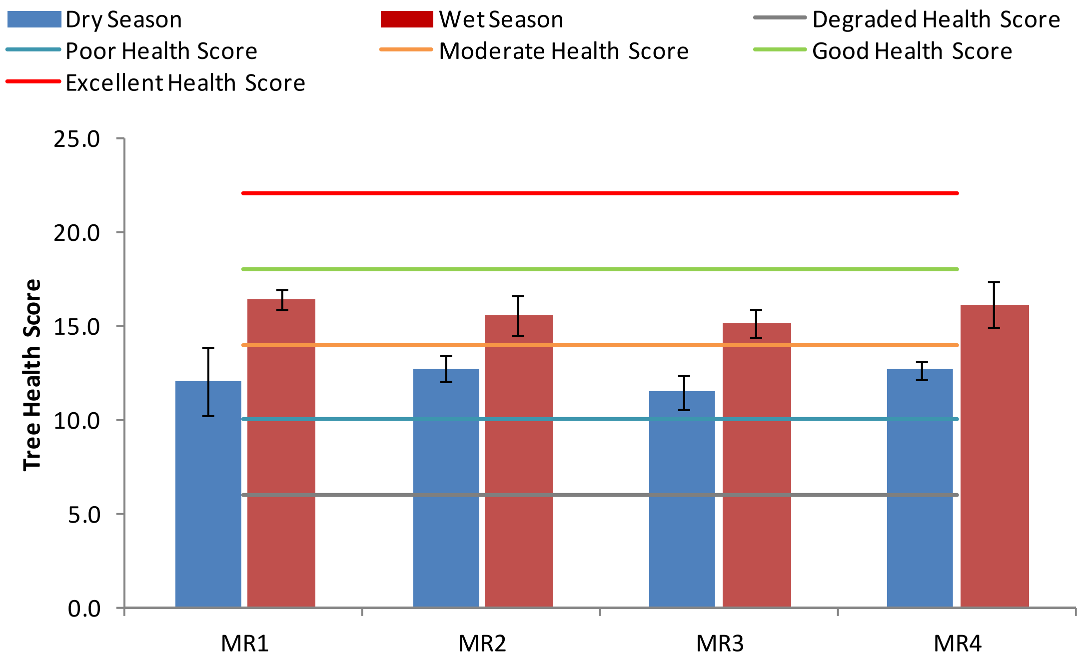



**Figure 10-13 Mean (± SE) Qualitative Visual Health Assessment for Reference Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route**

Tree Health Scores were not significantly different between sites within the area at risk of Material or Serious Environmental Harm and Reference Sites, in either the dry season or wet season surveys. There were also no significant differences in Tree Health Scores amongst the sites at risk of Material or Serious Environmental Harm or amongst the Reference Sites, in either the dry season or wet season surveys.

## 10.5 Discussion and Conclusions

*Avicennia marina* is the most widespread mangrove species in Australia, with a distribution that encompasses coastal areas throughout north-western and northern Australia, and also extending to temperate areas (Duke 2006). *Avicennia marina* was the dominant species at all sites surveyed at the mainland end of the DomGas Pipeline route. A total of five mangrove species were recorded in the baseline surveys (*Avicennia marina*, *Rhizophora stylosa*, *Ceriops australis*, *Aegialitis annulata* and *Aegiceras corniculatum*). All five species were observed at sites at risk of Material or Serious Environmental Harm, while only three species were observed at Reference Sites (*A. marina*, *R. stylosa* and *C. australis*).

The mangrove flora recorded at the mainland end of the DomGas Pipeline route was typical of sites distributed along the Pilbara coast. Studies elsewhere (e.g. Paling *et al*. 2003, 2008;

Jones 2004) indicate that *A. marina*, *R. stylosa* and *C. australis* comprise the dominant species through the broader region, while *A. annulata* and *A. corniculatum*, the two species not recorded at Reference Sites, are less common, but nevertheless widespread regionally. One additional species, *Bruguiera exaristata*, has been observed in the study area (Section 5.5); however, it was not recorded at the survey sites.

The mangroves at the sites at risk of Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline, and at Reference Sites were relatively healthy during the March 2011 wet season survey. Visual Tree Health Scores translated into the ‘Moderate’ category for health, with scores ranging from 15.1 to 16.4. In addition, a considerable proportion of leaves (>40%) in the canopy of each tree at the sites at risk of Material or Serious Environmental Harm and Reference Sites generally had no pathological conditions present. Due to the passage of tropical cyclones, rainfall in the two months that preceded the March 2011 wet season survey was well above average (Section 3.4). This rainfall may have benefited the health of mangroves in positions at or above the high tidal zone by leaching salts from the soil profile (Clough and Sim 1989). The removal of salt and dust from leaf surfaces may also have benefited the health of mangroves in all positions (reviewed in Paling *et al.* 2001).

When compared to the results of the October 2010 dry season survey, the March 2011 wet season survey results indicate that the health of the mangroves had improved. The dry season survey values for the Tree Health Scores ranged from 11.9 to 14.7 within the area at risk of Material or Serious Environmental Harm, and from 11.5 to 12.7 within the Reference Sites. In contrast, the wet season survey Tree Health Scores ranged from 15.1 to 15.9 within the area at risk of Material or Serious Environmental Harm and 15.1 and 16.4 for Reference Sites. Pneumatophore density was also lower during the dry season survey; mean values were 79/m$^2$ for the area at risk of Material or Serious Environmental Harm and 109/m$^2$ for the Reference Sites, compared to mean values in the wet season survey of 121/m$^2$ and 159/m$^2$, respectively. In terms of leaf pathology, the major difference between the dry season and the wet season surveys was the higher incidence of leaves without any pathological condition in the wet season survey. Mean counts of leaves without a pathological condition per 100 leaves assessed, ranged from 42 to 59 in the area at risk of Material or Serious Environmental Harm and 50 to 64 at the Reference Sites in the wet season survey; and from 19 to 32 in the area at risk of Material or Serious Environmental Harm and 23 to 41 at the Reference Sites in the dry season survey. Measurements of canopy cover were slightly higher in the dry season survey than in the wet season survey: 72% in the area at risk of Material or Serious Environmental Harm and 75% at Reference Sites in the dry season survey, compared to 60% and 68%, respectively, in the wet season survey. The very low rainfall recorded during the wet season of 2010 (only 6 mm was received from January to March 2010 [BOM 2011]), followed by the period of low rainfall that defines the dry season, may account for the differences in the Tree Health Scores and canopy cover between the dry season and wet season surveys. While the differences between the dry season and wet season surveys may reflect different observers, or differences in tree selection between the two surveys, overall (with the exception of the canopy cover results) the results support the observed increase in Tree Health Scores in the wet season survey.

The results from the dry season and wet season baseline surveys of the mangroves at the mainland end of the DomGas Pipeline route, indicate that for all the measures of mangrove health assessed there is a high degree of homogeneity within the region investigated. There were no significant differences between the measurements of the mangroves at sites in the area at risk of Material or Serious Environmental Harm and Reference Sites, in either the dry season or the wet season survey. This is indicative that the Reference Sites selected would provide a good ecological benchmark for assessing any future impacts of disturbance to mangroves at risk of Material or Serious Environmental Harm.

# 11.0 Demersal Fish

## 11.1 Introduction

There have been few ecological studies conducted on the fish species of north-western Australia, but the survey work to date has revealed a species-rich assemblage (Allen 1996, 2000; Hutchins 1999, 2001, 2003, 2004; Travers *et al.* 2006), with the North West Shelf in particular being considered a hotspot in terms of species richness (Fox and Beckley 2005). This reflects the strong biogeographic links with Indonesia and the western Pacific, facilitated by the Indonesian Throughflow and the diversity of available habitats in these waters (DEWHA 2008). However, the degree of endemism in the fish fauna of the North West Shelf is low when compared to the temperate waters of southern Western Australia (Fox and Beckley 2005).

Sampling conducted in tropical north-western Australia (in the Kimberley, Canning and Pilbara regions) between 2000 and 2002, yielded 23 377 fish representing 32 families, 58 genera and 119 species (Travers *et al.* 2006). Of these, the most abundant species were *Lethrinus* sp., Stripey Snapper (*Lutjanus carponotatus*) and Grass Emperor (*Lethrinus laticaudis*) (Travers *et al.* 2006). In the Pilbara region specifically, the species that were found to typify fish assemblages were *Lethrinus* sp., Stripey Snapper, Grass Emperor and Starry Triggerfish (*Abalistes stellatus*) (at Cape Preston) and *Lethrinus* sp., Stripey Snapper and Spangled Emperor (*Lethrinus nebulosus*) (at Locker Point) (Allen 1998; Travers *et al.* 2006). Strong latitudinal effects on fish species composition have also been described in the Pilbara region (Travers *et al.* 2006). In addition, different environmental conditions (e.g. tidal regime, turbidity, proximity to mangrove habitat) create more localised effects, defining distinct bioregions (Travers *et al.* 2010). Seasonal processes have a significant influence on the composition of fish species in an area, with lethrinid species (e.g. Grass Emperor) recorded in greater abundances during the dry season (Travers *et al.* 2006). Seasonal processes may also influence the broader fish assemblage.

The Montebello/Barrow Islands region supports a rich diversity of fish fauna with 456 species from 75 families recorded during a Western Australian Museum survey in 1993 (Allen 2000), the majority of which exhibit wide distributions throughout the Indo–West Pacific region (DEC 2007). Two pipefish species recorded during this survey (*Doryrhamphus multiannulatus* and *Phoxocampus belcheri*) represent new records for Australia (DEC 2007). The region's fish fauna is considered to be closely related to that of the Dampier Archipelago, where 650 species were recorded across a range of habitats, during another survey by the Western Australian Museum (Hutchins 2003, 2004). In the Dampier Archipelago, reef fish made up the greatest number of species (476), with moderate numbers of soft sediment fish (117) and mangrove fish (121) (Hutchins 2003). The most dominant families in the area include Serranidae, Lethrinidae, Lutjanidae, Labridae, Pomacentridae, Gobiidae and Apogonidae (Hutchins 2003; Travers *et al.* 2006). The Dampier Archipelago, along with other outer reef systems upstream in the Leeuwin Current, is thought to act as a supplementary recruitment source for the Montebello/Barrow Islands region (DEC 2007). Similarly, the Montebello/Barrow Islands region may act as a source of recruits for locations further south (DEC 2007).

Surveys undertaken in Barrow Island waters during 2008/2009 identified distinct fish assemblages, in terms of species richness, relative abundance, composition and size structure, in different key habitats (Chevron Australia 2013a). In general, fish assemblages in sand and soft sediments with sessile benthic invertebrate habitats were less diverse than those in coral or macroalgal habitats. Fish assemblages in coral habitats were the most diverse, comprising high abundances of small-bodied pomacentrids (e.g. Six-banded Angelfish [*Pomacanthus sexstriatus*], Brown Demoiselle [*Neopomacentrus filamentosus*]; Bengal Sergeant [*Abudefduf bengalensis*]) and the common occurrence of larger serranids (e.g. Bar-cheek Coral Trout [*Plectropomus maculates*]), labrids (e.g. Blue Tuskfish [*Choerodon cyanodus*], Blackspot Tuskfish [*Choerodon schoenleinii*] and Moon Wrasse [*Thalassoma lunare*]), lethrinids (e.g. Yellowtail Emperor [*Lethrinus atkinsoni*]) and lutjanids (e.g. Stripey Snapper [*Lutjanus carponotatus*]). Habitats dominated by macroalgae had high abundances of labrids (e.g. Bluespotted Tuskfish [*Choerodon cauteroma*], Blue Tuskfish [*Choerodon cyanodus*], Blackspot

Tuskfish [*Choerodon schoenleinii*], lethrinids (e.g. Threadfin Emperor [*Lethrinus genivittatus*], Blue-lined Emperor [*Lethrinus* sp.]), nemipterids (e.g. Purple Threadfin Bream [*Pentapodus emeryii*], Northwest Threadfin Bream [*Pentapodus porosus*]). The presence of juveniles of many different species (in particular *Lethrinus* sp. and *Choerodon* spp.), indicated that macroalgae habitats act as important nursery grounds for numerous fish species, including those where adults were observed in different habitat types.

Sandy areas were often visited by transient predators, including carangids (e.g. Yellowstripe Scad [*Selaroides leptolepis*]) and Scombridae spp. Also high in abundance in sandy areas were monacanthids (e.g. Pigface Leatherjacket [*Paramonacanthus choirocephalus*]), nemipterids (e.g. *Nemipterus* spp., Western Butterfish [*Pentapodus vitta*]) and tetraodontids (e.g. Rusty-spotted Toadfish [*Torquigener pallimaculatus*]). In contrast, fish assemblages in soft sediments with sessile benthic invertebrate communities had high abundances of carangids (e.g. Gold-spotted Trevally [*Carangoides fulvoguttatus*], Golden Trevally [*Gnathanodon speciosus*], Yellowstripe Scad [*Selaroides leptolepis*]), lethrinids (e.g. Threadfin Emperor [*Lethrinus genivittatus*], Blue-lined Emperor [*Lethrinus* sp.]) and nemipterids (e.g. *Nemipterus* spp., Northwest Threadfin Bream [*Pentapodus porosus*], Western Butterfish [*Pentapodus vitta*]).

The demersal fish assemblages that characterised mangrove communities on the east coast of Barrow Island were surveyed in December 2009 using a combination of gill, seine, throw and scoop nets with varying mesh sizes (Chevron Australia 2013a). Differences in the fish assemblages characteristic of mangrove communities reflected the different substrate types (e.g. rocky substrate, sandy substrate), as well as the sampling methods. The size structure of the most abundant species recorded in the mangrove communities indicates that these communities provide habitat for juveniles and adults of small fish species, as well as juveniles of larger species. Larger fish (e.g. Giant Trevally [*Caranx ignobilis*], Giant Queenfish [*Scomberoides commersonnianus*] and Milkfish [*Chanos chanos*]), rays (e.g. Giant Shovelnose Ray [*Rhinobatus typus*]) and sharks (e.g. Nervous Shark [*Carcharhinus cautus*]) were observed using the mangrove habitat and adjacent intertidal flats as feeding areas during periods of inundation at high tide.

Numerous commercial and recreationally important fish species occur around Barrow Island (Chevron Australia 2005). The principal commercial fisheries in the North Coast Marine Bioregion (which includes the IMCRA Pilbara Offshore Marine Bioregion; Section 3.1) focus on finfish, particularly the emperors, snappers and cods that are caught by the Pilbara Demersal Fish Trawl Fishery and the Pilbara Demersal Trap Fishery (DoF 2009). These two fisheries target Blue-lined Emperor *(Lethrinus punctulatus),* threadfin bream (Nemipteridae), Brownstripe Snapper *(Lutjanus vitta),* Crimson Snapper *(Lutjanus erythropterus),* Red Emperor *(Lutjanus sebae),* Saddletail Snapper *(Lutjanus malabaricus),* Goldband Snapper *(Pristipomoides multidens),* Spangled Emperor *(Lethrinus nebulosus),* Frypan Snapper *(Argyrops spinifer)* and Rankin Cod *(Epinephelus multinotatus)* (DoF 2009). Other species targeted commercially and recreationally in Pilbara waters include Spanish Mackerel *(Scomberomorus commerson)* and Grey Mackerel *(Scomberomorus semifasciatus)* (DoF 2009).

A number of species occurring in the area are protected under Western Australian and Commonwealth legislation. These include, but are not limited to the Potato Cod (*Epinephelus tukula*) and the Double-headed Maori Wrasse (*Cheilinus undulatus*) and species of syngnathids (*Hippocampus hystrix* and *Phoxocampus belcheri*). Most of these species are regionally widespread (DEC 2007).

## 11.2 Scope

This Section records the demersal fish assemblages that characterise hard and soft coral, non-coral benthic macroinvertebrate, macroalgal, seagrass and mangrove communities (Condition 14.8.iii, Statement No. 800; Condition 11.8.III, EPBC Reference: 2003/1294 and 2008/4178) and describes the demersal fish assemblages:

- that are at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.vi, Statement No. 800; Condition 11.6.VI EPBC Reference: 2003/1294 and 2008/4178)
- at Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.vii, Statement No. 800; Condition 11.6.VII, EPBC Reference: 2003/1294 and 2008/4178).

Baseline surveys have been undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800 and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178.

There are no mangrove stands on the east coast of Barrow Island that are at risk of Material or Serious Environmental Harm due to the construction or operation of the Domestic Gas (DomGas) Pipeline. Therefore, no further field surveys of either the mangrove communities or the demersal fish assemblages that characterise these communities, have been undertaken on the east coast of Barrow Island as part of the Marine Baseline Program for the DomGas Pipeline. Field surveys of both the mangroves and the demersal fish assemblages that characterise these communities have been undertaken at sites on the east coast of Barrow Island as part of the Marine Baseline Program for the MOF, LNG Jetty and Dredge Spoil Disposal Ground (Chevron Australia 2013a).

## 11.3 Methods

### 11.3.1 Site Locations: East Coast of Barrow Island

Surveys of the demersal fish assemblages were undertaken at 22 sites, in depths between approximately 3 m and 17 m, in the waters on the eastern side of Barrow Island in the vicinity of the DomGas Pipeline route (Table 11-1; Figure 11-1) (Centre for Marine Futures, University of Western Australia [UWA] 2013). Sites were selected to represent the major inshore and offshore community types off the east coast of Barrow Island. These communities included hard and soft corals, sessile non-coral benthic macroinvertebrates, and macroalgae in shallow inshore waters; and soft sediments with sessile non-coral benthic macroinvertebrates and unvegetated sand further offshore. Note that hard and soft corals and macroalgae communities were not observed along the DomGas Pipeline route on the east coast of Barrow Island. For information on other demersal fish survey sites on the east coast of Barrow Island, refer to Chevron Australia 2013a).

Two sites (DGI1 and DGI2) were located within the DomGas Pipeline Marine Disturbance Footprint; i.e. in areas at risk of Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline (Table 11-1; Figure 11-1). Two coral survey sites (CN1 and CN2) were located in the Zone of Influence Dredge Management Area associated with the generation of turbidity and sediment deposition from dredging and spoil disposal activities on the east coast of Barrow Island (Section 2.3.4). Three sites (SIN2, SINR4 and DSN3) were located in the indicative anchoring area. Fifteen Reference Sites were located in the surrounding waters and are not at risk of Material or Serious Environmental Harm due to the construction or operation of the Marine Facilities.

**Table 11-1 Demersal Fish Assemblage Survey Site Locations and Associated Dominant Community Types in Waters off the East Coast of Barrow Island**

| Location | Dominant Community Type | Site Code | Easting | Northing | Latitude | Longitude | October 2008 | | March 2009 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | (GDA94, MGA Zone 50) | | (GDA94) | | Average Depth (m) | Average Horizontal Visibility (m) | Average Depth (m) | Average Horizontal Visibility (m) |
| At risk of Material or Serious Environmental Harm | Sessile | DGI1 | 342897 | 7690677 | 20° 52.647' S | 115° 29.383' E | 14.2 | 5.3 | 15.1 | 3.9 |
| | Sand | DGI2* | 344626 | 7688726 | 20° 53.713' S | 115° 30.370' E | 16.0 | 5.1 | 15.1 | 2.7 |
| | Coral | CN1* | 340700 | 7692144 | 20° 51.841' S | 115° 28.124' E | 7.2 | 6.6 | 5.6 | 5.8 |
| | Coral | CN2* | 344097 | 7694687 | 20° 50.480' S | 115° 30.097' E | 8.1 | 6.5 | 8.2 | 7.4 |
| Indicative Anchoring Area | Sessile | SIN2* | 342722 | 7695390 | 20° 50.092' S | 115° 29.308' E | 11.4 | 3.8 | 12.2 | 3.2 |
| | Sessile | SINR4* | 342273 | 7693700 | 20° 51.006' S | 115° 29.040' E | 12.8 | 5.8 | - | - |
| | Sand | DSN3* | 347316 | 7687119 | 20° 54.598' S | 115° 31.913' E | - | - | 15.0 | 5.5 |
| Reference Sites | Sand | DGI3 | 351488 | 7684848 | 20° 55.849' S | 115° 34.307' E | 15.0 | 9.3 | 15.0 | 4.1 |
| | Sand | SAFR1 | 353578 | 7687306 | 20° 54.527' S | 115° 35.526' E | 15.5 | 9.3 | 14.8 | 8.0 |
| | Sand | SAFR2 | 351563 | 7697793 | 20° 48.833' S | 115° 34.417' E | 16.7 | 8.6 | 15.8 | 2.5 |
| | Sand | SAFR3 | 354461 | 7690944 | 20° 52.559' S | 115° 36.053' E | 15.8 | 6.4 | 15.7 | 2.5 |
| | Sand | SAN1 | 352507 | 7681998 | 20° 57.398' S | 115° 34.881' E | - | - | 15.2 | 3.1 |
| | Sessile | SIFR2 | 343955 | 7684283 | 20° 56.118' S | 115° 29.959' E | 16.2 | 5.3 | 15.0 | 3.1 |
| | Sessile/Sand | SIFR3 | 348372 | 7677876 | 20° 59.612' S | 115° 32.473' E | 15.4 | 5.5 | 14.8 | 3.6 |
| | Sand | SIFR4 | 350426 | 7681232 | 20° 57.803' S | 115° 33.676' E | - | - | 15.3 | 3.6 |
| | Sessile | SINR5 | 345289 | 7692529 | 20° 51.655' S | 115° 30.772' E | 15.5 | 4.5 | - | - |
| | Sand | SIN6 | 341649 | 7689484 | 20° 53.287' S | 115° 28.657' E | - | - | 15.0 | 2.8 |
| | Sessile | SIN7 | 350254 | 7681367 | 20° 57.729' S | 115° 33.577' E | 16.9 | 8.0 | 16.2 | 5.5 |
| | Coral | CNR5 | 342823 | 7692363 | 20° 51.733' S | 115° 29.350' E | 6.7 | 8.2 | - | - |
| | Sand | DSN1* | 351119 | 7692085 | 20° 51.925' S | 115° 34.132' E | 14.3 | 5.9 | 15.6 | 2.0 |
| | Macroalgae | MN2* | 340620 | 7697336 | 20° 49.027' S | 115° 28.107' E | 4.2 | 9.0 | 2.9 | 4.0 |
| | Macroalgae | MNR4* | 340737 | 7693377 | 20° 51.173' S | 115° 28.152' E | 5.0 | 5.1 | - | - |

** Denotes a sampling site located in a Dredge Management Area. Source: Chevron Australia (2013a).*

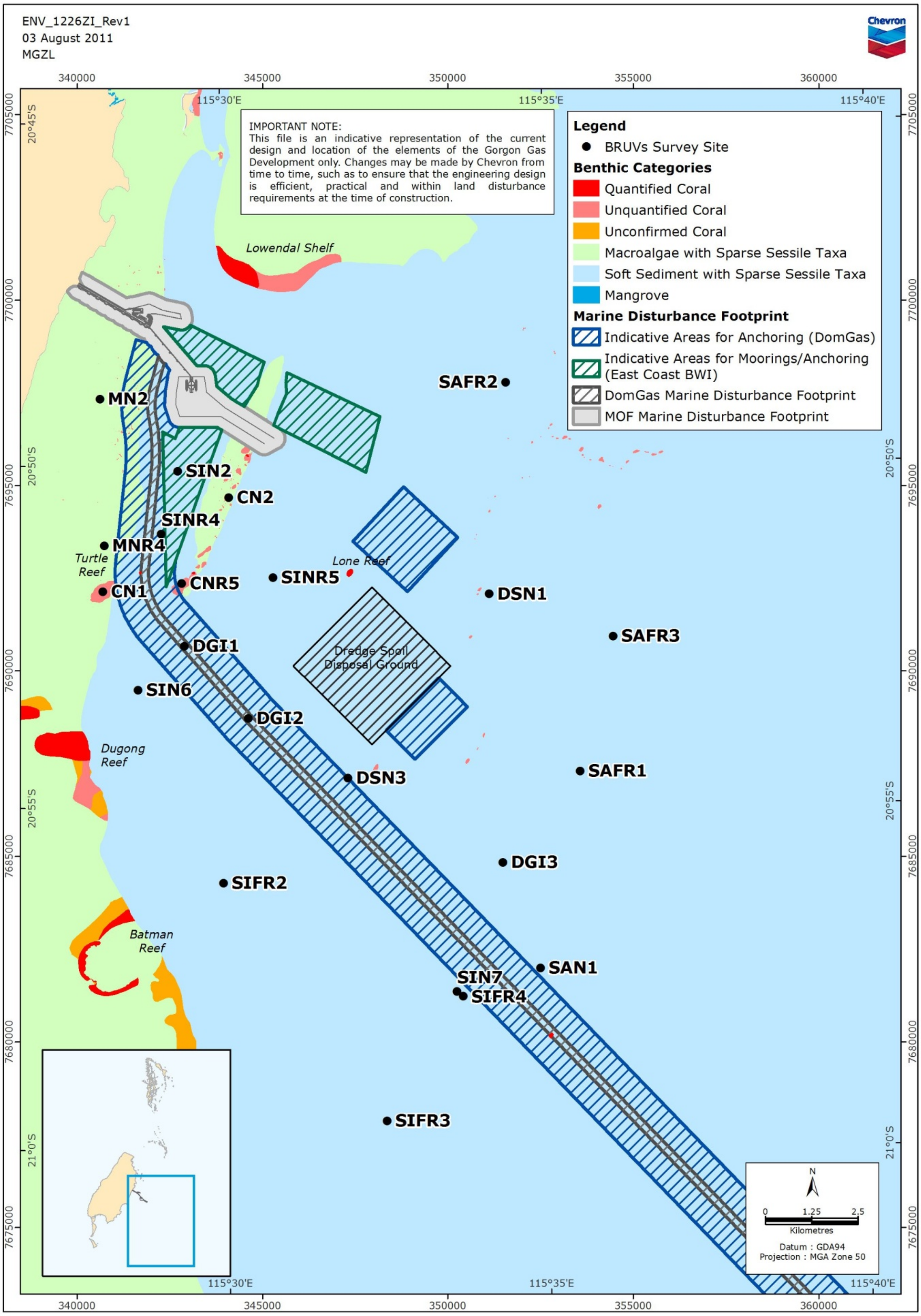



**Figure 11-1 Demersal Fish Survey Sites in Waters off the East Coast of Barrow Island**

### 11.3.2 Site Locations: Mainland End of the DomGas Pipeline Route

Surveys of the demersal fish assemblages that characterised hard and soft corals, non-coral benthic macroinvertebrates, macroalgae and seagrass communities, were undertaken at 15 sites in October 2010 and 17 sites in April 2011,[17] in the waters adjacent to the Pilbara coast in the vicinity of the DomGas Pipeline route (Table 11-2; Figure 11-2). Eight sites (CI1, CI2, BI1, BI2, MAI1, MAI2, SGI1, SGI2) were located in areas at risk of Material or Serious Environmental Harm within the trenching and jetting Marine Disturbance Footprint; and nine Reference Sites (CR1, CR2, CR3, BR1, BR2, MAR1, MAR2, SGR1, SGR2) were located in areas not at risk of Material or Serious Environmental Harm, outside the trenching and jetting Marine Disturbance Footprint (Section 2.3.3.2). Survey sites were located in depths between <1 m and ~11 m.

### 11.3.3 Site Locations: Mangrove Communities at the Mainland End of the DomGas Pipeline Route

Surveys of demersal fish assemblages that characterised the mangrove communities on the mainland Pilbara coast were undertaken at eight sites in the vicinity of the mainland shore crossing for the DomGas Pipeline (Table 11-3; Figure 11-3). Note that surveys of the demersal fish assemblages in mangrove communities were undertaken at three sites at risk of Material or Serious Environmental Harm (N1, N3 and N4) in the October 2010 survey and at four sites (N1, N2, N3 and N4) in the April 2011 survey. The original intent was to include a fourth site further up the tidal creek in the October 2010 survey, however site access issues prevented the site being sampled. Survey sites were in the vicinity of the locations where mangrove vegetation surveys were undertaken (Section 10.3.1).

[17] In October 2010, only one seagrass site at risk of Material or Serious Environmental Harm and one seagrass Reference Site not at risk of Material or Serious Environmental Harm, were surveyed using BRUVs. Additional sites were identified in April 2011 and were included in the BRUVs survey.

**Table 11-2 Demersal Fish Assemblage Survey Site Locations and Associated Dominant Community Types at the Mainland End of the DomGas Pipeline Route**

| Location | Dominant Community Type | Site Code | Easting | Northing | Latitude | Longitude | October 2010 | | April 2011 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | GDA94, MGA Zone 50 | | GDA94 | | Horizontal Visibility (m) | Depth (m) | Horizontal Visibility (m) | Depth (m) |
| At risk of Material or Serious Environmental Harm | Coral | CI1 | 374881 | 7656522 | 21° 11.306' S | 115° 47.679' E | 3.0–4.0 | 2.6–3.6 | 1.5–3.5 | 3.0–4.5 |
| | | CI2 | 378978 | 7663075 | 21° 07.771' S | 115° 50.075' E | 1.0–3.0 | 2.7–3.4 | 1.5 | 2.0–3.4 |
| | Benthic Macroinvertebrate | BI1 | 374493 | 7656021 | 21° 11.576' S | 115° 47.453' E | 4.0–5.0 | 3.8–4.1 | 2.0–2.5 | 3.8–4.1 |
| | | BI2 | 374934 | 7665393 | 21° 06.498' S | 115° 47.749' E | 2.5–3.0 | 9.8–10.4 | 2.0–2.5 | 6.8–11.3 |
| | Macroalgae | MAI1 | 374984 | 7656623 | 21° 11.252' S | 115° 47.739' E | 3.5–4.5 | 0.9–2.3 | 4.0–5.0 | 1.3–2.0 |
| | | MAI2 | 374122 | 7666175 | 21° 06.071' S | 115° 47.283' E | 4.0–4.5 | 1.8–3.1 | 3.5–4.0 | 1.5–3.4 |
| | Seagrass | SGI1 | 371992 | 7657550 | 21° 10.737' S | 115° 46.014' E | 4.0–4.5 | 5.6–6.0 | 3.5–4.0 | 5.0–5.3 |
| | | SGI2* | 372830 | 7664333 | 21° 07.064' S | 115° 46.529' E | - | - | 3.0–4.0 | 5.4–6.0 |
| Reference Sites | Coral | CR1 | 373545 | 7666308 | 21° 05.996' S | 115° 46.941' E | 4.0–4.5 | 4.0–4.7 | 2.5–3.5 | 3.4–4.5 |
| | | CR2 | 368230 | 7662300 | 21° 08.146' S | 115° 43.862' E | 4.0–5.0 | 2.6–6.6 | 5.0 | 2.5–3.6 |
| | | CR3 | 379404 | 7672825 | 21° 02.487' S | 115° 50.362' E | 5.0–6.0 | 2.9–3.8 | 3.0–5.0 | 3.6–4.0 |
| | Benthic Macroinvertebrate | BR1 | 372921 | 7651675 | 21° 13.925' S | 115° 46.525' E | 3.5–4.5 | 2.5–3.3 | 3.0–3.5 | 2.0–2.3 |
| | | BR2 | 378928 | 7669621 | 21° 04.223' S | 115° 50.074' E | 2.5–4.0 | 3.1–3.8 | 1.5–2.0 | 3.6–4.8 |
| | Macroalgae | MAR1 | 376512 | 7668191 | 21° 04.988' S | 115° 48.672' E | 3.0–4.0 | 1.8–2.4 | 5.0 | 2.1–3.6 |
| | | MAR2 | 367236 | 7661459 | 21° 08.598' S | 115° 43.284' E | 4.5–5.0 | 3.0–4.0 | 4.5–5.0 | 1.9–2.7 |
| | Seagrass | SGR1 | 372638 | 7652067 | 21° 13.711' S | 115° 46.363' E | 4.0–4.5 | 4.0–4.5 | 1.5 | 4.2–5.2 |
| | | SGR2* | 368515 | 7661176 | 21° 08.757' S | 115° 44.022' E | - | - | 3.5 | 4.7–6.4 |

*Note: * Site surveyed in April 2011 only.*

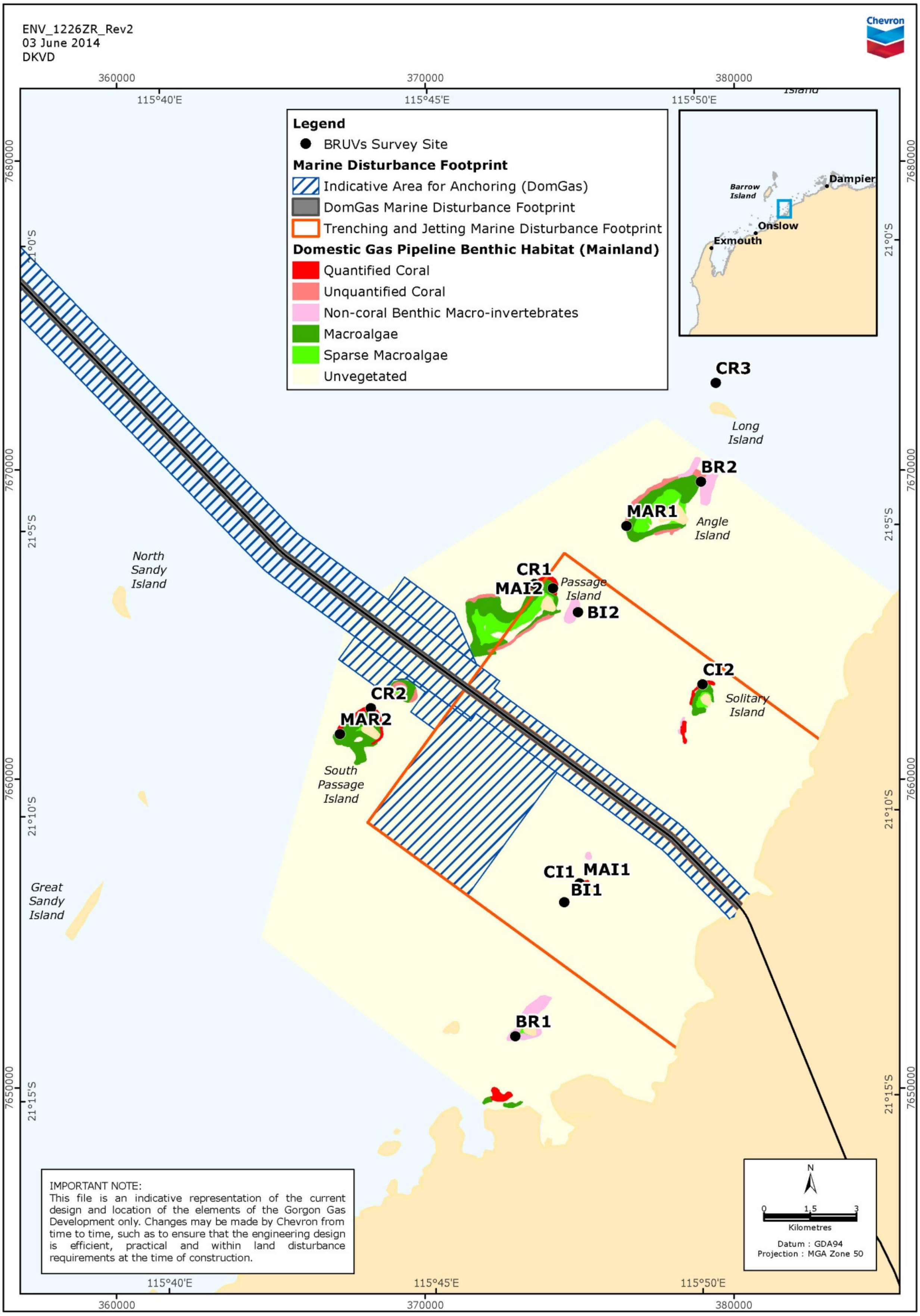



**Figure 11-2 Demersal Fish Survey Sites at the Mainland End of the DomGas Pipeline Route**

## Table 11-3 Demersal Fish Assemblage Survey Sites in Areas of Mangrove Habitat at the Mainland End of the DomGas Pipeline Route

| Location | Site Code | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|---|
| | | GDA94, MGA Zone 50 | | GDA94 | |
| At risk of Material or Serious Environmental Harm | N1 | 381257 | 7655836 | 21° 11.703' S | 115° 51.361' E |
| | N2* | 381497 | 7656294 | 21° 11.465' S | 115° 51.502' E |
| | N3 | 380363 | 7656029 | 21° 11.595' S | 115° 50.845' E |
| | N4 | 380216 | 7655252 | 21° 12.016' S | 115° 50.757' E |
| Reference Sites | NR1 | 383089 | 7660160 | 21° 09.367' S | 115° 52.438' E |
| | NR2 | 383298 | 7660003 | 21° 09.453' S | 115° 52.558' E |
| | NR3 | 379318 | 7652981 | 21° 13.243' S | 115° 50.229' E |
| | NR4 | 379575 | 7652533 | 21° 13.487' S | 115° 50.375' E |

*Note: * Site surveyed in April 2011 only.*

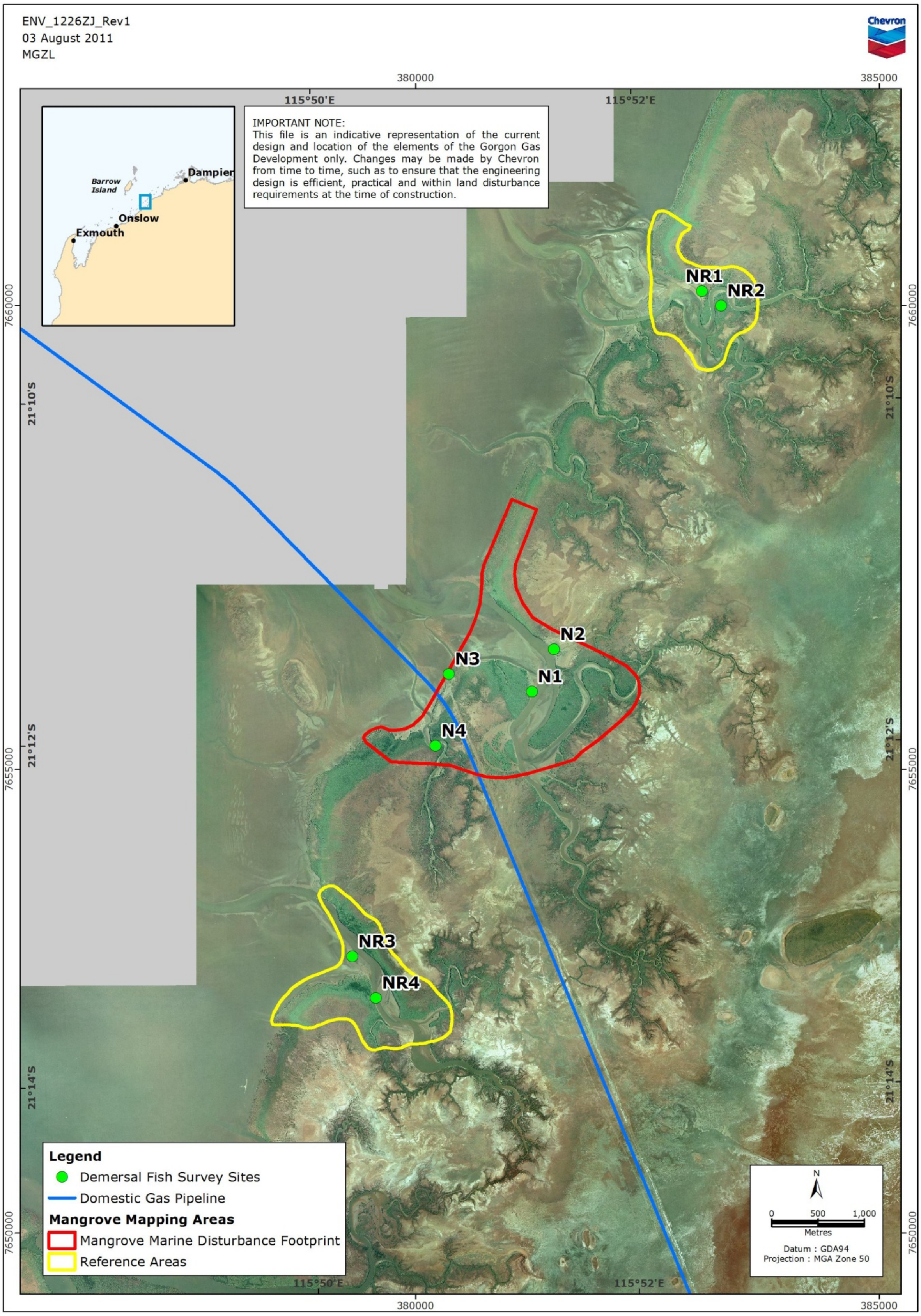



**Figure 11-3 Demersal Fish Survey Sites in Mangrove Communities at the Mainland End of the DomGas Pipeline Route**

### 11.3.4 Methods

#### 11.3.4.1 Baited Remote Underwater Stereo-video Systems (BRUVs)

The demersal fish assemblages that characterised hard and soft corals, non-coral benthic macroinvertebrates, macroalgae and seagrass communities were surveyed using baited remote underwater stereo-video systems (stereo BRUVs; Figure 11-4) (Centre for Marine Futures, UWA 2013; UWA Oceans Institute and School of Plant Biology, UWA 2011). Stereo BRUVs were selected to survey fish assemblages as they are non-extractive and provide information on the composition of fish assemblages, as well as the metrics of species richness and diversity, relative abundance and accurate measures of fish length (Harvey *et al.* 2001, 2002, 2004; Watson *et al.* 2005). The use of stereo BRUVs to survey demersal fish assemblages has undergone expansion in recent years with the technique now used around Australia, including Western Australia (Centre for Marine Futures, UWA 2013). Stereo BRUVs were selected over other more traditional survey techniques (e.g. Underwater Visual Census) because the systems are safer and faster to deploy in the field as divers are not required and because they also remove the limitations of dive time due to decompression limits. The use of stereo BRUVs also removes fish-diver interactions and minimises intra- and inter-observer variability (Harvey *et al.* 2001, 2001a, 2004, 2007; Cappo *et al.* 2003, 2004). The collection of high-definition video provides a permanent record that can be repeatedly viewed at any time, and permits accurate identification of fish to species level using image libraries in the laboratory, thus reducing the risk of incorrect fish identifications (Cappo *et al.* 2003; Cappo *et al.* 2007). Nevertheless, it is acknowledged that BRUVs do have some limitations and biases, including a reliance on good visibility (usually >3 m) and the complexities in determining the true area sampled due to variability in the bait plume which is dependent on a range of environmental factors (Priede and Merrett 1998). In addition, the responses of different species to the bait and the distances they will travel to get to the bait is unknown, which limits the counts of fish from stereo BRUVs to measures of relative abundance rather than density (Harvey *et al.* 2007). While stereo BRUVs are unsuitable for estimating density, they are a powerful and cost-effective method for detecting spatial and temporal changes in the relative abundance and lengths of fish assemblages (Cappo *et al.* 2004, 2007; Langlois *et al.* 2010; Watson *et al.* 2010a), attributes which make the method suitable for the Marine Baseline Program.

Five replicate stereo BRUVs were deployed synchronously at each site for at least one hour. Deployment times of approximately 40 minutes have been shown to adequately sample fish assemblages in Western Australia (Birt *et al*. 2010). The stereo BRUVs were deployed with at least 200–250 m between each deployment to avoid overlap of bait plumes and to reduce the likelihood of fish moving between deployments within the sampling period (Cappo *et al*. 2001). In the surveys at the mainland end of the DomGas Pipeline route, where the spatial extent of the community type was too small to accommodate five simultaneous deployments with 200–250 m between each stereo BRUV, sampling was undertaken over two deployments separated by no more than two hours (e.g. three systems were initially deployed 250 m apart and two further systems then deployed as far as possible from the first three deployments).

The stereo BRUVs used two full high definition SONY handy cams (CX7, CX12 and CX500 models) in underwater housings. The housings were mounted 0.7 m apart on a base bar mounted in a lightweight frame and inwardly converged at approximately 8° to maximise the field of view. A synchronising diode and bait basket were positioned in the field of view of both cameras. Stereo BRUVs were baited with 800 g of crushed (to maximise dispersal of fish oil) pilchards placed in a plastic-coated wire basket suspended 1.2 m in front of the two cameras. The use of bait in the stereo BRUVs increases the relative abundance and diversity of observed fish, particularly of piscivores, without precluding the sampling of prey or herbivorous species (Watson *et al.* 2005; Harvey *et al.* 2007). Bait also entices cryptic species out of crevices and into view (e.g. Moray Eels [*Gymnothorax* spp.]), while also drawing in pelagic and transient species (e.g. Mackerel [Scombridae spp.]) (Watson *et al.* 2007). Where visibility was poor or the stereo BRUVs landed with the camera facing upwards, the deployment was repeated. Each stereo BRUV was calibrated before and after each survey. Further information on the design, measurement and calibration procedures are available in Harvey and Shortis (1996, 1998) and Shortis and Harvey (1998).

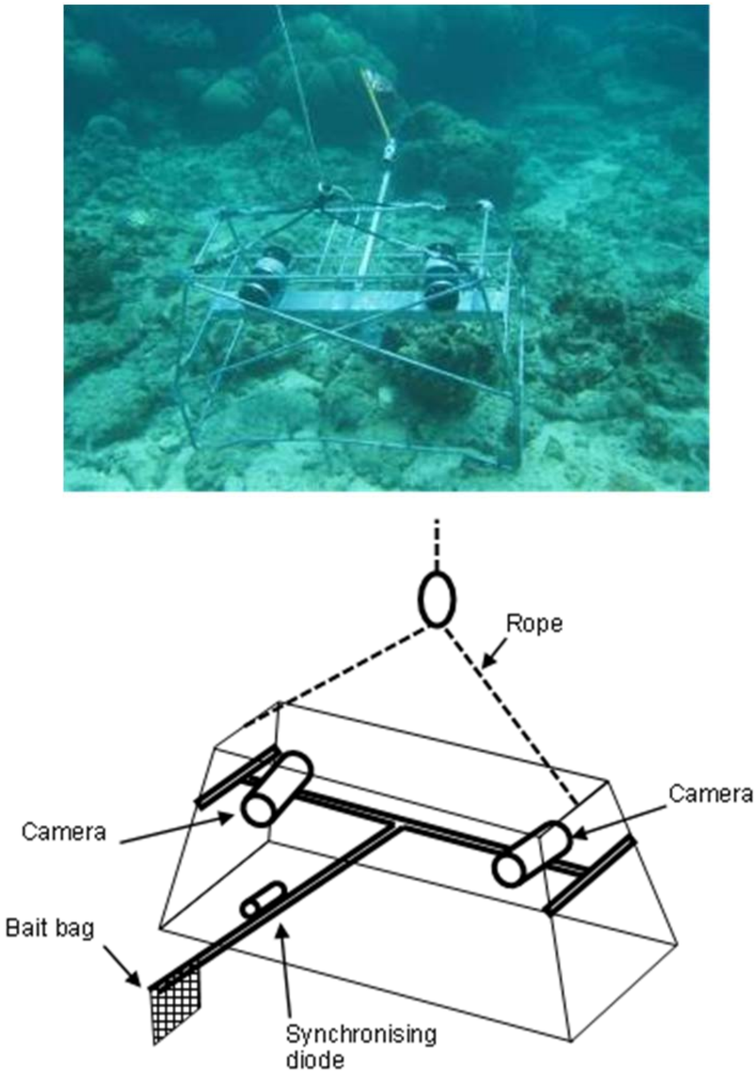



**Figure 11-4 Baited Remote Underwater Stereo-video System**

*Source: Centre for Marine Futures, University of Western Australia 2013.*

### 11.3.4.2 Netting

Stereo BRUVs were trialled as a method for surveying the demersal fish assemblages within the tidal creek mangrove habitats at the mainland shore crossing for the DomGas Pipeline. However, due to poor visibility, stereo BRUVs were not considered to be a suitable tool for assessing demersal fish assemblages in these habitats. Even at slack tide and on the seaward edge of the mangrove habitat, where the visibility was best, the visibility was not sufficient to allow the identification of most of the fish that were attracted to the bait (UWA Oceans Institute and School of Plant Biology, UWA 2011).[18]

Given the practical constraints associated with undertaking field work at the mainland sites, alternative demersal fish sampling methods (including seine nets, gill nets, cast [throw] nets, fish

[18] It is important to note that this was a trial and the results are only applicable to this study (sites/times). In other mangrove habitats, streo BRUVs may be a useful tool for describing demersal fish assemblages.

traps, fyke nets, trawl nets, rotenone poisoning, and electrofishing) were considered in terms of their respective advantages and disadvantages, specific requirements, and feasibility. The original intent of the program to survey the demersal fish assemblages characteristic of the mangrove communities was to use a combination of multi-mesh gill nets and seine nets, so as to ensure adequate sampling of both the shallow and deeper habitats. However, following pilot trials using gill nets carried out in August 2010, sampling using multi-mesh gill nets was not undertaken due to concerns relating to the entanglement of turtles.[19] Therefore, the demersal fish assemblages that characterised the mangrove communities were surveyed using a combination of seine nets (dry season and wet season surveys) and cast (throw) nets (wet season survey only). It is recognised that no one fish sampling method effectively samples all fish within all habitats in a location, and the netting regime employed does not effectively sample deeper water habitats or those in which seine nets cannot be deployed. The use of a restricted suite of sampling methods means that the range of species and the sizes of captured fish is likely to represent a subset of the broader fish assemblages present at the survey sites, which in turn limits the broader interpretation/generalisation of the survey results. Nevertheless, the array and size range of fish species captured in the seine nets (small Gobies and schooling Ponyfish, to large sharks and rays) suggests that the seine nets effectively sampled the majority of the demersal fish species that were present and thus provides appropriate baseline descriptions of the demersal fish assemblages characteristic of the mangrove communities at the mainland end of the DomGas Pipeline route.

The seine nets used to sample the demersal fish assemblages were 25 m long, with a drop of 1.5 m and comprised two 10 m long wings of 9 mm stretched mesh and a 5 m long, 1.5 m high central pocket (bunt) of 6.8 mm mesh. Seine nets are an appropriate sampling method for capturing demersal fish, and a net of this size has a demonstrated ability to capture many demersal fish species within a range of size-classes (Dr Chris Hallett, Murdoch University, pers. comm. June 2011). The cast nets employed in the wet season survey to supplement the sampling regime using seine nets, were pocketed, monofilament cast nets with an open diameter of 2.44 m and a stretched mesh size of 25 mm.

Six non-overlapping, replicate seine net hauls were performed at each of the eight surveyed sites over a period of one to three hours, depending on the tidal conditions. This level of replication was considered the most appropriate to obtain sufficient data for each site in the field time available within the constrained tidal window available for sampling. The seine net was walked out from the beach to a maximum depth of approximately 1.5 m, deployed parallel to the shore, and then rapidly dragged towards and onto the shore, sweeping a circular area of approximately 50 $m^2$. Twelve replicate cast net samples were also taken at each survey site during the wet season, with the cast nets deployed between seine net deployments. This higher level of replication for cast nets was considered appropriate as preliminary trials indicated that six cast nets would not provide sufficient data on the demersal fish assemblages, whilst collection of more than 12 cast net replicates was not practicable within the constrained tidal window available for sampling.

For each sample, the fish that could be readily identified to species (e.g. those larger species which were caught in relatively low numbers) were identified, counted, measured, and returned to the water alive. All other fish caught in the nets were euthanized in ice and preserved on ice in the field, then frozen on-board the vessel, prior to subsequent identification and measurement in the laboratory. All fish were identified to the lowest reliable taxonomic level (to genus and species level where possible) in the laboratory using appropriate reference guides (Gloerfelt-Tarp and Kailola 1984; Sainsbury *et al.* 1984; Allen and Swainston 1988; Allen 2004; Andrawartha and Tuma 2007; Last and Stevens 2009). All scientific and common names were

[19] While the gill nets can be managed to ensure zero (or minimal) mortality, the high turbidity levels at the survey sites would have made it diifcult to ensure zero mortality of turtles and other large vertebrates, potentially including species of conservation significance such as *Pristis zijsron* (Dr Chris Hallett, Murdoch University, pers. comm. June 2011). To do so would have required constant checking of the gill nets by pulling them from the water as they were not visible under the surface, which would in turn have reduced their effectiveness in sampling the demersal fish assemblages.

standardised by referencing the Checklist of Australian Aquatic Biota (CAAB) database (Rees *et al.* 2006). Voucher samples for those species that could not be reliably identified were catalogued for identification by Dr Susan Morrison (Western Australian Museum). Large numbers of small, juvenile whiting were sometimes caught, which could not be readily identified to species without the use of genetic methods or detailed anatomical dissection. These individuals were grouped together as 'unidentified whiting (juveniles)' for the purposes of subsequent analyses.

Following their identification, all fish were counted and their fork lengths measured to the nearest millimetre on a measuring board. Where large numbers of fish were collected, a random sub-sample of approximately 50 individuals[20] of each species was measured for fork length.

## 11.3.5 Timing and Frequency of Surveys

Stereo BRUV surveys of demersal fish assemblages were undertaken in October 2008 (spring; dry season) and March 2009 (late summer; wet season) in east coast Barrow Island waters, and in October 2010 (spring; dry season) and April 2011 (late summer: wet season) at the mainland end of the DomGas Pipeline route. Some field activities in the wet season were delayed until April 2011 due to the passage of tropical cyclones, adverse weather conditions or logistical constraints. Multiple surveys were undertaken to assess fish assemblages in different seasons to ensure adequate coverage of community types. Surveys at sites at the mainland end of the DomGas Pipeline route were undertaken during neap tides when water movement and turbidity were likely to be lowest, and thus visibility highest. Wherever practicable, inshore sites were sampled close to slack water during neap tides to maximise the visibility in these turbid areas.

Demersal fish assemblages were surveyed using the stereo BRUVs during daylight hours. Crepuscular (twilight) and night-time sampling of fish assemblages was not undertaken due to unacceptable health and safety risks. Daylight sampling provides for the greatest sampling efficiency while also removing the requirement to introduce any additional bias associated with the use of artificial light.

Surveys of demersal fish in mangrove communities were undertaken in October 2010 (spring; dry season) and February 2011 (summer; wet season). Surveys were undertaken during and either side of the low spring tide (i.e. during incoming, low slack water, and outgoing tidal conditions) and during daylight hours. Crepuscular and night-time sampling of the mangrove fish assemblages, and sampling around high tides when the sites were inundated with deep, rapidly moving water, were not undertaken due to unacceptable health and safety risks.

## 11.3.6 Treatment of Survey Data

### 11.3.6.1 Stereo BRUVs

Stereo BRUVs footage was converted from the proprietary high definition MTS format to a general high definition format (Centre for Marine Futures, UWA 2013; UWA Oceans Institute and School of Plant Biology, UWA 2011). EventMeasure (SeaGIS 2008, 2010, 2011) was used to view and analyse footage for measures of relative abundance of fish species. Sixty minutes of bottom-time was analysed for all video recordings, commencing immediately after the cameras reached the seabed. Relative abundance counts were recorded as the maximum number of individual fish belonging to each species, present in the field of view of the stereo BRUVs at any single time during the footage (MaxN) (Priede *et al.* 1994; Cappo *et al.* 2004). This measure avoids repeated counts of the same individual, ensures independence in the counts, and provides a conservative measure of relative abundance, as only a portion of the total number of individuals in the area may be viewed at one time (Cappo *et al.* 2003).

[20] In estuarine environments where large schools of fish are encountered belonging to the same year-class, and thus of fairly similar size-class, approximately 50 individuals is considered to be an appropriate subset size for collection of length data (Dr Chris Hallett, Murdoch University, pers. comm. June 2011).

The stereo component of the BRUVs allows for the collection of length measurements for the majority of fish recorded in the MaxN for each species. PhotoMeasure (SeaGIS 2008, 2010a) or EventMeasure (SeaGIS 2011) were used to collect length measurements from the left and right stereo pair of images (Figure 11-5). To avoid making repeated measurements of the same individuals, measures of length (snout to caudal fork, i.e. fork length) were made at the time of MaxN. To ensure good measurement accuracy and precision, as well as consistency across samples, all measurements of fish length were limited to those individuals within a maximum distance of approximately 6–7 m from the cameras (Harvey *et al.* 2002a); at distances greater than this, measurement accuracy can deteriorate.

Sampling was designed to examine differences in fish assemblage structure (composition, richness, abundance, size) across community types and between sites at risk of Material or Serious Environmental Harm and Reference Sites that are not at risk of Material or Serious Environmental Harm (Centre for Marine Futures, UWA 2013; UWA Oceans Institute and School of Plant Biology, UWA 2011). Three-factor multivariate analyses were undertaken for all survey dates separately, with factors including: 'Community Type' (east coast Barrow Island—two levels, fixed: sessile benthic macroinvertebrates, unvegetated sand; mainland end of the DomGas Pipeline Route—four levels, fixed: coral, non-coral benthic macroinvertebrates, macroalgae and seagrass), 'Area' (two levels, fixed: at risk of Material or Serious Environmental Harm, Reference Sites not at risk of Material or Serious Environmental Harm) and 'Site' (nested in 'Community Type' × 'Area', random with varying levels). For the east coast Barrow Island hard and soft corals and macroalgae communities, the model did not include the factor 'Area', i.e. two-way multivariate analysis for 'Community Type' × 'Site'.

The multivariate relative abundance data were analysed using permutational multivariate analysis of variance with 9999 permutations (PERMANOVA; Anderson 2001, 2001b) in the PRIMER-E software package (Plymouth Routines in Multivariate Ecological Research; Anderson *et al.* 2008) (Centre for Marine Futures, UWA 2013; UWA Oceans Institute and School of Plant Biology, UWA 2011). This permutational approach was used for analyses because the relative abundances of fish were highly skewed and contained many zero counts (non-normal data). Data were fourth-root transformed prior to analysis to down weight the influence of very abundant species. The multivariate analysis was undertaken using the Bray-Curtis dissimilarity matrix. Significant interactions were investigated using *a posteriori* pair-wise comparisons with the PERMANOVA *p*-value and 9999 permutations. Univariate species richness analyses were undertaken using the same design as multivariate analyses, using the Euclidean Distance dissimilarity measure. Where significant relationships were evident, similarity percentages (SIMPER: Clarke 1993; Clarke and Warwick 2001) on fourth-root transformed data, were used to examine which individual species contributed to any observed differences in assemblage composition by identifying those species with a ratio of dissimilarity to standard deviation >1. The ratios of standard deviation/dissimilarity output from SIMPER were used instead of multiple species-specific ANOVAs.

Patterns in the size structure of assemblages were compared using length-frequency histograms and tested using a Kolmogorov-Smirnov distribution test (Centre for Marine Futures, UWA 2013; UWA Oceans Institute and School of Plant Biology, UWA 2011).

Identification of fish was only undertaken by analysts with experience in fish identification on video and the use of the video interrogation software. Identification of fish to species level from high definition video was aided by relevant literature (Randall *et al*. 1997; Allen *et al*. 1998; Lieske and Myers 2001; Randall 2002; Allen *et al*. 2003; Hutchins 2003; Allen 2004). Several common species could not be reliably identified to species level from the video images and were identified to genus level only (e.g. species of Mackerel [referred to as Scombridae spp.], Threadfin Bream [referred to as *Nemipterus* spp.] and Whiting [referred to as *Sillago* spp.]).

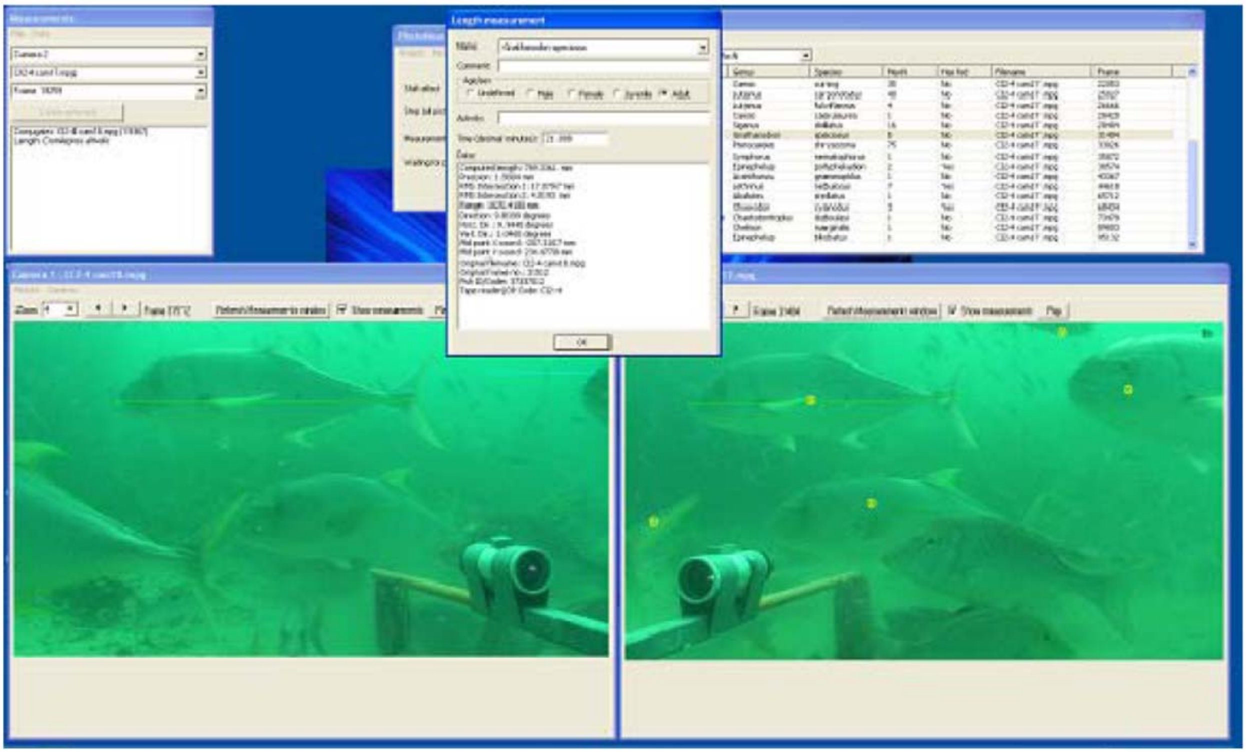


**Figure 11-5 PhotoMeasure Software used to Measure Lengths of Individual Fish. The Golden Trevally *Gnathanodon speciosus* is pictured here.**

*Source: Centre for Marine Futures, University of Western Australia 2013.*

Differences in turbidity, which influences horizontal visibility, can affect the recorded fish assemblage in stereo BRUVs surveys in at least two ways. Firstly, high turbidity reduces the visibility of the fish assemblages to the stereo BRUVs. This might lead to a decrease in the number of individuals or species observed, or decrease the possibility of identifying an individual to species level. Secondly, consistently high turbidity levels can alter the structure of the benthic community composition itself, which in turn will affect the composition of the fish assemblages making use of that habitat.

During the stereo BRUVS surveys in waters off the east coast of Barrow Island, horizontal visibility ranged from approximately 3.5 m to 10 m in October 2008, and from approximately 2 m to 10 m in March 2009 (Centre for Marine Futures, UWA 2013). In October 2008, horizontal visibility had no effect on measures of species richness; nevertheless, there was a significant influence of visibility on the relative abundance of individuals observed (DISTLM, $p<0.01$), although this explained only 6% of the variability across sites.[21] In March 2009, a strong positive linear relationship was evident between visibility and species richness (DISTLM, $p<0.01$), which was largely driven by the higher species richness at coral sites where the visibility was greatest. Horizontal visibility had no influence on the relative abundance of individuals observed in March 2009.

During the stereo BRUVs surveys off the mainland end of the DomGas Pipeline route, horizontal visibility ranged from approximately 1 m to 6 m in October 2010 and 1.5 m to 5 m in April 2011 (UWA Oceans Institute and School of Plant Biology, UWA 2011). In both October 2010 and April 2011, horizontal visibility was found to be significantly correlated with both the relative abundance and the species richness of the fish assemblages (DISTLM, $p<0.001$). With

[21] The influence of horizontal visibility on measures of species richness and relative abundance was examined using DISTLM (Distance-based Linear Model) (PRIMER-E; Plymouth Routines in Multivariate Ecological Research; Anderson *et al.* 2008).

the exception of April 2011, where up to 20% of the variation in species richness may be attributable to horizontal visibility, the proportion of the variation in both species richness and relative abundance that could be attributed to horizontal visibility was generally low. Species richness of fish assemblages at some sites, and the total number of individuals per deployment, appeared to be influenced by differences in visibility from one sampling period to another. Other sites had different visibilities over different sampling periods but were not affected.

#### 11.3.6.2 Netting

The demersal fish assemblages at sites at risk of Material or Serious Environmental Harm and at Reference Sites were described in terms of the number of species, the relative abundance of each species (expressed as density of fish per 50 $m^2$) and the size structure of the assemblage. Descriptive statistics (e.g. range, mean ± Standard Error [SE]) for the replicate samples were used to summarise the relative abundance and length data for the eight most abundant (i.e. 'dominant') species. The Shannon Diversity Index (*H'*) and Pielou's Evenness Index (*J'*) were calculated for each sample. Patterns in the overall size structure of fish assemblages at sites at risk of Material or Serious Environmental Harm and those at Reference Sites were compared using length–frequency histograms and tested using non-parametric Kolmogorov–Smirnov distribution tests.

Due to the small number of fish collected in cast net samples during the wet season survey, these data are presented only as pooled totals for the sites at risk of Material or Serious Environmental Harm and the northern and southern Reference Sites. There was insufficient data for more detailed analysis.

Multivariate analyses were undertaken to investigate differences in the overall species composition of the fish assemblages at sites at risk of Material or Serious Environmental Harm and at Reference Sites using procedures in the PRIMER-E software package (Clarke and Gorley 2006). The abundance data were square root-transformed to stabilise the variance and to down weight the influence of common species. Non-metric multidimensional scaling (MDS) ordinations were undertaken using the Bray-Curtis similarity matrix to illustrate the extent of any differences in fish assemblage composition between sites and seasons. Two-way Analysis of Similarities (ANOSIM; Clarke and Green 1988) were used to determine the extent of any significant differences in community composition between fish assemblages in each season at sites at risk of Material or Serious Environmental Harm and at Reference Sites. For these tests, 'Site' was treated as a random factor and was nested in the factor 'Area' (at risk of Material or Serious Environmental Harm, Reference Site not at risk of Material or Serious Environmental Harm), the latter factor being considered fixed. A one-way ANOSIM test was performed to determine whether fish assemblage composition differed between the dry season and wet season surveys.

## 11.4 Results

### 11.4.1 Description of Demersal Fish Assemblages Characteristic of Hard and Soft Corals, Non-coral Benthic Macroinvertebrates, Macroalgae and Seagrass Communities in the Vicinity of the DomGas Pipeline Route

#### 11.4.1.1 Barrow Island: Hard and Soft Corals and Macroalgae Communities

During the first survey in October 2008, a total of 1083 individuals from 100 species and 29 families were recorded from 11 stereo BRUV deployments at three coral community sites (CN1, CN2 and CNR5), and 683 individuals from 47 species and 22 families were recorded from nine deployments at two macroalgae community sites (MN2 and MNR4) on the east coast of Barrow Island (Centre for Marine Futures, UWA 2013). Numbers recorded in the second survey in March 2009 were similar, with a total of 1285 individuals from 99 species and 24 families recorded from 10 stereo BRUV deployments at two coral community sites (CN1 and CN2), and 488 individuals from 32 species and 15 families recorded from five deployments at one macroalgae community site (MN2). Of the total of 111 species observed in the October

2008 survey and the total of 116 species observed in the March 2009 survey at both coral and macroalgae community sites, approximately 50% were common to both surveys. The majority of the species unique to a given survey were only viewed on a single stereo BRUV deployment, reflecting the high frequency of relatively rare species in inshore coral and macroalgae communities.

The highest number of species observed on a single deployment in the October 2008 survey was 41 at CNR5 and in the March 2009 survey was 39 at CN1, both at coral community sites (Centre for Marine Futures, UWA 2013). In both the October 2008 and March 2009 surveys, mean species richness was higher in coral communities (2008: 27.6 species ± 2.9 SE; 2009: 30.2 species ± 1.7 SE) than in macroalgae communities (2008: 15.6 species ± 1.0 SE; 2009: 21.4 species ± 1.1 SE) (Figure 11-6), however the difference was only significant in the October 2008 survey (Pseudo-F = 61.7, *p(perm)* <0.01). In the October 2008 survey, the relative abundance and composition of the fish assemblages was significantly different in coral and macroalgae communities (Pseudo-F = 5.7, *p(perm)* <0.01), with coral communities supporting relatively higher abundances of fish species. Relatively higher abundances of species, including Moon Wrasse (*Thalassoma lunare*), Doubleline Fusilier (*Pterocaesio digramma*), Spangled Emperor (*Lethrinus nebulosus*), Muddy Damselfish (*Pomacentrus limosus*), Chinamanfish (*Symphorus nematophorus*) and Bengal Sergeant (*Abudefduf bengalensis*), were recorded in coral communities than in macroalgae communities. Compared to coral communities, higher abundances of Blue-lined Emperor (*Lethrinus punctulatus*), Western Butterfish (*Pentapodus vitta*), Northwest Threadfin Bream (*Pentapodus porosus*) and Threadfin Emperor (*Lethrinus genivittatus*) were recorded in macroalgae communities. There were no significant differences in relative abundance and composition between coral and macroalgae communities in the March 2009 survey.

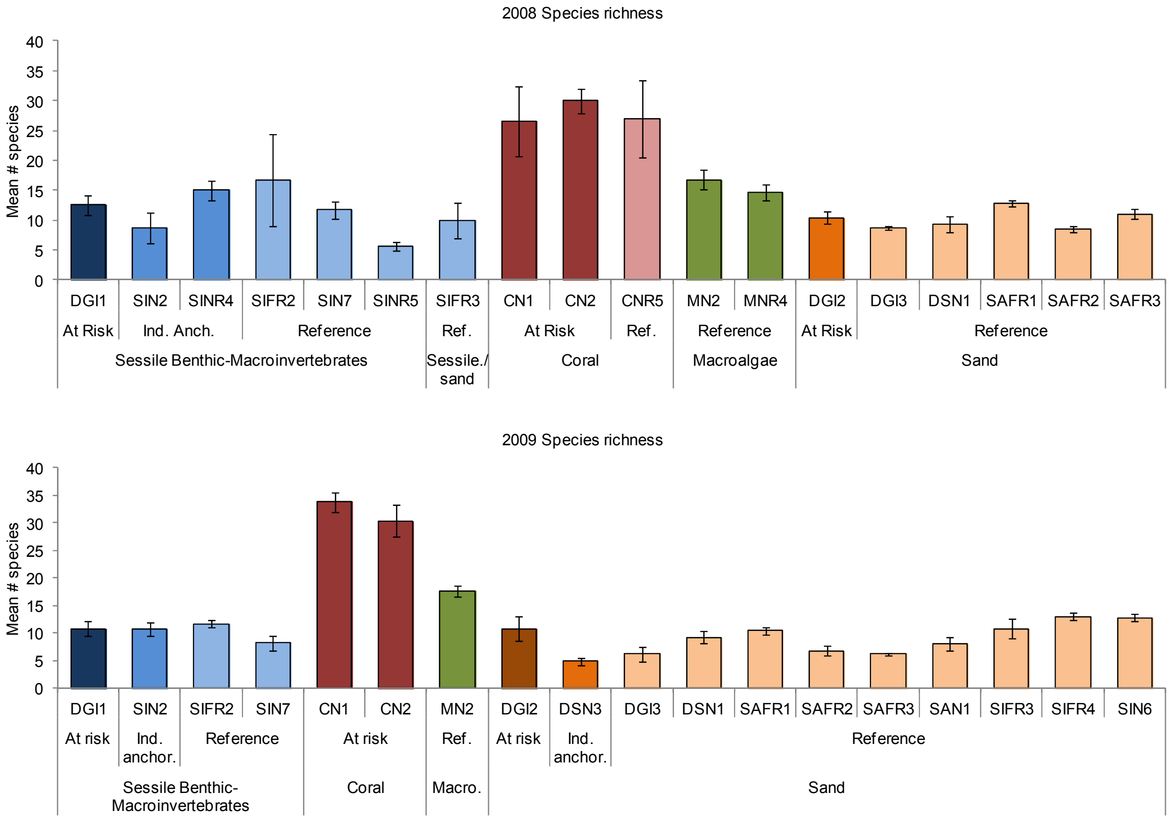



**Figure 11-6 Mean (± SE) Species Richness for Each 'Site', 'Community Type' and 'Area' (at Risk of Material or Serious Environmental Harm and Reference Sites) in the October 2008 and March 2009 Surveys**

The most common and abundant species observed at the inshore coral and macroalgae communities are included in Table 11-4 (Centre for Marine Futures, UWA 2013). In coral communities, 10 of the 15 species (75%) were common and abundant in both the October 2008 and March 2009 surveys, while 12 of the 15 species (80%) were common and abundant in macroalgae communities during both surveys. In coral communities, the majority of the fish species that were common and abundant in both surveys, had higher abundances, on average, in the March 2009 survey. Abundances were not consistently higher in one survey than the other in macroalgae communities. There were high abundances of many different juvenile fish species (including Blue-lined Emperor, Dusky Rabbitfish [*Siganus fuscescens*] and various Tuskfish species [*Choerodon* spp.]) frequently observed in the macroalgae communities.

**Table 11-4 Fifteen Most Common and Abundant Fish Species in Coral, Macroalgae and Sand/Sessile Invertebrates Community Types Surveyed in the October 2008 and March 2009 Surveys**

| October 2008 Survey | | | | March 2009 Survey | | | |
|---|---|---|---|---|---|---|---|
| **Genus species** | **Total #** | **% of drops** | **Mean MaxN ± SE** | **Genus species** | **Total #** | **% of drops** | **Mean MaxN ± SE** |
| **Coral** | | | | | | | |
| *Abudefduf bengalensis* | 20 | 64 | 1.8 ± 0.5 | *Abudefduf bengalensis* | 30 | 70 | 3.0 ± 3.6 |
| *Chaetodontoplus duboulayi* | 10 | 73 | 0.9 ± 0.2 | *Acanthurus grammoptilus* | 26 | 60 | 2.6 ± 3.0 |
| *Choerodon cyanodus* | 19 | 82 | 1.7 ± 0.3 | *Choerodon cyanodus* | 20 | 90 | 2.0 ± 0.9 |
| *Choerodon schoenleinii* | 16 | 91 | 1.5 ± 0.3 | *Choerodon schoenleinii* | 17 | 90 | 1.7 ± 1.1 |
| *Lethrinus atkinsoni* | 21 | 82 | 1.9 ± 0.6 | *Heniochus acuminatus* | 15 | 70 | 1.5 ± 1.6 |
| *Lethrinus nebulosus* | 32 | 45 | 2.9 ± 1.8 | *Lethrinus atkinsoni* | 35 | 80 | 3.5 ± 3.9 |
| *Lutjanus carponotatus* | 19 | 73 | 1.7 ± 1.0 | *Lutjanus carponotatus* | 60 | 100 | 6.0 ± 7.9 |
| *Pentapodus emeryii* | 14 | 64 | 1.3 ± 0.4 | *Neopomacentrus filamentosus* | 124 | 60 | 12.4 ± 1 4.1 |
| *Plectropomus* spp. | 19 | 82 | 1.7 ± 0.4 | *Pentapodus emeryii* | 16 | 80 | 1.6 ± 1.5 |
| *Pomacanthus sexstriatus* | 10 | 64 | 0.9 ± 0.3 | *Plectropomus* spp. | 19 | 100 | 1.9 ± 1.0 |
| *Pomacentrus limosus* | 28 | 64 | 2.5 ± 1.4 | *Pomacanthus sexstriatus* | 13 | 100 | 1.3 ± 0.5 |
| *Scarus schlegeli* | 13 | 64 | 1.2 ± 0.4 | *Pterocaesio digramma* | 351 | 60 | 35.1 ± 48. 9 |
| *Siganus doliatus* | 73 | 55 | 6.6 ± 3.0 | *Scarus rivulatus* | 9 | 70 | 0.9 ± 0.9 |
| *Symphorus nematophorus* | 10 | 73 | 0.9 ± 0.3 | *Siganus doliatus* | 24 | 60 | 2.4 ± 2.8 |
| *Thalassoma lunare* | 45 | 73 | 4.1 ± 1.2 | *Thalassoma lunare* | 36 | 90 | 3.6 ± 2.5 |
| **Macroalgae** | | | | | | | |
| *Anampses lennardi* | 18 | 44 | 2.0 ± 1.1 | *Choerodon cauteroma* | 7 | 100 | 1.4 ± 0.5 |
| *Chiloscyllium punctatum* | 5 | 56 | 0.6 ± 0.2 | *Choerodon cyanodus* | 8 | 100 | 1.6 ± 0.9 |
| *Choerodon cauteroma* | 17 | 100 | 1.9 ± 0.3 | *Gnathanodon speciosus* | 35 | 40 | 7.0 ± 13. 5 |
| *Choerodon cyanodus* | 14 | 100 | 1.6 ± 0.2 | *Lethrinus genivittatus* | 17 | 100 | 3.4 ± 2.2 |
| *Gnathanodon speciosus* | 12 | 44 | 1.3 ± 0.6 | *Lethrinus laticaudis* | 5 | 60 | 1.0 ± 1.2 |
| *Lethrinus genivittatus* | 47 | 56 | 5.2 ± 2.5 | *Lethrinus punctulatus* | 99 | 100 | 19.8 ± 5.1 |
| *Lethrinus laticaudis* | 16 | 33 | 1.8 ± 1.1 | *Lethrinus variegatus* | 15 | 100 | 3.0 ± 1.2 |
| *Lethrinus punctulatus* | 195 | 100 | 21.7 ± 4.0 | *Lutjanus carponotatus* | 5 | 80 | 1.0 ± 0.7 |
| *Lutjanus carponotatus* | 7 | 56 | 0.8 ± 0.3 | *Parupeneus barberinoides* | 4 | 80 | 0.8 ± 0.4 |

| October 2008 Survey | | | | March 2009 Survey | | | |
|---|---|---|---|---|---|---|---|
| **Genus species** | **Total #** | **% of drops** | **Mean MaxN ± SE** | **Genus species** | **Total #** | **% of drops** | **Mean MaxN ± SE** |
| *Pentapodus emeryii* | 24 | 78 | 2.7 ± 0.7 | *Pentapodus emeryii* | 10 | 60 | 2.0 ± 2.9 |
| *Pentapodus porosus* | 15 | 67 | 1.7 ± 0.6 | *Pentapodus porosus* | 12 | 100 | 2.4 ± 1.3 |
| *Pentapodus vitta* | 56 | 67 | 6.2 ± 2.0 | *Pentapodus vitta* | 65 | 100 | 13.0 ± 2.1 |
| *Scombridae* spp. | 5 | 56 | 0.6 ± 0.2 | *Scaevius milii* | 35 | 60 | 7.0 ± 13.0 |
| *Siganus fuscescens* | 32 | 56 | 3.6 ± 1.4 | *Siganus fuscescens* | 107 | 100 | 21.4 ± 17 |
| *Upeneus tragula* | 47 | 44 | 5.2 ± 4.3 | *Upeneus tragula* | 22 | 80 | 4.4 ± 5.0 |
| **Sand and sessile invertebrates** | | | | | | | |
| *Choerodon cauteroma* | 24 | 24 | 0.5 ± 0.1 | *Atule mate* | 218 | 19 | 3.0 ± 1.8 |
| *Choerodon cyanodus* | 16 | 24 | 0.3 ± 0.1 | *Carangoides fulvoguttatus* | 87 | 44 | 1.2 ± 0.3 |
| *Echeneis naucrates* | 29 | 28 | 0.6 ± 0.2 | *Echeneis naucrates* | 41 | 35 | 0.6 ± 0.1 |
| *Herklotsichthys* spp. | 1016 | 16 | 20.3 ± 10.9 | *Gnathanodon speciosus* | 231 | 28 | 3.2 ± 0.9 |
| *Lethrinus punctulatus* | 141 | 20 | 2.82 ± 1.08 | *Lethrinus genivittatus* | 128 | 29 | 1.8 ± 0.5 |
| *Loxodon macrorhinus* | 37 | 38 | 0.7 ± 0.2 | *Nemipterus* spp. | 101 | 61 | 1.4 ± 0.2 |
| *Nemipterus* spp. | 175 | 60 | 3.5 ± 0.6 | *Paramonacanthus choirocephalus* | 96 | 50 | 1.3 ± 0.3 |
| *Paramonacanthus choirocephalus* | 56 | 48 | 1.1 ± 0.2 | *Parapercis nebulosa* | 64 | 61 | 0.9 ± 0.1 |
| *Parapercis nebulosa* | 43 | 54 | 0.9 ± 0.1 | *Pentapodus porosus* | 598 | 68 | 8.3 ± 1.1 |
| *Pentapodus porosus* | 635 | 88 | 12.7 ± 1.6 | *Pentapodus vitta* | 203 | 49 | 2.8 ± 0.5 |
| *Pentapodus vitta* | 437 | 44 | 8.7 ± 1.7 | *Pristotis obtusirostris* | 96 | 13 | 1.3 ± 0.5 |
| *Scombridae* spp. | 77 | 82 | 1.5 ± 0.2 | *Scombridae* spp. | 139 | 93 | 1.9 ± 0.1 |
| *Selaroides leptolepis* | 546 | 54 | 10.9 ± 2.3 | *Selaroides leptolepis* | 574 | 42 | 8.0 ± 1.4 |
| *Siganus fuscescens* | 86 | 24 | 1.7 ± 0.8 | *Synodontidae* spp. | 24 | 28 | 0.3 ± 0.1 |
| *Upeneus tragula* | 75 | 38 | 1.5 ± 0.5 | *Torquigener pallimaculatus* | 80 | 32 | 1.1 ± 0.3 |

*Note: Total # = sum of abundances for each deployment; % of drops = percent of stereo BRUV deployments observed at; Mean MaxN = average relative abundance. Note that the species are ordered alphabetically by genus.*

There were significant differences in the distribution of fish lengths in coral and macroalgae communities in the October 2008 and March 2009 surveys (Kolmogorov-Smirnov test, D >0.2, $p$ <0.01) (Centre for Marine Futures, UWA 2013). Macroalgae communities had higher proportions of individuals in the size-class 120–200 mm than coral communities, due to the high abundance of Western Butterfish and juvenile Blue-lined Emperor, Tuskfish (*Choerodon* spp.) and Dusky Rabbitfish in this size range. Fish assemblages characteristic of coral communities had very broad size distributions, reflecting an assemblage comprising a mix of small (e.g. Brown Demoiselle [*Neopomacentrus filamentosus*]), medium (e.g. Stripey Snapper [*Lutjanus carponotatus*]) and large (e.g. Blackspot Tuskfish [*Choerodon schoenleinii*] fish species. While the size structures were similar in the October 2008 and March 2009 surveys, mean lengths were greater in the October 2008 survey than in March 2009 survey in both the coral (2008: 266 mm ± 6.9 SE; 2009: 204 mm ± 4.3 SE) and macroalgae (2008: 192 mm ± 6.4 SE; 2009: 145 mm ± 3.1 SE) communities.

Note that while the focus of the stereo BRUVs surveys was on describing the demersal fish assemblages that characterised hard and soft corals, non-coral benthic macroinvertebrates, macroalgae and seagrass communities, pelagic and more mobile species (e.g. Mackerel species [scombrids], Trevally species [*Carangoides* spp.], Sharks) were also recorded and included in the analyses as a number of these species were consistently observed regardless of survey period, habitat or location and they likely comprise an important component of the fish assemblages.

#### 11.4.1.2 Barrow Island: Soft Sediments with Sessile Benthic Macroinvertebrates and Unvegetated Sand

During the first survey in October 2008, a total of 3830 individuals from 94 species and 37 families were recorded from 50 stereo BRUV deployments at 13 sites on the east coast of Barrow Island (Centre for Marine Futures, UWA 2013). In the second survey in March 2009, a total of 3078 individuals from 81 species and 33 families were recorded from 72 stereo BRUV deployments at 15 sites. Of the 94 species observed in the October 2008 survey, 55 (58%) were common to both surveys. Of the 81 species observed in the March 2009 survey, 53 (65%) were also observed in the October 2008 survey. The majority of the species unique to a given survey were only observed on a single stereo BRUV deployment. Many of these were large-bodied transient species, including Sharks (*Carcharhinus* spp.), Stingrays (*Himantura* spp.) and Trevally (*Carangoides* spp.). A number of large Cod (Serranids), were observed in the October 2008 survey but not in the March 2009 survey, including Frostback Rockcod (*Epinephelus bilobatus*), Goldspotted Rockcod (*E. coioides*), Blacktip Rockcod (*E. fasciatus*), Rankin Cod (*E. multinotatus*) and Coral Trout (*Plectropomus* spp.). Two Emperor species (Lethrinids: *Lethrinus lentjan* and *L. nebulosus*) were observed only in the March 2009 survey. Only a few species unique to each survey were regularly observed (e.g. Whiting [*Sillago* spp.] in 2008, Herring [*Herklotsichthys* sp.] in 2008, and Silver Toadfish [*Lagocephalus sceleratus*] in 2009).

Species richness did not differ between soft sediments with sessile benthic macroinvertebrates and unvegetated sand in either the October 2008 or the March 2009 surveys (Centre for Marine Futures, UWA 2013). There were, however, significant differences in species richness between the sites surveyed (2008: Pseudo-F = 2.6, *p(perm)* = 0.03; 2009: Pseudo-F = 5.6, *p(perm)* <0.01), reflecting high variability at relatively small spatial scales. There were no differences in the relative abundance or composition of the fish assemblages characteristic of soft sediments with sessile benthic macroinvertebrates and unvegetated sand. However, there were significant differences in relative abundance and composition of fish assemblages between sites (Table 11-5; Figure 11-6), reflecting high turnover of species and shifts in abundance across relatively small spatial scales.

**Table 11-5 PERMANOVA based on Bray Curtis dissimilarities of 4th-root transformed relative abundance data for the October 2008 and March 2009 surveys in response to the factors 'Area' (at risk of Material or Serious Environmental Harm vs Reference Sites), 'Community Type' (Soft sediments with sessile benthic macroinvertebrates vs unvegetated sand) and 'Site'**

| | Source | df | MS | Pseudo-F | *P(perm)* | Unique perms |
|---|---|---|---|---|---|---|
| October 2008 | Area | 1 | 13765 | 3.10 | **0.02** | 9936 |
| | Community Type | 1 | 4184.5 | 0.97 | 0.43 | 9941 |
| | Area × Community Type | 1 | 5037.5 | 1.16 | 0.32 | 9934 |
| | Site(Area × Community Type) | 9 | 3891.9 | 3.23 | **<0.01** | 9823 |
| | Residual | 37 | 1203.7 | - | - | - |
| | Total | 49 | - | - | - | - |
| March 2009 | Area | 1 | 7041.2 | 1.20 | 0.29 | 9873 |
| | Community Type | 1 | 2312.9 | 0.40 | 0.86 | 9902 |
| | Area × Community Type | 1 | 2055.4 | 0.35 | 0.88 | 9921 |
| | Site(Area × Community Type) | 11 | 5794.7 | 4.20 | **<0.01** | 9837 |
| | Residual | 57 | 1373.4 | - | - | - |
| | Total | 71 | - | - | - | - |

The most common and abundant species observed at soft sediments with benthic macroinvertebrates communities and unvegetated sand sites are presented in Table 11-4 (Centre for Marine Futures, UWA 2013). Eight of the 15 species were common and abundant in both the October 2008 and the March 2009 surveys. Four of these eight species were more abundant, on average, in the October 2008 survey, while only one (Mackerel) of the remaining four species were more abundant, on average, in the March 2009 survey.

There were significant differences in the size structure of the demersal fish assemblages in soft sediments with benthic macroinvertebrates communities (mean length 2008: 234 mm ± 6.9 SE; 2009: 215 mm ± 8.9 SE) and unvegetated sand (mean length 2008: 177 mm ± 5.8 SE; 2009: 223 mm ± 6.0 SE) in the October 2008 survey (Kolmogorov-Smirnov test, D = 0.31, $p$ <0.01), but not in the March 2009 survey (Centre for Marine Futures, UWA 2013). In the October 2008 survey, the unvegetated sand sites had a higher proportion of the fish assemblage in the 121–160 mm size range than the soft sediments with benthic macroinvertebrates communities, which was attributable to a higher abundance of Yellowstripe Scad (*Selaroides leptolepis*) and Herring at these sites, resulting in a smaller mean length at the unvegetated sand sites. In the October 2008 survey, the soft sediments with benthic macroinvertebrates communities had a higher proportion of the fish assemblage in the 161–240 mm size range than unvegetated sand sites due to a higher abundance of Northwest Threadfin Bream (*Pentapodus porosus*). The size-frequency histograms of the fish assemblages surveyed in March 2009 were broader than those surveyed in October 2008 (Kolmogorov-Smirnov test, D >0.27, $p$ <0.01). In the March 2009 survey, the absence of schools of Herring at unvegetated sand sites reduced the proportion of individuals in the small size-classes and there were higher proportions of larger individuals in the March 2009 survey than in the October 2008 survey (e.g. Golden Trevally [*Gnathanodon speciosus*]; Sharksucker [*Echeneis naucrates*]).

#### 11.4.1.3 Mainland End of the DomGas Pipeline Route

In the October 2010 survey, there was high variability in the number of demersal fish species observed between sites and within the different community types (Table 11-6) (UWA Oceans Institute and School of Plant Biology, UWA 2011). Mean demersal fish species richness ranged from an average of 2.8 species ± 0.7 SE at the seagrass site SGR1, to 23.4 species ± 1.03 SE at the coral site CR2. In general, coral communities had the highest species richness, followed by non-coral benthic macroinvertebrates, macroalgae, and seagrass communities (Figure 11-7). However, the differences were only significant between the coral communities (mean species richness: 16.12 species ± 1.7 SE) and seagrass communities (4.6 species ± 1.0 SE). In the April 2011 survey, demersal fish species richness did not differ significantly between the sites, but did differ significantly between the different community types (Table 11-6). Mean species richness was significantly higher in coral communities (15 species ± 1.5 SE) than in macroalgae communities (13.2 species ± 1.2 SE) or seagrass communities (6.9 species ± 0.9 SE). The differences between the coral communities and the non-coral benthic macroinvertebrates communities (12.0 species ± 1.2 SE) were marginal.

**Table 11-6 PERMANOVA based on Euclidean Distance dissimilarities of species richness data for the October 2010 and April 2011 surveys in response to the factors 'Area' (at risk of Material or Serious Environmental Harm vs Reference Sites), 'Community Type' and 'Site'**

| | Source | df | MS | Pseudo-F | *P(perm)* | Unique perms |
|---|---|---|---|---|---|---|
| October 2010 | Area | 1 | 2.65 | 0.035 | 0.86 | 9831 |
| | Community Type | 3 | 336.85 | 4.46 | **0.05** | 9957 |
| | Area × Community Type | 3 | 260.52 | 0.345 | 0.08 | 9961 |

| | Source | df | MS | Pseudo-F | *P(perm)* | Unique perms |
|---|---|---|---|---|---|---|
| | Site(Area × Community Type) | 7 | 75.57 | 2.87 | **0.01** | 9934 |
| | Residual | 60 | 26.37 | - | - | - |
| | Total | 74 | - | - | - | - |
| April 2011 | Area | 1 | 324.24 | 10.54 | **0.01** | 9825 |
| | Community-type | 3 | 210.8 | 6.85 | **0.01** | 9957 |
| | Area × Community Type | 3 | 164.06 | 5.33 | **0.02** | 9949 |
| | Site(Area × Community Type) | 9 | 30.76 | 1.29 | 0.25 | 9942 |
| | Residual | 68 | 23.78 | - | - | - |
| | Total | 84 | - | - | - | - |

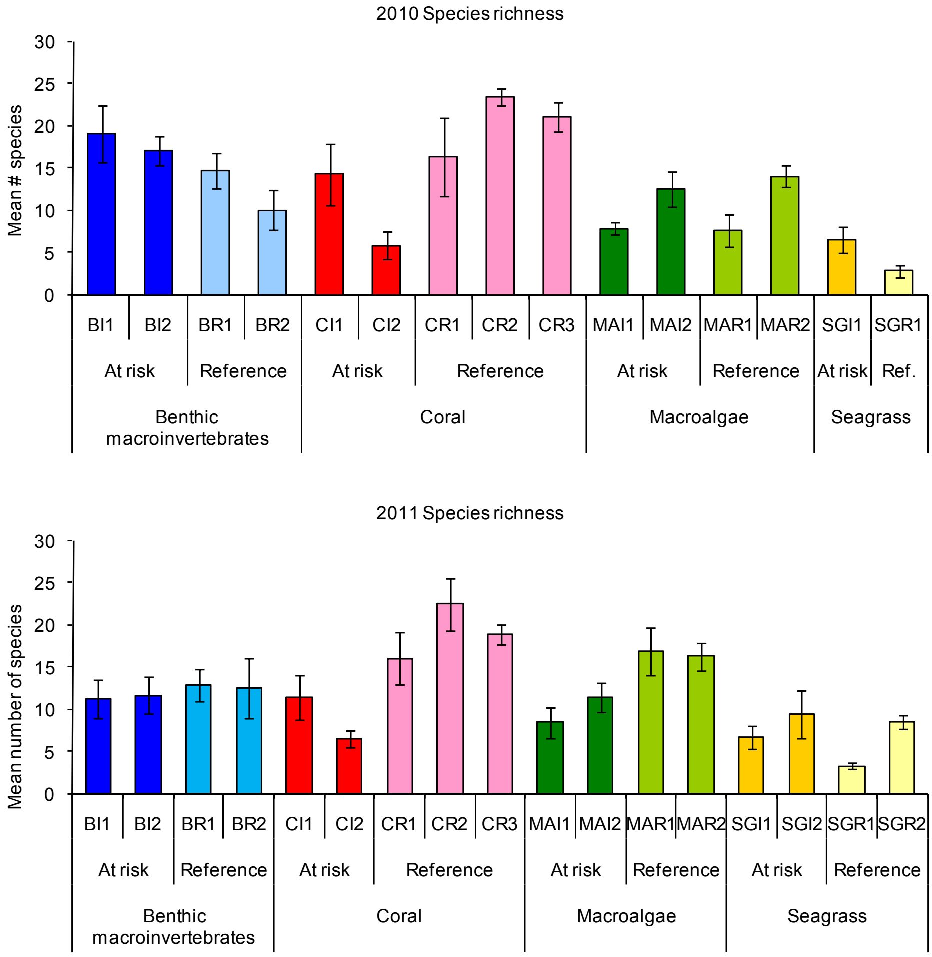



**Figure 11-7 Mean (± SE) Species Richness for Each 'Site', 'Community Type' and 'Area' (at Risk of Material or Serious Environmental Harm and Reference Sites) in the October 2010 and April 2011 Surveys**

Mean species richness was higher in the October 2010 survey than in the April 2011 survey for fish assemblages associated with non-coral benthic macroinvertebrate communities (2010: 14.5 species ± 1.4 SE; 2011: 12.0 species ± 1.2 SE) and coral communities (2010: 16.1 species ± 1.7 SE; 2011: 15.1 species ± 1.5 SE) (Figure 11-7) (UWA Oceans Institute and School of Plant Biology, UWA 2011). Mean species richness in macroalgae communities was higher in the April 2011 survey (2010: 10.5 species ± 1.0 SE; 2011: 13.2 species ± 1.2 SE) and similarly at the seagrass communities (2010: 4.6 species ± 1.0 SE; 2011: 6.9 species ± 0.9 SE). In the case of the seagrass communities, this pattern is as likely to be due to the increased sampling effort in the April 2011 survey as any seasonal patterns.

In the October 2010 survey, the total mean relative abundance of demersal fish assemblages was highest in coral communities (52.4 ± 10 SE) followed by non-coral benthic macroinvertebrates communities (48.1 ± 7.9 SE) and macroalgae communities (33.3 ± 4.2 SE); the lowest total mean relative abundance was recorded in seagrass communities (11.3 ± 3.3 SE) (UWA Oceans Institute and School of Plant Biology, UWA 2011). In the April 2011 survey, the total mean relative abundance of fish assemblages was highest in macroalgae communities (141.2 ± 43.8 SE) followed by coral communities (56.8 ± 7.4 SE) and non-coral benthic macroinvertebrates communities (46.1 ± 7.6 SE); the lowest total mean relative abundances were again recorded in seagrass communities (42.5 ± 9.7 SE). In both the October 2010 and the April 2011 surveys, mean relative abundance differed significantly across all factors (Table 11-7), with the significant results for sites indicating high variability in the relative abundance and composition of fish assemblages at the relatively small spatial scales of between sites. The SIMPER analysis identified a number of species responsible for the differences between the different community types surveyed in October 2010. On average, Dusky Rabbitfish (*Siganus fuscescens*) had a higher relative abundance in non-coral benthic macroinvertebrates communities than in all the other community types. These communities also had higher relative abundances of Mackerel (Scombridae spp.) and Stripey Snapper (*Lutjanus carponotatus*) than most of the other community types. Coral communities had higher relative abundances of Bengal Sergeant (*Abudefduf bengalensis*), Inshore Surgeonfish (*Acanthurus grammoptilus*), Goldstripe Butterflyfish (*Chaetodon aureofasciatus*) and Darktail Snapper (*Lutjanus lemniscatus*), than all the other community types. On average, macroalgae communities had higher relative abundances of Yellowspot Goatfish (*Parupeneus indicus*), while seagrass communities had high abundances of Bartail Goatfish (*Upeneus tragula*). In general, however, seagrass communities had fewer species and a lower total number of individuals than all other community types. Similarly, in April 2011, the SIMPER analyses identified a number of species responsible for the differences between the different community types. On average, non-coral benthic macroinvertebrate communities had higher relative abundances of Yellowstripe Scad (*Selaroides leptolepis*) than all the other community types. Bengal Sergeant, Inshore Surgeonfish, Grass Emperor (*Lethrinus laticaudis*), Stripey Snapper, Darktail Snapper, and Miller's Damsel (*Pomacentrus milleri*) were present in higher average relative abundances in coral communities compared to the other community types. On average, macroalgae communities had higher relative abundances of Blue-lined Emperor (*Lethrinus punctulatus*). Macroalgae communities also had higher relative abundances of Western Butterfish (*Pentapodus vitta*) than coral or non-coral benthic macroinvertebrates communities. Seagrass communities had lower relative abundances of most species, with the exception of Western Butterfish, which was most abundant in this community type.

**Table 11-7 PERMANOVA based on Bray Curtis dissimilarities of 4th-root transformed relative abundance data for the October 2010 and April 2011 surveys in response to factors 'Area' (at risk of Material or Serious Environmental Harm vs Reference Sites), 'Community Type' and 'Site'**

| | Source | df | MS | Pseudo-F | *P(perm)* | Unique perms |
|---|---|---|---|---|---|---|
| October 2010 | Area | 1 | 9545.1 | 2.4 | **0.03** | 9936 |
| | Community Type | 3 | 19738 | 4.96 | **<0.01** | 9912 |
| | Area × Community Type | 3 | 7109.6 | 1.77 | **0.02** | 9901 |
| | Site(Area × Community Type) | 7 | 3980.1 | 2.13 | **<0.01** | 9773 |
| | Residual | 60 | 1869 | - | - | - |
| | Total | 74 | - | - | - | - |

| | Source | df | MS | Pseudo-F | *P(perm)* | Unique perms |
|---|---|---|---|---|---|---|
| April 2011 | Area | 1 | 13217 | 2.47 | **0.02** | 9938 |
| | Community Type | 3 | 19525 | 3.65 | **<0.01** | 9917 |
| | Area × Community Type | 3 | 8588.1 | 1.60 | **0.02** | 9890 |
| | Site(Area × Community Type) | 9 | 5352.6 | 2.84 | **<0.01** | 9788 |
| | Residual | 68 | 1886.3 | - | - | - |
| | Total | 84 | - | - | - | - |

There were differences in the relative abundances of common and abundant species recorded in the October 2010 and April 2011 surveys (UWA Oceans Institute and School of Plant Biology, UWA 2011). Coral communities surveyed in October 2010 had higher relative abundances and commonality of Blackspot Tuskfish (*Choerodon schoenleinii*), Grass Emperor and Brown Demoiselle (*Neopomacentrus filamentosus*). Inshore Surgeonfish, Scribbled Angelfish (*Chaetodontoplus duboulayi*), Miller's Damsel and Scombridae spp. were more abundant, on average, and more frequently observed on BRUVs deployments at coral sites in the April 2011 survey. The non-coral benthic macroinvertebrates communities surveyed in October 2010 had higher relative abundances of Blue Tuskfish (*Choerodon cyanodus*), Grass Emperor and Blue-lined Emperor, while other species such as Bluespotted Tuskfish (*Choerodon cauteroma*), Frostback Rockcod (*Epinephelus bilobatus*), and Bluelined Rabbitfish (*Siganus doliatus*), were much more commonly observed than in non-coral benthic macroinvertebrates site surveys in April 2011. The April 2011 survey recorded higher abundances and commonality of Barred Yellowtail Scad (*Atule mate*), Bumpnose Trevally (*Carangoides hedlandensis*), Western Butterfish, and Yellowstripe Scad. Surveys of macroalgae sites in October 2010 recorded higher relative abundances and more frequent observations of Yellowspot Goatfish and Grass Emperor, while in the April 2011 survey, higher relative abundances and more frequent observations were recorded of Herring (*Herklotsichthys* spp.), Stripey Snapper, Western Butterfish, Mackerel, Dusky Rabbitfish and Striped Barracuda (*Sphyraena obtusata*).

In the October 2010 survey, the length frequency distributions of the demersal fish assemblages at both the non-coral benthic macroinvertebrates and the macroalgae communities were strongly skewed towards the smaller size-classes, with the modal length classes being between 100 mm and 199 mm (UWA Oceans Institute and School of Plant Biology, UWA 2011). A broader length frequency distribution was observed in the coral communities, with a larger modal length range of between 50 mm and 299 mm. As fewer fish were recorded at the seagrass sites, the patterns were not as clear; however, the length distributions of the fish assemblages in seagrass communities were skewed towards the smaller size-classes, with most fish measured between the 50 mm and 149 mm length classes.

In the April 2011 survey, the length frequency distributions of the demersal fish assemblages in non-coral benthic macroinvertebrates communities were skewed towards the smaller length classes, with a modal range of between 50 mm and 199 mm (UWA Oceans Institute and School of Plant Biology, UWA 2011). The length frequency distributions of fish associated with both coral and macroalgae communities showed a broad modal range between 50 mm and 250 mm. The length distribution of fish associated with seagrass communities showed a narrow modal size class of 100 mm to 149 mm.

### 11.4.2 Description of Demersal Fish Assemblages Characteristic of Mangrove Communities at Mainland Sites in the Vicinity of the DomGas Pipeline Route

#### 11.4.2.1 Seine Netting

A total of 4985 fish, representing 36 species from 24 families, were recorded from the 42 seine net deployments during the October 2010 survey (Table 11-8). The most diverse family recorded was the Gobiidae, with five species recorded. Thirteen of the 36 species were recorded from all three of the surveyed areas (i.e. from at least one of the three sites at risk of Material or Serious Environmental Harm and in at least one of the two Reference Areas in each of the northern and southern reference creeks), whilst eight species were recorded only from Reference Sites. With the exception of three species (Short Silverbiddy [*Gerres erythrourus*], Yellow-spotted Tongue Sole [*Paraplagusia guttata*] and an unidentified species of Stinkfish), all species recorded from sites at risk of Material or Serious Environmental Harm were also present at one or more Reference Sites.

In contrast, a total of 23 554 fish, representing 49 species from 30 families, were recorded from the 48 seine net deployments during the February 2011 survey (Table 11-8). The most diverse families recorded during the wet season survey were the Gobiidae, Carangidae, Sillaginidae, Platycephalidae, Atherinidae and Clupeidae, each with three species recorded. Twenty-five of the 49 species were recorded from all three of the surveyed areas (i.e. from at least one of the four sites at risk of Material or Serious Environmental Harm and from at least one of the two Reference Sites in each of the northern and southern reference creeks), whilst eight species were recorded only from Reference Sites. With the exception of seven taxa (Diamondscale Mullet [*Liza vaigiensis*], Largetooth Flounder [*Pseudorhombus arsius*], Coloured Righteye Flounder [*Poecilopsetta colorata*], Blacktip Silverbiddy [*Gerres oyena*], Shortfin Batfish [*Zabidius novemaculeatus*], unidentified Rockcod [*Epinephelus* sp.] and an unidentified species of Grubfish), most taxa present at sites at risk of Material or Serious Environmental Harm were also present at one or more Reference Sites. Note that, with the exception of a single individual of Barred Javelin (*Pomadasys kaakan*) caught in a cast net, all the species caught during the February 2011 survey using cast nets were also recorded in the seine net samples.

**Table 11-8 Demersal fish species at sites at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline (At risk) and at Reference Sites that are not at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline, recorded (X) from seine net samples during the October 2010 and February 2011 (bold) surveys**

| Family | Genus species | Common name | Sites | | |
|---|---|---|---|---|---|
| | | | At risk (*n* = 24 wet) (*n* = 18 dry) | Northern Reference (*n* = 12) | Southern Reference (*n* = 12) |
| Carcharhinidae | *Carcharhinus cautus* | Nervous Shark | | | **X** |
| Rhinobatidae | *Glaucostegus typus* | Giant Shovelnose Ray | | X **X** | |
| Dasyatidae | *Himantura leoparda* | Leopard Whipray | | X **X** | |
| Clupeidae | *Escualosa thoracata* | White Sardine | X **X** | **X** | X **X** |
| | *Nematalosa come* | Hairback Herring | X **X** | X **X** | **X** |
| | *Sardinella* sp. | A Sardinella | | | X |
| | *Herklotsichthys koningsbergeri* | Koningsberger's Herring | | **X** | |
| Pristigasteridae | *Ilisha* sp. | An Ilisha | X **X** | X **X** | **X** |
| Engraulidae | *Stolephorus indicus* | Indian Anchovy | X **X** | X **X** | X **X** |
| | *Thryssa hamiltonii* | Hamilton's Thryssa | **X** | **X** | **X** |
| Ariidae | *Arius* sp. | A Catfish | | | X |
| | *Neoarius graeffei* | Blue Catfish | **X** | **X** | **X** |
| Synanceiidae | *Synanceia horrida* | Estuarine Stonefish | | X | |
| Mugilidae | *Liza vaigiensis* | Diamondscale Mullet | **X** | | |
| | *Valamugil buchanani* | Bluetail Mullet | X **X** | X **X** | **X** |

| Family | Genus species | Common name | Sites | | |
|---|---|---|---|---|---|
| | | | **At risk (*n* = 24 wet) (*n* = 18 dry)** | **Northern Reference (*n* = 12)** | **Southern Reference (*n* = 12)** |
| Atherinidae | *Atherinomorus lacunosus* | Slender Hardyhead | **X** | **X** | |
| | *Craterocephalus mugiloides* | Spotted Hardyhead | X **X** | X **X** | X |
| | *Craterocephalus pauciradiatus* | Few-ray Hardyhead | **X** | **X** | **X** |
| Hemiramphidae | *Arrhamphus sclerolepis* | Northern Snubnose Garfish | X **X** | X **X** | **X** |
| | *Hyporhamphus quoyi* | Longtail Garfish | **X** | | **X** |
| | *Hyporhamphus neglectissimus* | Neglected Garfish | X **X** | | X **X** |
| Belonidae | *Strongylura strongylura* | Blackspot Needlefish | X **X** | **X** | X **X** |
| Platycephalidae | *Platycephalus arenarius* | Northern Sand Flathead | X | X | X |
| | *Platycephalus indicus* | Bartail Flathead | **X** | **X** | |
| | *Platycephalus westraliae* | Yellow-tailed Flathead | X **X** | X | X **X** |
| Ambassidae | *Ambassis interruptus* | Long-spined Glass Perchlet | X **X** | X **X** | X **X** |
| Serranidae | *Epinephelus* sp. | A Rockcod | **X** | | |
| Sillaginidae | *Sillago burrus* | Western Trumpeter Whiting | X **X** | X **X** | X **X** |
| | *Sillago analis* | Golden Line Whiting | X **X** | X **X** | X **X** |
| | Unidentified whiting | A Whiting (juvenile) | X **X** | X **X** | X **X** |
| Carangidae | *Gnathanodon speciosus* | Golden Trevally | | **X** | |
| | *Caranx ignobilis* | Giant Trevally | **X** | **X** | **X** |
| | *Scomberoides tol* | Needleskin Queenfish | **X** | **X** | **X** |
| Leiognathidae | *Leiognathus bindus* | Orangefin Ponyfish | X **X** | X **X** | X **X** |
| Lutjanidae | *Lutjanus argentimaculatus* | Mangrove Jack | **X** | **X** | X |
| | *Lutjanus russellii* | Moses' Snapper | **X** | | **X** |
| Gerreidae | *Gerres oyena* | Blacktip Silverbiddy | X **X** | X | |
| | *Gerres erythrourus* | Short Silverbiddy | X **X** | **X** | **X** |
| Sparidae | *Acanthopagrus latus* | Western Yellowfin Bream | X **X** | X **X** | X **X** |
| | *Acanthopagrus palmaris* | Northwest Black Bream | X **X** | X **X** | X **X** |
| Sciaenidae | *Johnius* sp. | A Jewfish | | **X** | **X** |
| Ephippidae | *Zabidius novemaculeatus* | Shortfin Batfish | **X** | | |
| Sphyraenidae | *Sphyraena forsteri* | Blackspot Barracuda | **X** | **X** | **X** |
| Pinguipedidae | Unidentified grubfish | A Grubfish | **X** | | |
| Callionymidae | Unidentified stinkfish | A Stinkfish | X | | |
| Gobiidae | *Acentrogobius caninus* | Green-shoulder Goby | | X | |
| | *Amoya gracilis* | Blue-spotted Mangrove Goby | | X**X** | |
| | *Favonigobius melanobranchus* | Blackthroat Goby | X**X** | X**X** | X**X** |
| | *Pseudogobius* sp. 3 (Larson) | A Goby | X | X | |
| | *Glossogobius circumspectus* | Mangrove Flathead Goby | X **X** | **X** | X |

| **Family** | **Genus species** | **Common name** | **Sites** | | |
|---|---|---|---|---|---|
| | | | **At risk (*n* = 24 wet) (*n* = 18 dry)** | **Northern Reference (*n* = 12)** | **Southern Reference (*n* = 12)** |
| Scombridae | *Scomberomorus commerson* | Spanish Mackerel | | **X** | |
| Paralichthyidae | *Pseudorhombus arsius* | Largetooth Flounder | **X** | X | X |
| Pleuronectidae | *Poecilopsetta colorata* | Coloured Righteye Flounder | X **X** | | X |
| Cynoglossidae | *Paraplagusia guttata* | Yellow-spotted Tongue Sole | X **X** | **X** | **X** |
| Tetraodontidae | *Chelonodon patoca* | Milkspot Toadfish | X **X** | X **X** | X **X** |
| | *Marilyna pleurosticta* | Banded Toadfish | **X** | **X** | **X** |

Seven taxa recorded during the October 2010 survey were not recorded during the February 2011 survey. These included unidentified species of Catfish, Sardinella and Stinkfish, the gobies *Acentrogobius caninus* and *Pseudogobius* sp. 3, the Estuarine Stonefish (*Synanceia horrida*) and the Northern Sand Flathead (*Platycephalus arenarius*). In contrast, 20 species recorded during the February 2011 survey were not recorded in the October 2010 survey, including six small schooling taxa (e.g. Hamilton's Thryssa [*Thryssa hamiltonii*] and two species of atherinid) and the juveniles of ten larger, predatory species (e.g. Nervous Shark [*Carcharhinus cautus*], Moses' Snapper [*Lutjanus russellii*], Blackspot Barracuda [*Sphyraena forsteri*] and three species of carangid).

In the October 2010 survey, the highest total number of fish (1446 individuals) were recorded at NR3 in the southern Reference Area, with the lowest numbers recorded at the other Reference Sites (315–452 individuals) and intermediate numbers (733–822 individuals) recorded at sites at risk of Material or Serious Environmental Harm (Table 11-9). The mean total fish density across all the sites surveyed was 118.7/50m$^2$ ± 22.4 SE, with a mean of 6.9 species ± 0.3 SE recorded from each seine net sample during the October 2010 survey. The highest number of species recorded from a single sample was 11 species at N4 and NR4. In the February 2011 survey, the highest total number of fish were sampled at NR3 in the southern Reference Area (5091 individuals) and the lowest number (1213) at NR2 in the northern Reference Area (Table 11-10). At every site, fish abundances recorded during the February 2011 survey were higher (up to four-fold increase) than those observed at the same sites during the October 2010 survey, in particular at the Reference Sites. The mean total fish density was 490.7/50m$^2$ ± 67.8 SE, with a mean of 10.7 species ± 0.4 SE recorded from each seine net sample during the February 2011 survey. The highest number of species recorded from a single sample was 16 species at N2 and NR4. In general, sites exhibited a relatively low species diversity and moderate evenness across both survey periods (Table 11-9 and Table 11-10).

The MDS ordination of the sites indicates that the species composition of the fish assemblages sampled at sites at risk of Material or Serious Environmental Harm was broadly similar to that of the fish assemblages caught at Reference Sites in both surveys. There was no clear separation between samples from Reference Sites and those from sites at risk of Material or Serious Environmental Harm. However, samples from Reference Sites appeared to be more broadly dispersed across the ordination, suggesting that, in both surveys, the composition of the fish assemblages was more variable than at sites at risk of Material or Serious Environmental Harm. Samples from the northern Reference Area were largely responsible for these patterns, being distributed more broadly and slightly to the right of samples from the other sites. There was a clear separation of samples between surveys, with samples from the February 2011 survey being distributed largely to the left of those from the October 2010 survey (Figure 11-8). The results of the two-way ANOSIM identified a significant and moderate difference in fish assemblage composition between sites at risk of Material or Serious Environmental Harm and/or between Reference Sites during the October 2010 survey (R = 0.439, *p* = 0.001) and the February 2011 survey (R = 0.33, *p* = 0.001). The fish assemblage data were averaged at the site level to test for differences between sites at risk of Material or Serious Environmental Harm and Reference Areas. The results of the ANOSIM test indicated that there were no significant differences in fish assemblage composition in the dry season or wet season surveys (October 2010: R = -0.033, *p* = 1.0; February 2011: R = 0.208, *p* = 0.086). Despite the occurrence of similar patterns in fish assemblage composition in each survey, a one-way ANOSIM test identified a moderate and significant difference in the composition of the fish assemblages between the October 2010 and February 2011 surveys (R = 0.532, *p* = 0.001).

In general in the October 2010 survey, the size structure of the fish assemblages at sites at risk of Material or Serious Environmental Harm was broadly similar to that of the fish assemblages at Reference Sites, with the majority of fish <100 mm in fork length. This suggests that the fish assemblages recorded from sites at risk of Material or Serious Environmental Harm and those from Reference Sites largely comprised of juveniles, in addition to the adults of smaller species. There was a significant difference in size structure if all the fish were included in the analysis (Kolmogorov-Smirnov test, D = 0.605, *p* <0.001). However, it is important to note that the capture at northern Reference Sites of a number of individuals belonging to two larger species (the Giant Shovelnose Ray [*Glaucostegus typus*] and the Leopard Whipray [*Himantura leopard*]) caused the observed length frequency distribution of fish recorded from Reference Sites to be more strongly right-skewed towards the larger size-classes. When the individuals >300 mm in length were excluded from the analysis, the length frequency distributions were not significantly different. Similarly in the February 2011 survey, the majority of fish were <100 mm in length. This suggests that the fish assemblages recorded from sites at risk of Material or Serious Environmental Harm and Reference Sites were predominantly comprised of juveniles, in addition to adults of smaller species. There was a significant difference in size structure in the February 2011 survey (Kolmogorov-Smirnov test, D = 0.2206, *p* <0.0001). However, when the individuals >300 mm length were excluded, the length frequency distributions remained significantly different (Kolmogorov-Smirnov test, D = 0.2203, *p* <0.0001).

**Table 11-9 Total numbers, densities, numbers of species and diversity of demersal fish at sites at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline and at Reference Sites that are not at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline, recorded from seine net samples collected during the October 2010 survey**

| Site | At risk of Material or Serious Environmental Harm | | | Reference Sites | | | | All |
|---|---|---|---|---|---|---|---|---|
| | N1 | N3 | N4 | NR1 | NR2 | NR3 | NR4 | |
| Number of samples (*n*) | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 42 |
| | 18 | | | 24 | | | | |
| **Fish abundance** | | | | | | | | |
| Total number of fish captured | 795 | 733 | 822 | 452 | 422 | 1446 | 315 | 4985 |
| | 2350 | | | 2635 | | | | |
| Mean density (fish/50 $m^2$) ± SE | 132.5 ± 64.0 | 122.2 ± 96.8 | 137.0 ± 102.7 | 75.3 ± 30.3 | 70.3 ± 28.5 | 241.0 ± 52.6 | 52.5 ± 20.2 | 118.7 ± 22.4 |
| | 130.6 ± 45.6 | | | 109.8 ± 22.3 | | | | |
| Range of fish density (fish/50 $m^2$) | 12–365 | 20–563 | 24–603 | 13–169 | 9–156 | 100–425 | 13–118 | 9–603 |
| | 12–603 | | | 9–425 | | | | |
| **Number of species** | | | | | | | | |
| Mean ± SE | 7.0 ± 1.3 | 6.5 ± 1.2 | 7.3 ± 1.1 | 7.2 ± 0.5 | 6.5 ± 0.7 | 7.2 ± 0.8 | 6.7 ± 1.1 | 6.9 ± 0.3 |
| | 6.9 ± 0.6 | | | 6.9 ± 0.4 | | | | |
| Range | 4–10 | 3–10 | 5–11 | 6–9 | 4–9 | 4–9 | 4–11 | 3–11 |
| | 3–11 | | | 4–11 | | | | |
| **Diversity Indices** | | | | | | | | |
| Mean Shannon Diversity Index (*H’*) ± SE | 1.15 ± 0.16 | 1.12 ± 0.15 | 1.14 ± 0.18 | 1.27 ± 0.21 | 1.20 ± 0.10 | 0.74 ± 0.21 | 1.13 ± 0.12 | 1.11 ± 0.06 |
| | 1.14 ± 0.08 | | | 1.08 ± 0.09 | | | | |
| Mean Pielou’s Evenness index (*J’*) ± SE | 0.64 ± 0.12 | 0.64 ± 0.06 | 0.58 ± 0.08 | 0.64 ± 0.10 | 0.66 ± 0.07 | 0.37 ± 0.09 | 0.62 ± 0.07 | 0.59 ± 0.03 |
| | 0.62 ± 0.05 | | | 0.58 ± 0.04 | | | | |

**Table 11-10 Total numbers, densities, numbers of species and diversity of demersal fish at sites at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route and at Reference Sites that are not at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route, recorded from seine net samples collected during the February 2011 Survey**

| Site | At risk of Material or Serious Environmental Harm | | | | Reference Sites | | | | All |
|---|---|---|---|---|---|---|---|---|---|
| | N1 | N2 | N3 | N4 | NR1 | NR2 | NR3 | NR4 | |
| Number of samples (*n*) | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 48 |
| | 24 | | | | 24 | | | | |
| **Fish abundance** | | | | | | | | | |
| Total number of fish captured | 1769 | 2843 | 2389 | 3924 | 1885 | 1213 | 5091 | 4440 | 23 554 |
| | 10,925 | | | | 12,629 | | | | |
| Mean density (fish/50 $m^2$) ± SE | 294.8 ± 38.7 | 473.8 ± 150.7 | 389.2 ± 212.0 | 654.0 ± 228.5 | 314.2 ± 130.6 | 202.2 ± 42.6 | 848.5 ± 164.4 | 740.0 ± 395.4 | 490.7 ± 67.8 |
| | 455.2 ± 80.7 | | | | 551.8 ± 111.1 | | | | |
| Range of fish density (fish/50 $m^2$) | 192–430 | 81–901 | 25–1311 | 47–1,240 | 73–858 | 86–374 | 305–1256 | 45–2356 | 25–2356 |
| | 25–1311 | | | | 45–2356 | | | | |
| **Number of species** | | | | | | | | | |
| Mean ± SE | 11.2 ± 0.7 | 11.3 ± 1.8 | 10.0 ± 1.5 | 8.3 ± 1.1 | 11.2 ± 1.2 | 10.2 ± 1.2 | 12.3 ± 1.1 | 11.0 ± 1.7 | 10.7 ± 0.4 |
| | 10.2 ± 0.6 | | | | 10.6 ± 0.6 | | | | |
| Range | 9–13 | 6–16 | 6–15 | 5–12 | 7–14 | 6–14 | 9–15 | 5–16 | 5–16 |
| | 5–16 | | | | 5–16 | | | | |
| **Diversity Indices** | | | | | | | | | |
| Mean Shannon Diversity Index (*H'*) ± SE | 0.94 ± 0.12 | 1.11 ± 0.17 | 1.02 ± 0.19 | 0.70 ± 0.22 | 1.10 ± 0.23 | 1.47 ± 0.15 | 1.38 ± 0.10 | 1.13 ± 0.22 | 1.11 ± 0.06 |
| | 0.94 ± 0.08 | | | | 1.27 ± 0.09 | | | | |
| Mean Pielou's Evenness index (*J'*) ± SE | 0.39 ± 0.04 | 0.48 ± 0.10 | 0.48 ± 0.11 | 0.36 ± 0.12 | 0.47 ± 0.10 | 0.64 ± 0.05 | 0.56 ± 0.05 | 0.50 ± 0.11 | 0.49 ± 0.03 |
| | 0.43 ± 0.04 | | | | 0.54 ± 0.04 | | | | |

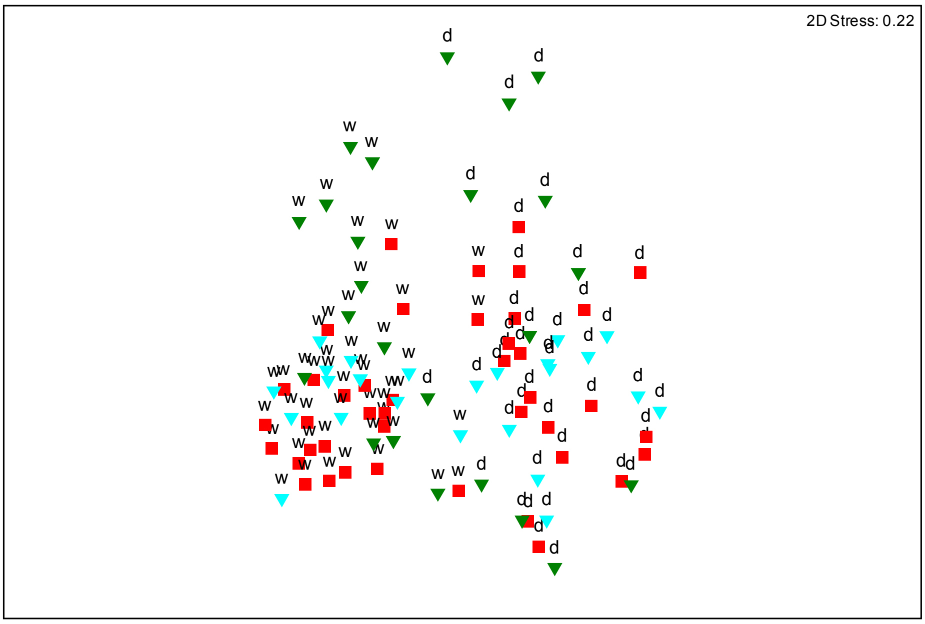



**Figure 11-8 Non-metric Multidimensional Scaling (MDS) ordination of samples from sites at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route (red squares), and northern (green triangles) and southern (turquoise triangles) Reference Sites that are not at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route, based on the composition of their fish assemblages during the wet (w) and dry (d) seasons**

#### 11.4.2.2 Cast Nets

A total of 318 fish, representing 19 species from 14 families, were recorded from the 96 cast net deployments undertaken during the wet season survey (Table 11-11). Twenty-nine of the 96 cast net deployments returned a zero catch.[22] The most diverse families (each with two species recorded) were Clupeidae, Mugilidae, Sillaginidae, Sparidae and Tetraodontidae; in general, and given their larger mesh-size, the most common fish among cast net samples belonged to larger-bodied species (e.g. Sparidae, Mugilidae, Sillaginidae) or were larger individuals of smaller species (e.g. Orangefin Ponyfish [*Leiognathus bindus*]). With the exception of a single individual of Barred Javelin (*Pomadasys kaakan*), all species caught in cast net samples were also encountered (and commonly in greater numbers) in the corresponding seine net samples. Five of the 19 species were recorded at sites at risk of Material or Serious Environmental Harm and at sites in at least one of the two Reference Areas; two species (Giant Shovelnose Ray [*Glaucostegus typus*] and White Sardine [*Escualosa thoracata*]) were recorded only from Reference Sites. Eight taxa were recorded from sites at risk of Material or Serious Environmental Harm, but not from one or more Reference Sites.

[22] The finding that around one-third of cast net deployments returned a zero catch is typical for this method when it is used to sample randomly, rather than visually targeting fish (Dr Chris Hallett, Murdoch University, pers. comm. June 2011).

**Table 11-11 Total numbers of individuals of demersal fish species at sites at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route (At risk) and at Reference Sites that are not at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland end of the DomGas Pipeline Route, recorded from cast net samples during the February 2011 Survey**

| Family | Genus species | Common name | Sites | | |
|---|---|---|---|---|---|
| | | | At risk (*n* = 48) | Northern Reference (*n* = 24) | Southern Reference (*n* = 24) |
| Rhinobatidae | *Glaucostegus typus* | Giant Shovelnose Ray | | | 1 |
| Clupeidae | *Escualosa thoracata* | White Sardine | | 7 | |
| | *Nematalosa come* | Hairback Herring | 28 | 63 | |
| Engraulidae | *Thryssa hamiltonii* | Hamilton's Thryssa | 1 | | |
| Ariidae | *Neoarius graeffei* | Blue Catfish | 2 | | |
| Mugilidae | *Liza vaigiensis* | Diamondscale Mullet | 1 | | |
| | *Valamugil buchanani* | Bluetail Mullet | 4 | 35 | 2 |
| Hemiramphidae | *Hyporhamphus neglectissimus* | Neglected Garfish | 5 | | |
| Platycephalidae | *Platycephalus indicus* | Bartail Flathead | 1 | | |
| Ambassidae | *Ambassis interruptus* | Long-spined Glass Perchlet | 4 | | |
| Sillaginidae | *Sillago analis* | Golden Line Whiting | 9 | 5 | 7 |
| | Unidentified whiting | A Whiting (juvenile) | 5 | | |
| Leiognathidae | *Leiognathus bindus* | Orangefin Ponyfish | 52 | 4 | 7 |
| Lutjanidae | *Lutjanus argentimaculatus* | Mangrove Jack | 3 | 1 | |
| Haemulidae | *Pomadasys kaakan* | Barred Javelin | 1 | | |
| Sparidae | *Acanthopagrus latus* | Western Yellowfin Bream | 17 | 1 | 2 |
| | *Acanthopagrus palmaris* | Northwest Black Bream | 17 | 9 | 17 |
| Tetraodontidae | *Chelonodon patoca* | Milkspot Toadfish | 1 | | 1 |
| | *Marilyna pleurosticta* | Banded Toadfish | 1 | | 4 |
| **TOTAL** | | | **152** | **125** | **41** |

### 11.4.3 Description of Demersal Fish Assemblages at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

#### 11.4.3.1 East Coast of Barrow Island: Soft Sediments with Sessile Benthic Macroinvertebrates and Unvegetated Sand

In October 2008 and March 2009, one unvegetated sand site was surveyed in the DomGas Pipeline Marine Disturbance Footprint (DGI2)[23] (Centre for Marine Futures, UWA 2013). In the 2008 survey, 180 individuals from 27 species and 16 families were recorded at this site. The most common species observed were Gold-spotted Trevally (*Carangoides fulvoguttatus*), Threadfin Emperor (*Lethrinus genivittatus*), Pinkbanded Grubfish (*Parapercis nebulosa*), Northwest Threadfin Bream (*Pentapodus porosus*) and Mackerel (Scombridae spp.) (Table 11-12). Northwest Threadfin Bream represented 45% of the individuals observed. In the March 2009 survey, 227 individuals from 27 species and 15 families were recorded at DGI2. The most commonly observed species were Northwest Threadfin Bream, Mackerel and Dusky Rabbitfish

[23] For the purposes of this assessment the focus was on the demersal fish assemblages characteristic of benthic habitat within the 200 m-wide Marine Disturbance Footprint (Section 2.3.2) associated with the Barrow Island end of the DomGas Pipeline.

(*Siganus fuscescens*). Northwest Threadfin Bream represented 30% of the individuals, Gulf Damsel (*Pristotis obtusirostris*) 16%, and Golden Trevally (*Gnathanodon speciosus*) 13%.

The size structure of the fish assemblages recorded at DGI2 were very similar in the October 2008 and March 2009 surveys (Centre for Marine Futures, UWA 2013). In the October 2008 survey, sizes ranged from 151.5 mm to 155.8 mm, both Western Butterfish (*Pentapodus vitta*). In the March 2009 surveys, the sizes ranged from a 67.7 mm Gulf Damsel to a >2 m Tawny Shark (*Nebrius ferrugineus*).

In October 2008 and March 2009, one soft sediments with sessile benthic macroinvertebrates site was surveyed in the DomGas Pipeline Marine Disturbance Footprint (DGI1)[24] (Centre for Marine Futures, UWA 2013). In the October 2008 survey, 212 individuals from 27 species and 16 families were recorded at this site. The most common species observed were Threadfin Bream (*Nemipterus* spp.), Pinkbanded Grubfish, Northwest Threadfin Bream and Mackerel (Table 11-12). Northwest Threadfin Bream represented 53% of the individuals observed. In the March 2009 survey, 230 individuals from 28 species and 16 families were recorded at DGI1. The most commonly observed species were Pinkbanded Grubfish, Northwest Threadfin Bream and Mackerel. Northwest Threadfin Bream represented 33% of the individuals, Threadfin Emperor 23%, and Golden Trevally 12%.

In the October 2008 survey, sizes ranged from an 164 mm Yellowstripe Scad (*Selaroides leptolepis*) to a 175.2 mm Threadfin Bream; and in the March 2009 survey, sizes ranged from a 35.5 mm juvenile Golden Trevally to a 721.9 mm Mackerel (Centre for Marine Futures, UWA 2013). In the March 2009 survey, the highest proportion of individuals were between 121 mm and 200 mm, reflecting a large number of Northwest Threadfin Bream, Threadfin Bream and Blue-lined Emperor (*Lethrinus punctulatus*). The mean length at this site was 223 mm ± 11.0 SE in the March 2009 survey.

Species richness did not differ between sites at risk of Material or Serious Environmental Harm and reference sites[25] in the October 2008 or March 2009 surveys (Centre for Marine Futures, UWA 2013). In the October 2008 survey, the relative abundance and composition of fish assemblages differed between sites at risk of Material or Serious Environmental Harm and reference sites (Table 11-5); however, this difference was not evident in the March 2009 survey. The fish assemblages at sites at risk of Material or Serious Environmental Harm were less variable than at reference sites in the October 2008 survey. SIMPER identified a number of species contributing to this difference observed in the October 2008 survey (Dissimilarity/Standard Deviation measure >1). Species that were more abundant, on average, at sites at Risk of Material or Serious Environmental Harm, included Dusky Rabbitfish, Northwest Threadfin Bream, Sliteye Shark (*Loxodon macrorhinus*), Blue Tuskfish (*Choerodon cyanodus*), Bluespotted Tuskfish (*Choerodon cauteroma*), and Purple Tuskfish (*Choerodon cephalotes*). The species that were, on average, more abundant at reference sites than at sites at risk of Material or Serious Environmental Harm, included Western Butterfish (*Pentapodus vitta*), Pigface Leatherjacket (*Paramonacanthus choirocephalus*), Threadfin Bream, and Yellowstripe Scad (*Selaroides leptolepis*).

The size structure of fish assemblages differed between reference sites and sites at risk of Material or Serious Environmental Harm in the October 2008 and March 2009 surveys (Kolmogorov-Smirnov test, $D > 0.2$, $p < 0.01$) (Centre for Marine Futures, UWA 2013). In the October 2008 survey, fish in the size categories 121–160 mm and 161–200 mm only were recorded at sites at risk of Material or Serious Environmental Harm, and the fish assemblages at these sites had a smaller mean length (164 mm ± 0.5 SE) than at reference Sites (210 mm ± 5.2 SE). The size structure of fish assemblages differed between the October 2008

[24] For the purposes of this assessment the focus was on the demersal fish assemblages characteristic of benthic assemblages within the 200 m-wide DomGas Pipeline Marine Disturbance Footprint (Section 2.3.2) associated with the Barrow Island end of the DomGas Pipeline.

[25] For the purpose of this assessment reference sites included those sites located within the indicative anchoring area.

and March 2009 surveys (Kolmogorov-Smirnov test, D = 0.26, $p$ <0.01), with the March 2009 assemblages represented by a broader range of size-classes compared to the October 2008 survey. In the March 2009 survey, sites at risk of Material or Serious Environmental Harm had a higher proportion of fish in the size range 161–240 mm (mean length: 219 mm ± 10.7 SE) than reference Sites (220 mm ± 5.6 SE), due to the large number of Northwest Threadfin Bream at these sites.

**Table 11-12 Fifteen Most Common and Abundant Fish Species Recorded at Sand and Sessile Invertebrate Sites at Risk of Material or Serious Environmental Harm in the October 2008 and March 2009 Surveys**

| October 2008 Survey | | | | March 2009 Survey | | | |
|---|---|---|---|---|---|---|---|
| **Genus species** | **Total #** | **% of drops** | **Mean MaxN** | **Genus species** | **Total #** | **% of drops** | **Mean MaxN** |
| **Sand (DGI2)** | | | | | | | |
| *Atule mate* | 4 | 20 | 0.8 ± 0.8 | *Carangoides fulvoguttatus* | 5 | 60 | 1.0 ± 0.6 |
| *Carangoides fulvoguttatus* | 8 | 100 | 1.6 ± 0.2 | *Carangoides gymnostethus* | 9 | 60 | 1.8 ± 0.8 |
| *Carangoides gymnostethus* | 3 | 40 | 0.6 ± 0.4 | *Chaetodontoplus duboulayi* | 3 | 60 | 0.6 ± 0.3 |
| *Chaetodontoplus duboulayi* | 2 | 40 | 0.4 ± 0.2 | *Choerodon cauteroma* | 4 | 40 | 0.8 ± 0.5 |
| *Choerodon cyanodus* | 3 | 40 | 0.6 ± 0.4 | *Choerodon cephalotes* | 3 | 40 | 0.6 ± 0.4 |
| *Gnathanodon speciosus* | 27 | 40 | 5.4 ± 3.5 | *Choerodon cyanodus* | 3 | 60 | 0.6 ± 0.3 |
| *Lethrinus genivittatus* | 53 | 100 | 10.6 ± 3.1 | *Lethrinus genivittatus* | 3 | 40 | 0.6 ± 0.4 |
| *Nemipterus* sp. | 3 | 40 | 0.6 ± 0.4 | *Loxodon macrorhinus* | 3 | 60 | 0.6 ± 0.3 |
| *Parapercis nebulosa* | 9 | 100 | 1.8 ± 0.4 | *Nemipterus* sp. | 3 | 20 | 0.6 ± 0.6 |
| *Pentapodus porosus* | 77 | 100 | 15.4 ± 1.6 | *Paramonacanthus choirocephalus* | 2 | 40 | 0.4 ± 0.3 |
| *Pentapodus vitta* | 2 | 40 | 0.4 ± 0.2 | *Pentapodus porosus* | 81 | 100 | 16.2 ± 0.9 |
| *Scombridae* spp. | 10 | 100 | 2.0 ± 0.0 | *Pristotis obtusirostris* | 17 | 20 | 3.4 ± 3.4 |
| *Siganus doliatus* | 4 | 20 | 0.8 ± 0.8 | *Scombridae* spp. | 5 | 80 | 1.0 ± 0.3 |
| *Siganus fuscescens* | 3 | 20 | 0.6 ± 0.6 | *Siganus fuscescens* | 21 | 80 | 4.2 ± 2.0 |
| *Torquigener pallimaculatus* | 4 | 20 | 0.8 ± 0.8 | *Sphyraena obtusata* | 3 | 20 | 0.6 ± 0.6 |
| **Sessile invertebrates (DGI1)** | | | | | | | |
| *Carangoides fulvoguttatus* | 7 | 80 | 1.4 ± 0.8 | *Abalistes stellatus* | 2 | 50 | 0.5 ± 0.3 |
| *Chaetodontoplus duboulayi* | 6 | 60 | 1.2 ± 0.5 | *Choerodon cauteroma* | 4 | 75 | 1.0 ± 0.4 |
| *Choerodon vitta* | 4 | 40 | 0.8 ± 0.6 | *Choerodon cephalotes* | 5 | 75 | 1.3 ± 0.5 |
| *Echeneis naucrates* | 3 | 20 | 0.6 ± 0.6 | *Choerodon cyanodus* | 3 | 75 | 0.8 ± 0.3 |
| *Gnathanodon speciosus* | 29 | 20 | 5.8 ± 5.8 | *Gnathanodon speciosus* | 8 | 25 | 2.0 ± 2.0 |
| *Lethrinus genivittatus* | 17 | 40 | 3.4 ± 2.1 | *Loxodon macrorhinus* | 14 | 75 | 3.5 ± 1.8 |
| *Lethrinus punctulatus* | 5 | 40 | 1.0 ± 0.8 | *Nemipterus* sp. | 15 | 25 | 3.8 ± 3.8 |
| *Nemipterus* sp. | 9 | 100 | 1.8 ± 0.4 | *Paramonacanthus choirocephalus* | 3 | 50 | 0.8 ± 0.5 |
| *Parapercis nebulosa* | 7 | 100 | 1.4 ± 0.3 | *Parapercis nebulosa* | 8 | 100 | 2.0 ± 0.4 |

| October 2008 Survey | | | | March 2009 Survey | | | |
|---|---|---|---|---|---|---|---|
| **Genus species** | **Total #** | **% of drops** | **Mean MaxN** | **Genus species** | **Total #** | **% of drops** | **Mean MaxN** |
| *Pentapodus porosus* | 69 | 100 | 13.8 ± 3.5 | *Pentapodus porosus* | 112 | 100 | 28.0 ± 4.5 |
| *Pristotis obtusirostris* | 37 | 60 | 7.4 ± 4.3 | *Pristotis obtusirostris* | 4 | 50 | 1.0 ± 0.7 |
| *Scombridae* spp. | 5 | 100 | 1.0 ± 0.0 | *Scombridae* spp. | 6 | 100 | 1.5 ± 0.5 |
| *Siganus fuscescens* | 4 | 20 | 0.8 ± 0.8 | *Siganus fuscescens* | 4 | 50 | 1.0 ± 0.6 |
| *Torquigener pallimaculatus* | 4 | 40 | 0.8 ± 0.6 | *Torquigener pallimaculatus* | 3 | 50 | 0.8 ± 0.5 |
| *Xyrichtys* sp. | 4 | 20 | 0.8 ± 0.8 | *Upeneus tragula* | 5 | 50 | 1.3 ± 0.8 |

*Note: Total # = sum of abundances for each deployment; % of drops = percent of stereo BRUV deployments observed at; Mean MaxN = average relative abundance. Note that the species are ordered alphabetically by genus.*

#### 11.4.3.2 Mainland End of the DomGas Pipeline Route

In October 2010 and April 2011, two hard and soft coral sites at risk of Material or Serious Environmental Harm were surveyed (CI1 and CI2) (UWA Oceans Institute and School of Plant Biology, UWA 2011). In the October 2010 survey, a total of 262 individuals from 44 species and 23 families were recorded. Relative abundances and numbers of species were similar in the April 2011 survey, when 218 individuals from 43 species and 26 families were recorded. Coral communities at risk of Material or Serious Environmental Harm were characterised by high abundances of Stripey Snapper (*Lutjanus carponotatus*) and frequent observations of Blue Tuskfish (*Choerodon cyanodus*), Goldspotted Rockcod (*Epinephelus coioides*), Stripey Snapper and Darktail Snapper (*Lutjanus lemniscatus*) (Table 11-13).

Two non-coral benthic macroinvertebrates sites at risk of Material or Serious Environmental Harm were surveyed (BI1 and BI2) in October 2010 and April 2011. In the October 2010 survey, a total of 713 individuals from 55 species and 23 families were recorded; and in the April 2011 survey, 557 individuals from 42 species and 21 families were recorded. Higher abundances and species richness were recorded in the October 2010 survey than in the April 2011 survey at these sites. Non-coral benthic macroinvertebrates sites at risk of Material or Serious Environmental Harm were characterised by common and abundant small-bodied carangids (Yellowstripe Scad [*Selaroides leptolepis*], Barred Yellowtail Scad [*Atule mate*]) and nemipterids (Northwest Threadfin Bream [*Pentapodus porosus*], Western Butterfish [*Pentapodus vitta*]), and by larger Mackerel (Scombridae spp.) (Table 11-13).

In the October 2010 survey, a total of 328 individuals from 47 species and 25 families were recorded at the two macroalgae sites at risk of Material or Serious Environmental Harm (MI1 and MI2). In the April 2011 survey, a total of 953 individuals from 37 species and 22 families were recorded from the same sites. The fish assemblages recorded during the October 2010 survey were more species rich, with 22% more species recorded than in the April 2011 survey; while higher abundances of individuals (66% more individuals) were recorded in the April 2011 survey. Blue Tuskfish, Stripey Snapper and Blue-lined Emperor (*Lethrinus punctulatus*) were characteristic of the macroalgae communities, and were frequently recorded during both the October 2010 and April 2011 surveys (Table 11-13). The Herring (*Herklotsichthys* spp.) was present in high relative abundance in macroalgae communities at risk of Material or Serious Environmental Harm in the April 2011 survey, but was not observed in the October 2010 survey.

A total of 99 individuals from 17 species and 14 families were recorded at the one seagrass site at risk of Material or Significant Environmental Harm (SI1) surveyed in October 2010. In the April 2011 survey, a total of 470 individuals from 40 species and 25 families were recorded at the two sites at risk of Material or Serious Environmental Harm (SI1 and SI2). Fish species characterising seagrass communities on both sampling occasions included Pigface Leatherjacket (*Paramonacanthus choirocephalus*), Western Butterfish, and Mackerel. Yellowstripe Scad were also abundant and common in the April 2011 survey, when additional sites were surveyed (Table 11-13).

**Table 11-13 Summary of Relative Abundance and Species Information for Each Community Type Surveyed at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route in the October 2010 and April 2011 Surveys**

| | Coral | Non-coral Benthic Macroinvertebrates | Macroalgae | Seagrass |
|---|---|---|---|---|
| **October 2010 at sites at risk of Material or Serious Environmental Harm** | | | | |
| Total # individuals | 262 | 713 | 328 | 99 |
| Total # species | 44 | 55 | 47 | 17 |
| Total # families | 23 | 23 | 25 | 14 |
| Mean MaxN ± SE per deployment | 26.2 ± 9.7 | 71.3 ± 10.3 | 63.1 ± 27.5 | 19.8 ± 3.7 |
| Mean species richness ± SE per deployment | 10.0 ± 2.3 | 18.0 ± 1.8 | 16.3 ± 4.7 | 6.4 ± 1.6 |
| Five most abundant species | *Abudefduf bengalensis*<br>*Lutjanus carponotatus*<br>*Selaroides leptolepis*<br>*Acanthurus grammoptilus*<br>*Lutjanus lemniscatus* | *Selaroides leptolepis*<br>*Lethrinus punctulatus*<br>*Pentapodus porosus*<br>*Siganus fuscescens*<br>*Lethrinus laticaudis* | *Pentapodus vitta*<br>*Hyporhamphus* spp.<br>*Monodactylus argenteus*<br>*Lethrinus punctulatus*<br>*Choerodon cyanodus* | *Pentapodus vitta*<br>*Paramonacanthus choirocephalus*<br>*Upeneus tragula*<br>*Sillago sihama*<br>*Scombridae* spp. |
| Five most common species | *Lutjanus carponotatus*<br>*Lutjanus lemniscatus*<br>*Choerodon cyanodus*<br>*Epinephelus coioides*<br>*Abudefduf bengalensis** | *Pentapodus porosus*<br>*Scombridae* spp.<br>*Lethrinus laticaudis*<br>*Choerodon cyanodus*<br>*Lethrinus punctulatus** | *Choerodon cyanodus*<br>*Parupeneus indicus*<br>*Lutjanus carponotatus*<br>*Scombridae* spp.<br>*Lethrinus punctulatus** | *Upeneus tragula*<br>*Scombridae* spp.<br>*Pentapodus vitta*<br>*Paramonacanthus choirocephalus*<br>*Parapercis nebulosa** |
| **April 2011 at sites at risk of Material or Serious Environmental Harm** | | | | |
| Total # individuals | 218 | 557 | 953 | 470 |
| Total # species | 43 | 42 | 37 | 40 |
| Total # families | 26 | 21 | 22 | 25 |
| Mean MaxN ± SE per deployment | 21.8 ± 5.4 | 55.7 ± 12.4 | 95.3 ± 21.7 | 47.0 ± 12.4 |
| Mean species richness ± SE per deployment | 8.9 ± 1.6 | 11.4 ± 1.5 | 9.9 ± 1.3 | 8.0 ± 1.5 |
| Five most abundant species | *Siganus fuscescens*<br>*Herklotsichthys* spp.<br>*Lutjanus russellii* | *Selaroides leptolepis*<br>*Atule mate*<br>*Pentapodus vitta* | *Herklotsichthys* spp.<br>*Amniataba caudavittata*<br>*Siganus fuscescens* | *Selaroides leptolepis*<br>*Rastrelliger kanagurta*<br>*Pentapodus vitta* |

| | Coral | Non-coral Benthic Macroinvertebrates | Macroalgae | Seagrass |
|---|---|---|---|---|
| | *Lutjanus carponotatus*<br>*Pentapodus vitta* | *Pelates quadrilineatus*<br>*Carangoides hedlandensis* | *Pentapodus vitta*<br>*Caesio teres* | *Paramonacanthus choirocephalus*<br>*Atule mate** |
| Five most common species | *Choerodon cyanodus*<br>*Lutjanus carponotatus*<br>*Epinephelus coioides*<br>*Lutjanus lemniscatus*<br>*Pentapodus vitta** | *Scombridae* spp.<br>*Selaroides leptolepis*<br>*Carangoides hedlandensis*<br>*Pentapodus vitta*<br>*Atule mate** | *Choerodon cyanodus*<br>*Lutjanus carponotatus*<br>*Pentapodus vitta*<br>*Abudefduf bengalensis*<br>*Scombridae* spp. | *Scombridae* spp.<br>*Paramonacanthus choirocephalus*<br>*Selaroides leptolepis*<br>*Pentapodus vitta*<br>*Trachinocephalus myops* |

*Note: The five most abundant and common fish species are presented, ordered by most abundant/common to least. An '*' indicates there were additional species present with the same relative abundance, or at the same number of sites that are not presented in the top five listed here.*

In the October 2010 survey, mean species richness at sites at risk of Material or Serious Environmental Harm (11.8 species ± 1.2 SE) was higher than in April 2011 (9.6 species ± 0.7 SE), but was similar at Reference Sites not at risk of Material or Serious Environmental Harm on both sampling occasions (2010: 13.7 species ± 1.3 SE; 2011: 14.1 species ± 1.1 SE). There was no significant difference in the species richness of the demersal fish assemblages at sites at risk of Material or Serious Environmental Harm and at References Sites in the October 2010 survey (Table 11-6). In the April 2011 survey, species richness was significantly different between sites at risk of Material or Serious Environmental Harm and Reference Sites and there was a significant interaction between 'Area' and 'Community Type' (Table 11-6). No significant differences were found between sites at risk of Material or Serious Environmental Harm and Reference Sites for all levels of the factor 'Community Type' or between the community types within both levels of the factor 'Area'. While the differences were not significant, there was a trend for species richness of the demersal fish assemblages at coral sites at risk of Material or Serious Environmental Harm to be lower than at Reference Sites. Mean species richness was higher at Reference Sites (14.1 species ± 0.7 SE) than at sites at risk of Material or Serious Environmental Harm (9.6 species ± 1.1 SE) (Figure 11-7).

There was a significant difference in relative abundance at sites at risk of Material or Serious Environmental Harm and Reference Sites not at risk of Material or Serious Environmental Harm in the October 2010 survey; as well as a significant interaction effect between 'Area' and 'Community Type' (Table 11-7). There were no significant differences in the relative abundance of demersal fish between sites at risk of Material or Serious Environmental Harm and Reference Sites in any of the four community types. Furthermore, there were no differences in the relative abundance of fish between each of the community types when each level of 'Area' was examined separately. SIMPER was used to examine which fish species were driving the observed differences observed between the sites at risk of Material or Serious Environmental Harm and Reference Sites; however, no fish species scored a Dissimilarity/Standard Deviation measure >1. There were a number of species with higher relative abundances at Reference Sites during the October 2010 survey, including Inshore Surgeonfish (*Acanthurus grammoptilus*), Blue Tuskfish, Blackspot Tuskfish (*Choerodon schoenleinii*) and Grass Emperor (*Lethrinus laticaudis).* Conversely, species with higher relative abundances at sites at risk of Material or Serious Environmental Harm were Goldspotted Rockcod, Blue-lined Emperor, Western Butterfish, Yellowstripe Scad, Mackerel and Bartail Goatfish (*Upeneus tragula*).

There was also a significant difference in relative abundance at sites at risk of Material or Serious Environmental Harm and Reference Sites not at risk of Material or Serious Environmental Harm in April 2011; as well as a significant interaction effect between 'Area' and 'Community Type' (Table 11-7). There were no significant differences in the relative abundance of demersal fish between sites at risk of Material or Serious Environmental Harm and Reference Sites in any of the four community types. There were also no differences in the relative abundance of fish between each of the community types when each level of 'Area' was examined separately. Therefore, like the October 2010 data, SIMPER was used to examine which fish species were driving the observed differences; however, only a single species scored a Dissimilarity/Standard Deviation measure >1. Stripey Snapper was three times more abundant, on average, at Reference Sites than at sites at risk of Material or Serious Environmental Harm. SIMPER identified a number of species with higher abundances at Reference Sites during the April 2011 survey, including Bengal Sergeant (*Abudefduf bengalensis*), Inshore Surgeonfish, Blue Tuskfish, Grass Emperor, Darktail Snapper and Miller's Damsel (*Pomacentrus milleri*). Species with higher relative abundances, on average, at sites at risk of Material or Serious Environmental Harm were Bumpnose Trevally (*Carangoides hedlandensis*), Herring, Western Butterfish, Yellowstripe Scad and Mackerel.

Sites at risk of Material or Serious Environmental Harm surveyed in October 2010 had higher relative abundances of Bluespotted Tuskfish (*Choerodon cauteroma*), Blue Tuskfish, Grass Emperor, Blue-lined Emperor, Yellowspot Goatfish (*Parupeneus indicus*) and Bartail Goatfish, than the same sites surveyed in April 2011. Conversely, Barred Yellowtail Scad, Bumpnose Trevally, Herring, Pigface Leatherjacket and Western Butterfish were more abundant at sites at risk of Material or Serious Environmental Harm in the April 2011 survey. Some of the most common and abundant species were recorded in similar relative abundances at sites at risk of Material or Serious Environmental Harm on both sampling occasions, e.g. Goldspotted Rockcod, Stripey Snapper, Mackerel and Yellowstripe Scad. Reference Sites surveyed in October 2010 had higher relative abundances of Blue Tuskfish, Bluespotted Tuskfish, Brown Demoiselle (*Neopomacentrus filamentosus*) and Bluelined Rabbitfish (*Siganus doliatus*) than those surveyed in April 2011. Conversely, Inshore Surgeonfish, Blacktip Reef Shark (*Carcharhinus melanopterus*), Stripey Snapper, Western Butterfish, Miller's Damsel and Mackerel were more abundant at Reference Sites surveyed in April 2011. Species with similar relative abundances at Reference Sites on both sampling occasions included Bengal Sergeant, Blue Tuskfish, Blackspot Tuskfish and Yellowspot Goatfish.

In the October 2010 survey, the smallest individual measured at sites at risk of Material or Serious Environmental Harm, was a 38.6 mm Brown Demoiselle and the largest a 2.0 m Tiger Shark (*Galeocerdo cuvier*). The median fish length was 169.1 mm. The mean length of fish measured per deployment was 225.4 mm ± 9.4 SE. The median and mean lengths of demersal fish assemblages associated with coral (median: 176.0 mm; mean: 241.3 mm ± 24.6 SE), non-coral benthic macroinvertebrates (median: 176.4 mm; mean: 233.8 mm ± 10.7 SE) and macroalgae (median: 167.5 mm; mean: 223.0 mm ± 17.5 SE) communities at risk of Material or Serious Environmental Harm were broadly similar. However, the fish assemblage associated with the seagrass communities was smaller, with lower mean and median lengths (median: 113.2 mm; mean: 190.8 mm ± 27.3 SE). In the April 2011 survey, the smallest individual measured at sites at risk of Material or Serious Environmental Harm, was a 27.5 mm Brown Demoiselle, and the largest a 2.5 m Tiger Shark. The median fish length was 133.6 mm. The mean length of fish measured per deployment was 203.2 mm ± 15.7 SE. The demersal fish assemblages associated with coral communities were larger with higher mean and median lengths (median: 156.6 mm; mean: 277.0 mm ± 46.0 SE) than in the other community types at risk of Material or Serious Environmental Harm. In contrast to the October 2010 survey, the fish assemblages associated with seagrass communities in the April 2011 survey, were larger on average (median: 120.5 mm; mean: 197.4 mm ± 26.8 SE), while the fish assemblages associated with both non-coral benthic macroinvertebrates (median: 144.1 mm; mean: 171.9 mm ± 13.0 SE) and macroalgae (median: 118.7 mm; mean: 166.6 mm ± 20.5 SE) communities were smaller on average than in the October 2010 survey. Note that an additional seagrass site was surveyed in April 2011, thus the number of fish measured increased, and the data for April 2011 might better represent the length structure of fish assemblages associated with seagrass sites.

A comparison of the length frequency distributions for the demersal fish assemblages at sites at risk of Material of Serious Environmental Harm and Reference Sites highlighted some differences in both the October 2010 and April 2011 surveys. In the October 2010 survey, both length distributions covered broadly the same range, with most fish between 50 mm and 599 mm. However, the length distribution of fish at sites at risk of Material of Serious Environmental Harm was more heavily skewed toward the smaller size classes. Within sites at risk of Material or Serious Environmental Harm, the modal length classes were between 100 mm and 199 mm, attributable to the higher abundances of the small-bodied species Yellowstripe Scad and Western Butterfish, both of which were observed at higher relative abundances at sites at risk of Material or Serious Environmental Harm in the October 2010 survey. Within the Reference Sites, however, a wider modal length range was observed, ranging between 100 mm and 249 mm, and the percentage composition of each length class decreased more slowly away from the modal length class. The wider modal range at larger length classes was possibly a consequence of the greater numbers of the larger-bodied schooling species Inshore Surgeonfish and Bluelined Rabbitfish. The demersal fish assemblage length frequency distributions were significantly different between sites at risk of Material or Serious Environmental Harm when compared to Reference Sites (Kolmogorov-Smirnov test, $D = 0.130$, $p < 0.001$). In the October 2010 survey, the length frequency distributions of the fish assemblages at sites at risk of Material or Serious Environmental Harm and Reference Sites were similar for each of the four community types surveyed.

In the April 2011 survey, the length distribution of fish within sites at risk of Material or Serious Environmental Harm was also skewed towards the smaller length classes. Within sites at risk of Material or Serious Environmental Harm, the modal length classes were between 50 mm and 199 mm, with 37% of the lengths between 100 mm and 149 mm. Similar to the October 2010 survey, this peak is interpreted as being due to higher numbers of Western Butterfish and Yellowstripe Scad. However, in the April 2011 survey, Barred Yellowtail Scad were also abundant at sites at risk of Material or Serious Environmental Harm, as was the Herring, which was only recorded during this survey. These species also contributed to the modal peak in the length frequency distribution. Within the Reference Sites, a broader modal range was again observed in April 2011. Most fish were between 50 mm and 249 mm in length, with no obvious peak in length frequency class. This wider peak is likely due to higher abundances of larger-bodied species such as Inshore Surgeonfish and Stripey Snapper at the Reference Sites. The demersal fish assemblage length frequency distributions were significantly different between sites at risk of Material or Serious Environmental Harm and Reference Sites (Kolmogorov-Smirnov test, D = 0.254, $p$ <0.001).

The length distributions of the demersal fish assemblages characteristic of non-coral benthic macroinvertebrates communities at risk of Material or Serious Environmental Harm were different to those at non-coral benthic macroinvertebrates communities at Reference Sites in the April 2011 survey. The length distribution at sites at risk of Material or Serious Environmental Harm showed a narrower modal range, with 79% of recorded lengths occurring in a peak between 100 mm and 199 mm, when compared with the flatter modal range, with 77% of lengths between 50 mm and 249 mm at the Reference Sites. There was a significant difference in the length frequency distributions between sites at risk of Material or Serious Environmental Harm and Reference Sites for non-coral benthic macroinvertebrates communities (Kolmogorov-Smirnov test, D = 0.300, $p$ <0.001). This difference is likely to be attributable to the high abundances of the schooling scad species Yellowstripe Scad, which was most abundant in non-coral benthic macroinvertebrates communities at risk of Material or Serious Environmental Harm in the April 2011 survey. The length distributions of the demersal fish assemblages characteristic of the macroalgae communities at risk of Material or Serious Environmental Harm were significantly different to those at the macroalgae communities at Reference Sites in the April 2011 survey (Kolmogorov-Smirnov test, D = 0.348, $p$ <0.001). The length distributions of fish assemblages within sites at risk of Material or Serious Environmental Harm showed a modal range between 50 mm and 149 mm, while the Reference Sites distributions showed a modal range between 150 mm and 249 mm. The peak at smaller length classes at sites at risk of Material or Serious Environmental Harm is likely to be attributable to higher abundances of Western Butterfish, while the peak at the longer length classes at Reference Sites is possibly due to higher numbers of Stripey Snapper in the macroalgae communities in the April 2011 survey. The length frequency distributions of fish assemblages in coral, non-coral benthic macroinvertebrates, macroalgae and seagrass communities at risk of Material or Serious Environmental Harm were not significantly different to those at Reference Sites in October 2010. Similarly, there were no significant differences between the length frequency distributions of fish assemblages in coral and seagrass communities at risk of Material or Serious Environmental Harm and Reference Sites in April 2011.

#### 11.4.3.3 Mangrove Communities at the Mainland End of the DomGas Pipeline Route

Twenty-seven of the 36 species recorded in the October 2010 survey were sampled at sites at risk of Material or Serious Environmental Harm, of which three species (Short Silverbiddy [*Gerres erythrourus*], Yellow-spotted Tongue Sole [*Paraplagusia guttata*] and an unidentified Stinkfish) were not recorded at any of the Reference Sites (Table 11-8). Forty-one of the 49 species recorded in the February 2011 survey were sampled at sites at risk of Material or Serious Environmental Harm. Seven of these species (Diamondscale Mullet [*Liza vaigiensis*], Largetooth Flounder [*Pseudorhombus arsius*], Coloured Righteye Flounder [*Poecilopsetta colorata*], Blacktip Silverbiddy [*Gerres oyena*], Shortfin Batfish [*Zabidius novemaculeatus*], an unidentified Rockcod [*Epinephelus* sp.] and an unidentified species of Grubfish) were not recorded at any of the Reference Sites.

In the October 2010 survey, similar mean total fish densities of between 122 and 137 fish/50 $m^2$ were recorded at the sites at risk of Material or Serious Environmental Harm, although the total density of fish in any single replicate sample varied from 12 to 603 fish/50 $m^2$ (Table 11-9). The mean number of species was lowest at N3 (6.5 species ± 1.2 SE) and highest at N4 (7.3 species ± 1.1 SE), varying between three and 11 species in any single replicate sample. Mean diversity and evenness were similar across the three sites sampled. In the February 2011 survey, the total density of fish in any single replicate seine sample from sites at risk of Material or Serious Environmental Harm was highly variable, ranging from 25 to 1311 fish/50 $m^2$ (Table 11-10). Mean total fish densities per site ranged from 294.8 fish/50 $m^2$ ± 38.7 SE at N1 to 654.0 fish/50 $m^2$ ± 228.4 SE at N4. The mean number of species was lowest at N4 (8.3 species ± 1.1 SE) and highest at N2 (11.3 species ± 1.8 SE), varying between five species and 16 species in any single replicate sample. Thus, in general, sites at risk of Material or Serious Environmental Harm exhibited greater total abundance of fish and higher species richness in the February 2011 survey than the October 2010 survey. Mean diversity was, on average, lower and exhibited greater variation between sites in the February 2011 survey. The observed increase in total number of species from dry to wet season indicates that the decrease in diversity was driven by a decrease in evenness (i.e. a greater numerical dominance of the demersal fish community by a small number of taxa).

The demersal fish assemblages at sites at risk of Material or Serious Environmental Harm recorded during October 2010 were dominated by a combination of small-bodied species (including Indian Anchovy [*Stolephorus indicus*], Long-spined Glass Perchlet [*Ambassis interruptus*], White Sardine [*Escualosa thoracata*] and Blackthroat Goby [*Favonigobius melanobranchus*]) and the juveniles of larger species (e.g. mugilids and sillaginids; Table 11-14). None of the individuals of the species that dominated the seine net catches were >80 mm in length. Individuals of the larger species (e.g. Whiting and Bluetail Mullet [*Valamugil buchanani*]) were also abundant, but largely restricted to individuals <150 mm in length. Similarly, during the February 2011 survey, the demersal fish assemblages at sites at risk of Material or Serious Environmental Harm were dominated by small-bodied species (including Orangefin Ponyfish [*Leiognathus bindus*] and Long-spined Glass Perchlet) and the juveniles of larger species (e.g. sillaginids; Table 11-15). None of the eight taxa that dominated the catches from these sites were >100 mm in length. The Golden Line Whiting (*Sillago analis*) was also abundant at these sites; however, individuals of this larger species were generally <100 mm in length (mean fork length 36.53 mm ± 1.50 SE).

In the October 2010 survey, the demersal fish assemblages at sites at risk of Material or Serious Environmental Harm were dominated by a similar suite of species to that observed during the February 2011 survey. Five taxa (long-spined Glass Perchlet, Golden Line Whiting, Indian Anchovy, White Sardine and unidentified juvenile Whiting) were among the eight dominant taxa in both surveys. However, there was a notable increase in the abundance of Orangefin Ponyfish at sites at risk of Material or Serious Environmental Harm, from only 13 individuals (at three sites) in the October 2010 survey, to 8461 individuals (at four sites) in the February 2011 survey.

**Table 11-14 Numbers (N) and Mean (± SE) densities (fish/50 m$^2$), with Mean (± SE) and Range of Fork Lengths (mm) for the eight most abundant species at sites at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route and at Reference Sites that are not at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route, recorded from seine net samples during the October 2010 Survey**

| Species | At risk of Material or Serious Environmental Harm (*n* = 18) | | | | Reference Sites (*n* = 24) | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean density ± SE | Mean fork length ± SE | Range of fork length | N | Mean density ± SE | Mean fork length ± SE | Range of fork length | N |
| *Stolephorus indicus* | 82.4 ± 38.2 | 36.2 ± 0.6 | 13–55 (285) | 1,484 | 62.8 ± 21.3 | 40.8 ± 0.5 | 15–60 (486) | 1,508 |
| *Ambassis interruptus* | 20.6 ± 6.7 | 45.5 ± 0.3 | 19–60 (309) | 371 | 12.3 ± 3.5 | 44.2 ± 0.3 | 32–64 (267) | 296 |
| Unidentified whiting | 10.7 ± 3.3 | 21.6 ± 0.3 | 15–41 (186) | 193 | 13.3 ± 3.7 | 23.2 ± 0.2 | 15–38 (301) | 320 |
| *Favonigobius melanobranchus* | 3.4 ± 1.9 | 22.2 ± 0.4 | 15–33 (61) | 61 | 0.9 ± 0.3 | - | - | 21 |
| *Ilisha* sp. | 2. 7 ± 2.7 | 70.0 ± 0.6 | 62–79 (48) | 48 | 0.1 ± 0.1 | - | - | 2 |
| *Escualosa thoracata* | 1. 9 ± 1.2 | 52.5 ± 0.7 | 45–59 (34) | 34 | 2. 7 ± 1.3 | 58.8 ± 0.5 | 48–65 (64) | 64 |
| *Valamugil buchanani* | 1.5 ± 1.1 | 107.7 ± 2.8 | 76–145 (27) | 27 | 2.3 ± 1.3 | 114.6 ± 3.7 | 87–280 (56) | 56 |
| *Sillago analis* | 1.4 ± 0.8 | 103.0 ± 8.0 | 44–196 (25) | 25 | 1. 7 ± 0.5 | 92.2 ± 5.3 | 25–185 (40) | 40 |
| *Hyporhamphus neglectissimus* | 1.3 ± 0.7 | - | - | 24 | 0.04 ± 0.04 | - | - | 1 |
| *Acanthopagrus latus* | 0.9 ± 0.3 | - | - | 17 | 0.8 ± 0.2 | - | - | 20 |
| *Leiognathus bindus* | 0.7 ± 0.5 | - | - | 13 | 1.6 ± 1.5 | 45.0 ± 1.0 | 20–53 (39) | 39 |
| *Sillago burrus* | 0.7 ± 0.4 | - | - | 13 | 0.1 ± 0.1 | - | - | 2 |
| *Gerres oyena* | 0. 6 ± 0.3 | - | - | 10 | 0.5 ± 0.3 | - | - | 12 |
| *Acanthopagrus palmaris* | 0.3 ± 0.2 | - | - | 6 | 0.4 ± 0.2 | - | - | 10 |
| *Platycephalus westraliae* | 0.3 ± 0.1 | - | - | 6 | 0.1 ± 0.1 | - | - | 3 |
| *Platycephalus arenarius* | 0.2 ± 0.1 | - | - | 3 | 0.2 ± 0.1 | - | - | 4 |
| *Nematalosa come* | 0.1 ± 0.1 | - | - | 2 | 7.1 ± 5.2 | 86.6 ± 0.5 | 72–101 (100) | 171 |
| *Arrhamphus sclerolepis* | 0.1 ± 0.1 | - | - | 2 | 0.7 ± 0.4 | - | - | 17 |
| *Craterocephalus mugiloides* | 0.1 ± 0.1 | - | - | 2 | 0.1 ± 0.1 | - | - | 2 |
| *Glossogobius circumspectus* | 0.1 ± 0.1 | - | - | 2 | 0.1 ± 0.1 | - | - | 2 |
| *Chelonodon patoca* | 0.1 ± 0.1 | - | - | 1 | 0.3 ± 0.1 | - | - | 7 |

| **Species** | **At risk of Material or Serious Environmental Harm (*n* = 18)** | | | | **Reference Sites (*n* = 24)** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Mean density ± SE** | **Mean fork length ± SE** | **Range of fork length** | **N** | **Mean density ± SE** | **Mean fork length ± SE** | **Range of fork length** | **N** |
| *Pseudogobius* sp. 3 | 0.1 ± 0.1 | - | - | 1 | 0.1 ± 0.1 | - | - | 2 |
| *Poecilopsetta colorata* | 0.1 ± 0.1 | - | - | 1 | 0.04 ± 0.04 | - | - | 1 |
| *Strongylura strongylura* | 0.1 ± 0.1 | - | - | 1 | 0.04 ± 0.04 | - | - | 1 |
| Unidentified Stinkfish | 0.1 ± 0.1 | - | - | 1 | - | - | - | - |
| *Gerres erythrourus* | 0.1 ± 0.1 | - | - | 1 | - | - | - | - |
| *Paraplagusia guttata* | 0.1 ± 0.1 | - | - | 1 | - | - | - | - |
| *Amoya gracilis* | - | - | - | - | 0.5 ± 0.5 | - | - | 12 |
| *Glaucostegus typus* | - | - | - | - | 0.4 ± 0.2 | - | - | 9 |
| *Pseudorhombus arsius* | - | - | - | - | 0.2 ± 0.1 | - | - | 5 |
| *Himantura leoparda* | - | - | - | - | 0.1 ± 0.1 | - | - | 2 |
| *Acentrogobius caninus* | - | - | - | - | 0.1 ±0.1 | - | - | 2 |
| *Arius* sp. | - | - | - | - | 0.04 ± 0.04 | - | - | 1 |
| *Lutjanus argentimaculatus* | - | - | - | - | 0.04 ± 0.04 | - | - | 1 |
| *Sardinella* sp. | - | - | - | - | 0.04 ± 0.04 | - | - | 1 |
| *Synanceia horrida* | - | - | - | - | 0.04 ± 0.04 | - | - | 1 |

*Note: The number in () after fork-length is the number of fish measured.*

**Table 11-15 Numbers (N) and Mean (± SE) densities (fish/50 m$^2$), with Mean (± SE) and Range of Fork Lengths (mm) for the eight most abundant species at sites at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route and at Reference Sites that are not at risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route, recorded from seine net samples during the February 2011 Survey**

| Species | At risk of Material or Serious Environmental Harm (*n* = 24) | | | | Reference Sites (*n* = 24) | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean density ± SE | Mean fork length ± SE | Range of fork length | N | Mean density ± SE | Mean fork length ± SE | Range of fork length | N |
| *Leiognathus bindus* | 352.5 ± 80.7 | 18.9 ± 0.2 | 11–62 (965) | 8,461 | 198.8 ± 86.9 | 19.1 ± 0.3 | 12–50 (692) | 4,772 |
| *Ambassis interruptus* | 31. 7 ± 7. 7 | 33.1 ± 0.4 | 10–63 (574) | 760 | 77.3 ± 34.8 | 36.9 ± 0.2 | 21–65 (640) | 1,854 |
| Unidentified whiting | 25.9 ± 10.0 | 23.1 ± 0.2 | 13–39 (382) | 622 | 21.9 ± 6.1 | 23.7 ± 0.2 | 14–40 (396) | 526 |
| *Sillago analis* | 19.4 ± 5.8 | 36.5 ± 1.5 | 18–215 (335) | 466 | 121.7 ± 50.6 | 34.0 ± 1.3 | 16–248 (584) | 2,920 |
| *Stolephorus indicus* | 4.9 ± 2.3 | 36.4 ± 0.9 | 12–66 (118) | 118 | 7.7 ± 2.6 | - | - | 184 |
| *Escualosa thoracata* | 4.1 ± 2.1 | 32.3 ± 0. 5 | 25–41 (98) | 98 | 43.5 ± 12.8 | 34.9 ± 0.3 | 21–65 (501) | 1,044 |
| *Atherinomorus lacunosus* | 3.1 ± 1.9 | 64.2 ± 0.6 | 40–75 (75) | 75 | 0.04 ± 0.04 | - | - | 1 |
| *Thryssa hamiltonii* | 3.1 ± 1.5 | 42.2 ± 1.8 | 23–96 (75) | 75 | 10.1 ± 4.4 | 29.5 ± 0.5 | 20–68 (177) | 243 |
| *Arrhamphus sclerolepis* | 1.7 ± 0.7 | - | - | 28 | 8.3 ± 5.0 | 88.6 ± 1.9 | 49–210 (137) | 198 |
| *Lutjanus russellii* | 1.0 ± 0.2 | - | - | 23 | 0.04 ± 0.04 | - | - | 1 |
| *Favonigobius melanobranchus* | 0.9 ± 0.3 | - | - | 22 | 0.5 ± 0.3 | - | - | 13 |
| *Chelonodon patoca* | 0.9 ± 0.3 | - | - | 21 | 1.2 ± 0.4 | - | - | 29 |
| *Sillago burrus* | 0.8 ± 0.4 | - | - | 19 | 1.8 ± 0.6 | - | - | 44 |
| *Valamugil buchanani* | 0.8 ± 0.3 | - | - | 18 | 4.0 ± 1.2 | - | - | 95 |
| *Acanthopagrus latus* | 0.6 ± 0.3 | - | - | 14 | 1.0 ± 0.5 | - | - | 25 |
| *Acanthopagrus palmaris* | 0.5 ± 0.2 | - | - | 13 | 0.7 ± 0.4 | - | - | 16 |
| *Craterocephalus mugiloides* | 0.5 ± 0.4 | - | - | 12 | 3.0 ± 2.1 | - | - | 73 |
| *Scomberoides tol* | 0.5 ± 0.2 | - | - | 12 | 0.7 ± 0.3 | - | - | 16 |
| *Platycephalus indicus* | 0.3 ± 0.1 | - | - | 7 | 0.04 ± 0.04 | - | - | 1 |
| *Caranx ignobilis* | 0.3 ± 0.1 | - | - | 6 | 0.1 ± 0.1 | - | - | 3 |
| *Craterocephalus pauciradiatus* | 0.2 ± 0.2 | - | - | 5 | 4.8 ± 4.5 | - | - | 116 |
| *Gerres erythrourus* | 0.2 ± 0.1 | - | - | 5 | 0.3 ± 0.1 | - | - | 8 |
| *Hyporhamphus neglectissimus* | 0.2 ± 0.2 | - | - | 5 | 0.1 ± 0.1 | - | - | 2 |

| Species | At risk of Material or Serious Environmental Harm (*n* = 24) | | | | Reference Sites (*n* = 24) | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean density ± SE | Mean fork length ± SE | Range of fork length | N | Mean density ± SE | Mean fork length ± SE | Range of fork length | N |
| *Hyporhamphus quoyi* | 0.2 ± 0.1 | - | - | 5 | 0.1 ± 0.1 | - | - | 2 |
| *Neoarius graeffei* | 0.2 ± 0.1 | - | - | 5 | 0.21 ± 0.11 | - | - | 5 |
| *Nematalosa come* | 0.2 ± 0.1 | - | - | 4 | 15.8 ± 8.1 | 59.1 ± 0.3 | 48−75 (241) | 379 |
| *Sphyraena forsteri* | 0.2 ± 0.1 | - | - | 4 | 0.6 ± 0.4 | - | - | 14 |
| *Strongylura strongylura* | 0.1 ± 0.1 | - | - | 3 | 0.3 ± 0.1 | - | - | 7 |
| *Gerres oyena* | 0.1 ± 0.1 | - | - | 2 | - | - | - | - |
| *Glossogobius circumspectus* | 0.1 ± 0.1 | - | - | 2 | 0.04 ± 0.04 | - | - | 1 |
| *Ilisha* sp. | 0.1 ± 0.1 | - | - | 2 | 0.2 ± 0.1 | - | - | 4 |
| *Paraplagusia guttata* | 0.1 ± 0.1 | - | - | 2 | 0.3 ± 0.1 | - | - | 7 |
| *Poecilopsetta colorata* | 0.1 ± 0.1 | - | - | 2 | - | - | - | - |
| *Pseudorhombus arsius* | 0.1 ± 0.1 | - | - | 2 | - | - | - | - |
| *Epinephelus* sp. | 0.04 ± 0.04 | - | - | 1 | - | - | - | - |
| *Liza vaigiensis* | 0.04 ± 0.04 | - | - | 1 | - | - | - | - |
| *Lutjanus argentimaculatus* | 0.04 ± 0.04 | - | - | 1 | 0.04 ± 0.04 | - | - | 1 |
| *Marilyna pleurosticta* | 0.04 ± 0.04 | - | - | 1 | 0.2 ± 0.1 | - | - | 4 |
| *Platycephalus westraliae* | 0.04 ± 0.04 | - | - | 1 | 0.04 ± 0.04 | - | - | 1 |
| Pinguipedidae | 0.04 ± 0.04 | - | - | 1 | - | - | - | - |
| *Zabidius novemaculeatus* | 0.04 ± 0.04 | - | - | 1 | - | - | - | - |
| *Amoya gracilis* | - | - | - | - | 0.04 ± 0.04 | - | - | 1 |
| *Carcharhinus cautus* | - | - | - | - | 0.04 ± 0.04 | - | - | 1 |
| *Glaucostegus typus* | - | - | - | - | 0.2 ± 0.1 | - | - | 4 |
| *Gnathanodon speciosus* | - | - | - | - | 0.04 ± 0.04 | - | - | 1 |
| *Herklotsichthys koningsbergeri* | - | - | - | - | 0.1 ± 0.1 | - | - | 3 |
| *Himantura leoparda* | - | - | - | - | 0.1 ± 0.1 | - | - | 3 |
| *Johnius* sp. | - | - | - | - | 0.3 ± 0.1 | - | - | 6 |
| *Scomberomorus commerson* | - | - | - | - | 0.04 ± 0.04 | - | - | 1 |

*Note: The number in () after fork-length is the number of fish measured.*

### 11.4.4 Description of Demersal Fish Assemblages at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

#### 11.4.4.1 East Coast of Barrow Island: Soft Sediments with Sessile Benthic Macroinvertebrates and Unvegetated Sand

In the October 2008 survey, 2206 individuals from 32 species and 21 families were recorded from 18 stereo BRUV deployments at five unvegetated sand reference sites[26] (Centre for Marine Futures, UWA 2013). In the March 2009 survey, 2058 individuals from 65 species and 31 families were recorded from 49 deployments at 10 unvegetated sand reference sites.[27] Of the 32 species observed in the October 2008 survey, 20 (62%) were also observed in the March 2009 survey; of the 65 species observed in the March 2009 survey, only 20 (31%) were also observed in the October 2008 survey. The majority of the species unique to each survey were only observed on a single deployment. A few species were commonly observed (>20% deployments), including Herring (*Herklotsichthys* sp.), Goldband Goatfish (*Upeneus moluccensis*), Whiting (*Sillago* spp.), and Sliteye Shark (*Loxodon macrorhinus*) in the October 2008 survey; Gold-spotted Trevally (*Carangoides fulvoguttatus*), Blackbanded Amberjack, (*Seriolina nigrofasciata*) and Barred Yellowtail Scad (*Atule mate*) in the March 2009 survey.

Size frequency distributions were significantly different between the October 2008 and March 2009 surveys (Kolmogorov-Smirnov test, D = 0.2, $p$ <0.01) (Centre for Marine Futures, UWA 2013). The mean length was 179 mm ± 6.2 SE in the October 2008 survey and 224 mm ± 6.3 SE in the March 2009 survey. In the October 2008 survey, the fish assemblages included a higher proportion of individuals in the size range 121–160 mm than in the March 2009 survey, due to the presence and high abundance of Herring. The fish assemblages characteristic of unvegetated sand sites were characterised by a high abundance of small-bodied individuals, 81–200 mm in length. In the October 2008 survey, sizes ranged from a 59.6 mm Pigface Leatherjacket (*Paramonacanthus choirocephalus*) to a 2.6 m Guitarfish (*Rhynchobatus* spp.). In the March 2009 survey, the sizes ranged from a 31.8 mm juvenile Golden Trevally (*Gnathanodon speciosus*) to a 2.2 m Guitarfish.

In the October 2008 survey, 1226 individuals from 75 species and 32 families were recorded from 23 stereo BRUV deployments at six soft sediments with sessile benthic macroinvertebrates sites (Centre for Marine Futures, UWA 2013). In the March 2009 survey, 563 individuals from 45 species and 22 families were recorded from 13 deployments at three soft sediments with sessile benthic macroinvertebrates sites. Of the 75 species observed in the October 2008 survey, 34 (45%) were also observed in the March 2009 survey; of the 45 species observed in the March 2009 survey, 34 (76%) were also observed in the October 2008 survey. The majority of the species unique to each survey were only observed on a single deployment. The most common and abundant species observed soft sediments with sessile benthic macroinvertebrates and unvegetated sand sites are presented in Table 11-16). The majority of the most common and abundant species observed at these reference sites (11 of 15) were common and abundant in both the October 2008 and March 2009 surveys. The species present in highest abundances included Northwest Threadfin Bream (*Pentapodus porosus*), Blue-lined Emperor (*Lethrinus punctulatus*), Yellowstripe Scad (*Selaroides leptolepis*) and Western Butterfish (*Pentapodus vitta*).

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[26] For the purpose of this assessment reference sites included those sites located within the indicative anchoring area.

[27] For the purpose of this assessment reference sites included those sites located within the indicative anchoring area.

## Table 11-16 Fifteen Most Common and Abundant Fish Species Recorded at Sand and Sessile Invertebrates Sites in the October 2008 and March 2009 Surveys

| October 2008 Survey | | | | March 2009 Survey | | | |
|---|---|---|---|---|---|---|---|
| **Genus species** | **Total #** | **% of drops** | **Mean MaxN** | **Genus species** | **Total #** | **% of drops** | **Mean MaxN** |
| **Sand** | | | | | | | |
| *Echeneis naucrates* | 17 | 39 | 0.9 ± 0.3 | *Atule mate* | 203 | 22 | 4.1 ± 2.6 |
| *Herklotsichthys* spp. | 1016 | 44 | 56.4 ± 28.8 | *Carangoides fulvoguttatus* | 46 | 35 | 0.9 ± 0.4 |
| *Lethrinus genivittatus* | 12 | 17 | 0.7 ± 0.6 | *Echeneis naucrates* | 29 | 35 | 0.6 ± 0.1 |
| *Loxodon macrorhinus* | 7 | 28 | 0.4 ± 0.2 | *Gnathanodon speciosus* | 160 | 27 | 3.3 ± 1.2 |
| *Nemipterus* spp. | 89 | 100 | 4.9 ± 0.5 | *Lethrinus genivittatus* | 46 | 22 | 0.9 ± 0.3 |
| *Paramonacanthus choirocephalus* | 42 | 89 | 2.3 ± 0.3 | *Nemipterus* spp. | 70 | 57 | 1.4 ± 0.3 |
| *Parapercis nebulosa* | 18 | 56 | 1.0 ± 0.2 | *Paramonacanthus choirocephalus* | 67 | 61 | 1.4 ± 0.2 |
| *Pentapodus porosus* | 62 | 89 | 3.4 ± 0.6 | *Parapercis nebulosa* | 39 | 55 | 0.8 ± 0.1 |
| *Pentapodus vitta* | 413 | 100 | 22.9 ± 2.0 | *Pentapodus porosus* | 291 | 55 | 5.9 ± 1.2 |
| *Rhynchobatus* spp. | 5.0 | 28 | 0.3 ± 0.1 | *Pentapodus vitta* | 150 | 57 | 3.1 ± 0.5 |
| *Scombridae* spp. | 18 | 67 | 1.0 ± 0.2 | *Scombridae* spp. | 103 | 94 | 2.1 ± 0.1 |
| *Selaroides leptolepis* | 379 | 100 | 21.1 ± 3.7 | *Selaroides leptolepis* | 497 | 55 | 10.1 ± 1.7 |
| *Sillago* spp. | 33 | 50 | 1.8 ± 0.8 | *Seriolina nigrofasciata* | 14 | 24 | 0.3 ± 0.1 |
| *Upeneus moluccensis* | 10 | 22 | 0.6 ± 0.3 | *Synodontidae* spp. | 21 | 35 | 0.4 ± 0.1 |
| *Upeneus tragula* | 41 | 56 | 2.3 ± 1.3 | *Torquigener pallimaculatus* | 68 | 37 | 1.4 ± 0.4 |
| **Sessile invertebrates** | | | | | | | |
| *Atule mate* | 25 | 35 | 1.1 ± 0.5 | *Atule mate* | 11 | 15 | 0.8 ± 0.2 |
| *Carangoides fulvoguttatus* | 24 | 26 | 1.0 ± 0.6 | *Carangoides fulvoguttatus* | 26 | 54 | 2.0 ± 0.6 |
| *Chaetodontoplus duboulayi* | 10 | 30 | 0.4 ± 0.2 | *Echeneis naucrates* | 8 | 46 | 0.6 ± 0.2 |
| *Choerodon cauteroma* | 16 | 30 | 0.7 ± 0.3 | *Gnathanodon speciosus* | 15 | 31 | 1.2 ± 0.3 |
| *Echeneis naucrates* | 11 | 26 | 0.5 ± 0.2 | *Lagocephalus sceleratus* | 10 | 23 | 0.8 ± 0.2 |
| *Lethrinus punctulatus* | 141 | 43 | 6.1 ± 2.2 | *Lethrinus genivittatus* | 12 | 23 | 0.9 ± 0.3 |
| *Loxodon macrorhinus* | 13 | 35 | 0.6 ± 0.2 | *Lethrinus punctulatus* | 16 | 23 | 1.2 ± 0.3 |
| *Nemipterus* spp. | 68 | 43 | 3.0 ± 0.9 | *Nemipterus* spp. | 19 | 69 | 1.5 ± 0.4 |
| *Parapercis nebulosa* | 16 | 52 | 0.7 ± 0.2 | *Paramonacanthus choirocephalus* | 28 | 38 | 2.2 ± 0.6 |

| October 2008 Survey | | | | March 2009 Survey | | | |
|---|---|---|---|---|---|---|---|
| **Genus species** | **Total #** | **% of drops** | **Mean MaxN** | **Genus species** | **Total #** | **% of drops** | **Mean MaxN** |
| *Pentapodus porosus* | 380 | 83 | 16.5 ± 2.4 | *Parapercis nebulosa* | 9 | 54 | 0.7 ± 0.2 |
| *Pentapodus vitta* | 24 | 17 | 1.0 ± 0.6 | *Pentapodus porosus* | 161 | 92 | 12.4 ± 3.4 |
| *Scombridae* spp. | 48 | 91 | 2.1 ± 0.2 | *Pentapodus vitta* | 49 | 31 | 3.8 ± 1.0 |
| *Selaroides leptolepis* | 167 | 39 | 7.3 ± 3.2 | *Scombridae* spp. | 21 | 85 | 1.6 ± 0.4 |
| *Siganus fuscescens* | 61 | 26 | 2.7 ± 1.7 | *Selaroides leptolepis* | 77 | 23 | 5.9 ± 1.6 |
| *Upeneus tragula* | 29 | 30 | 1.3 ± 0.5 | *Upeneus tragula* | 25 | 23 | 1.9 ± 0.5 |

*Note: Total # = sum of abundances for each deployment; % of drops = percent of stereo BRUV deployments observed at; Mean MaxN = average relative abundance. Note that the species are ordered alphabetically by genus.*

Size distributions were significantly different in the October 2008 and March 2009 surveys (Kolmogorov-Smirnov test, D = 0.17, $p < 0.01$) (Centre for Marine Futures, UWA 2013). The mean length was 249 mm ± 8.5 SE in the October 2008 survey and 211 mm ± 11.7 SE in the March 2009 survey. The higher mean length recorded in the October 2008 survey was attributable to a greater proportion of 121–200 mm individuals, while in the March 2009 survey there was a higher proportion of 81–120 mm individuals. A very small proportion of the fish were >280 mm in length at the soft sediments with sessile benthic macroinvertebrates reference sites. In the October 2008 survey, sizes ranged from a 46.4 mm Brown Demoiselle (*Neopomacentrus filamentosus*) to a 2.6 m Tiger Shark (*Galeocerdo cuvier*). In the March 2009 survey, the sizes ranged from a 41.9 mm Western Butterfish to a 2.6 m Great Hammerhead Shark (*Sphyrna mokarran*).

#### 11.4.4.1.1 Mainland End of the DomGas Pipeline Route

In the October 2010 survey, a total of 1047 individuals from 70 species and 26 families were recorded at the three soft and hard coral Reference Sites not at risk of Material or Serious Environmental Harm (CR1, CR2 and CR3) (UWA Oceans Institute and School of Plant Biology, UWA 2011). Relative abundances and numbers of species and families were similar at the same sites in the April 2011 survey, where 1197 individuals from 61 species and 23 families were recorded. On both sampling occasions, coral Reference Sites were characterised by high abundances of schooling Inshore Surgeonfish (*Acanthurus grammoptilus*), Blue Fusilier (*Caesio teres*) and Brown Demoiselle (*Neopomacentrus filamentosus*) and frequent observations of Bengal Sergeant (*Abudefduf bengalensis*), Grass Emperor (*Lethrinus laticaudis*) and Stripey Snapper (*Lutjanus carponotatus*) (Table 11-17).

In the October 2010 and April 2011 surveys, two non-coral benthic macroinvertebrates Reference Sites were surveyed (BR1 and BR2). A total of 249 individuals from 45 species and 22 families were recorded in the October 2010 survey. At the same sites in the April 2011 survey, 364 individuals from 52 species and 29 families were recorded. The April 2011 survey recorded higher numbers of individuals, species and families. Species that were frequently observed at the non-coral benthic macroinvertebrates Reference Sites included Inshore Surgeonfish, Blue Tuskfish (*Choerodon cyanodus*) and Stripey Snapper (Table 11-17). Stripey Snapper were abundant in both the October 2010 and April 2011 surveys. Non-coral benthic macroinvertebrates Reference Sites were characterised by a different suite of most abundant and most common species to those recorded at sites at risk of Material or Serious Environmental Harm.

A total of 338 individuals from 42 species and 23 families were recorded at the two macroalgae Reference Sites (MAR1 and MAR2) surveyed in October 2010. In the April 2011 survey, a total of 1868 individuals from 47 species and 24 families were recorded from the same sites. Blue Tuskfish, Stripey Snapper and Blue-lined Emperor (*Lethrinus punctulatus*) characterised the macroalgae Reference Sites and were frequently recorded during both the October 2010 and April 2011 surveys (Table 11-17). In the April 2011 survey, 82% more individuals were recorded than in the October 2010 survey, largely due to the presence of schooling Herring (*Herklotsichthys* spp.).

A total of 14 individuals from 10 species and 7 families were recorded at the one seagrass Reference Site (SGR1) in the October 2010 survey. The most commonly recorded and most abundant species were Mackerel (Scombridae spp.), Short-headed Sabretooth Blenny (*Petroscirtes breviceps*), Barred Yellowtail Scad (*Atule mate*), and Giant Trevally (*Caranx ignobilis*). In the April 2011 survey, a total of 380 individuals from 26 species and 16 families were recorded at the two seagrass Reference Sites (SGR1 and SGR2). Given the extremely low abundances of individuals observed in the October 2010 survey, it is likely that the April 2011 survey provides a more accurate description of the demersal fish assemblages at the seagrass Reference Sites. Based on the April 2011 survey, the fish species characterising seagrass Reference Sites included, Western Butterfish (*Pentapodus vitta*), Yellowstripe Scad (*Selaroides leptolepis*), and Mackerel.

**Table 11-17 Summary of Relative Abundance and Species Information for Each Community Type Surveyed at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the DomGas Pipeline at the Mainland End of the DomGas Pipeline Route in the October 2010 and April 2011 Surveys**

| | Coral | Non-Coral Benthic Macroinvertebrates | Macroalgae | Seagrass |
|---|---|---|---|---|
| **October 2010 at Reference Sites not at risk of Material or Serious Environmental Harm** | | | | |
| Total # individuals | 1047 | 249 | 338 | 14 |
| Total # species | 70 | 45 | 42 | 10 |
| Total # families | 26 | 22 | 23 | 7 |
| Mean MaxN ± SE per deployment | 69.8 ± 13.9 | 24.9 ± 6.3 | 33.8 ± 7.2 | 2.8 ± 0.7 |
| Mean species richness ± SE per deployment | 20.3 ± 1.7 | 12.3 ± 1.7 | 10.8 ± 1.5 | 2.8 ± 0.8 |
| Five most abundant species | *Caesio teres*<br>*Acanthurus grammoptilus*<br>*Siganus doliatus*<br>*Abudefduf bengalensis*<br>*Neopomacentrus filamentosus* | *Siganus fuscescens*<br>*Lutjanus russellii*<br>*Lutjanus carponotatus*<br>*Choerodon cyanodus*<br>*Selaroides leptolepis* | *Siganus fuscescens*<br>*Lethrinus punctulatus*<br>*Choerodon cyanodus*<br>*Lethrinus laticaudis*<br>*Choerodon* spp. | *Scombridae* spp.<br>*Petroscirtes breviceps*<br>*Atule mate*<br>*Caranx ignobilis*<br>*Feroxodon multistriatus** |
| Five most common species | *Lethrinus laticaudis*<br>*Choerodon cyanodus*<br>*Chaetodon aureofasciatus*<br>*Lutjanus carponotatus*<br>*Abudefduf bengalensis* | *Choerodon cyanodus*<br>*Lutjanus carponotatus*<br>*Lethrinus laticaudis*<br>*Parupeneus indicus*<br>*Acanthurus grammoptilus** | *Choerodon cyanodus*<br>*Lethrinus laticaudis*<br>*Lethrinus punctulatus*<br>*Lutjanus carponotatus*<br>*Choerodon schoenleinii** | *Scombridae* spp.<br>*Petroscirtes breviceps*<br>*Atule mate*<br>*Caranx ignobilis*<br>*Feroxodon multistriatus** |
| **April 2011 at Reference Sites not at risk of Material or Serious Environmental Harm** | | | | |
| Total # individuals | 1197 | 364 | 1868 | 380 |
| Total # species | 61 | 52 | 47 | 26 |
| Total # families | 23 | 29 | 24 | 16 |
| Mean MaxN ± SE per deployment | 79.8 ± 7.1 | 36.4 ± 8.2 | 186.8 ± 84.6 | 38 ± 15.5 |
| Mean species richness ± SE per deployment | 19.1 ± 1.6 | 12.6 ± 1.9 | 16.5 ± 1.5 | 5.8 ± 1 |

| | Coral | Non-Coral Benthic Macroinvertebrates | Macroalgae | Seagrass |
|---|---|---|---|---|
| Five most abundant species | *Acanthurus grammoptilus*<br>*Caesio teres*<br>*Pomacentrus milleri*<br>*Scomberoides commersonnianus*<br>*Neopomacentrus filamentosus* | *Selaroides leptolepis*<br>*Herklotsichthys* spp.<br>*Pomacentrus milleri*<br>*Lutjanus carponotatus*<br>*Abudefduf bengalensis** | *Herklotsichthys* spp.<br>*Sphyraena obtusata*<br>*Lethrinus punctulatus*<br>*Caesio teres*<br>*Lutjanus carponotatus* | *Selaroides leptolepis*<br>*Pentapodus vitta*<br>*Scombridae* spp.<br>*Gnathanodon speciosus*<br>*Scomberoides lysan* |
| Five most common species | *Lutjanus carponotatus*<br>*Acanthurus grammoptilus*<br>*Pomacentrus milleri*<br>*Lethrinus laticaudis*<br>*Abudefduf bengalensis* | *Lutjanus carponotatus*<br>*Choerodon cyanodus*<br>*Pomacentrus milleri*<br>*Acanthurus grammoptilus*<br>*Carcharhinus* spp.* | *Lutjanus carponotatus*<br>*Lethrinus punctulatus*<br>*Choerodon cyanodus*<br>*Scombridae* spp.<br>*Parupeneus indicus** | *Scombridae* spp.<br>*Pentapodus vitta*<br>*Selaroides leptolepis*<br>*Lutjanus malabaricus*<br>*Upeneus tragula* |

In the October 2010 survey, the smallest individual measured at Reference Sites not at risk of Material or Serious Environmental Harm, was a 40.3 mm Brown Demoiselle and the largest a 1.2 m Pickhandle Barracuda (*Sphyraena jello*). The median fish length was 192.5 mm. The mean length of fish measured per deployment was 264.3 mm ± 20.4 SE. At Reference Sites, the mean length per deployment of coral (median: 200.4 mm; mean: 228.7 mm ± 24.3 SE) and non-coral benthic macroinvertebrates (median: 186.4 mm; mean: 233.0 mm ± 12.1 SE) demersal fish assemblages was broadly similar in the October 2010 survey. The mean fish length per deployment at macroalgae sites (median: 179.0 mm; mean: 258.7 mm ± 25.2 SE) was larger than fish in coral or non-coral benthic macroinvertebrate communities. The mean length of the fish assemblages associated with the seagrass communities was very large, and with a large standard error (median: 178.1 mm; mean: 446.1 mm ± 114.2 SE). However, only 11 fish were measured and the mean length was skewed by the presence of a 75 cm Giant Trevally. The median length of the fish assemblage in the seagrass communities was similar to that of the macroalgae community fish assemblage.

In the April 2011 survey, the smallest individual measured at Reference Sites, was a 20.2 mm Brown Demoiselle and the largest a 1.1 m Whitetip Reef Shark (*Triaenodon obesus*). The median fish length was 188.5 mm. The mean length of fish measured per deployment was 206.6 mm ± 12.5 SE. At Reference Sites, the mean fish length per deployment at non-coral benthic macroinvertebrates (median: 125.4 mm; mean: 228.2 mm ± 36.5 SE) and macroalgae (median: 201.5 mm; mean: 227.3 mm ± 12.1 SE) sites were similar, while at coral sites the mean length was smaller (median: 210.7 mm; mean: 215.4 mm ± 14.6 SE). In the April 2011 survey, fish assemblages associated with seagrass communities were the smallest on average (median: 121.3 mm; mean: 151.3 mm ± 31.5 SE), and were also smaller than in the October 2010 survey.

#### 11.4.4.2 Mangrove Communities at the Mainland End of the DomGas Pipeline Route

In the October 2010 survey, the mean density of demersal fish at the Reference Sites was 109.8 fish/50 $m^2$ ± 22.3 SE, which was broadly comparable to the density observed among sites at risk of Material or Serious Environmental Harm. The mean density of fish recorded at individual Reference Sites was highly variable, ranging from 52.5 fish/50 $m^2$ ± 20.2 SE at NR4 to 241.0 fish/50 $m^2$ ± 52.6 SE at NR3 (Table 11-9). The mean number of species was very similar to that observed among sites at risk of Material or Serious Environmental Harm. The mean number of species was lowest at NR2 (6.5 species ± 0.7 SE) and highest at NR1 and NR3 (approximately seven species). The values for mean diversity and evenness for Reference Sites were slightly lower than those observed for the sites at risk of Material or Serious Environmental Harm during the October 2010 survey.

The fish assemblages recorded at Reference Sites in the October 2010 survey were largely dominated by a combination of individuals belonging to species that attain a small total length and the juveniles of larger species. However, the length frequency distribution of fish recorded from Reference Sites was more strongly right-skewed due to the capture of several individuals of the larger ray species, Giant Shovelnose Ray (*Glaucostegus typus*) and Leopard Whipray (*Himantura leopard*) (Table 11-14).

As was recorded among sites at risk of Material or Serious Environmental Harm, the most abundant species at Reference Sites in the October 2010 survey was the Indian Anchovy (*Stolephorus indicus*) (Table 11-14). The three most abundant species at Reference Sites in the October 2010 survey (Indian Anchovy, Long-spined Glass Perchlet [*Ambassis* interruptus] and unidentified juvenile Whiting) were the same three taxa that were dominant at sites at risk of Material or Serious Environmental Harm. Furthermore, six of the eight dominant species at sites at risk of Material or Serious Environmental Harm were also among the eight dominant species at Reference Sites. These six species included the White Sardine (*Escualosa thoracata*), Bluetail Mullet (*Valamugil buchanani*) and Golden Line Whiting (*Sillago analis*). The remaining two species that dominated catches from Reference Sites were the Orangefin Ponyfish (*Leiognathus bindus*) and Hairback Herring (*Nematalosa come*).

Forty-two of the 49 species recorded during the February 2011 survey were caught at Reference Sites, of which eight (including the predatory species, the Nervous Shark [*Carcharhinus cautus*], Giant Shovelnose Ray, Leopard Whipray, Spanish Mackerel [*Scomberomorus commerson*], Golden Trevally [*Gnathanodon speciosus*] and an unidentified Jewfish [*Johnius* sp.].) were caught only at these sites (Table 11-8). The mean density of fish at Reference Sites in the February 2011 survey was 551.8 fish/50 $m^2$ ± 111.1 SE, which is higher than that observed at sites at risk of Material or Serious Environmental Harm but which was also highly variable, ranging from 202.2 fish/50 $m^2$ ± 42.6 SE at NR2 to 848.5 fish/50 $m^2$ ± 164.4 SE at NR3 (Table 11-10). This is in contrast to the October 2010 survey, during which sites at risk of Material or Serious Environmental Harm recorded higher mean fish densities than Reference Sites (Table 11-9).

In the February 2011 survey, the mean number of species at Reference Sites was very similar to that recorded at sites at risk of Material or Serious Environmental Harm, with the lowest number recorded at NR2 (10.2 species ± 1.2 SE) and the highest at NR3 (12.3 species ± 1.1 SE). However, the numbers of species observed during the February 2011 survey were consistently greater than those recorded during the preceding October 2010 survey. The values for mean diversity and evenness for Reference Sites were generally higher than those observed at sites at risk of Material or Serious Environmental Harm during the February 2011.

Similar to sites at risk of Material or Serious Environmental Harm, the most abundant species recorded at the Reference Sites during the February 2011 survey was the Orangefin Ponyfish (Table 11-15). Six of the eight most abundant taxa at Reference Sites were also among the eight dominant taxa at sites at risk of Material or Serious Environmental Harm (i.e. Orangefin Ponyfish, Long-spined Glass Perchlet, Golden Line Whiting, White Sardine, Hamilton's Thryssa [*Thryssa hamiltonii*] and unidentified juvenile Whiting). Two other species that were dominant at Reference Sites were Hairback Herring and Northern Snubnose Garfish (*Arrhamphus sclerolepis*). None of these eight dominant taxa exhibited a mean length >90 mm. However, as in the October 2010 survey, the length frequency distribution of fish at Reference Sites was more strongly right-skewed than that of fish at sites at risk of Material or Serious Environmental Harm.

The demersal fish recorded at Reference Sites during the February 2011 survey were dominated by a similar suite of species to that observed during the October 2010 survey. Six taxa (Long-spined Glass Perchlet, Golden Line Whiting, Sardine, Ponyfish, Hairback Herring and unidentified juvenile Whiting) were among the eight dominant species at these sites in both the October 2010 and February 2011 surveys. There was a notable increase in the abundance of Ponyfish, from only 39 individuals in the October 2010 survey, to 4772 individuals in the February 2011 survey.

## 11.5 Discussion and Conclusions

Comprehensive field surveys have been undertaken to describe the composition, relative abundance and size structure of the demersal fish assemblages that characterise soft and hard corals, non-coral benthic macroinvertebrates, macroalgae and seagrass communities at sites at risk of Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline and at Reference Sites not at risk of Material or Serious Environmental Harm. The stereo BRUV surveys identified clear differences in the composition, relative abundance and size structure of the demersal fish assemblages that characterised the different community types on the east coast of Barrow Island. These differences are most likely a reflection of the varying dependence of the different fish species on different aspects of habitat for shelter and food (Parrish 1989; Beukers and Jones 1997). Inshore macroalgae communities were characterised by high abundances of juvenile Tuskfish (e.g. *Choerodon* spp.), Emperor (e.g. *Lethrinus genivittatus*, *Lethrinus laticaudis*, *Lethrinus punctulatus*, *Lethrinus variegatus*) and Rabbitfish (e.g. *Siganus fuscescens*) and high abundances of Butterfish (e.g. *Pentapodus* *porosus*, *Pentapodus vitta*), which most likely reflects the dependence of fish of different ages on specific habitats. The coral communities were characterised by particularly high species richness and increased occurrences of small Damselfish (e.g. *Abudefduf bengalensis*, *Neopomacentrus filamentosus*, *Pomacentrus limosus*), schooling small Trevally (carangids), Snapper (e.g. *Lutjanus carponotatus*), Cod and Grouper (serranids) and Emperor (e.g. *Lethrinus atkinsoni*, *Lethrinus nebulosus*) compared to other community types. High fish assemblage diversity associated with coral reefs has been widely documented (e.g. Grigg 1994; Roberts and Ormond 1987; Friedlander *et al*. 2003) and is a reflection of habitat quality, extent and complexity (e.g. Beukers and Jones 1997; Bellwood and Hughes 2001). Soft sediments with sessile benthic macroinvertebrates communities had high abundances of Emperor (e.g. *Lethrinus genivittatus*, *Lethrinus punctulatus*), Tuskfish (e.g. *Choerodon* spp.) and Butterfish (*Pentapodus porosus*, *Pentapodus vitta*), while unvegetated sand sites were characterised by a high abundance of Butterfish (*Pentapodus porosus*, *Pentapodus vitta*). Sand habitats were also characterised by many small sand-affiliated species (e.g. Leatherjackets [e.g. *Paramonacanthus choirocephalus*], Grubfish [e.g. *Parapercis nebulosa*], Lizardfish [e.g. Synodontidae spp.], Toadfish [e.g. *Torquigener pallimaculatus*]) and large transient pelagic predators (e.g. Mackerel [Scombridae spp.], Trevally [e.g. *Carangoides fulvoguttatus*, *Gnathanodon speciosus*]). Changes in species presence from one unvegetated sand site to the next and from one soft sediments with sessile benthic macroinvertebrates site to the next was much lower compared to the other community types and most likely a reflection of lower habitat complexity and patchiness in these habitats relative to coral and macroalgae communities.

In addition to differences between the community types, the demersal fish assemblages differed to a lesser degree between surveys, and in some instances from site to site, the latter indicative of a highly complex and dynamic marine ecosystem (Centre for Marine Futures, UWA 2013). Furthermore, many individual species observed in one survey (e.g. October 2008) were not observed on the subsequent survey (e.g. March 2009), with many of these species only observed on one or two stereo BRUV deployments. Preliminary analyses of temporal variability in assemblages across the BRUV surveys undertaken at Barrow Island indicate that temporal variability is relatively low compared to among community type variability (Prof. J. Meeuwig, Centre for Marine Futures, UWA, pers. comm. September 2010). There were some differences evident in the composition, relative abundance and size structure of the demersal fish assemblages between Reference Sites and sites at risk of Material or Serious Environmental Harm.

Similarly, there were clear differences in the composition, relative abundance and size structure of the demersal fish assemblages that characterised the different community types at the mainland end of the DomGas Pipeline route. Fish assemblages associated with coral communities were characterised by a variety of species which include Damselfish (e.g. *Abudefduf bengalensis*, *Pomacentrus milleri*), Surgeonfish (e.g. *Acanthurus grammoptilus*), Butterflyfish (e.g. *Chaetodon aureofasciatus*) and Emperor (e.g. *Lethrinus laticaudis*). Fish assemblages associated with coral communities were found to be the most diverse in both the dry season and wet season surveys. The greatest numbers of fish were also recorded at these sites in the dry season, and the second highest numbers were recorded in the wet season survey. Fish assemblages associated with non-coral benthic macroinvertebrates communities were less diverse, and with a lower relative abundance during both the dry season and wet season surveys. However, the composition of the fish assemblages was variable with few species being characteristic of these communities. Fish assemblages associated with macroalgae communities were overall less diverse than those characteristic of coral and non-coral benthic macroinvertebrates communities, but had a higher relative abundance than at the other community types in the wet season survey. Emperor (Lethrinidae spp.) were abundant in macroalgae communities and these communities were also characterised by the Yellowspot Goatfish (*Parupeneus indicus*). Extensive seagrass beds were not observed at the mainland end of the DomGas Pipeline route; and the seagrass community was dominated by fish more often associated with soft sediment habitats, with low fish species diversity and relative abundance over both the dry season and wet season surveys. The most abundant and commonly occurring species recorded in seagrass communities included Bartail Goatfish

(*Upeneus tragula*), Western Butterfish (*Pentapodus vitta*), Leatherjackets (e.g. *Paramonacanthus choirocephalus*), and larger mackerel (Scombridae spp.). The dominance of Goatfish species in both macroalgae and seagrass communities is likely due to the large patches of sand substrate between the biotic benthos in which Goatfish forage for small invertebrates (Froese and Pauly 2011). The Tuskfish *Choerodon cyanodus* was common throughout all the community types, except seagrass, in both the dry season and wet season surveys. The observed differences between the demersal fish assemblages characteristic of the different community types at Barrow Island and the mainland, highlights the importance of undertaking surveys that assess a broad suite of ecological communities to assess demersal fish assemblages.

Differences in the demersal fish assemblages were also observed between the dry season and wet season surveys, which may reflect seasonal patterns of change in the fish assemblages. These may in turn reflect seasonal changes in their habitat, for example, the increase in macroalgae cover (specifically *Sargassum* spp.) in the wet season survey, may have influenced the observed seasonal patterns in fish assemblages. Some species, such as Grass Emperor (*Lethrinus laticaudis*), were more commonly observed in the dry season survey than in wet season survey. Travers *et al*. (2006) also reported that this species was more important in catches using traps during the dry season than the wet season in the Pilbara region. Similarly, some species were found to be much more abundant during only one of the sampling periods. For example, Blue-Lined Emperor (*Lethrinus punctulatus*) in the October 2010 survey, and the herring species *Herklotsichthys* spp. and Western Butterfish (*Pentapodus vita*) in the April 2011 survey. *Lethrinus punctulatus* has been reported to be more important in trap catches in the dry season rather than the wet season (Travers *et al*. 2006). Seasonal changes in the relative abundance of the herring species *Herklotsichthys* spp. were also recorded further offshore in Barrow Island waters (Centre for Marine Futures, UWA 2013); in these surveys, *Herklotsichthys* spp. were recorded in the dry season (October 2008) and not in the wet season (March 2009 or February 2010) (UWA Oceans Institute and School of Plant Biology, UWA 2011). These observations suggest that there may be a cross-shelf movement of this species that is influenced by season. In the wet season survey, non-coral benthic macroinvertebrate communities had higher abundances, on average, of Yellowstripe Scad (*Selaroides leptolepis*) than all other community-types. However, this species is a small schooling scad and differences were likely driven by the presence of large schools occurring in some of the non-coral benthic macroinvertebrate sites.

In general, there were no consistent differences in the demersal fish assemblages characteristic of sites at risk of Material or Serious Environmental Harm and Reference Sites at the mainland end of the DomGas Pipeline route. Nevertheless, there were some significant differences in the relative abundance of the demersal fish assemblages between sites at risk of Material or Serious Environmental Harm and Reference Sites. In the April 2011 survey, Stripey Snapper (*Lutjanus carponotatus*) was three times more abundant, on average, at Reference Sites than at sites at risk of Material or Serious Environmental Harm. This species is a wide-ranging predatory snapper (Froese and Pauly 2011) with no obvious biological reason to be associated with either sites at risk of Material or Serious Environmental Harm or at Reference Sites. The observed differences are likely to be driven by a more complex interaction between fish assemblage composition and the relative abundances of fish in different community types, rather than a direct differences between the sites at risk of Material or Serious Environmental Harm and Reference Sites (UWA Oceans Institute and School of Plant Biology, UWA 2011). Factors such as proximity to the shoreline and its associated tidal flats and mangrove habitats, with sites closer to the shoreline generally more turbid than sites further offshore and in closer proximity to deeper generally less turbid open water, may be expected to result in differences in both the benthic community and the associated demersal fish assemblages.

The length distributions of the demersal fish assemblages also differed between the sites at risk of Material or Serious Environmental Harm and Reference Sites during both the dry season and wet season surveys. During both surveys, a higher frequency of fish were recorded in the smaller size-classes at sites at risk of Material or Serious Environmental Harm. These differences appear to be driven by higher numbers of small-bodied species such as Yellowstripe Scad (*Selaroides leptolepis*), Western Butterfish (*Pentapodus vita*), and in April 2011 Herring (*Herklotsichthys* spp.), at the inshore sites at risk of Material or Serious Environmental Harm. These species are likely to be more abundant at sites at risk of Material or Serious Environmental Harm due to the prevailing environmental conditions, with these sites being generally closer inshore and thus more turbid. *Selaroides leptolepis* is a characteristic species of catches taken over nearshore soft substrates in this region (Travers *et al*. 2010). In the October 2010 survey, there was a higher frequency of smaller Grass Emperor (*Lethrinus laticaudis*) at the sites at risk of Material or Serious Environmental Harm when compared to the Reference Sites. This may be due to an association of smaller or juvenile fish of this species with the inshore coral sites during the dry season, although to date such a pattern has not been reported.

The results from seine netting surveys of the demersal fish assemblages characteristic of the mainland mangrove communities similarly indicated that the fish assemblages at sites at risk of Material or Serious Environmental Harm did not generally exhibit notable differences from those at Reference Sites in either the dry season or wet season surveys. The numbers of species, relative abundance and assemblage diversity and evenness were broadly comparable between Reference Sites and those sites at risk of Material or Serious Environmental Harm during the dry season survey. Similarly, although mean fish density at Reference Sites was greater than that observed at sites at risk of Material or Serious Environmental Harm during the wet season survey, the mean numbers of species at sites at risk of Material or Serious Environmental Harm and those at Reference Sites were broadly similar, as was the overall species composition of the fish assemblages. It is nevertheless important to note that the variability in fish assemblage composition was greater at the Reference Sites than at the sites at risk of Material or Serious Environmental Harm. This was largely attributable to the difference in fish assemblage composition between the northern Reference Sites and all the other sites.

The size structure of the demersal fish assemblages characteristic of the mainland mangroves at sites at risk of Material or Serious Environmental Harm was also significantly different from that of the fish recorded at Reference Sites in both the dry season and the wet season surveys. The demersal fish at the Reference Sites were characterised (most notably during the wet season) by a higher proportion of individuals in the 20–120 mm fork length range. However, in general, the fish assemblages at sites at risk of Material or Serious Environmental Harm and those at Reference Sites were dominated by fish <100 mm in length. This was the case in both the dry season and wet seasons surveys, and largely reflected the high abundances of juvenile fish belonging both to small-bodied species such as Orangefin Ponyfish (*Leiognathus bindus*), Long-spined Glass Perchlet (*Ambassis interruptus*), White Sardine (*Escualosa thoracata*) and Indian Anchovy (*Stolephorus indicus*), and to larger-bodied taxa including the Sillaginidae and Mugilidae. Such numerical dominance by a few relatively small species is typical of the shallow, nearshore fish faunas of north-western Australia (Black *et al.* 1990; Pember 2006). Differences in the morphology, topography, habitat types, and substrates of the various creeks, as well as in the timing of the recruitment of different species, may be important in influencing the observed distribution and abundance of the different species.

There were also differences in the demersal fish assemblage composition between the dry season and wet season surveys. All of the sites surveyed showed marked increases in both species richness and total fish abundance between the dry season and the wet season surveys. Twenty species that were not recorded during the dry season surveys were recorded from seine net samples during the wet season surveys, including juveniles of ten larger, predatory species (e.g. Nervous Shark [*Carcharhinus cautus*], Moses' Snapper [*Lutjanus russellii*], Blackspot Barracuda [*Sphyraena forsteri*] and three species of carangid). Other studies have reported seasonal changes in the abundance of several fish species in nearshore mangrove habitats that have been attributed to the sequential recruitment of certain fish into these habitats (Robertson and Duke 1990; Pember 2006).

# 12.0 Surficial Sediments

## 12.1 Introduction

Barrow Island lies on the shallow (generally <5 m depth) limestone shelf that underlies the Montebello/Barrow Islands group. There is a broad intertidal platform adjacent to the Island that grades to the subtidal limestone shelf. Veneers of carbonate sands overlay limestone rock and generally vary in thickness between 0 and 0.5 m in the area of the MOF and 0.5–4.5 m further offshore in the deeper waters (Chevron Australia 2005; URS Australia 2004, 2006). Off the east coast of Barrow Island, surficial sediments are generally dominated by medium-to-fine grained sand fractions with a silt and clay content (reported as <75 µm) generally ranging between 1% and 15% (Chevron Australia 2010c, 2013a). Increased quantities of rubble are present on exposed pavement reef where strong water currents are present (Chevron Australia 2005, 2010e, 2013a). The surficial sediments of the Montebello/Barrow Islands region are generally in an undisturbed condition, apart from localised areas affected by drilling and aquaculture (DEC 2007). On the west coast of Barrow Island, unconsolidated sediments overlay a cemented calcarenite substrate (Chevron Australia 2005). These sediments are mostly calcareous, are dominated by sand, and contain shells and shell fragments (Chevron Australia 2005).

Sediments along the Domestic Gas Pipeline route include bare, rippled sand in higher energy areas, fine bioturbated sediments, sandy sediments with stoloniferous macroalgae and seagrass, and silty sediments in turbid water near the mainland coast (Chevron Australia 2005). Pavement habitats between Barrow Island and the mainland are covered by a sediment veneer that appears to periodically move, exposing areas of pavement reef. Surficial sediments sampled at six locations along the DomGas Pipeline route were mostly classified as ‘poorly graded sands’, with one exception that was classified as ‘sand with fines’ (Advanced Geomechanics 2009). These results indicated that the spatial scale of variation in particle-size distribution in nearshore sediments occurred on a scale of kilometres rather than hundreds of metres. The sediments collected near Barrow Island had a carbonate content of >95%, compared to approximately 50% in surficial sediments collected close to the mainland shore crossing. The Domestic Gas Pipeline route crosses an extensive intertidal sand and mud flat on the mainland shore that extends up to 3 km from the mangrove zone (Chevron Australia 2005). The surficial sediments in the nearshore area at the mainland shore crossing predominantly consist of a high proportion of ‘fine sand’ and ‘coarse sand’, with a degree of variability between sites (on a scale of kilometres rather than hundreds of metres) in terms of silt content (APASA 2009).

The intertidal substrates adjacent to the Pilbara coast are characterised by muddy sediments largely derived from land run-off, and transition to sandy sediments further offshore (CSIRO 2007). The large tidal range characteristic of the Pilbara region induces strong turbulence that results in sediment resuspension, and transports sediments back and forth with each tidal cycle (APASA 2010). These processes result in a high turbidity zone that extends from the coastline to approximately the 20 m isobath (CSIRO 2007). During surveys conducted in 2009 near the Domestic Gas Pipeline mainland shore crossing, the levels of suspended sediments in the near-bottom waters ranged from 20 mg/L to 100 mg/L, and surface levels ranged from 5 mg/L to 30 mg/L, with large temporal variability as a result of the varying tidal currents (APASA 2009). Suspended sediment concentrations in the nearshore regions adjacent to the mainland are consistently one or two orders of magnitude greater than the ambient levels characteristic of the offshore marine environment surrounding Barrow Island (APASA 2010). Cyclones are a major climatic feature of the Pilbara region, and are known to enhance sediment resuspension rates and increase sediment loads in rivers and nearshore coastal waters, producing extremely turbid conditions (Margvelashvili *et al*. 2006; CSIRO 2007).

## 12.2 Scope

This Section describes and maps the surficial sediment characteristics:

- that are at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iii, Statement No. 800; Condition 11.6.III, EPBC Reference: 2003/1294 and 2008/4178)
- at Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.iv, Statement No. 800; Condition 11.6.IV, EPBC Reference: 2003/1294 and 2008/4178).

Baseline surveys have been undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800 and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178.

## 12.3 Methods

### 12.3.1 Site Locations

Surficial sediment sampling was undertaken as part of the Marine Baseline Program associated with the MOF, LNG Jetty and Dredge Spoil Disposal Ground in the waters off the east coast of Barrow Island, prior to the commencement of marine construction (Chevron Australia 2013a). Of the sites sampled at the Barrow Island end of the DomGas Pipeline route, seven sites were located along the DomGas Pipeline route within the DomGas Pipeline Marine Disturbance Footprint; i.e. in areas at risk of Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline (Table 12-1; Figure 12-2). Twelve sites were located in the indicative anchoring area and eight Reference Sites were located in the surrounding waters. A number of these sites were located in Dredge Management Areas associated with the generation of turbidity and sediment deposition from dredging and spoil disposal activities on the east coast of Barrow Island (Section 2.3.4). For information on other surficial sediment sampling sites on the east coast of Barrow Island refer to Chevron Australia (2013a).

Surficial sediment sampling was conducted at ten sites along the DomGas Pipeline route from the Barrow Island Port limits to the Passage Islands (Table 12-2; Figure 12-3), at 30 sites in nearshore areas adjacent to the mainland (Table 12-3; Figure 12-4), and at eight sites in intertidal mangrove areas on the mainland (Table 12-4; Figure 12-4).

**Table 12-1 Sediment Sampling Sites along the DomGas Pipeline Route in Waters off the East Coast of Barrow Island**

| Site Code | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|
| | (GDA94, MGA Zone 50) | | (GDA94) | |
| **Sites at Risk of Material or Serious Environmental Harm from the Construction or Operation of the East Coast Barrow Island Marine Facilities** | | | | |
| TP4* | 342407 | 7698457 | 20° 48.428' S | 115° 29.143' E |
| TPC3* | 342102 | 7694973 | 20° 50.315' S | 115° 28.948' E |
| SS59* | 342105 | 7694973 | 20° 50.315' S | 115° 28.950' E |
| SS61* | 341883 | 7693671 | 20° 51.019' S | 115° 28.815' E |
| DG1 | 342795 | 7690816 | 20° 52.571’ S | 115° 29.325' E |
| SS68 | 343248 | 7690179 | 20° 52.919' S | 115° 29.583' E |
| SS62* | 344793 | 7688422 | 20° 53.879' S | 115° 30.464' E |
| **Sites within the Indicative Anchoring Area** | | | | |

| Site Code | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|
| | (GDA94, MGA Zone 50) | | (GDA94) | |
| MOF2* | 341709 | 7697690 | 20° 48.840' S | 115° 28.736' E |
| SS18* | 342834 | 7695331 | 20° 50.125' S | 115° 29.372' E |
| SS24* | 342472 | 7693189 | 20° 51.284' S | 115° 29.152' E |
| SS53* | 341872 | 7698244 | 20° 48.541' S | 115° 28.833' E |
| SS58* | 342645 | 7694222 | 20° 50.725' S | 115° 29.257' E |
| SS55* | 341354 | 7695830 | 20° 49.847' S | 115° 28.522' E |
| SS57* | 340994 | 7693216 | 20° 51.261' S | 115° 28.300' E |
| SS60* | 341692 | 7692073 | 20° 51.884' S | 115° 28.696' E |
| SS30* | 345404 | 7688694 | 20° 53.734' S | 115° 30.818' E |
| SS34* | 345800 | 7687820 | 20° 54.210' S | 115° 31.042' E |
| DSR1 | 347711 | 7684857 | 20° 55.825' S | 115° 32.129' E |
| SS36 | 347693 | 7684827 | 20° 55.842' S | 115° 32.118' E |
| **Reference Sites not at Risk of Material or Serious Environmental Harm from the Construction and Operation of the East Coast Barrow Island Marine Facilities** | | | | |
| SS32 | 343615 | 7688392 | 20° 53.889' S | 115° 29.785' E |
| SS33 | 341716 | 7688123 | 20° 54.025' S | 115° 28.688' E |
| SS35 | 344026 | 7686040 | 20° 55.166' S | 115° 30.009' E |
| Jetty-S-Ref | 342595 | 7686019 | 20° 55.170' S | 115° 29.184' E |
| SS38 | 347568 | 7681027 | 20° 57.901' S | 115° 32.026' E |
| SS63 | 350773 | 7685057 | 20° 55.732' S | 115° 33.096' E |
| SS27 | 344841 | 7691021 | 20° 52.471' S | 115° 30.506' E |
| SS26 | 343959 | 7691828 | 20° 52.029' S | 115° 30.002' E |

** Denotes a sampling site located in a Dredge Management Area. Source: Chevron Australia (2013a).*

### Table 12-2 Sediment Sampling Sites along the DomGas Pipeline Route between Barrow Island Port and the Passage Islands

| Site Code | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|
| | (GDA94, MGA Zone 50) | | (GDA94) | |
| **Sites at Risk of Material or Serious Environmental Harm from the Construction or Operation of the DomGas Pipeline** | | | | |
| S11 | 367581 | 7665784 | 21° 6.255' S | 115° 43.503' E |
| S12 | 356367 | 7676523 | 21° 0.384' S | 115° 37.081' E |
| S13 | 353156 | 7679906 | 20° 58.535' S | 115° 35.244' E |
| S14 | 349940 | 7683289 | 20° 56.686' S | 115° 33.406' E |
| S15 | 344528 | 7689008 | 20° 53.560' S | 115° 30.315' E |
| **Sites within the Indicative Anchoring Area** | | | | |
| SR11 | 366529 | 7666086 | 21° 6.127' S | 115° 42.893' E |
| SR12 | 363453 | 7668936 | 21° 4.529' S | 115° 41.134' E |
| SR13 | 362240 | 7670895 | 21° 3.462' S | 115° 40.443' E |
| SR14 | 357778 | 7674869 | 21° 1.287' S | 115° 37.887' E |
| SR15 | 346265 | 7687656 | 20° 54.302' S | 115° 31.309' E |

**Table 12-3 Subtidal Sediment Sampling Sites in the Vicinity of the DomGas Pipeline Mainland Crossing**

| Site Code | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|
| | (GDA94, MGA Zone 50) | | (GDA94) | |
| **Sites at Risk of Material or Serious Environmental Harm from the Construction or Operation of the DomGas Pipeline** | | | | |
| S1 | 377173 | 7657905 | 21° 10.566' S | 115° 49.012' E |
| S2 | 373622 | 7656767 | 21° 11.168' S | 115° 46.953' E |
| S3 | 374284 | 7658509 | 21° 10.226' S | 115° 47.343' E |
| S4 | 372357 | 7659844 | 21° 9.495' S | 115° 46.236' E |
| S5 | 371476 | 7662373 | 21° 8.120' S | 115° 45.738' E |
| S6 | 377578 | 7659719 | 21° 9.584' S | 115° 49.252' E |
| S7 | 377911 | 7662004 | 21° 8.347' S | 115° 49.454' E |
| S8 | 376439 | 7663885 | 21° 7.322' S | 115° 48.612' E |
| S9 | 375056 | 7662886 | 21° 7.857' S | 115° 47.809' E |
| S10 | 372815 | 7663349 | 21° 7.597' S | 115° 46.516' E |
| S16 | 378153 | 7654794 | 21° 12.256' S | 115° 49.563' E |
| S17 | 376963 | 7655271 | 21° 11.992' S | 115° 48.877' E |
| S18 | 378319 | 7656115 | 21° 11.541' S | 115° 49.665' E |
| S19 | 380115 | 7657660 | 21° 10.710' S | 115° 50.709' E |
| S20 | 380788 | 7658655 | 21° 10.174' S | 115° 51.102' E |
| **Reference Sites not at Risk of Material or Serious Environmental Harm from the Construction or Operation of the DomGas Pipeline** | | | | |
| SR1 | 371215 | 7651362 | 21° 14.087' S | 115° 45.537' E |
| SR2 | 369386 | 7652608 | 21° 13.404' S | 115° 44.486' E |
| SR3 | 371466 | 7654460 | 21° 12.409' S | 115° 45.697' E |
| SR4 | 369960 | 7656755 | 21° 11.159' S | 115° 44.836' E |
| SR5 | 367732 | 7656712 | 21° 11.173' S | 115° 43.549' E |
| SR6 | 381601 | 7664094 | 21° 7.229' S | 115° 51.594' E |
| SR7 | 381696 | 7666013 | 21° 6.189' S | 115° 51.657' E |
| SR8 | 379693 | 7666176 | 21° 6.093' S | 115° 50.501' E |
| SR9 | 376922 | 7666957 | 21° 5.658' S | 115° 48.904' E |
| SR10 | 379539 | 7668803 | 21° 4.668' S | 115° 50.423' E |
| SR16 | 376931 | 7650089 | 21° 14.801' S | 115° 48.836' E |
| SR17 | 377834 | 7650929 | 21° 14.349' S | 115° 49.362' E |
| SR18 | 377671 | 7651961 | 21° 13.789' S | 115° 49.272' E |
| SR19 | 382723 | 7661741 | 21° 8.509' S | 115° 52.233' E |
| SR20 | 383338 | 7664508 | 21° 7.011' S | 115° 52.599' E |

**Table 12-4 Intertidal Mangrove Sediment Sampling Sites in the Vicinity of the DomGas Pipeline Mainland Crossing**

| Site Code | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|
| | (GDA94, MGA Zone 50) | | (GDA94) | |
| **Sites at Risk of Material or Serious Environmental Harm from the Construction or Operation of the DomGas Pipeline** | | | | |
| M1 | 381244 | 7655802 | 21° 11.722' S | 115° 51.353' E |
| M2 | 381546 | 7655820 | 21° 11.713' S | 115° 51.529' E |

| Site Code | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|
| | (GDA94, MGA Zone 50) | | (GDA94) | |
| M3 | 380475 | 7656089 | 21° 11.563' S | 115° 50.91' E |
| M4 | 380091 | 7655290 | 21° 11.995' S | 115° 50.685' E |
| **Reference Sites not at Risk of Material or Serious Environmental Harm from the Construction or Operation of the DomGas Pipeline** | | | | |
| MR1 | 382774 | 7660298 | 21° 9.291' S | 115° 52.256' E |
| MR2 | 383266 | 7660134 | 21° 9.381' S | 115° 52.54' E |
| MR3 | 379253 | 7652769 | 21° 13.358' S | 115° 50.19' E |
| MR4 | 379752 | 7652567 | 21° 13.469' S | 115° 50.478' E |

### 12.3.2 Sampling Methods

Collection, handling and analysis of surficial sediment samples were consistent with the methods in the approved Scope of Works (RPS 2009). Samples collected in the waters of the east coast of Barrow Island were collected using grabs or cores, or multiple scrapes of the surficial sediments within a 4 $m^2$ area (Chevron Australia 2013a). Only the surficial sediments (<5 cm) were sampled as this is considered to include the sedimentologically most recent and active layer, representing an important part of the sediment profile in terms of biological effects (benthic habitat, sediment feeding and water/sediment interactions) and the most likely to influence the distribution and abundance of benthic macrofauna.

Van Veen grabs were used to collect surficial sediment samples in subtidal areas and at two of the eight intertidal sites (where the water depth was >1 m) sampled under the DomGas Pipeline Marine Baseline Program. Multiple grabs were performed at each site to obtain approximately 500 mL of sediment from within a 4 $m^2$ area. The sediments were carefully removed from the grab and then mixed together to form two composite samples (of 250 mL volume) for each site. Sediments were carefully transferred into pre-cleaned sample jars (for Total Organic Carbon [TOC] and Total Inorganic Carbon [TIC] analysis), or into plastic bags (for Particle-size Distribution [PSD] analysis).

Surficial sediments at the six other intertidal sites were collected by hand. As for the grab samples, multiple scrapes from the top 5 cm of sediments were collected from within a 4 $m^2$ area. The sediment was either scraped directly into pre-cleaned sample jars using the jar lid (for TOC and TIC analysis), or into plastic bags using a plastic scoop (for PSD analysis).

Jars and plastic bags were supplied by the analytical laboratory in a pre-cleaned condition. The plastic scoop was cleaned between sites to avoid cross-contamination.

Where visibility permitted, photographs or video recordings were taken of the seabed at each site for visual documentation of the sediments. A description of the dominant physical characteristics of the sediment samples was recorded on proforma log sheets, as were the site coordinates and the date and time of sampling.

Standard laboratory analytical procedures were employed throughout and laboratories with National Association of Testing Authorities (NATA)-accredited methods (or laboratories with demonstrated Quality Assurance/Quality Control [QA/QC] procedures in place) undertook the analyses. The sediment samples were analysed for:

- Particle-size Distribution (PSD) – laser diffraction and wet sieving
- Total Organic Carbon (TOC) (organically bound carbon) – furnace combustion
- Total Inorganic Carbon (TIC) – furnace combustion.

Analysis of sediment organic and inorganic carbon content was undertaken by the Chemistry Centre of Western Australia (for samples in Table 12-1) and Australian Laboratory Services

(ALS) (for samples in Table 12-2, Table 12-3 and Table 12-4). Samples were analysed for total carbon by combustion in a LECO furnace in the presence of strong oxidants/catalysts and the evolved carbon (as $CO_2$) measured by infra-red detection. Samples were analysed for TOC by acidification to remove inorganic carbonates, followed by combustion in a LECO furnace in the presence of strong oxidants/catalysts and the evolved organic carbon (as $CO_2$) measured by infra-red detection. TIC was determined as the difference between total carbon and total organic carbon. Total organic carbon and total inorganic carbon content were reported as a percentage of total dry weight.

Particle-size analysis was undertaken by the CSIRO Division of Minerals (for samples in Table 12-1) and by Microanalysis Australia (for samples in Table 12-2, Table 12-3 and Table 12-4). The results are expressed as a cumulative percentage volume of particles that occupy six different size ranges.

### 12.3.3 Timing and Frequency of Surveys

The sediment samples listed in Table 12-1 were collected in May–June 2004 on the east coast of Barrow Island as part of the Sea Dumping Permit Application to the then DEWHA (URS Australia 2006) and from September 2008 to April 2009 for the Marine Baseline Program for the MOF, LNG Jetty and Dredge Spoil Disposal Ground (Chevron Australia 2013a). Samples listed in Table 12-2, Table 12-3 and Table 12-4 were collected in March 2011.

### 12.3.4 Treatment of Survey Data

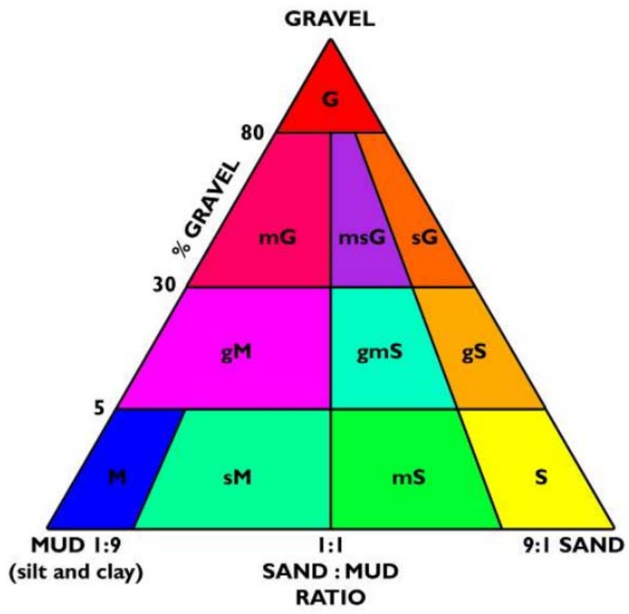
Based on the results of particle-size analysis, each sediment sample was classified into a sediment type according to a simplified version of the scheme proposed by Folk (1954). This scheme was also used for the National Marine Sediments Database and Seafloor Characteristics Project (Passlow *et al.* 2005). The simplified version has four fewer categories than the full version as it amalgamates some categories that contain less than 5% gravel content. Most of the sediments around Barrow Island were expected to contain relatively large gravel fractions and so the extra differentiation offered by the full scheme at the lower end of the gravel content scale was not considered necessary.

The sediment classification scheme is based on a triangular diagram divided into sediment textural groups according to measured percentages of gravel, sand and mud constituents (Figure 12-1). The method provides an approach to describing the sediments with a complete range of mixtures of the three components, producing a single description and classification value (Passlow *et al.* 2005).

According to the classification scheme, sediment grains were a categorised into three size-classes based on their diameter:

- mud <0.063 mm
- sand 0.063–2 mm
- gravel >2 mm.

The percentage composition of each of the grain-size classes and the ratios between them were then used to classify the sediment into 11 discrete sediment types (Figure 12-1).




| Abbreviation | Description |
|---|---|
| G | Gravel |
| mG | muddy Gravel |
| msG | muddy sandy Gravel |
| sG | sandy Gravel |
| gM | gravelly Mud |
| gmS | gravelly muddy Sand |
| gS | gravelly Sand |
| M | Mud |
| sM | sandy Mud |
| mS | muddy Sand |
| S | Sand |

**Figure 12-1 Simplified Folk Triangle Sediment Classification Scheme**

*Note: This diagram is not to scale – it is a representation of the classification subdivisions.*

Sediments were also categorised using additional particle size-classes, which provide more detailed information of the physical characteristics of marine sediments located along the DomGas Pipeline route:

- Clay <4 µm
- Silt 4–63 µm
- Fine Sand 63–250 µm
- Medium Sand 250–500 µm
- Coarse Sand 500–2000 µm
- Gravel >2000 µm.

Results for both classifications are presented and discussed.

## 12.4 Results

The spatial distribution of sediment types on the east coast of Barrow Island and along the DomGas Pipeline route are presented as spatially rectified point observations (Figure 12-2, Figure 12-3 and Figure 12-4).

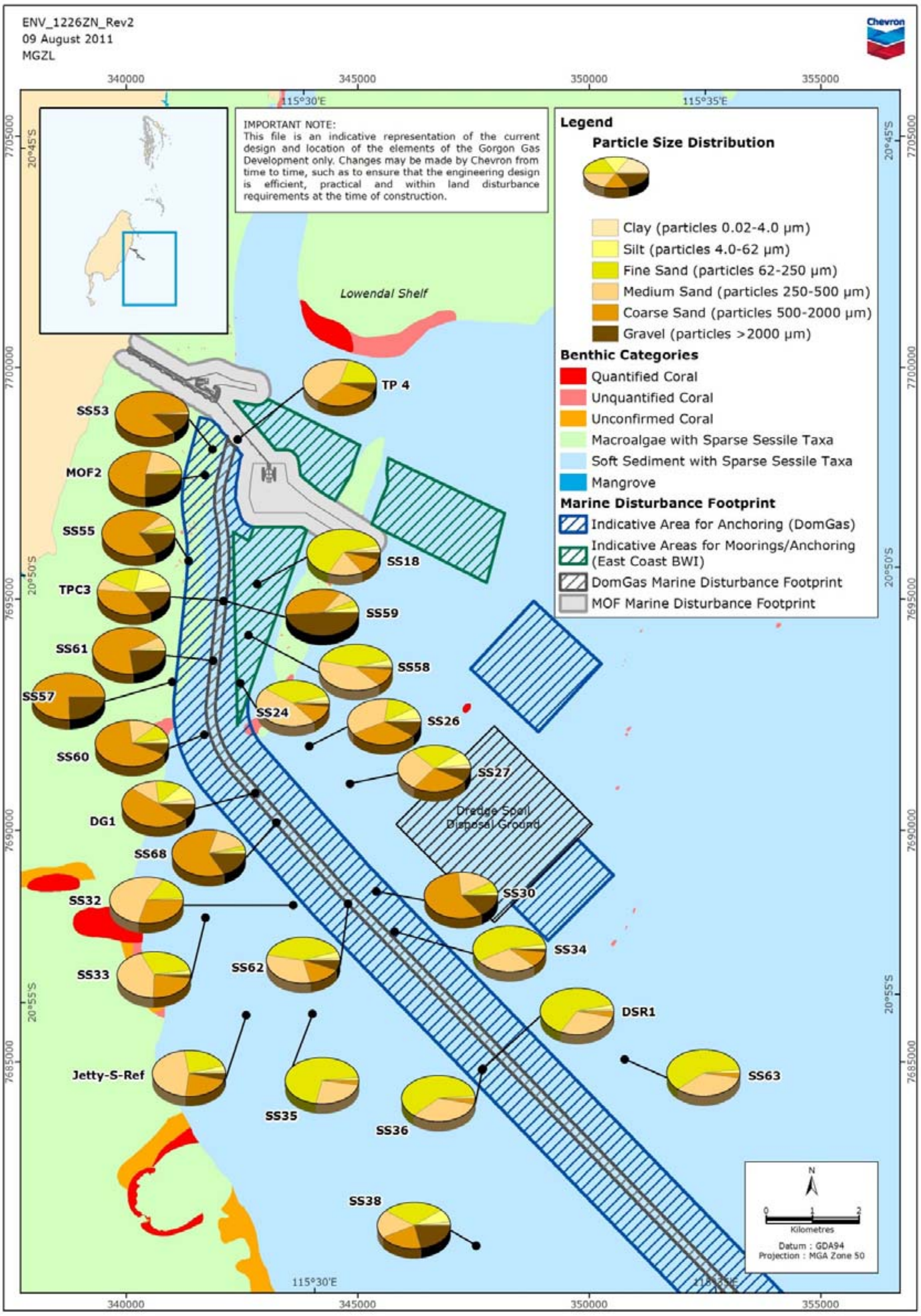



**Figure 12-2 Surficial Sediment Characteristics along the DomGas Pipeline Route on the East Coast of Barrow Island**

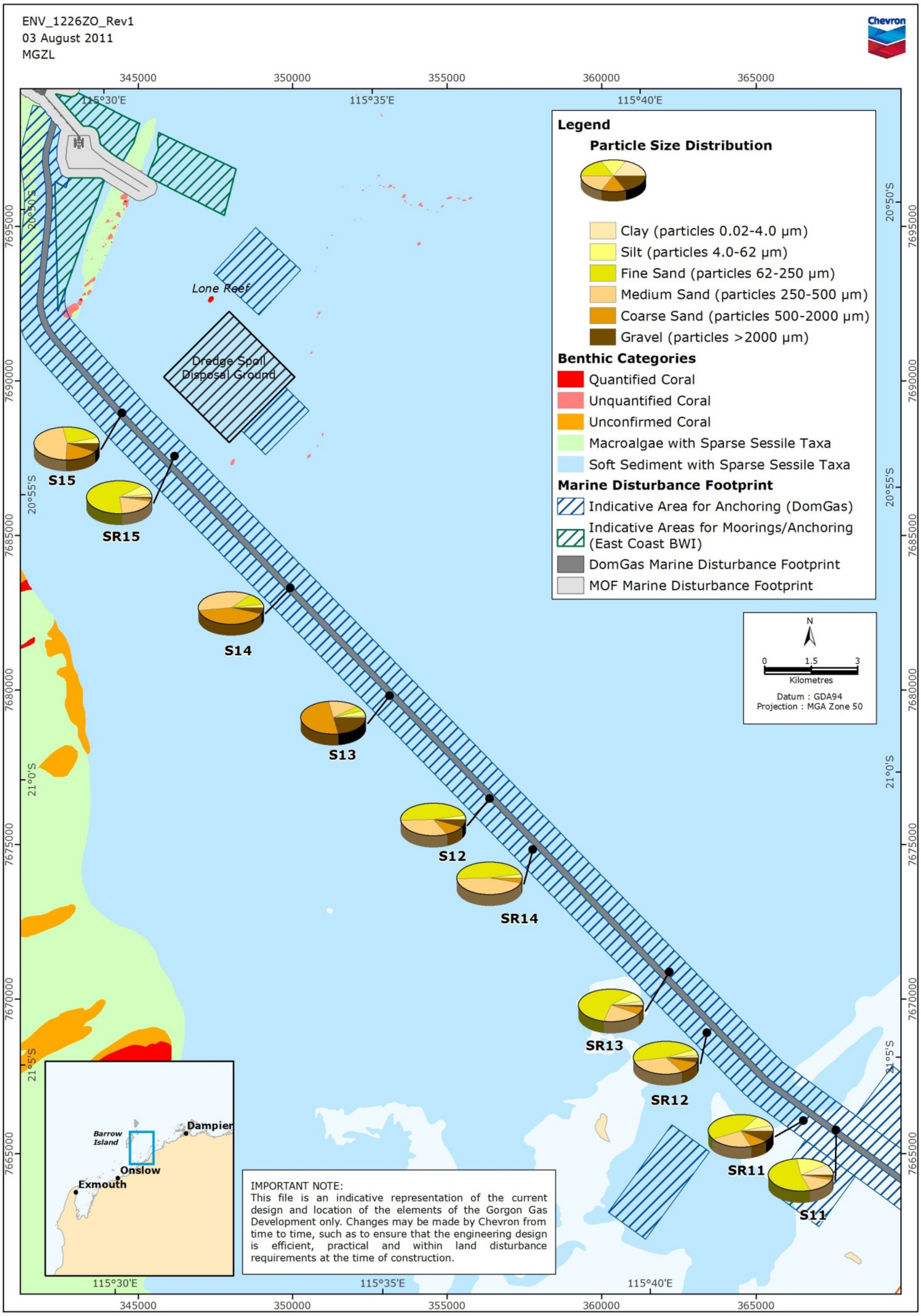



**Figure 12-3 Surficial Sediment Characteristics in the Vicinity of the DomGas Pipeline Route Between Barrow Island and the Passage Islands**

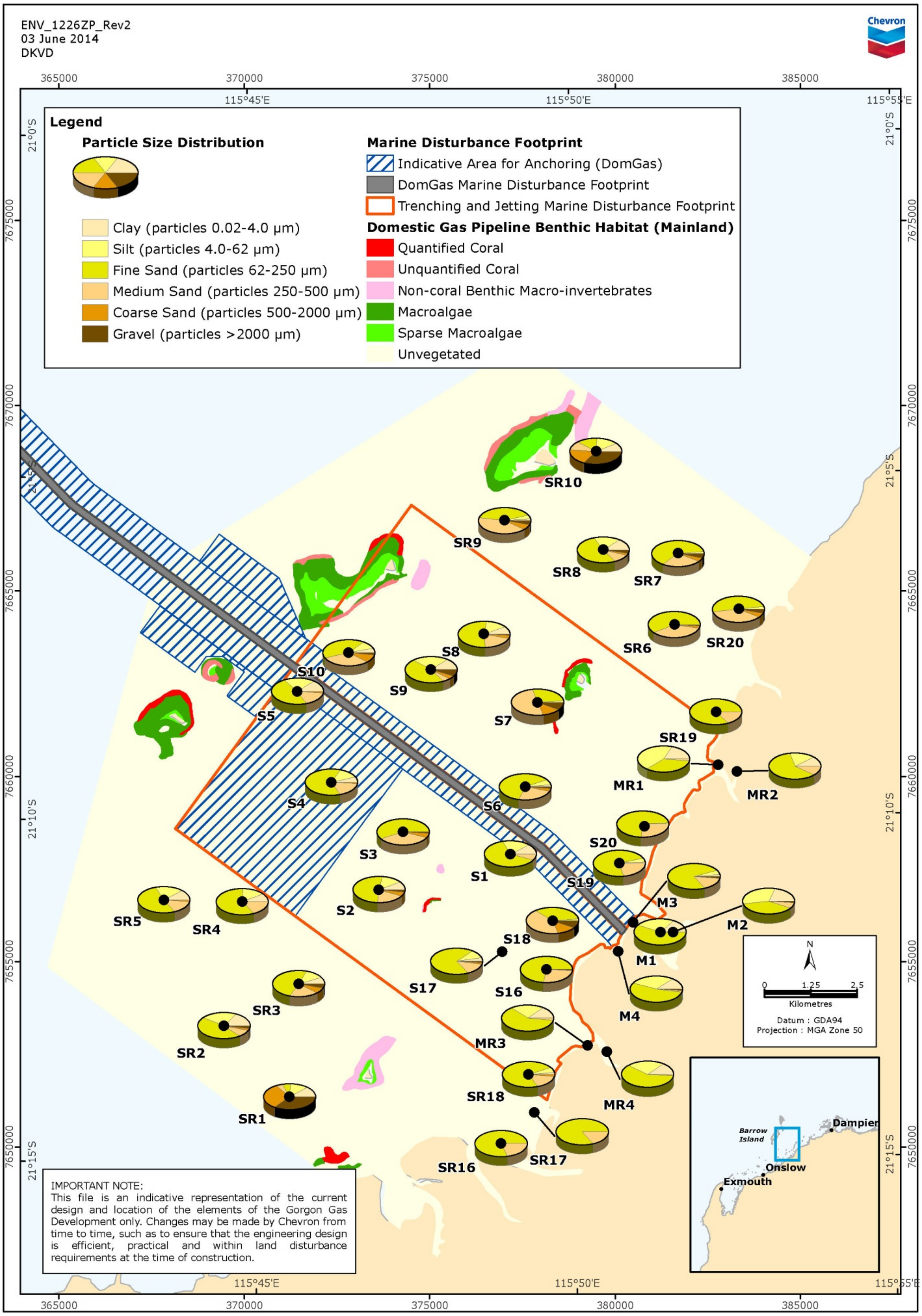



**Figure 12-4 Surficial Sediment Characteristics in the Vicinity of the DomGas Pipeline Mainland Crossing**

### 12.4.1 Description of Surficial Sediment Characteristics at Sites at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

#### 12.4.1.1 East Coast of Barrow Island

Sediments at sites at risk of Material or Serious Environmental Harm within the DomGas Pipeline Marine Disturbance Footprint adjacent to the east coast of Barrow Island were generally dominated by sand particles, with fine sands ranging from 0.9–42.8%, medium sands ranging from 6.3–42.0%, and coarse sands ranging from 15.4–68.8% (Figure 12-2). The exception was SS59, which was dominated by gravel particles (48.7%). The sediments were characterised by low clay (<5%) and silt (<10%) contents; except at TPC3, where the silt content was 17.5%. The sediments in this area were variable and were classed as 'sandy Gravel' (one site), 'gravelly Sand' (four sites), 'gravelly muddy Sand' (two sites) (Figure 12-2). Total Organic Carbon (TOC) and Total Inorganic Carbon (TIC) were low, with TOC varying between 0.1% and 0.7% dry weight and TIC between 9.7% and 10.8% dry weight.

The surficial sediments on the shallow nearshore pavement east of the DomGas Pipeline Marine Disturbance and within the indicative anchoring area (represented by sites SS53, MOF2, SS55 and SS57), were all classed as 'gravelly Sand', with gravel content ranging from 12.3–24.7% (Figure 12-2). These sediments were dominated by coarse sand fractions that ranged from 53.1–85.0%, and had low levels of medium sand (0.6–18.7%), and very low levels of fine sand (0.3–3.3%), silt (0.7–1.8%) and clay (0.2–0.6%) particles.

The sediments from the other sites in the indicative anchoring area (Figure 12-2) were also dominated by sands, which varied from 84.2–97.8%. Sediments at SS18, SS58, SS34, DSR1 and SS36 were dominated by fine sand particles (41.8–62.5%). Sediments at SS24 were dominated by medium sand particles (46.1%), and sediments at SS60 and SS30 were dominated by coarse sand particles (66.4% and 59.4%, respectively). Gravel contents were low, ranging from 0.6–13.5%. Silt and clay contents were very low, <3.5% and <1.5%, respectively. These sediments were generally variable and were classified as 'Sand' (six sites) and 'gravelly Sand' (six sites).

TOC in these sediments was low and varied between 0.1% and 0.7% dry weight; TIC varied between 9.7% and 11.1% dry weight.

**Plate 12-1 Seabed in the Channel between East Barrow Ridge and the Shallow Inshore Pavement**

*Note: Heart urchins (*Echinocardium cordatum*) can be seen on the sediment surface.*

#### 12.4.1.2 Sites between Barrow Island and the Passage Islands

Surficial sediments from sites at risk of Material or Serious Environmental Harm within the DomGas Pipeline Marine Disturbance Footprint between Barrow Island and the Passage Islands had low clay content (0.3–8.2%), relatively low silt content (2.6–19.8%), and low gravel content (1.9–21.8%) (Figure 12-3). These sites were generally dominated by sands, with fine sand content varying from 4.0–53.4%, medium sand content from 15.0–46.2%, and coarse sand content varying from 1.7–50.0%. The classifications of sediments along this section of the DomGas Pipeline route were 'gravelly Sand' (S12, S13 and S15), 'Sand' (S14), and 'muddy Sand' (S11). Similar to the sites off the east coast of Barrow Island (Section 12.4.1.1), TOC was low, and varied between 0.1% and 0.2% dry weight. TIC was also low and varied between 8.7% and 10.7% dry weight.

Surficial sediments at sites within the indicative anchoring area between Barrow Island and the Passage Islands were dominated by sands (Figure 12-3), particularly those in the fine and medium fractions which ranged from 42.6–67.1% and 20.0–45.7%, respectively. Coarse sand content was lower and varied from 1.8–10.8%; gravel content was also low (0.6–8.8%). The clay and silt content was very low and ranged from 0.7–3.9% and 2.9–9.8% respectively. Reference Sites along this section of the DomGas Pipeline route were classed as 'Sand' (two sites), 'muddy Sand' (two sites), and 'gravelly muddy Sand' (one site). TOC was low and varied from 0.1% to 0.2% dry weight, and TIC varied from 9.0% to 10.3% dry weight.

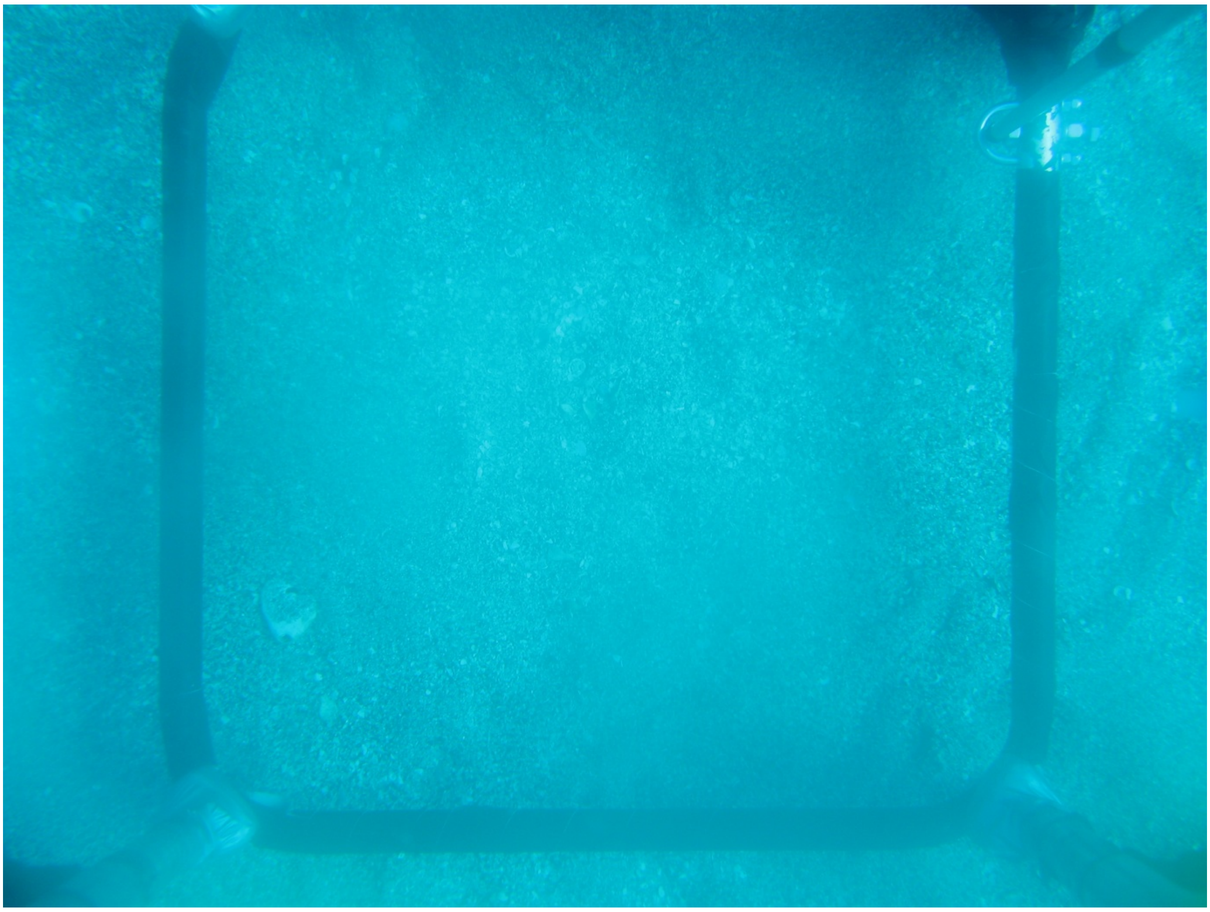


**Plate 12-2 Seabed along the DomGas Pipeline Route between Barrow Island and the Passage Islands**

### 12.4.1.3 Subtidal Sites in the Vicinity of the DomGas Pipeline Mainland Crossing

Surficial sediments collected from sites within the trenching and jetting area were dominated by sands, with low clay content (0–11.5%), low silt content (0–28.4%) and low gravel content (0.3–7.5%) (Figure 12-4). The sand content was generally dominated by fine-medium sands, ranging from 28.2–72.8% for fine sands and 4.9–50.2% for medium sands. The coarse sand content was lower and varied from 0.6–12.8%. The classifications of sediments within the trenching and jetting area, fell into four categories; ‘muddy Sand’ (seven sites), ‘Sand’ (five sites), ‘gravelly Sand’ (two sites) and ‘gravelly muddy Sand’ (one site).

TOC in these sediments was low and varied between 0.06% and 0.4% dry weight. TIC varied between 4.6% and 7.8% dry weight and was slightly lower than sediments located closer to Barrow Island (Sections 12.4.1.1 and 12.4.1.2).

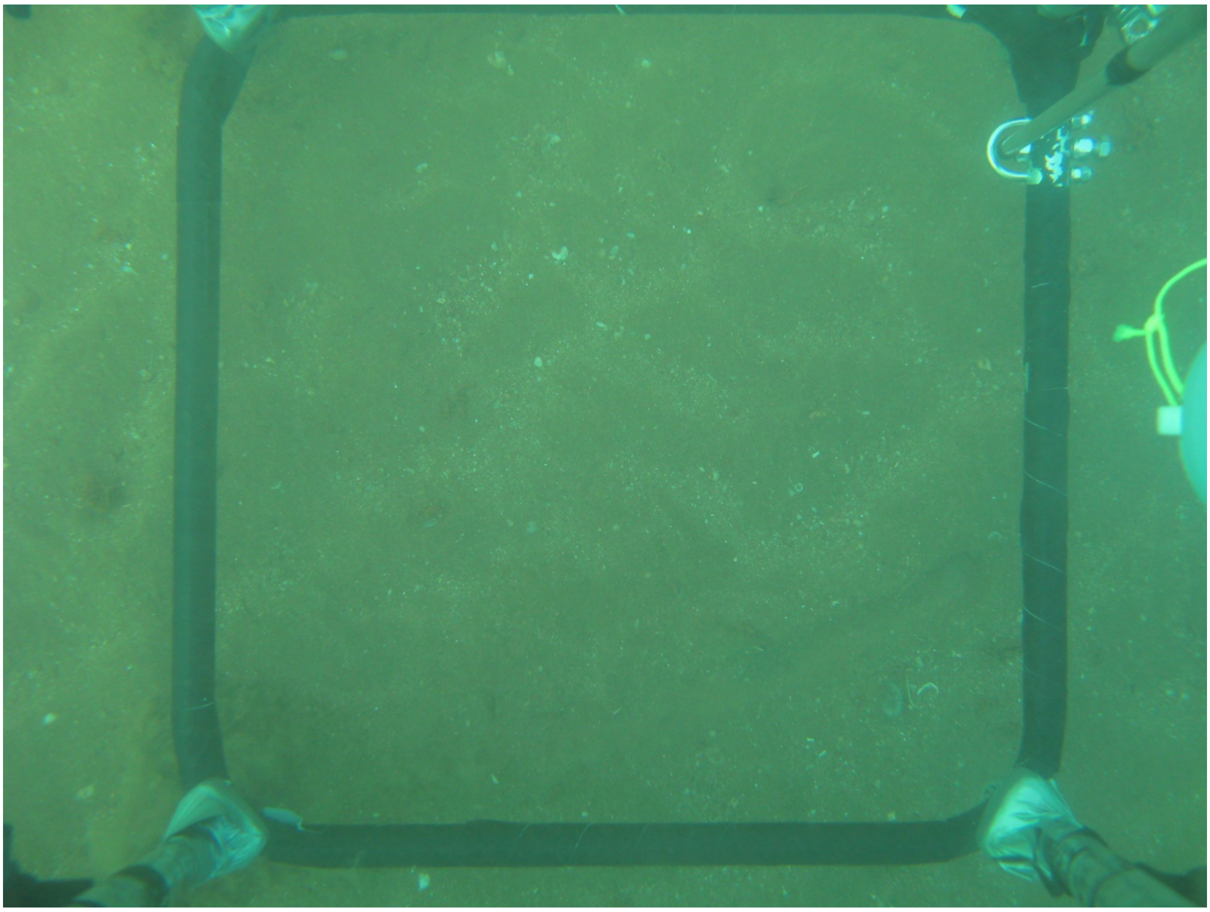


**Plate 12-3 Seabed in the Shallow, Nearshore Waters Adjacent to the DomGas Pipeline Mainland Crossing**

#### 12.4.1.4 Intertidal Mangrove Sites in the Vicinity of the DomGas Pipeline Mainland Crossing

Surficial sediments at intertidal mangrove sites were dominated by fine sands, with contents ranging from 40.8–78.3% (Figure 12-4). Medium sand fractions were lower and ranged from 0.4–14.0% and the coarse sand fractions were very low (<1%). The clay content at intertidal mangrove sites was higher than at subtidal sites along the DomGas Pipeline route, ranging from 1.6–19.6%, as was silt, which ranged from 4.1–32.5%. Gravel content was very low at these sites compared to subtidal sites along the DomGas Pipeline route, varying from 0.3–1.6%. The classifications of sediments fell into three categories; 'muddy Sand' (two sites), 'Sand' (one site), and 'sandy Mud' (one site).

TOC was low and varied from 0.2% to 0.5% dry weight, which was similar to other sediments along the DomGas Pipeline route. TIC was slightly lower than other sediments, varying from 3.8% to 6.4% dry weight.

**Plate 12-4 Intertidal Mangrove Sediments along the DomGas Pipeline Route at the Mainland Crossing**

### 12.4.2 Description of Surficial Sediment Characteristics at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

#### 12.4.2.1 East Coast of Barrow Island

Sediments at Reference Sites were generally dominated by sand particles, with fine sands ranging from 13.9–68.8%, medium sands ranging from 15.6–54.7%, and coarse sands ranging from 2.3–34.6% (Figure 12-2). The sediments were characterised by low clay (<2.5%) and silt (<10%) contents. The sediments in this area were variable and were classified as 'Sand' (five sites), 'gravelly Sand' (one site) and 'gravelly muddy Sand' (two sites).

Total Organic Carbon (TOC) and Total Inorganic Carbon (TIC) were low, with TOC varying between 0.4% and 0.8% dry weight, and TIC between 9.6% and 10.3% dry weight.

#### 12.4.2.2 Subtidal Sites in the Vicinity of the DomGas Pipeline Mainland Crossing

Surficial sediments at nearshore Reference Sites located both north and south of the trenching and jetting area were dominated by sands, and had low clay (0–14.9%) and silt (0–27.1%) contents (Figure 12-4). Sediments from this area also had very low levels of gravel (<5%), with the exception of SR1 (37.6%) and SR10 (35.1%). Within the sand fractions, sediments comprised mostly fine-medium particles, with content varying from 6.8–83.9% (fine sands) and 5.4–43.5% (medium sands). Coarse sand content in samples from this area varied from 0.3–26.0%. Sediments were classed as 'Sand' (eight sites), 'muddy Sand' (five sites), and 'muddy sandy Gravel' (two sites).

TOC was low and varied from 0.06% to 0.3% dry weight; TIC varied from 3.6% to 7.8% dry weight.

#### 12.4.2.3 Intertidal Mangrove Sites in the Vicinity of the DomGas Pipeline Mainland Crossing

Surficial sediments collected from intertidal mangrove Reference Sites (Figure 12-4) were dominated by fine sands ranging from 36.5–60.9%. Medium sand contents were low, ranging from 1.1–9.1%, and the coarse sand fractions and gravel fractions were very low (<0.5% and <1%, respectively).

Clay content in these sediments was generally higher than at subtidal Reference sites (see Sections 12.4.2.1 and 12.4.2.2) ranging from 9.8–17.9%, as was the silt content, which ranged from 19.8–42.6%. Sediments collected at three sites (MR2, MR3 and MR4) had a generally consistent composition and were classified as ‘muddy Sand’. The most northern intertidal Reference Site (MR1) had the highest clay (17.9%) and silt (42.6%) content and was classified as ‘sandy Mud’.

TOC was generally slightly higher in these sediments than at the subtidal sites sampled (see Sections 12.4.2.1 and 12.4.2.2), but was still low overall, approximately 0.5% dry weight. TIC varied from 3.4% to 4.5% dry weight, which was generally lower than TIC in sediments collected from subtidal sites.

## 12.5 Discussion and Conclusions

The surficial sediments along the DomGas Pipeline route were characterised by seven sediment classifications: ‘muddy sandy Gravel’, ‘gravelly muddy Sand’, ‘gravelly Sand’, ‘muddy Sand’, ‘Sand’, ‘sandy Gravel’, and ‘sandy Mud’. Most sediments were dominated by sands, with varying levels of clay, silt and gravel depending on their location along the DomGas Pipeline route.

Surficial sediments off the east coast of Barrow Island were variable, but were dominated by sands (Figure 12-2). These sediments also had the highest levels of gravel found along the DomGas Pipeline route, ranging from 0.6–48.7%. Gravel content in sediments decreased further along the DomGas Pipeline route towards the Passage Islands, whilst levels of fine-medium sands increased. Surficial sediments located in the vicinity of the trenching and jetting area between the Passage Islands and the mainland (Figure 12-3) were characterised by fine-medium sands and had higher levels of clay and silt compared to sediments located closer to Barrow Island (Figure 12-2). Sediments from the intertidal mangrove areas along the mainland coast (Figure 12-3) were characterised by high levels of clay, silt, and fine sand, and very low levels of coarse sand and gravel.

The differences between the surficial sediment grain-size distributions are a reflection of the hydrodynamic characteristics along the DomGas Pipeline route. Sediments on the exposed pavement reef off the east coast of Barrow Island had relatively high sand and gravel contents, reflecting strong currents, which transport the finer sediment fractions away from the area (Figure 12-2) (Margvelashvili *et al.* 2006). Similarly, the higher energy areas further along the DomGas Pipeline route were characterised by sediments that were relatively high in gravel and sand fractions, and low in clay, silt and fine sand content.

Sediments in the nearshore, turbid waters adjacent to the mainland were characterised by higher levels of clay, silt and fine sand (Figure 12-3). The large tidal range in this area generates strong tidal currents, which transport sediments back and forth with each tidal cycle (APASA 2010). Therefore, there is limited opportunity for net transport of sediments away from the coast, which effectively means that the finer sediment particles such as clay and silt are confined to the intertidal and estuarine habitats along the mainland (APASA 2010).

Overall, TOC and TIC were low, ranging from 0.1% to 0.8% (median 0.5%), and from 9.6% to 11.1% (median 10.2%) respectively. Sediments from areas closer to the mainland and in the intertidal mangrove area had lower levels of TIC than sediments located between Barrow Island and the Passage Islands.

There was no indication of marked differences in the characteristics of surficial sediments in areas at risk of Material or Serious Environmental Harm, and at Reference Sites not at risk of Material or Serious Environmental Harm.

# 13.0 Water Quality (Turbidity and Light)

## 13.1 Introduction

The prevailing oceanographic processes and water circulation in the region (Section 3.5) influence the transport, dispersal and mixing of sediments, biota and pollutants and, consequently, the quality of the waters of the Montebello/Barrow Islands region (DEC 2007). Nearshore water movement and mixing patterns in the region are primarily driven by strong currents, moderate tidal ranges, and winds, with wave action, seabed topography and the effect of islands and reefs in the area also playing an important role (DEC 2007).

The water quality of the Montebello/Barrow Islands region is generally considered pristine, apart from some areas of localised disturbance (DEC 2007). Sources of localised disturbance include sewage outfalls from the accommodation facilities on Barrow Island and Varanus Island, and discharges from the pearling industry, and recreational and commercial fishing vessels. Water turbidity generally increases towards the south-eastern side of Barrow Island, mainly due to the influence of coastal water discharges that have a high load of fine sediments (DEC 2007).

The nearshore region in the vicinity of the mainland crossing of the Domestic Gas Pipeline is classified as a tide-dominated estuarine environment, consisting of a landward-tapering funnel-shaped valley, including intertidal flats, mangroves, salt marshes and salt flats (APASA 2010). The nearshore region is regularly dissected by muddy tidal creeks with highly turbid water (Chevron Australia 2005). Such areas are highly turbid due to the large tidal range inducing strong turbulence that resuspends sediments; these sediments are effectively trapped within the estuary, moving back and forth with each tidal cycle without being able to move away from the coast (APASA 2010). Surveys near the Domestic Gas Pipeline mainland shore crossing recorded levels of suspended sediments in the near-bottom waters ranging from 20 mg/L to 100 mg/L and surface levels ranging from 5 mg/L to 30 mg/L (APASA 2009). Suspended sediment concentrations (SSC) in the nearshore regions adjacent to the mainland are considered approximately one or two orders of magnitude greater than the ambient levels characteristic of the offshore marine environment surrounding Barrow Island.

## 13.2 Scope

This Section describes the water quality, including measures of turbidity and light attenuation:

- that is at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.vii, Statement No. 800; Condition 11.6.VII, EPBC Reference: 2003/1294 and 2008/4178)
- of Reference Sites that are not at risk of Material or Serious Environmental Harm due to construction or operation of the Domestic Gas Pipeline (Condition 14.6.viii, Statement No. 800; Condition 11.6.VIII, EPBC Reference: 2003/1294 and 2008/4178).

Baseline surveys have been undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800 and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178.

Note that turbidity (measured as Nephelometric Turbidity Units [NTU]) was used in the Marine Baseline Program as a surrogate for concentrations of Total Suspended Solids (TSS). While TSS is of more relevance to coral health and survival, it is not practicable to measure TSS continuously in situ. There is no universal relationship between turbidity and suspended solids, as TSS depends on the total weight of particles in suspension and is a direct function of the number, sizes and specific gravities of the particles, while turbidity is a direct function of the number, surface areas and refractive indices of the particles, but is an inverse function of their size (Thackston and Palermo 2000). Turbidity can be only used to estimate suspended solids concentrations if site-specific algorithms are developed based on field data.

The small-scale changes in turbidity and light attenuation recorded by the Light-Turbidity-Deposition (LTD) loggers as part of the Marine Baseline Program for the east coast Barrow Island Marine Facilities, and subsequently throughout the Dredge Monitoring Program (Chevron Australia 2011, 2012, 2013a) were specifically relevant to monitoring the potential impacts associated with dredging and spoil disposal program on the coral communities off the east coast of Barrow Island. The predominantly unvegetated open sand benthic habitat within the area at risk of Material or Serious Environmental Harm, and the short-term (scheduled to occur over three months) duration of the turbidity generating activities associated with the construction of the Domestic Gas Pipeline at the mainland shore crossing (Section 2.3.2.2), does not warrant semi-continuous water quality monitoring over a prolonged period. Therefore, a synoptic approach was adopted for the mainland Domestic Gas Pipeline baseline water quality surveys, and this is considered appropriate for a tidal dominated estuarine environment where the focus should be on techniques suitable to capturing changes in turbidity and light attenuation over a broad spatial scale. The synoptic approach involved undertaking sampling at sites over a wide spatial area, once in the dry season (October 2010) and once in the wet season (April 2011), and capturing both spring and neap, and ebb and flood tide conditions within each season. By capturing both the tidal cycle and seasonal variation over one full annual cycle, this approach is considered appropriate to capture the range of water quality in the region. Results of modelling in the area (e.g. APASA 2010) support this synoptic approach with variability in TSS recorded over spatial (e.g. distance offshore) gradients over temporal scales (e.g. tidal cycles). Deployment of loggers in the naturally turbid nearshore waters of the Domestic Gas Pipeline mainland shore crossing was also not a practical option due to the very rapid biofouling of the instruments that would occur under such conditions. Baseline surveys were undertaken using methodologies consistent with those described in the approved Coastal and Marine Baseline State and Environmental Impact Report Scope of Works (RPS 2009) developed to meet the requirements of Condition 14.1, Statement No. 800, Condition 12.1, Statement No. 769, and Condition 11.1, EPBC Reference: 2003/1294 and 2008/4178.

## 13.3 Methods

### 13.3.1 Site Locations: East Coast of Barrow Island

#### 13.3.1.1 LTD Loggers and Water Column Profiles

As part of the Marine Baseline Program for the Gorgon Project, Light-Turbidity-Deposition (LTD) loggers were deployed at 16 sites in the waters surrounding Barrow Island to provide a semi-continuous record of temporal changes in water quality and light climate at the seabed (Figure 13-1) (Chevron Australia 2013a). Five of these sites are in the vicinity of the DomGas Pipeline route, but outside the DomGas Pipeline Marine Disturbance Footprint, and the data from these loggers are presented in this Report (Table 13-1; Figure 13-1). One of the sites (MOF1) was located within the Zone of Moderate Impact and two of the sites (MOF2 and MOF3) were located within the Zone of Influence, associated with the generation of turbidity and sediment deposition from dredging and spoil disposal activities on the east coast of Barrow Island (Section 2.3.4). Two of the sites (LNG3 and DUG) are Reference Sites, which are not at risk of Material or Serious Environmental due to construction or operation of the Marine Facilities. For information on other water quality sites on the east coast of Barrow Island refer to Chevron Australia (2013a). Water column profiles were also collected at each of the LTD Logger sites.

**Table 13-1 LTD Logger and Water Quality Profile Sites in Waters off the East Coast of Barrow Island**

| Site Code | Easting | Northing | Latitude | Longitude | Depth (m) |
|---|---|---|---|---|---|
| | (GDA94, MGA Zone 50) | | (GDA94) | | |

| Site Code | Easting | Northing | Latitude | Longitude | Depth (m) |
|---|---|---|---|---|---|
| | (GDA94, MGA Zone 50) | | (GDA94) | | |
| MOF1 | 342089 | 7698785 | 20° 48.249' S | 115° 28.961' E | 6.0 |
| MOF2 | 341709 | 7697690 | 20° 48.840' S | 115° 28.736' E | 5.8 |
| MOF3 | 341412 | 7696411 | 20° 49.532' S | 115° 28.558' E | 5.5 |
| LNG3 | 343157 | 7692657 | 20° 51.575' S | 115° 29.544' E | 6.5 |
| DUG | 340102 | 7687962 | 20° 54.104' S | 115° 27.757' E | 6.3 |

#### 13.3.1.2 Terrestrial Light Logger

To measure the irradiance incident at the sea surface, a Licor LI-192 2π light sensor attached to a Licor LI-1400 data logger (the ‘terrestrial light logger’) (Plate 13-1) was installed on the east coast of Barrow Island adjacent to the camp facilities (338251E, 7696175N), remote from any source of non-atmospheric shading. The sensor was subsequently relocated to the Terminal Tanks Facility near Town Point (339974E, 7701581N) (Figure 13-1). The 2π sensor only records downward irradiance, thus avoiding any potential errors as a result of light being reflected upwards from surfaces below the sensor (e.g. the ground). The sensor provided a measure of the incident Photosynthetically Active Radiation (PAR) reaching the sea surface and enabled the calculation of Light Attenuation Coefficients (LAC) at each site using the terrestrial light sensor and the subsurface LTD loggers.

**Plate 13-1 Terrestrial Light Sensor and Data Logger Deployed during the Marine Baseline Program for the MOF and LNG Jetty**

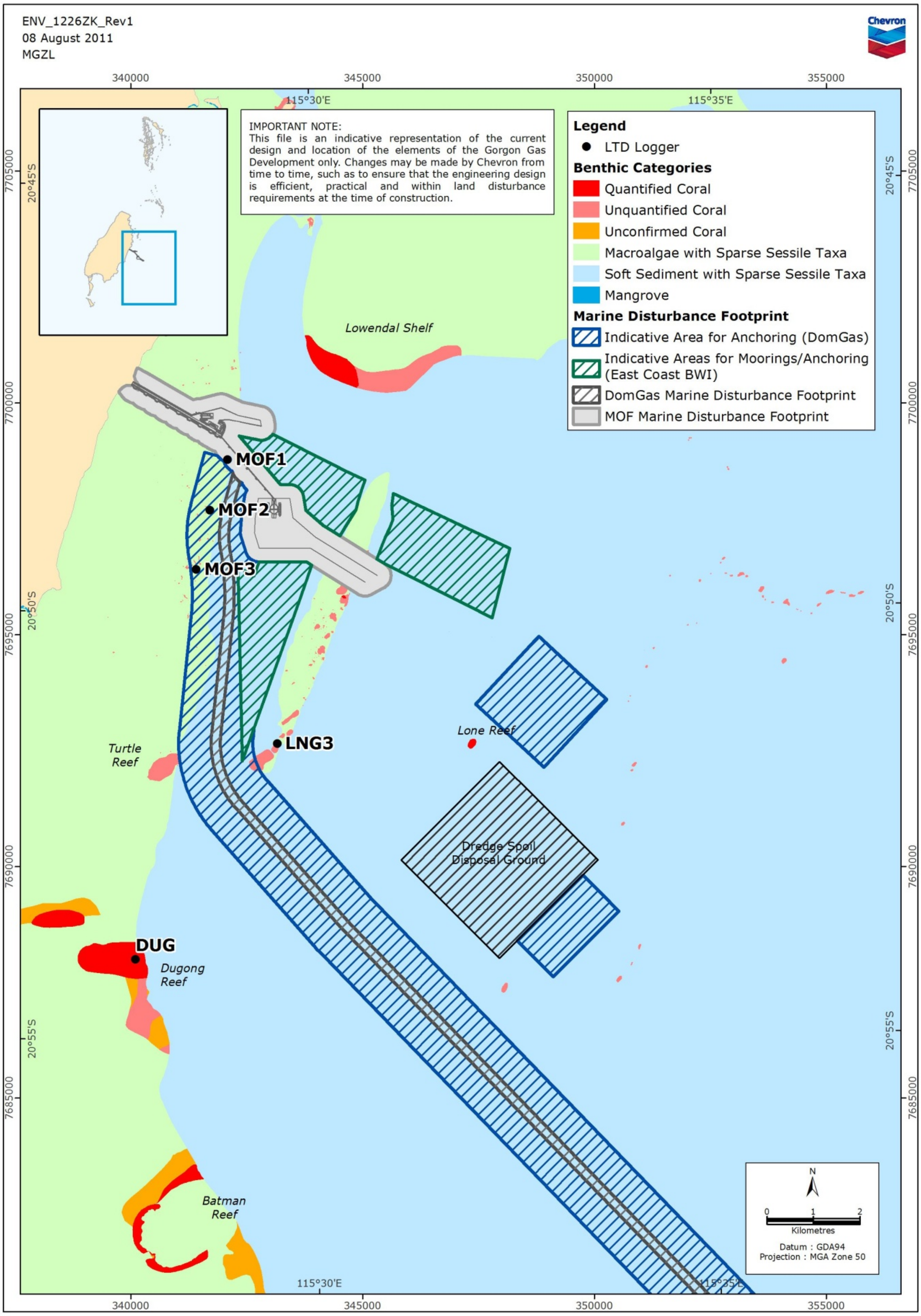



**Figure 13-1 LTD Logger Sites off the East Coast of Barrow Island**

### 13.3.2 Site Locations: Mainland End of the Domestic Gas Pipeline Route

Twenty-five sites were surveyed – five sites along each of five transects (Table 13-2; Figure 13-2). The most northern and southern transects are Reference Transects (i.e. Reference Sites) (Figure 13-2), located outside the trenching and jetting Marine Disturbance Footprint, and are not at risk of Material or Serious Environmental Harm due to construction or operation of the DomGas Pipeline (Section 2.3.3.2). The three inner transects are within the trenching and jetting Marine Disturbance Footprint, and represent sites at risk of Material or Serious Environmental Harm due to construction or operation of the DomGas Pipeline. The centre transect (Transect 3) follows the DomGas Pipeline route (Figure 13-2).

**Table 13-2 Water Quality Sampling Sites at the Mainland End of the DomGas Pipeline Route**

| Transect | Site | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|---|
| | | (GDA94, MGA Zone 50) | | (GDA94) | |
| **Transects (and Sites) in areas at risk of Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline** | | | | | |
| 2 | WQ6 | 375447 | 7655035 | 21° 12.115' S | 115° 48.000' E |
| | WQ7 | 373829 | 7656210 | 21° 11.471' S | 115° 47.070' E |
| | WQ8 | 372210 | 7657385 | 21° 10.827' S | 115° 46.140' E |
| | WQ9 | 370592 | 7658560 | 21° 10.183' S | 115° 45.210' E |
| | WQ10 | 368974 | 7659735 | 21° 9.540' S | 115° 44.280' E |
| 3 | WQ11 | 377788 | 7658254 | 21° 10.379' S | 115° 49.367' E |
| | WQ12 | 376173 | 7659433 | 21° 9.734' S | 115° 48.439' E |
| | WQ13 | 374557 | 7660612 | 21° 9.088' S | 115° 47.510' E |
| | WQ14 | 372942 | 7661791 | 21° 8.442' S | 115° 46.582' E |
| | WQ15 | 371326 | 7662970 | 21° 7.796' S | 115° 45.654' E |
| 4 | WQ16 | 380156 | 7661486 | 21° 8.637' S | 115° 50.749' E |
| | WQ17 | 378539 | 7662664 | 21° 7.992' S | 115° 49.820' E |
| | WQ18 | 376923 | 7663842 | 21° 7.347' S | 115° 48.891' E |
| | WQ19 | 375306 | 7665019 | 21° 6.702' S | 115° 47.962' E |
| | WQ20 | 373690 | 7666197 | 21° 6.057' S | 115° 47.034' E |
| **Reference Transects (and Sites) not at risk of Material or Serious Environmental Harm due to the construction or operation of the DomGas Pipeline** | | | | | |
| 1 | WQ1 | 371885 | 7650155 | 21° 14.744' S | 115° 45.919' E |
| | WQ2 | 370273 | 7651338 | 21° 14.096' S | 115° 44.993' E |
| | WQ3 | 368661 | 7652522 | 21° 13.448' S | 115° 44.066' E |
| | WQ4 | 367049 | 7653705 | 21° 12.800' S | 115° 43.140' E |
| | WQ5 | 365436 | 7654889 | 21° 12.151' S | 115° 42.213' E |
| 5 | WQ21 | 383681 | 7666316 | 21° 6.032' S | 115° 52.805' E |
| | WQ22 | 382067 | 7667498 | 21° 5.385' S | 115° 51.878' E |
| | WQ23 | 380454 | 7668680 | 21° 4.739' S | 115° 50.951' E |
| | WQ24 | 378840 | 7669862 | 21° 4.092' S | 115° 50.024' E |
| | WQ25 | 377227 | 7671044 | 21° 3.445' S | 115° 49.097' E |

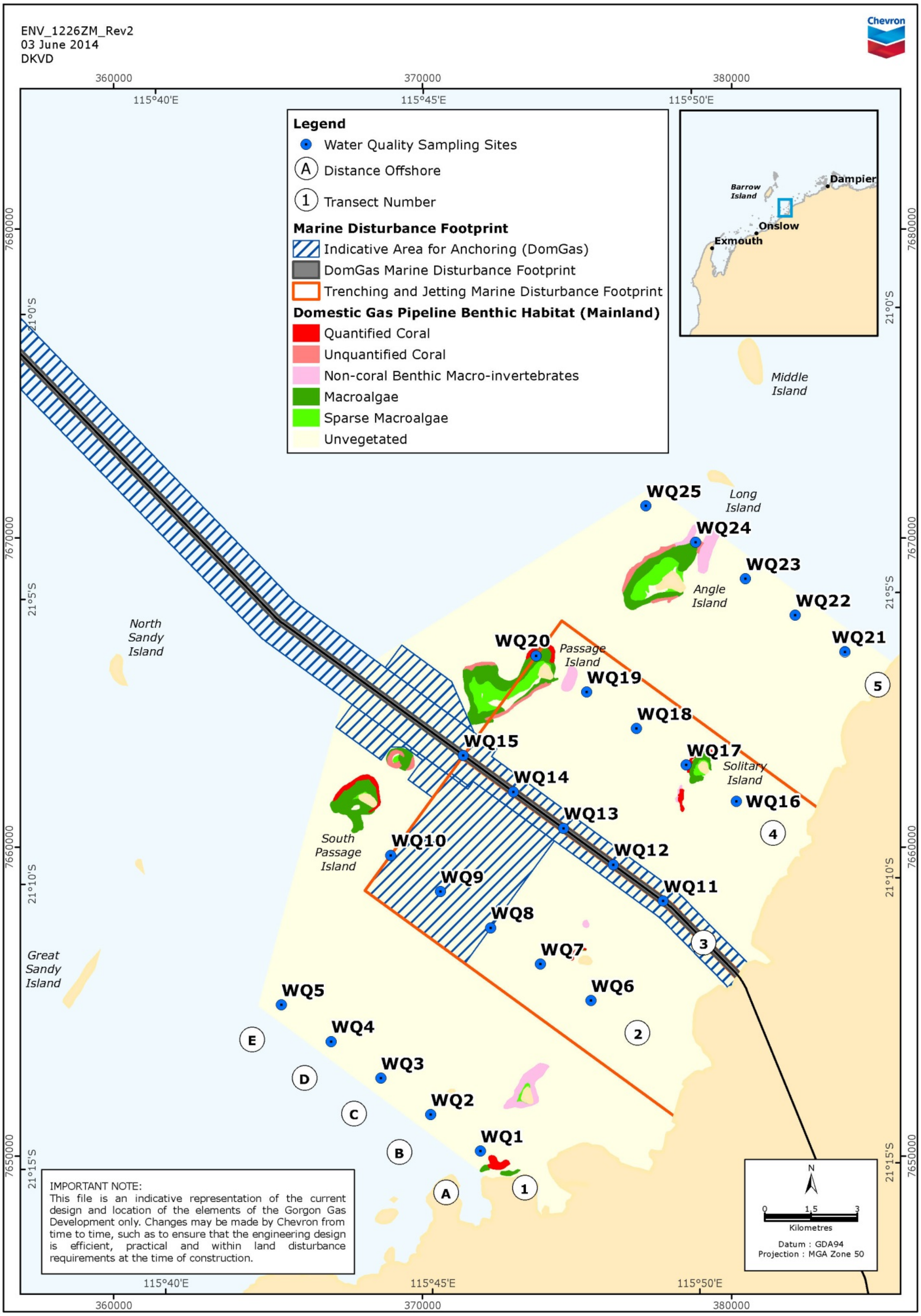



**Figure 13-2 Water Quality Sampling Sites at the Mainland End of the DomGas Pipeline Route**

### 13.3.3 Methods

#### 13.3.3.1 East Coast of Barrow Island

##### 13.3.3.1.1 Meteorological Data

Meteorological data recorded at the weather station on Barrow Island (Station ID 005094) were obtained from the Bureau of Meteorology. The weather station is situated at the Barrow Island airport (334210E, 7691864N), located approximately one kilometre from the east coast. Meteorological data recorded for the period November 2007 to May 2010 included:

- wind speed
- wind direction
- maximum wind gusts
- air temperature
- rainfall.

##### 13.3.3.1.2 LTD loggers

Simultaneous measurements of sediment deposition, turbidity and light (Photosynthetically Active Radiation [PAR]) at the seabed, as well as pressure, were recorded by the LTD loggers deployed at each site.[28] Each sensor was mounted in a common housing and the entire unit attached to a steel frame during deployment, such that the sensors were positioned approximately 40 cm from the seabed (Plate 13-2). The external surface of each sensor was automatically wiped clean every two hours by an automated wiper assembly to allow longer deployment periods where biofouling would affect the readings. The data were logged to an internal hard drive and downloaded during routine maintenance visits.

Turbidity was recorded using a sideways-oriented Optical Backscatter Sensor (OBS, also known as a nephelometer). Sediment deposition was measured using an upward-oriented OBS. The OBS response increases as particles accumulate on the sensor and the output is related to the amount of accumulated sediment. The difference in reading before and after wiping gives a measure of the mass of sediment deposited per unit area. The sediments that deposit on the sensor are subject to resuspension by hydrodynamic forces and the accumulation of sediments is not considered to be significantly biased by the design of the sensor and housing. If there is no deposition, the upward-oriented sensor records a value similar to the sideways-oriented turbidity sensor, as it is effectively the same sensor. Thus, the difference between the two sensors gives an indication of the quantity of material that has accumulated on the deposition sensor (Thomas and Ridd 2005). Light was recorded through an upward-oriented, 2π quantum sensor (Plate 13-2). Pressure was measured using an absolute pressure sensor, which is calibrated to give depth in metres. Ten readings were taken sequentially and used to calculate Root Mean Square water depth which gives an indication of wave height.

Site-specific correlation curves between TSS and turbidity have been derived for each site through laboratory measurements of the instrument response to water containing known (measured) concentrations of sediment collected from each site (refer Section 13.3.4.3 and Appendix 10 of Chevron Australia 2013a). To compare actual TSS concentrations and corresponding SSC estimates from the LTD loggers, water samples were collected at 12 monitoring sites on two occasions for the measurement of actual TSS concentrations. The measurements of TSS and the corresponding (daily median) estimated SSC values from the LTD loggers are presented in Section 13.3.4.3 of Chevron Australia (2013a).

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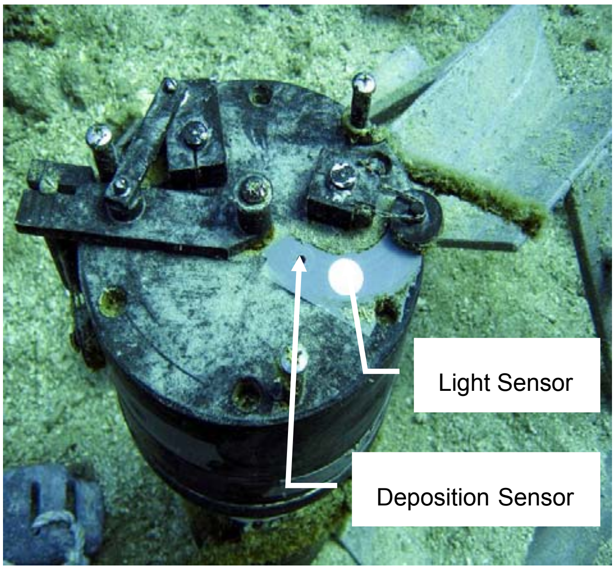
[28] The LTD loggers were developed by Professor Peter Ridd and colleagues at James Cook University, Queensland. Similar loggers have been used in other dredging programs in Western Australia (Pluto LNG, Woodside; Cape Lambert 85 MTPA Port Upgrade, Pilbara Iron).

LTD Logger




LTD Logger Showing Cleaned Light and Deposition Sensors

**Plate 13-2 LTD Loggers Deployed During the Marine Baseline Program**

#### 13.3.3.1.3 Water Column Profiles

A Seabird Electronics SBE19 SEACAT Profiler was deployed to provide in situ information on the physical-chemical characteristics of the water column at each water quality monitoring site. The SEACAT Profiler, a high-precision Conductivity-Temperature-Depth (CTD) meter with auxiliary sensors, measured conductivity, temperature, depth, dissolved oxygen (DO), pH, turbidity and Photosynthetically Active Radiation (PAR) at 0.5 second intervals. This information supplemented the semi-continuous measures at the seabed provided by the LTD loggers. Note that the SEACAT Profiler uses a different turbidity sensor to that used by the LTD loggers; thus the turbidity data from the SEACAT Profiler are not comparable with the LTD logger data.

#### 13.3.3.1.4 Light Attenuation

A daily Light Attenuation Coefficient (LAC) was calculated for each site using data from the terrestrial light logger on Barrow Island (Section 13.3.1.2) and the underwater light sensors (LTD loggers) deployed on the seabed at each site (Section 13.3.1.1). The data from the terrestrial light logger were used to represent the average incident light falling on the sea surface at each site for each time period. Details of a Pilot Study undertaken to assess the validity of this approach to the measurement of light attenuation in the waters around Barrow Island compared to the measurement of light attenuation using two in-water sensors (e.g. EPA 2005) are presented in Appendix 9 of Chevron Australia (2013a). In summary, this study demonstrated a significant, strong positive correlation between the results from both methods, indicating that the variation in light attenuation is adequately captured by the above-water to in-water method and that the results are comparable to the measurement of light attenuation using two in-water sensors.

The daily mean surface irradiance value was derived by averaging all measurements from the terrestrial light logger for the midday period (10:00–14:00 Australian Western Standard Time [WST]). Values outside this period may be subject to a continuum of variation associated with the angle of incidence of the sun, which changes incrementally (cyclically) due to the earth's orbit. Similarly, the daily mean irradiance at the seabed at each site was calculated by averaging all measurements recorded by the LTD loggers for the midday period.

An approximate measure of the amount of light penetrating the sea surface at each site was derived by applying a correction factor of 0.96 to account for the reflection of light at the air–water interface (Kirk 1994; Cooper *et al.* 2008). The LTD loggers also recorded water depth each time a light measurement was made. To account for fluctuating water height and effective vertical separation distance between the two observation points, an average depth for the midday period was calculated from the pressure data recorded by each LTD logger.

The light attenuation path (i.e. the distance that a beam of light travels from the air–water interface to the seabed sensor) is a function of the water depth and the angle of incidence of the incoming light due to the solar zenith angle.[29] To enable comparison of the LAC values throughout the year, the LAC values were normalised to account for the solar zenith angle.

The daily LAC for each site was calculated according to the following equation:

$$\text{LAC} = \frac{(\text{Log}_e \text{ average light at seabed} - \text{Log}_e \text{ average light at surface})}{\text{average water depth}}$$

This daily value was then normalised to account for changes in solar zenith angle (Mobley 1994). The following equation was used to calculate the underwater solar zenith angle:

$$S_{ZAUW} = \arcsin(\sin S_{ZA}/1.34)$$

where $S_{ZA}$ is the above-water solar zenith angle; 1.34 is the refractive index of water; and $S_{ZAUW}$ is the underwater solar zenith angle. The above-water solar zenith angle for Barrow Island was sourced from a solar elevation calculator (Geoscience Australia 2009).

The LAC was then normalised by applying the following equation:

$$LAC_n = LAC_m.\cos(S_{ZAUW})$$

where $LAC_n$ is the normalised LAC; $LAC_m$ is the measured LAC; and $S_{ZAUW}$ is the underwater solar zenith angle.

### 13.3.3.2 Mainland End of DomGas Pipeline Route

#### 13.3.3.2.1 Light Attenuation

PAR was measured using two 2π quantum light sensors. Where water depth was >2 m, the two separate light sensors were simultaneously deployed, measuring PAR at least 2 m (vertical distance) apart. Where water depth was <2 m, one light sensor was lowered through the water column, recording data at 0.1–0.2 m depth intervals. At the start and end of each sampling day, two ‘in-air’ light readings were obtained from each sensor.

The light attenuation coefficients (LAC) were calculated from PAR (measured as µmol/m$^2$/s) using the following formula:

$$\text{LAC} = \frac{[\log_{10}(\text{Irradiance at Depth}) - \log_{10}(\text{Irradiance at Surface})]}{\text{Depth interval (in metres)}}$$

Light was measured between 8 am and 5 pm. While light attenuation is best measured between 10 am and 2 pm, sampling during the baseline surveys needed to be undertaken outside these hours to collect all of the required data. As there was ample sunlight between the hours of 8 am and 5 pm, as well as very little shadow on site (i.e. from land or other features), this was considered to be acceptable. The key requirement for reliable light attenuation

[29] The midday solar zenith angle changes incrementally each day, following a cyclical (annual) pattern due to the tilt of the earth’s rotational axis with respect to its orbital plane. This cyclical change in zenith angle results in a longer light attenuation path for a given water depth when the sun is lower in the sky (e.g. during winter), than when the sun is higher in the sky.

measurements is sufficient light to penetrate the water column in a measureable amount and with minimum variation. The 'in-air' light readings assisted in determining whether sufficient and consistent light was available to carry out the measurements.

##### 13.3.3.2.2 Secchi Depth

Secchi depth was measured by lowering a 20 cm Secchi disc through the water column, on the sunny side of the survey vessel, until the black and white quadrants could no longer be differentiated. To reduce observer error, Secchi depths were measured by the same observer, where practicable.

##### 13.3.3.2.3 Water Column Profiles

Turbidity was measured, along with depth, salinity and temperature, using a multi-parameter water quality sensor (YSI 6600 multi-parameter probe). The probe was lowered through the water column, collecting a 'profile' at no greater than 0.5 m intervals.

##### 13.3.3.2.4 Total Suspended Solids

Water samples were collected at 0.5 m below the surface (near-surface) and 0.5 m above the bottom (near-bottom) of the water column using a Niskin bottle. A sample of water (volume dependent on water clarity) was then filtered through pre-dried and weighed 0.8–1.2 µm filter papers for subsequent TSS analysis. Following sample filtration, the filter papers were rinsed with deionised water to flush off salt residues, folded and wrapped in dry filter paper, stored in a labelled envelope and frozen. Samples were analysed for TSS by the Marine and Freshwater Research Laboratory (MARFL).

### 13.3.4 Timing and Frequency of Surveys

#### 13.3.4.1 East Coast of Barrow Island

##### 13.3.4.1.1 LTD Loggers

The LTD loggers at MOF1, MOF3, LNG3 and DUG were deployed during December 2007, and at MOF2 during April 2008 (Table 13-3). Data collection is ongoing at all sites except MOF2.

**Table 13-3 Deployment Dates of LTD Loggers and Number of Days of Data Collection**

| Site Code | Deployment Date | Demobilisation Date | No. of Data Days*[30] |
|---|---|---|---|
| MOF1 | 6/12/2007 | Ongoing | 612 |
| MOF2 | 2/04/2008 | 12/10/2009 | 456 |
| MOF3 | 6/12/2007 | Ongoing | 694 |
| LNG3 | 5/12/2007 | Ongoing | 628 |
| DUG | 4/12/2007 | Ongoing | 681 |

** From deployment to mid-March 2010.*

The LTD loggers measure light, turbidity and deposition in a burst of samples over a one-second (1 s) period, with depth measurements taken over a period of 10 s (10 bursts of samples). The average of each burst is logged to the internal memory as a single data point (see Thomas and Ridd 2005).

Due to rapid biofouling, all subsurface equipment was serviced at a maximum interval of eight weeks. During these times, the LTD loggers were removed from the seabed, the data

[30] A 'data day' is considered to be any day where data were collected from at least one of the four sensors on the LTD logger. The number of data days reported was the maximum number of days of data recorded by any one of the individual sensors at a site. This underestimates the total number of data days as it is likely that data would have been recorded by other sensors on at least some of the days.

downloaded, checked and visually verified, batteries replaced as required, and the sensors cleaned and anti-fouled as necessary. The wiper arm design was modified early in the Marine Baseline Program following damage to the wiper assemblies from fish interference and the consequent deterioration of data recovery and data quality. Despite this, ongoing fish interference has resulted in deterioration of data recovery throughout the Marine Baseline Program, including periods of complete data loss. LTD logger malfunctions were less common, but resulted in periods of data loss on occasion. Overall, data recovery rates from the LTD loggers were ~80% among all sites and parameters measured.

##### 13.3.4.1.2 Water Column Profiles

Between two and ten profile measurements were obtained over the period January 2008–November 2009 (Table 13-4) at each water quality monitoring site using a SEACAT Profiler. Note that as the field surveys were generally scheduled around neap tides, the profiles are mostly representative of the water column during periods of lower tidal flow; therefore, they may not be representative of conditions during periods of greater tidal flow. In addition, profiles were only undertaken during periods when wind speeds were <15 knots and thus do not represent the conditions that may occur during periods of rough weather.

**Table 13-4 Timing of Water Column Profiles**

| Date | Jan 08 | Mar 08 | May 08 | Jun 08 | Jul 08 | Sep 08 | Oct 08 | Nov 08 | Jun 09 | Jul 09 | Aug 09 | Sep 09 | Oct 09 | Nov 09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MOF1 | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | | | ✓ | ✓ |
| MOF2 | | | | | | ✓ | | | | | | ✓ | | |
| MOF3 | ✓ | ✓ | | | | ✓ | ✓ | | ✓ | ✓ | | ✓ | | ✓ |
| LNG3 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | | |
| DUG | ✓ | ✓ | ✓ | | | ✓ | | ✓ | | ✓ | | ✓ | | |

##### 13.3.4.1.3 Terrestrial Light Logger

The terrestrial light logger was installed on 9 September 2008 and relocated on 8 March 2009.[31] The sensor measures the incident irradiance in a burst of samples taken once every minute and averages the readings over 15-minute logging intervals. For the purposes of the Marine Baseline Program, only the data recorded during the midday period were used to calculate the LACs (see Section 13.3.3.1.4).

#### 13.3.4.2 Mainland End of DomGas Pipeline Route

The water quality surveys were carried out on the following dates:

- Dry season:
  - neap tide survey: 3–5 October 2010
  - spring tide survey: 12–13 October 2010.
- Wet season:
  - spring tide survey: 7–9 April 2011
  - neap tide survey: 12–15 April 2011.

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31 The terrestrial light logger was relocated in March 2009 because the original location was cleared for construction activities.

Note that sampling was logistically restricted during periods when wind speeds were >15 knots and thus does not represent the conditions that may occur during periods of rough weather. Neap tide surveys were completed on an ebb tide, and spring tide surveys were completed on a flood tide. For comparative purposes, two transects were re-sampled on the opposing tidal cycles during the October 2010 dry season spring tide survey and the April 2011 wet season neap and spring tide surveys. Sampling for all transects during a season were split over two to four days, with transects consistently sampled from inshore to offshore (e.g. for Reference Transect 1, from WQ1 to WQ5) and whole transects were completed on the same sampling day.

A partial wet season water quality survey was also completed during February 2011 (spring tide surveys: 5–8 February 2011; neap tide surveys: 14 February 2011). Due to weather conditions and logistical constraints, the survey was not completed; however, the data collected provides information on post-cyclonic[32] water quality conditions. Light attenuation, Secchi depth, TSS and turbidity data are summarised in Section 13.4.5. No statistical analyses on the partial February 2011 data were undertaken.

## 13.3.5 Treatment of Survey Data

### 13.3.5.1 East Coast of Barrow Island

#### 13.3.5.1.1 Meteorological Data

The meteorological data were visually checked for consistency and any incomplete or erroneous data records removed.

#### 13.3.5.1.2 LTD Loggers

On completion of each LTD logger in-water maintenance visit, the raw data downloaded from the LTD loggers were forwarded to James Cook University for conversion, analysis and preliminary interpretation. The instrument output readings were visually checked for accuracy and erroneous data (including those associated with periods of instrument malfunction that required recalibration and those suspected to be influenced by fouling of the sensors whilst in service) were removed. The LTD loggers were rotated through the monitoring sites such that any variability (and thus bias) was distributed amongst the sites. The data were converted and calibrated to units of measurement using site-specific algorithms to provide values of Suspended Sediment Concentrations (SSC) in mg/L (which is equivalent to Total Suspended Solids [TSS]), Accumulated Sediment Surface Density (ASSD) in mg/cm$^2$ and light (µE/m$^2$/s). Refer to Appendix 10 in Chevron Australia (2013a) for more detailed information.

All light measurements were coded according to whether the measurement fell within the midday period (Section 13.3.3.1.4). The use of midday period light was also supported by statistically significant autocorrelation results that showed a consistent cyclical pattern of light during midday periods (Chevron Australia 2013a). Absent and zero values were excluded from the data on the basis that zero light during the day was extremely unlikely at the depths of the loggers and instead reflected missed data recordings by the logger. The daily median light values for the midday period were calculated using SYSTAT v12 (Cranes Software International Pty. Ltd.) and a time-series plot and summary statistics were generated for each season.

Using similar techniques, distributions of daily median turbidity and SSC values were calculated for each season. In contrast to the light values, measurements were not excluded based on the time of day. Null and zero turbidity and SSC values were considered erroneous and excluded from the analysis as it was unlikely that the waters surrounding Barrow Island would ever be as clear as pure sea water (the zero reading).

Examination of the raw ASSD data indicated that patterns of increasing ASSD readings before clearing, generally observed with cumulative deposition and subsequent removal by the wiper

[32] Tropical Cyclone Bianca passed through the region approximately one week prior to the February 2011 wet season survey.

mechanism (Ridd *et al.* 2001), were not evident. Where deposition was detected, the readings were generally short-term (less than two hours). The lack of accumulation and periodic removal by the wiper suggests that the natural hydrodynamic regime of the area was sufficient to remove whatever sediment had deposited on the sensor prior to a wiping event. Because of the difficulty of establishing when a wiping event had occurred and when deposition was removed naturally, the 95$^{th}$ percentile of the calculated hourly deposition rates that occurred each day was selected as an indicative measurement of the maximum potential deposition rate. The 95$^{th}$ percentile was selected rather than the maximum, to remove erroneous data from the calculations that may have been caused by transitory fauna interfering with the sensor. The ASSD values were first divided by two to give an hourly deposition rate (as the measurement period is two hours), then the 95$^{th}$ percentile of the deposition rates was calculated for each day using SYSTAT v12. Time-series plots and summary statistics of the daily values were generated; however, given that the data were considered to be below the limits of accurate quantification[33], the ASSD data are not presented.

The water quality data presented in the Marine Baseline Report are subject to Quality Assurance and Quality Control (QA/QC) procedures that periodically involve some post-recovery amendments to data. These corrections are applied to the data when there is an indication that a calibration error has occurred; however, the correction often cannot be applied until there is sufficient contextual information to identify those data that require correction. Similarly, for data that require a correction through application of more recent calibration equations, the correction cannot be implemented until the LTD logger is recalibrated. Therefore, some (corrected) data may not be issued until some months after the initial reporting. Thus, data presented in this revision of the Marine Baseline Report represent the most reliable data from the information available at the time of analysis.

#### 13.3.5.1.3 Water Column Profiles

Water column profile data collected using the SEACAT Profiler were downloaded and converted into units of measurement using instrument-specific software (SEASOFT-WIN32). The raw data were imported into Microsoft Excel and visually checked to ensure all sensors had operated correctly during each profile.

Erroneous data associated with equilibration periods and any data that showed interference when the instrument was at shallow depths (e.g. depths <60 cm) were removed. Adjustments to pH data were applied as necessary, based on calibrations performed at the conclusion of each field program.

#### 13.3.5.1.4 Terrestrial Light Logger

The terrestrial light logger was regularly downloaded using instrument-specific software which output the data as units of measurement ($\mu E/m^2/s$). The sensor-specific calibration coefficient was input into the data logger, thus no calibration or conversion of raw data was required.

#### 13.3.5.1.5 Correlating LTD Logger Parameters with Meteorological and Oceanographic Variables

Daily measures of the LTD logger parameters (daily median SSC, daily median NTU, daily median Wave Height Index, LAC, and median midday light) were collated. Each data point was classified into two broad periods (‘summer’ and ‘winter’) based on preliminary analysis of data trends, which suggested that turbidity was largely influenced by season and therefore stratification of the data into seasons would produce clearer relationships. The seasonal periods were chosen to align with those used for modelling the extent of sediment plumes

[33] Generally the full range at low range, which is normally used in these types of environments, is around 0–100 NTU. The raw data has a 12-bit resolution, which can give 0.1 NTU resolution between consecutive readings in a time-series. The resolution of differences over longer time periods, or between sites, is more problematic as it is dependent on longer term drifts in the instrument (which is common for all instruments) and is especially problematic at very low turbidity levels (around 1 NTU). It is thus not usually possible to resolve differences of <1 NTU between sites or over long time periods. The accuracy of the reading is considered at best 1 NTU at low values and worse at higher values (1% of 100 NTU) (Prof. James Ridd, James Cook University, pers. comm. May 2009).

generated by the dredging and spoil disposal activities (GEMS 2008), which identified two major wind patterns that occur in the Barrow Island region. The ‘winter period’ was defined as May to October and the ‘summer period’ as November to April (Section 3.3).

A measure of daily tidal water movement was calculated from Bureau of Meteorology tide prediction data by subtracting the lowest daily water height measurement from the highest measurement. Daily measures of average air temperature, rainfall to 09:00 WST, and five measures of wind speed were calculated from the meteorological data. These daily wind measurements were:

- Average of the 30-minute average: In each half-hour sampling interval, the average wind speed for the last 10 minutes of that period is recorded by the Barrow Island weather station. The ‘average of the 30-minute average’ is the average of all half-hourly average wind speeds.
- Maximum of the 30-minute average: The maximum of the half-hourly average wind speeds.
- Average of the 30-minute maximum: In each half-hour sampling interval, the maximum wind speed (sustained gust) measured in that period is recorded by the Barrow Island weather station. The ‘average of the 30-minute maximum’ is the average of the half-hourly maximum wind speeds.
- Median of 30-minute maximum: The daily median of the half-hourly maximum wind speeds.
- Maximum of the 30-minute maximum: The maximum of the half-hourly maximum wind speeds.

To reduce the number of variables of interest, the relationships between all LTD logger parameters and meteorological measurements were first investigated in detail at two sites (Ant Point Reef and Ah Chong) using the program R (Ihaka and Gentleman 1996; Chevron Australia 2013a). Scatter plots with trend lines, Pearson’s $R^2$ values and levels of significance (*p*-values) were created for all pair-wise combinations of variables at these two sites. Visual inspection of the scatter plots and correlations allowed the identification of those relationships of most interest. Variables were eliminated if clear relationships were not evident (e.g. rainfall and SSC) or if more suitable measures of a variable were available (e.g. the daily median of 30-minute maximum wind reading was used instead of the other wind measurements as it had a strong relationship with SSC and reduced the impact of outlier measures).

The refined set of variables of interest was:

- Daily median of daily 30-minute maximum wind: The median of the half-hourly maximum wind speeds recorded on that day.
- Daily maximum tidal movement: The difference in water height between the predicted lowest low tide and the highest high tide on that day.
- Daily median SSC: The median of the SSC measurements recorded on that day.
- Daily median NTU: The median of the NTU measurements recorded on that day.
- LAC.
- Daily median of midday light: The median of the light measurements recorded between 10:00 and 14:00 WST.
- Daily median Wave Height Index: The median of the Wave Height Index (Root Mean Square water depth) measurements recorded for that day.

A matrix of scatter plots with trend lines, Pearson’s $R^2$ values and levels of significance was produced for the refined set of variables of interest. The corresponding scatter plots and correlations for any pair of variables are shown at the intersection of the respective rows and columns for each variable (Appendix 4). This matrix was used to assess the type, strength and ubiquity of relationships between variables.

### 13.3.5.2 Mainland End of DomGas Pipeline Route

#### 13.3.5.2.1 Water Column Profiles

Water quality profile data (turbidity, temperature and salinity) were processed and plotted across each transect as a contour plot using Matlab® software. The Matlab script interpolates the data over the depth of the profile and uses a plotting function that interpolates between the profiles to create the plot.

#### 13.3.5.2.2 Statistical Analysis: Analysis of Variance (ANOVA)

Only the full October 2010 and April 2011 datasets were used for statistical analysis. The transects were labelled 1 to 5 (as per Table 13-2), and the grouping of sites based on distance offshore were defined as A, B, C, D and E (Figure 13-2). Separate univariate analyses determined the effects of these factors: ‘Distance’ (distance offshore), ‘Transect’, ‘Area’ (at risk of Material or Serious Environmental Harm, Reference Transects not at risk of Material or Serious Environmental Harm), ‘Depth’ (surface, bottom), ‘Tide’, and ‘Day’. Analyses were run using Euclidian distance with the number of permutations set at n=9999.

Statistical analysis was undertaken using permutational multivariate analysis of variance (PERMANOVA; Anderson 2001, 2001a). PERMANOVA was used to test hypotheses related to the effect of individual factors; i.e. the extent of differences between factors (e.g. ‘Transects’), or the extent to which the factors interact. Interactions occur when differences exist between factors (e.g. ‘Transects’), but the differences in one factor are restricted to levels of another factor (e.g. ‘Depth’). Where differences between main effects or interactions were detected, *post hoc* pair-wise comparisons determined the source of the differences. Where there were insufficient data for ANOVA (i.e. less than three levels in a 1-factor design), hypothesis testing was undertaken using Student's t-tests.

##### *13.3.5.2.2.1 Light Attenuation and Secchi Depth*

Light attenuation and Secchi depth were analysed using 1-factor PERMANOVA to test for differences between distance offshore (factor: ‘Distance’) and transect (factor: ‘Transect’). A 2-factor PERMANOVA tested for differences between Reference Transects and transects at risk of Material or Serious Environmental Harm (factors: ‘Area’ × ‘Distance’). Comparisons used neap tide data (collected on an ebb tide) and spring tide data (collected on a flood tide). Neap and spring tide data, and dry season and wet season data, were analysed separately.

During both the dry and wet seasons, as data were collected over both a spring ebb and spring flood tide for two transects (Transect 3 and Transect 5), the extent to which ebb and flood tides differed was determined using 2-factor PERMANOVA (factors: ‘Tide’ × ‘Transect’).

At some sites, the depth of water was equal to the Secchi depth. For statistical comparisons, data where water depth was equal to Secchi depth were excluded from analyses. The decision to exclude these data meant there were not enough Transect 3 data (during the wet season) for analysis using 2-factor PERMANOVA (factors: ‘Tide’ × ‘Transect’). The extent to which Secchi depth differed between neap ebb and flood tides was therefore determined with a Student's t-test.

Duplication of the data over a four-day period during the wet season survey also allows the comparison of day-to-day differences in water quality during neap tides. These analyses were restricted to comparisons based on replication of Transect 3 (12 and 15 April 2011). For light attenuation and Secchi depth, Student's t-tests were used.

##### *13.3.5.2.2.2 Turbidity and TSS*

Turbidity and TSS were analysed using separate 2-factor PERMANOVA to test for differences between distance offshore and depth (factors: ‘Distance’ × ‘Depth’) and differences between transect and depth (factors: ‘Transect’ × ‘Depth’). A 3-factor PERMANOVA tested for differences between Reference Transects and transects at risk of Material or Serious

Environmental Harm (factors: 'Area' × 'Distance' × 'Depth'). Comparisons used neap tide data (collected on an ebb tide) and spring tide data (collected on a flood tide). Neap and spring tide data, and dry and wet season data were analysed separately.

During the dry season survey, as data was collected over both a spring ebb and spring flood tide for two transects (Transect 3 and Transect 5), the extent to which ebb and flood tides differed was determined using 3-factor PERMANOVA (factors: 'Tide' × 'Transect' × 'Depth').

Duplication of the data over a four-day period during the wet season survey also allows the comparison of day-to-day differences in water quality during neap tides. These analyses were restricted to comparisons based on replication of Transect 3 (12 and 15 April 2011). For TSS and turbidity, for which samples were collected from near-surface and near-bottom, 2-factor PERMANOVA was used.

*13.3.5.2.2.3 ANOVA limitations*

Light attenuation, Secchi depth, turbidity and TSS data provide an indication of wet and dry season conditions, based on data collected over a two- to four-day period.[34] The scale of the program resulted in some limitations for ANOVA analyses, particularly the interpretation of the results for 'Transect' and 'Area'. The levels for these factors (Transects 1 to 5 in the case of the factor 'Transect' and Reference Transects 1 and 5 vs Transect 2, 3 and 4 in the case of the factor 'Area') were sampled on different dates and times, thus concentrating the effect of short-term perturbations in water quality. Therefore, there is a potential for day-to-day differences in water quality to either be contributing to, or masking, actual inter-transect (or alongshore) differences. Results for 'Transect' and 'Area' should therefore be interpreted with caution. Other results, particularly those related to 'Depth' and 'Distance', can be interpreted with greater confidence as levels within these factors were sampled over a number of days (thus diluting the effects of short-term 24-hour perturbations).

## 13.4 Results

### 13.4.1 Description of the Water Quality (including measures of turbidity and light attenuation) at Sites at risk or Material or Serious Environmental Harm due to Construction or Operation of the Marine Facilities

#### 13.4.1.1 East Coast of Barrow Island

#### 13.4.1.1.1 MOF1

A seasonal pattern of greater daily median light levels in summer (191.4 µE/m$^2$/s) and lower levels in winter (167.7 µE/m$^2$/s) was recorded at MOF1, associated with the higher incident light levels that occurred in summer (Figure 13-3). Significant reductions in light levels were recorded throughout the deployment period.

Significant wave events at MOF1 were more frequent in winter, and the winter median Wave Height Index (0.012 m) was higher than during summer (0.008 m) (Figure 13-3). The Wave Height Index exhibited trends similar to other sites, with more frequent peaks during winter, and large peaks associated with tropical cyclones in summer.

Despite the higher median Wave Height Index in winter, the median SSC at MOF1 was greater in summer (2.4 mg/L) than winter (1.1 mg/L), due to what appeared to be a higher baseline level or lower limit of concentrations (Figure 13-3).

The level of significance and relatively high Pearson's $R^2$ values indicate that, in winter, Wave Height Index was correlated with SSC/NTU (Appendix 4). With the exception of wind and Wave

[34] There was insufficient replication to include 'date of sampling' as an ANOVA factor. Note, 'date of sampling' was tested separately, on smaller data sets (n=5), for Transect 3 during the April 2011 wet season.

Height Index, there were no strong relationships between the measured environmental variables and the analysed water quality variables during summer.

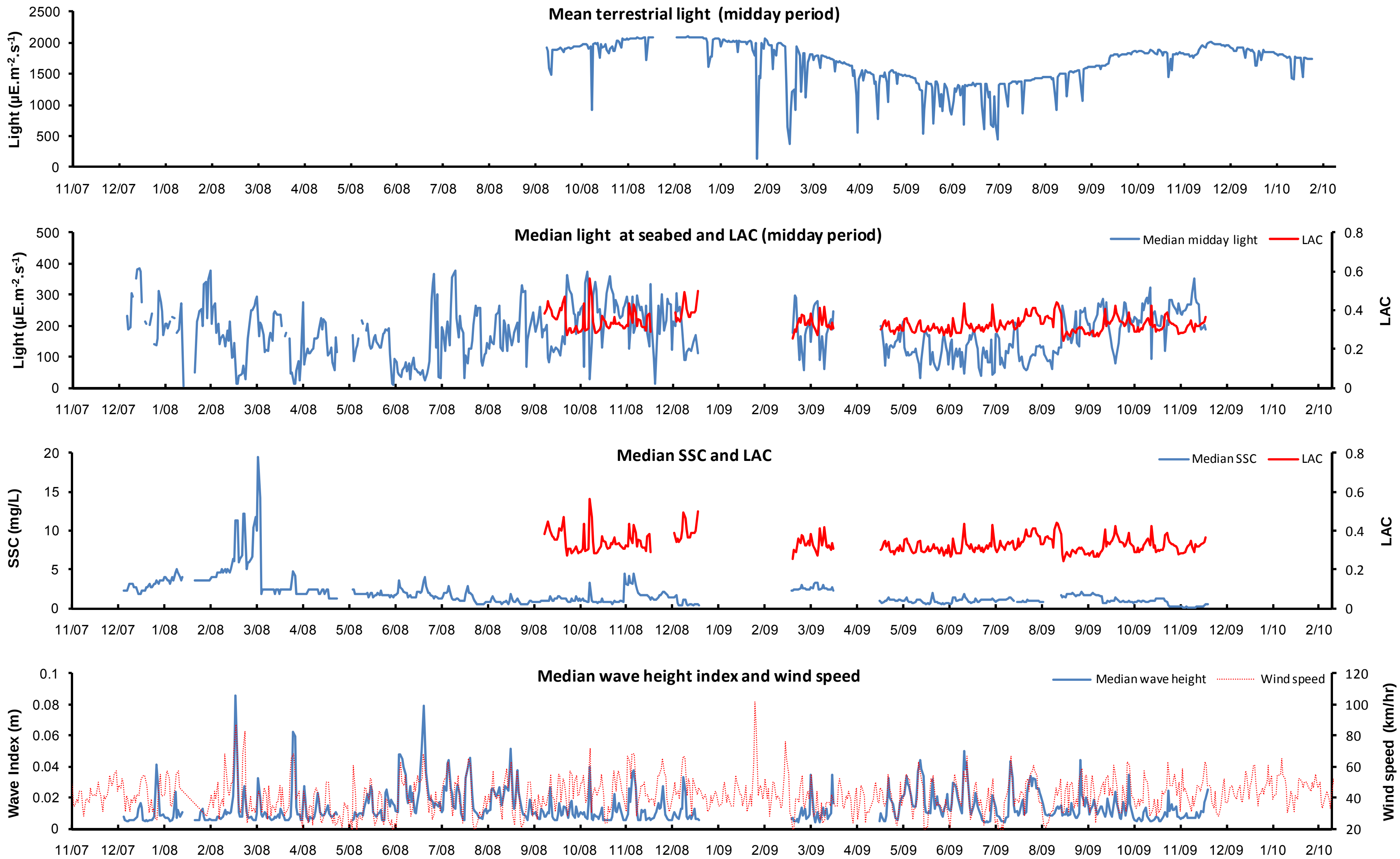


**Figure 13-3 Time-Series Plots of Daily Light, LAC, Median SSC and Median Wave Height Index at MOF1 and Daily Maximum Sustained Wind Speed at Barrow Island**

#### 13.4.1.1.2 MOF2

Collection of light, SSC and ASSD data at MOF2 was hindered by instrument malfunctions that occurred from late April to mid-July 2008. The median light levels recorded at MOF2 were greater in summer (231.5 $\mu E/m^2/s$) than winter (190.5 $\mu E/m^2/s$), and periods of greatly reduced light were recorded throughout the monitoring period (Figure 13-4).

Overall, the median Wave Height Index at MOF2 was consistent throughout the sampling period, though the wave events in winter were more frequent and intense, indicated by the higher 90th percentile in winter (0.035 m) compared with summer (0.024 m) (Figure 13-4).

The median SSC at MOF2 was 0.8 mg/L during summer and winter (Figure 13-4). There were significant elevations in SSC above the median levels recorded during periods of elevated wave height, such as those that occurred during the passage of tropical cyclones. Reduced light levels and increased light attenuation also coincided with these events, due to the increased turbidity in the water column.

During summer, the high levels of significance and relatively high Pearson‘s $R^2$ values indicate there were correlations between Wave Height Index with SSC/NTU and LAC; and between SSC/NTU and LAC (Appendix 4). There were no strong relationships between the measured environmental variables and the analysed water quality variables during winter.

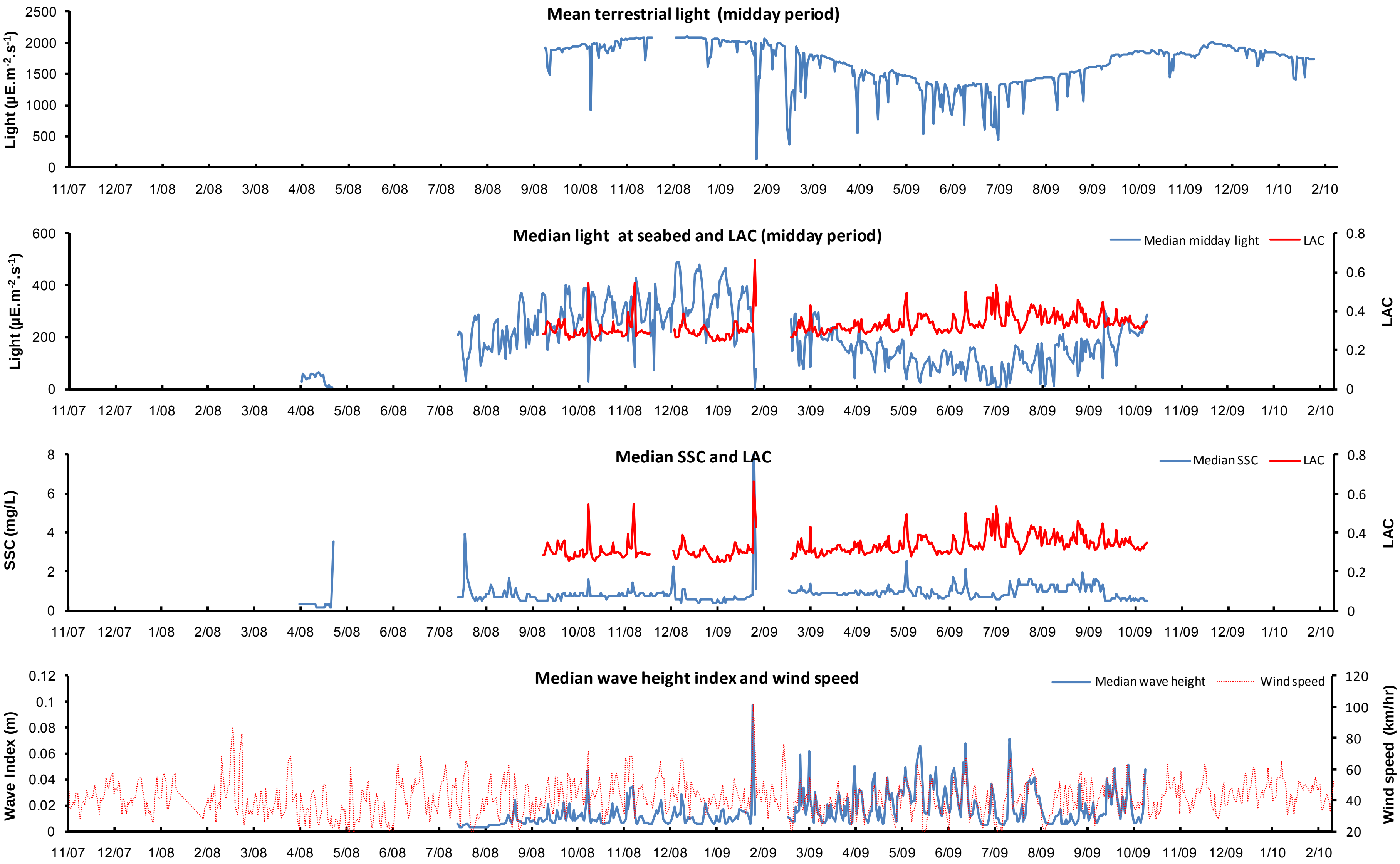


**Figure 13-4 Time-Series Plots of Daily Light, LAC, Median SSC and Median Wave Height Index at MOF2 and Daily Maximum Sustained Wind Speed at Barrow Island**

#### 13.4.1.1.3 MOF3

Daily median light levels at MOF3 were higher during summer (273.6 μE/m$^2$/s) than winter (258.0 μE/m$^2$/s), displaying the seasonal pattern evident at most of the monitoring sites (Figure 13-5). Periods of greatly reduced light levels were recorded throughout the monitoring period.

Wave events at MOF3 were more frequent in winter; this was reflected in the winter median Wave Height Index (0.013 m), which was approximately 50% higher than the summer median Wave Height Index (0.009 m) (Figure 13-5). While the median Wave Height at MOF3 was much lower in summer, significant wave events were recorded during the passage of the four tropical cyclones that passed close to Barrow Island during the 2007/2008 cyclone season and during Tropical Cyclone Dominic in January 2009.

The median SSC at MOF3 was generally similar throughout the sampling period (summer 2.1 mg/L; winter 2.4 mg/L) (Figure 13-5). Peaks in SSC often coincided with elevations in Wave Height Index, as recorded during tropical cyclones.

In summer, the levels of significance and the relatively high Pearson's $R^2$ values indicate there were significant correlations between Wave Height Index and LAC (Appendix 4). There were no strong relationships between the measured environmental variables and the analysed water quality variables during winter.

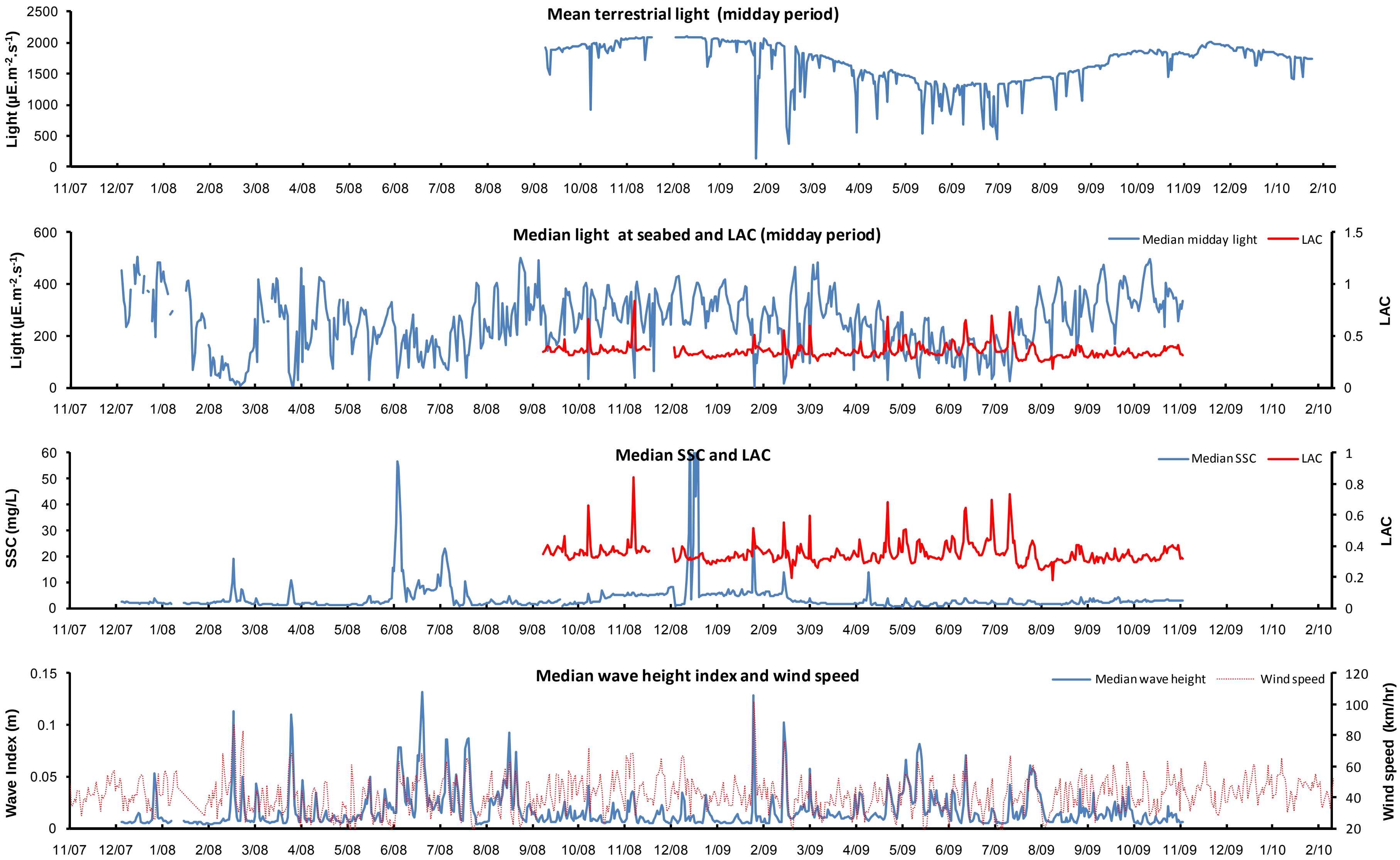


**Figure 13-5 Time-Series Plots of Daily Light, LAC, Median SSC and Median Wave Height Index at MOF3 and Daily Maximum Sustained Wind Speed at Barrow Island**

#### 13.4.1.2 Mainland End of the DomGas Pipeline Route

##### 13.4.1.2.1 Light Attenuation

###### *13.4.1.2.1.1 Dry Season*

Light attenuation typically decreased offshore along each transect at risk of Material or Serious Environment Harm (Transects 2, 3 and 4) (Figure 13-6) during the October 2010 survey. Tidal trends were not obvious, with no tidal component (spring vs neap, ebb vs flood) being consistently higher than its counterpart, apart from Transect 3, where light attenuation was markedly higher in spring flood tides than spring or neap ebb tides (Table 13-5). It was apparent from light attenuation, Secchi depth (Section 13.4.1.2.2), turbidity (Section 13.4.3.2.1), TSS (Section 13.4.1.2.3), and field observations that the water was markedly more turbid during the spring flood surveys, particularly at Transect 3.

The data collected during the October 2010 survey indicated that light attenuation was typically greater during spring tides than neap tides, and greater during flood tides than ebb tides. Larger water movements during spring tides are likely to stir up bottom sediments to a greater degree and to induce greater flows from tidal creeks, resulting in greater turbidity than during neap tides. Turbidity was typically greatest at the lowest point of the tide (i.e. beginning of the flood tide) when water depths were at a minimum.

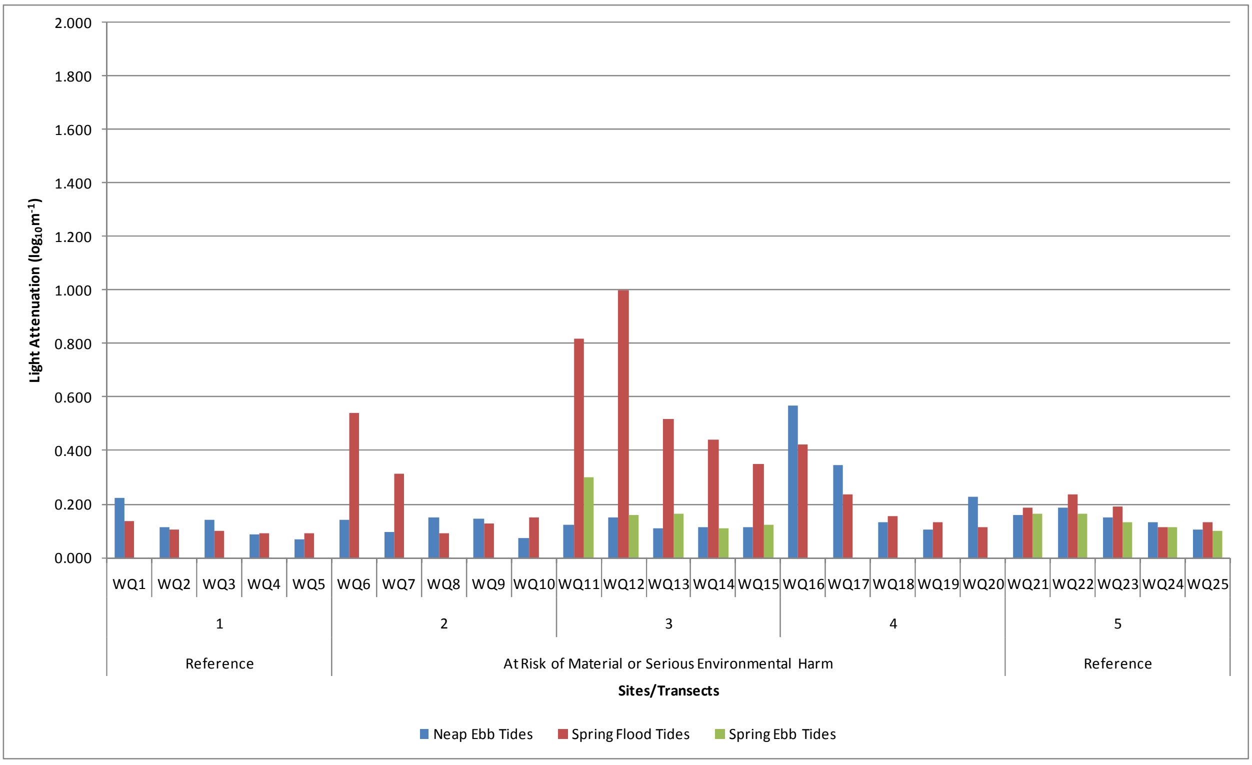


**Figure 13-6 Light Attenuation at Transects 1 to 5 during the October 2010 Dry Season Survey**

**Table 13-5 Summary of Results of Statistical Analyses for Light Attenuation during the October 2010 Dry Season Survey**

| Analysis | Summary |
|---|---|
| Neap ebb tide | Light attenuation did not differ significantly with distance offshore (likely due to the lack of consistent trends between transects), but did differ between transects ($F_{4,20}$ = 2.61, $p$ = 0.0347) during neap tides. Comparison of light attenuation values in Figure 13-6 suggests the differences between transects are driven by the relatively elevated |

| Analysis | Summary |
|---|---|
| | readings recorded at Transect 4, compared to other transects. However, as *post hoc* tests did not detect a difference, the source of the difference between transects was not statistically confirmed. |
| Spring flood tide | Light attenuation did not differ significantly with distance offshore, but did differ between transects ($F_{4,20}$ = 8.16, $p$ = 0.0007) during spring tides. Transect 3 had a significantly higher light attenuation than all other transects (Figure 13-6). Transect 1 recorded significantly lower light attenuation values relative to Transects 3, 4 and 5. There were no significant differences between Transects 1 and 2 and no significant differences between Transects 2, 4 and 5. |
| Spring tides, ebb vs flood | The 2-factor PERMANOVA identified a significant interaction between ebb and flood spring tides and transect ($F_{1,16}$ = 10.38, $p$ = 0.0044). The significant interaction indicated that light attenuation values were higher during flood tides, but only at Transect 3. There were no significant differences between tides at Transect 5. |

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

### *13.4.1.2.1.2 Wet Season*

In general, light attenuation decreased offshore for each transect at risk of Material or Serious Environment Harm (Transects 2, 3 and 4) during the April 2011 survey (Table 13-6; Figure 13-7). Light attenuation appeared generally higher during spring tides than neap tides; however, it was not consistently higher in either flood or ebb tides.

As during the October 2010 survey, the data collected during the April 2011 survey indicated that light attenuation was typically higher during spring tides than neap tides. This is attributed to the larger water movements associated with spring tides causing a greater degree of sediment suspension (particularly at the beginning of the flood tide when water depths were at a minimum) and greater outflows from tidal creeks.

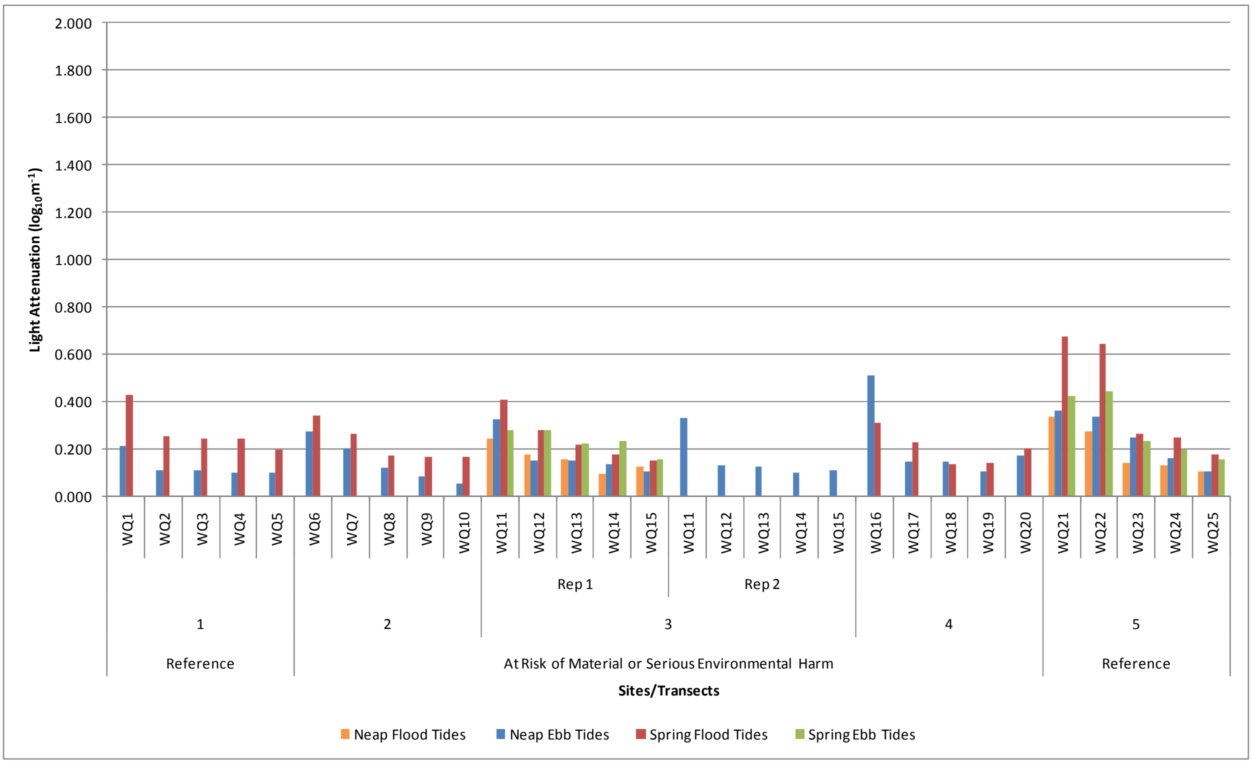


**Figure 13-7 Light Attenuation at Transects 1 to 5 during the April 2011 Wet Season Survey**

**Table 13-6 Summary of Results of Statistical Analyses for Light Attenuation during the April 2011 Wet Season Survey**

| Analysis | Summary |
|---|---|
| Neap ebb tide | Light attenuation did not differ between transects, but did differ with distance offshore ($F_{4,20}$ = 8.36, $p$ = 0.0006). An inshore to offshore gradient in light attenuation was apparent, with values generally decreasing with distance offshore. This was reflected in the *post hoc* analysis, with distance A (i.e. closest to shore) being significantly different to distances C, D and E. |
| Spring flood tide | Light attenuation did not differ between transects, but did differ with distance from shore ($F_{4,20}$ = 5.26, $p$ = 0.0043). *Post hoc* tests found that distance A (i.e. closest to shore) was significantly different to distances C, D and E. Differences were also detected between distances B and E. |
| Neap tides ebb vs flood | There were no significant differences in light attenuation between the ebb and flood neap tides and no significant differences between Transects 3 and 5. |
| Spring tide ebb vs flood | There were no significant differences in light attenuation between the ebb and flood spring tides, and no significant differences between Transects 3 and 5. |
| Neap day-to-day differences | The Student's t-test applied to light attenuation data sampled at Transect 3 found no significant differences between light attenuation values collected on 12 and 15 April 2011. |

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

#### 13.4.1.2.2 Secchi Depth

##### *13.4.1.2.2.1 Dry Season*

Secchi depth exhibited spatial and tidal trends over the October 2010 survey (Figure 13-8). In general, Secchi depth increased offshore along each transect at risk of Material or Serious Environment Harm (Transects 2, 3 and 4), except where limited by water depth (e.g. WQ20 on Transect 4) (Table 13-7). Differences between transects were not large, but Secchi depth was lower at Transect 3 during the spring flood tide sampling. Secchi depths were consistently greater during the neap tides than spring tides, with the majority of neap tide Secchi depths equal to the water depth. Secchi depths were also consistently greater during ebb tides than flood tides.

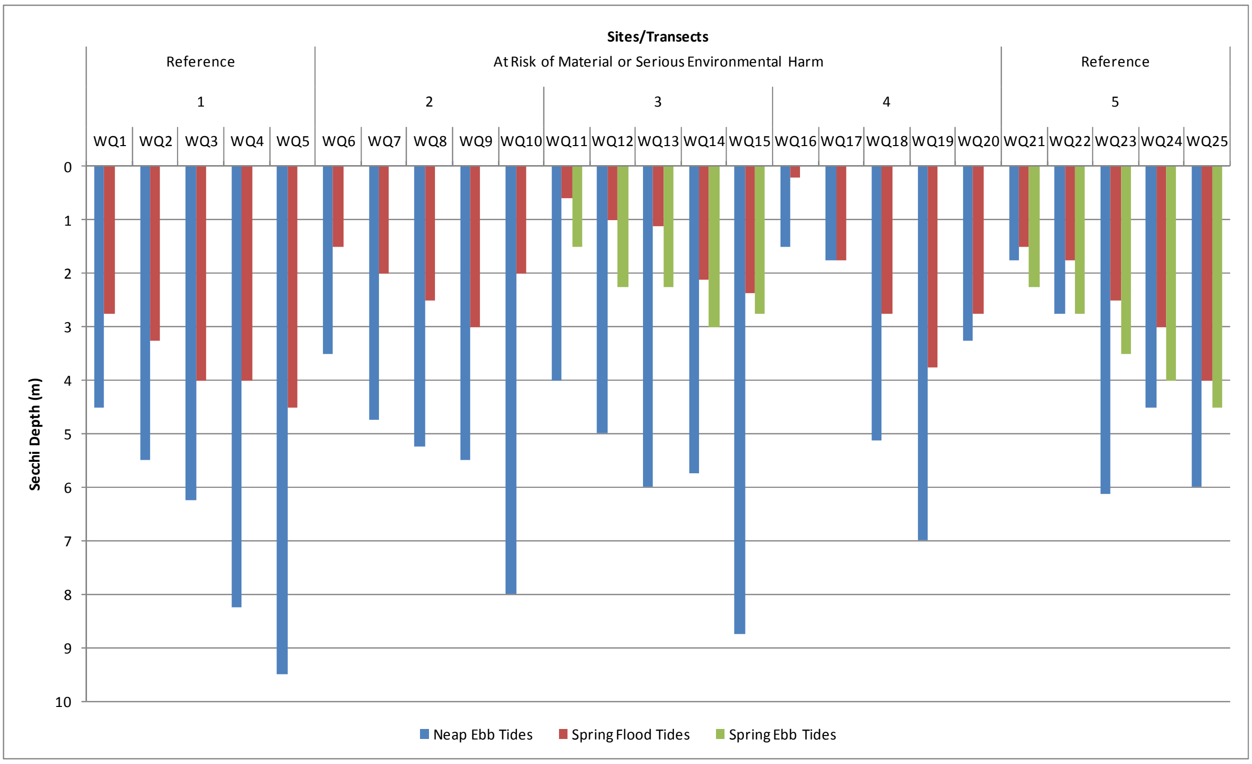


**Figure 13-8 Secchi depth at Transects 1 to 5 during the October 2010 Dry Season Survey**

**Table 13-7 Summary of Results of Statistical Analyses for Secchi Depth during the October 2010 Dry Season Survey**

| Analysis | Summary |
|---|---|
| Neap ebb tide | Secchi depth differed significantly with distance offshore ($F_{4,6}$ = 10.43, $p$ = 0.0122). Generally, Secchi depth increased with distance offshore, such that distance A had lower Secchi depth values relative to distance E (Figure 13-8). However, as *post hoc* tests did not detect a difference, the source of the difference could not be statistically confirmed. Secchi depth did not differ between transects during neap tides. |
| Spring flood tide | Secchi depth differed significantly with distance offshore ($F_{4,19}$ = 3.50, $p$ = 0.0311) and between transects ($F_{4,19}$ = 3.93, $p$ = 0.0165) during spring tides. Inshore sites (A and B) typically had lower Secchi depth than offshore sites (D and E) (Figure 13-8). Secchi depth at distance A (closest inshore) was statistically similar to distance B and C, but different from all other distances. There were no significant differences between distance B and distances C and E; likewise, there were no significant differences between distances C, D and E.<br>Between transects, Transect 1 generally had greater Secchi depths than other transects. Secchi depth at Transect 1 was statistically different from Transects 2 and 3 (*post hoc*; $p$ <0.05). There were no significant differences between other transects. |
| Spring tides ebb vs flood | There were significant differences in Secchi depth between ebb and flood spring tides ($F_{1,16}$ = 14.54, $p$ <0.05) and transects ($F_{1,16}$ = 14.54, $p$ <0.05). Secchi depth was greater at Transect 5 relative to Transect 3, and lower during flood tides relative to ebb tides (Figure 13-8). |

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

*13.4.1.2.2.2 Wet Season*

Secchi depth generally increased offshore for each transect at risk of Material or Serious Environment Harm (Transects 2, 3 and 4), except where limited by water depth, for the April 2011 survey (Table 13-8; Figure 13-9). Secchi depths were consistently greater during neap tides than spring tides, and there was no consistent trend between ebb and flood tides.

There was little difference between Day 1 and Day 4 for April 2011 neap ebb tide data at Transect 3 (Table 13-8; Figure 13-9).

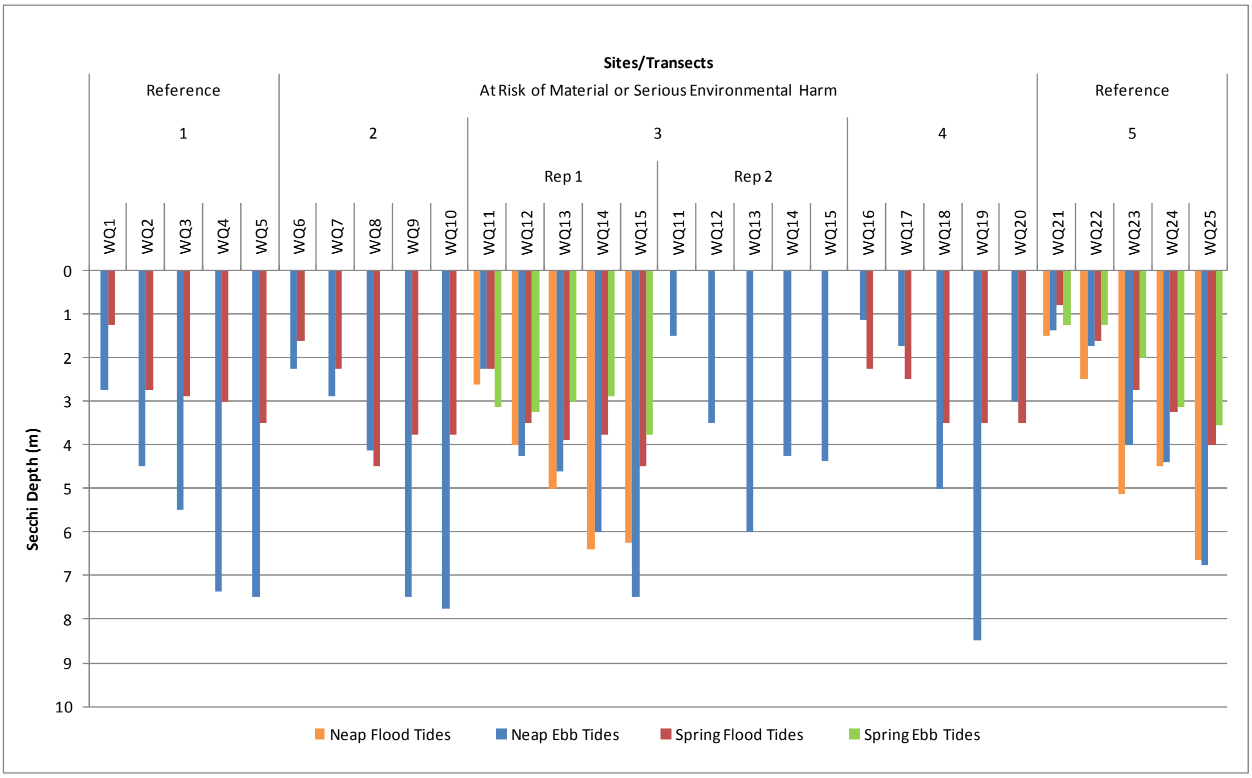


**Figure 13-9 Secchi Depth at Transects 1 to 5 during the April 2011 Wet Season Survey**

**Table 13-8 Summary of Results of Statistical Analyses for Secchi Depth during the April 2011 Wet Season Survey**

| Analysis | Summary |
|---|---|
| Neap ebb tide | Secchi depth did not differ between transects, but did differ with distance offshore ($F_{4,18}$ = 34.70, $p$ = 0.0001). As with the light attenuation data, an inshore to offshore gradient in Secchi depth was apparent, with values generally increasing with distance offshore (reflecting an increase in water clarity). This was reflected in the *post hoc* results with distance A (i.e. closest to shore) being significantly different to distances C, D and E. Differences were also detected between distances B and D, C and D, and C and E. |
| Spring flood tide | Secchi depth did not differ between transects, but did differ with distance offshore ($F_{4,20}$ = 12.16, $p$ = 0.0002). *Post hoc* tests found that distance A (i.e. closest to shore) was significantly different to distances C, D and E. Significant differences were also detected between distance B and distances D and E. |
| Neap tides ebb vs flood | The Student's t-test applied to Secchi depth data sampled at Transect 5 found no significant differences between the ebb and flood neap tides. |
| Spring tides ebb vs flood | No significant differences were found between the spring ebb and flood tides and no significant differences were found between Transects 3 and 5. |

| Analysis | Summary |
|---|---|
| Neap day-to-day differences | The Student's t-test applied to Secchi depth data sampled at Transect 3 found no significant differences between data collected on 12 and 15 of April 2011. |

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

### 13.4.1.2.3 Total Suspended Solids

#### *13.4.1.2.3.1 Dry Season*

Total Suspended Solid (TSS) concentrations showed spatial and tidal variation over the October 2010 survey (Figure 13-10). In general, TSS concentrations decreased moving offshore along each transect at risk of Material or Serious Environment Harm (Transects 2, 3 and 4; Table 13-9), were higher at Transects 3 and 4 than at Transect 2 (particularly inshore), and were generally higher during spring tides than neap tides, and, based on data for two transects, were higher during flood tides than ebb tides. Near-bottom water TSS concentrations were generally, but not exclusively, slightly higher than near-surface water TSS.

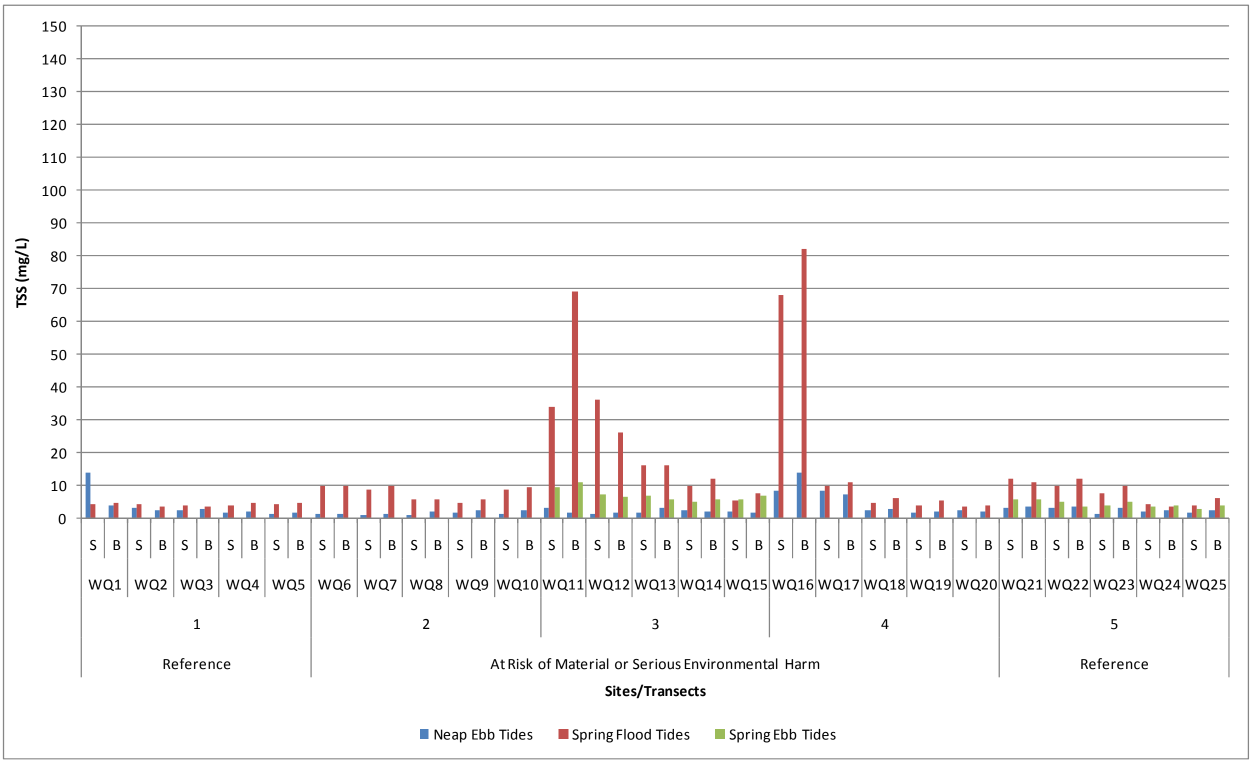


**Figure 13-10 Total Suspended Solids at Transects 1 to 5 during the October 2010 Dry Season Survey**

*Note: S = Near-surface, B = Near-bottom.*

**Table 13-9 Summary of Results of Statistical Analyses for Total Suspended Solids during the October 2010 Dry Season Survey**

| Analysis | Summary |
|---|---|
| Neap ebb tide | TSS was significantly different with distance offshore ($F_{4,40}$ = 3.11, $p$ = 0.0187) and between transects ($F_{4,40}$ = 2.77, $p$ = 0.0314), but not between near-surface and near- |

| Analysis | Summary |
|---|---|
| | bottom. Inshore sites (distance A) had a higher TSS than the offshore sites (distance E), but all other comparisons were not significantly different.<br>Transect 2 was statistically similar to Transect 1, but different to all other transects. Significant differences were also detected between Transects 3 and 4. All other transects were statistically similar. |
| Spring flood tide | TSS was significantly different with distance offshore ($F_{4,40}$ = 4.59, $p$ = 0.0025) and between transects ($F_{4,40}$ = 2.50, $p$ = 0.0440) but did not differ between near-surface and near-bottom during spring tides. An inshore to offshore gradient in TSS was apparent, with values generally decreasing with distance offshore. This was reflected in the *post hoc* analysis with inshore sites (A and B) having statistically higher TSS than offshore sites (D and E). TSS at distance A was statistically similar to distance B, but different to all other distances. Distances C, D and E (offshore) were statistically similar.<br>Transect 1 generally had lower TSS than other transects, and Transect 3 had generally higher TSS. *Post-hoc* tests identified significant differences between certain transects: Transect 1 differed from Transects 2, 3 and 5; Transect 2 differed from Transect 3; and Transect 3 differed from Transect 5. |
| Spring tides ebb vs flood | Significant differences in TSS between ebb and flood spring tides ($F_{1,32}$ = 9.27, $p$ = 0.0007) and transects ($F_{1,32}$ = 7.485, $p$ = 0.0034) were detected. TSS was greater at Transect 3 relative to Transect 5 and higher during flood tides relative to ebb tides. |

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

##### *13.4.1.2.3.2 Wet Season*

TSS concentrations generally decreased moving offshore for each transect at risk of Material or Serious Environment Harm (Transects 2, 3 and 4), during the April 2011 survey (Table 13-10; Figure 13-11). TSS generally appeared higher during spring tides than neap tides, but there was no consistent trend between flood and ebb tides. Near-bottom water TSS concentrations were generally, but not always, slightly higher than surface water TSS.

There was little difference between Day 1 and Day 4 for April 2011 neap ebb tide data at Transect 3 (Table 13-9; Figure 13-11).

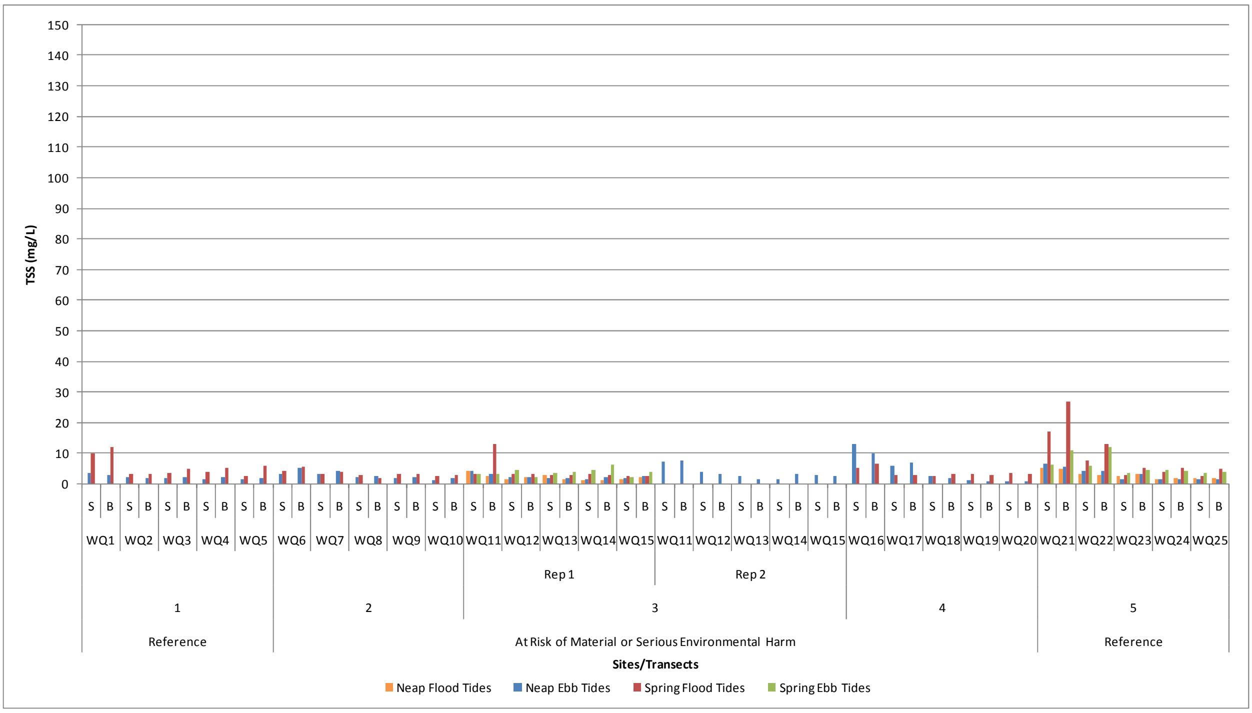


**Figure 13-11 Total Suspended Solids at Transects 1 to 5 during the April 2011 Wet Season Survey**

*Note: S: Near-surface, B: Near-bottom.*

**Table 13-10 Summary of Results of Statistical Analyses for Total Suspended Solids during the April 2011 Wet Season Survey**

| Analysis | Summary |
|---|---|
| Neap ebb tide | TSS did not differ between transects, but did differ with distance offshore ($F_{4,40}$ = 9.90, $p$ = 0.0002) during neap tides. An inshore to offshore gradient in TSS was apparent, with values generally decreasing with distance offshore (reflecting an increase in water clarity). This was reflected in the *post hoc* tests with distance A (i.e. closest to shore) being significantly different to distances C, D and E. Significant differences were also detected between distances B, D and E and distances C, D and E.<br>No significant differences were detected between depths i.e. between near-surface and near-bottom. |
| Spring flood tide | TSS was found to differ significantly between transects during spring tides ($F_{4,40}$ = 3.10, $p$ = 0.0201). *Post hoc* tests found that Transect 5 differed from Transect 2 and Transect 4. Significant differences were also detected between distance offshore ($F_{4,40}$ = 6.75, $p$ = 0.0009). *Post hoc* tests found that distance A was significantly different to all other distances.<br>No significant differences were detected between depths i.e. between near-surface and near-bottom. |
| Neap tides ebb vs flood | No significant differences between tide, depth or transect were detected. |
| Spring tides ebb vs flood | No significant differences between depth and transect for TSS were detected. A significant difference between Transects 3 and 5 ($F_{1,32}$ = 6.67, $p$ = 0.012) was detected. |
| Neap day-to-day differences | No significant differences between day of sampling or depth were detected for Transect 3 on 12 and 15 April 2011. |

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

### 13.4.2 Description of Water Quality (including measures of turbidity and light attenuation) at Reference Sites not at risk or Material or Serious Environmental Harm due to Construction or Operation of the Marine Facilities

#### 13.4.2.1 East Coast of Barrow Island

##### 13.4.2.1.1 LNG3

A seasonal pattern in light levels was not particularly evident at LNG3 (Figure 13-12). The median light level in winter (191.6 $\mu E/m^2/s$) was higher than in summer (164.1 $\mu E/m^2/s$).

The median Wave Height Index at LNG3 was higher in winter (0.014 m) than summer (0.012 m) (Figure 13-12). Distinct peaks in wave height during summer occurred during the passage of the four tropical cyclones in the 2007/2008 season.

The median SSC at LNG3 in summer (2.7 mg/L) was slightly lower than in winter (2.8 mg/L) (Figure 13-12). Peaks in SSC were often associated with peaks in Wave Height Index, as evident during the tropical cyclones.

In winter, there were significant correlations and relatively high Pearson's $R^2$ values between Wave Height Index and SSC/NTU, LAC and light (Appendix 4). There were no correlations evident between the measured environmental variables and the analysed water quality variables in summer.

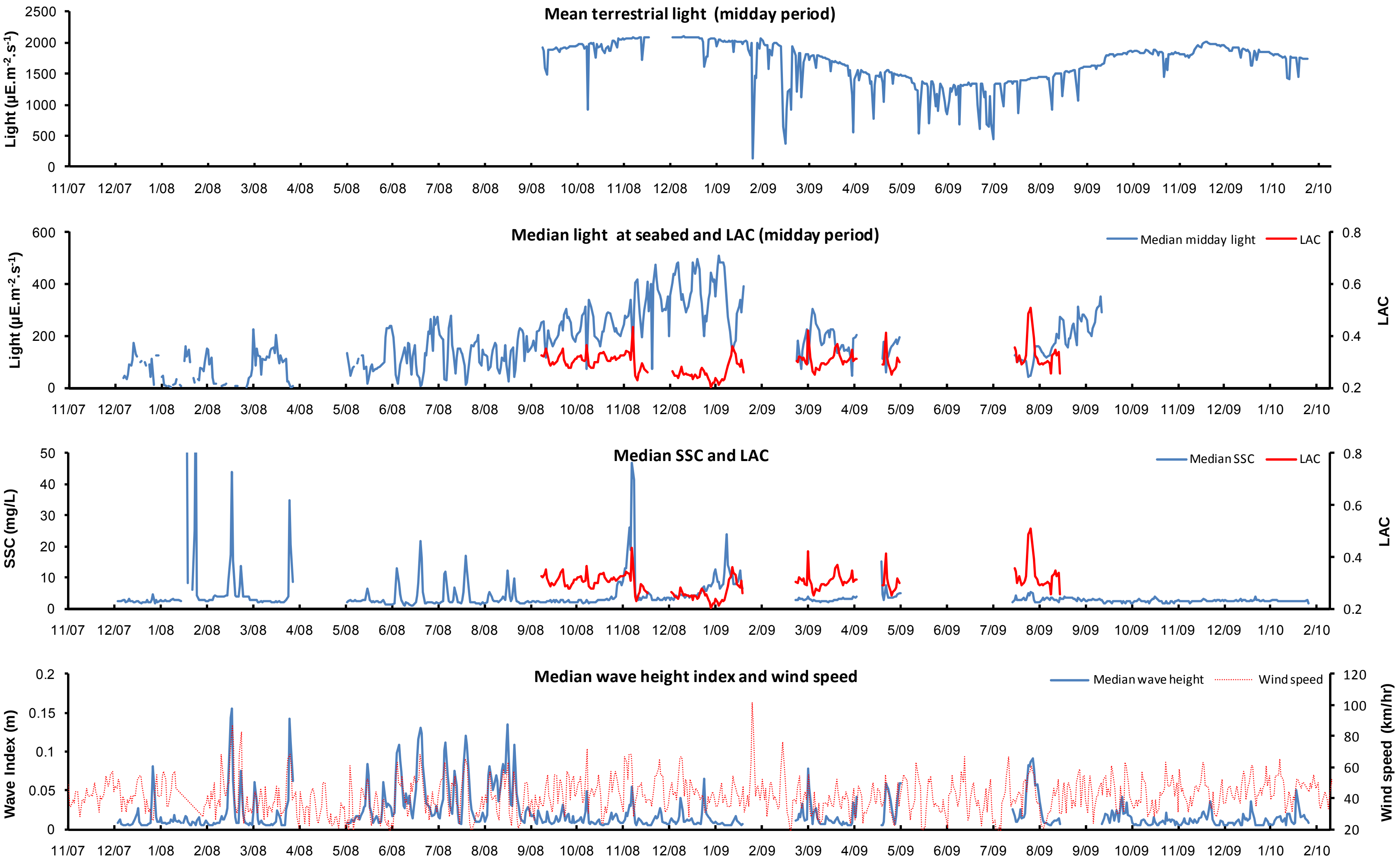


**Figure 13-12 Time-Series Plots of Daily Light, LAC, Median SSC and Median Wave Height Index at LNG3 and Daily Maximum Sustained Wind Speed at Barrow Island**

#### 13.4.2.1.2 Dugong Reef (DUG)

A seasonal pattern of greater daily median light levels in summer (285.2 $\mu E/m^2/s$) than in winter (230.9 $\mu E/m^2/s$) was evident at DUG (Figure 13-13). Periods of low light were recorded throughout the sampling period, although they were more frequent in winter.

The median Wave Height Index at DUG was higher in winter (0.013 m) than in summer (0.008 m), and significant wave events were also more frequent in winter (Figure 13-13). Large peaks in wave height during summer were recorded during the passage of tropical cyclones, and were associated with strong easterly breezes during winter.

The median SSC at DUG was 1.7 mg/L in both summer and winter, with elevations in SSC regularly coinciding with peaks in wave height during the passage of tropical cyclones and periods of strong easterly winds (Figure 13-13). Reduced light levels were recorded during peaks in SSC, presumably as a result of increased turbidity in the water column; LAC also increased during these periods.

During winter, the level of significance and relatively high Pearson's $R^2$ values suggest Wave Height Index was correlated with SSC/NTU, LAC and light; and SSC/NTU were correlated with LAC and light (Appendix 4). During summer, there was a correlation between Wave Height Index and LAC.

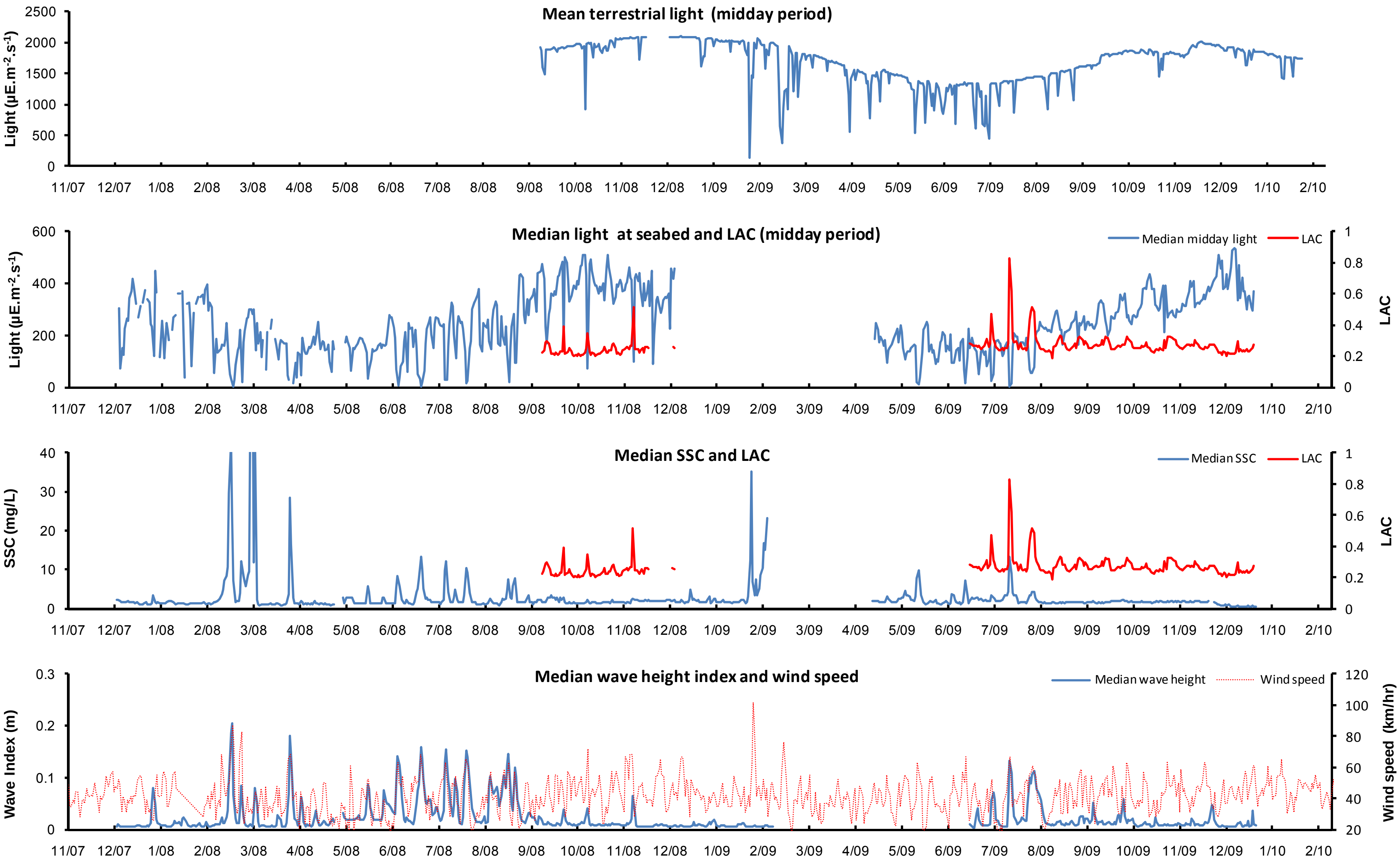


**Figure 13-13 Time-Series Plots of Daily Light, LAC, Median SSC and Median Wave Height Index at Dugong Reef and Daily Maximum Sustained Wind Speed at Barrow Island**

### 13.4.2.2 Mainland End of the DomGas Pipeline Route

#### 13.4.2.2.1 Light Attenuation

##### *13.4.2.2.1.1 Dry Season*

Light attenuation typically decreased offshore along the Reference Transects 1 and 5 (Figure 13-6) during the October 2011 survey. Tidal trends were not obvious, with no tidal component (spring vs neap, ebb vs flood) being consistently higher than its counterpart for the Reference Transects 1 and 5 (Table 13-5).

The data collected during the October 2010 survey indicated that light attenuation was typically greater during spring tides than neap tides, and greater during flood tides than ebb tides. Larger water movements during spring tides are likely to stir up bottom sediments to a greater degree and to induce greater flows from tidal creeks, resulting in greater turbidity than during neap tides. Turbidity was typically greatest at the lowest point of the tide (i.e. beginning of the flood tide), when water depths were at a minimum.

Results from statistical tests on all factors apart from 'Area' (i.e. 'Distance', 'Transect', 'Depth', 'Tide' and 'Day' [see Section 13.3.5.2.2]) are summarised in Table 13-5. Results from PERMANOVA tests for the difference between Reference Transects and transects at risk of Material or Serious Environmental Harm are summarised below:

- there was no significant difference in light attenuation between the Reference Transects and transects at risk of Material or Serious Environmental Harm during the October 2010 neap ebb tide survey
- there was a significant difference in light attenuation between the Reference Transects and the transects at risk of Material or Serious Environmental Harm ($F_{1,20}$ = 6.78, $p$ = 0.0211) during the October 2010 spring flood tide survey.

##### *13.4.2.2.1.2 Wet Season*

In general, light attenuation decreased offshore for Reference Transects 1 and 5 during the April 2011 survey (Table 13-6; Figure 13-7). Light attenuation appeared generally higher during spring tides than neap tides; however, it was not consistently higher in either flood or ebb tides.

As during the October 2010 survey, the data collected during the April 2011 survey indicated that light attenuation is likely to be higher during spring tides than neap tides. This is attributed to the larger water movements associated with spring tides causing a greater degree of sediment suspension (particularly at the beginning of the flood tide when water depths were at a minimum) and greater outflows from tidal creeks.

Results from statistical tests on all factors apart from 'Area' (i.e. 'Distance', 'Transect', 'Depth', 'Tide' and 'Day' [see Section 13.3.5.2.2]) are summarised in Table 13-6. Results from PERMANOVA tests for the difference between Reference Transects and transects at risk of Material or Serious Environmental Harm are summarised below:

- there was no significant difference in light attenuation between the Reference Transects and transects at risk of Material or Serious Environmental Harm during the April 2011 neap ebb tide survey
- there was a significant difference in light attenuation between the Reference Transects and transects at risk of Material or Serious Environmental Harm ($F_{1,15}$ = 9.67, $p$ = 0.0076) during the April 2011 spring flood tide survey. Transects at risk of Material or Serious Environmental Harm typically recorded lower values than Reference Transects. The significant result appeared to be driven particularly by the relative difference between transects at risk of Material or Serious Environmental Harm and Reference Transect 5 (note that Reference Transect 5 recorded higher light attenuation values than all other transects).

#### 13.4.2.2.2 Secchi Depth

*13.4.2.2.2.1 Dry Season*

In general, Secchi depth increased offshore along Reference Transects 1 and 5 (Table 13-7; Figure 13-8) during the October 2010 survey. Secchi depths were consistently greater during the neap tides than spring tides, with the majority of neap tide Secchi depths equal to the water depth. Secchi depths were also consistently greater during ebb tides than flood tides.

Results from statistical tests on all factors apart from ‘Area’ (i.e. ‘Distance’, ‘Transect’, ‘Depth’, ‘Tide’ and ‘Day’ [see Section 13.3.5.2.2]) are summarised in Table 13-7. Results from PERMANOVA tests for the difference between Reference Transects and transects at risk of Material or Serious Environmental Harm are summarised below:

- there was no difference in Secchi depth between the Reference Transects and transects at risk of Material or Serious Environmental Harm during the October 2010 neap ebb tide survey
- there was a significant difference in Secchi depth between the Reference Transects and the transects at risk of Material or Serious Environmental Harm ($F_{1,14}$ = 14.54, $p$ = 0.0018) during the October 2010 spring flood tide survey.

*13.4.2.2.2.2 Wet Season*

Secchi depth generally increased offshore for Reference Transects 1 and 5 for the April 2011 survey (Table 13-8; Figure 13-9). Secchi depths were consistently greater during neap tides than spring tides, and there was no consistent trend between ebb and flood tides.

Results from statistical tests on all factors apart from ‘Area’ (i.e. ‘Distance’, ‘Transect’, ‘Depth’, ‘Tide’ and ‘Day’ [see Section 13.3.5.2.2]) are summarised in Table 13-8. Results from PERMANOVA tests for the difference between Reference Transects and transects at risk of Material or Serious Environmental Harm are summarised below:

- there was no difference in Secchi depth between the Reference Transects and transects at risk of Material or Serious Environmental Harm during the April 2011 neap ebb tide survey
- there was a significant difference in Secchi depth between the Reference Transects and transects at risk of Material or Serious Environmental Harm ($F_{1,15}$ = 13.57, $p$ = 0.0021) during the April 2011 spring flood tide survey. The differences appear driven by the slightly higher Secchi values recorded at Transects 2 and 3 (representing transects at risk of Material or Serious Environmental Harm), relative to those recorded at the Reference Transects 1 and 5.

#### 13.4.2.2.3 Total Suspended Solids

*13.4.2.2.3.1 Dry Season*

In general, TSS concentrations decreased moving offshore along Reference Transects 1 and 5 (Table 13-9; Figure 13-10) during the October 2010 survey, and were generally higher during spring tides than neap tides, and higher during flood tides than ebb tides. Near-bottom water TSS concentrations were generally, but not exclusively, slightly higher than near-surface water TSS concentrations.

Results from statistical tests on all factors apart from ‘Area’ (i.e. ‘Distance’, ‘Transect’, ‘Depth’, ‘Tide’ and ‘Day’ [see Section 13.3.5.2.2]) are summarised in Table 13-9. Results from PERMANOVA tests for the difference between Reference Transects and transects at risk of Material or Serious Environmental Harm are summarised below:

- there was no difference in TSS between the Reference Transects and transects at risk of Material or Serious Environmental Harm during the October 2010 neap ebb tide survey
- the 3-factor PERMANOVA applied to Reference Transects vs transects at risk of Material or Serious Environmental Harm, distance offshore and depth (near-surface/near-bottom) found a significant interaction between Reference Transects and transects at risk of Material or

Serious Environmental Harm and distance offshore ($F_{4,30}$ = 2.94, $p$ = 0.0279) during the October 2011 dry season spring flood tides. The interaction indicated that although there were differences between the Reference Transects and transects at risk of Material or Serious Environmental Harm, the differences were inconsistent. For example, the transects at risk of Material or Serious Environmental Harm (encompassing Transects 3 and 4) showed a general decrease in TSS with increasing distance offshore, but Reference Transect 1 showed a slight increase with distance offshore.

###### *13.4.2.2.3.2 Wet Season*

TSS concentrations generally decreased moving offshore along Reference Transects 1 and 5 during the April 2011 survey (Table 13-10; Figure 13-11). TSS generally appeared higher during spring tides than neap tides, but there was no consistent trend between flood and ebb tides. Near-bottom water TSS concentrations were generally, but not always, slightly higher than surface water TSS.

Results from statistical tests on all factors apart from 'Area' (i.e. 'Distance', 'Transect', 'Depth', 'Tide' and 'Day' [see Section 13.3.5.2.2]) are summarised in Table 13-10. Results from PERMANOVA tests for the difference between Reference Transects and transects at risk of Material or Serious Environmental Harm are summarised below:

- there was no significant difference in TSS between the Reference Transects and sites at risk of Material or Serious Environmental Harm during the April 2011 neap ebb tide survey
- the 3-factor PERMANOVA applied to Reference Transects vs transects at risk of Material or Serious Environmental Harm, distance offshore and depth (near-surface/near-bottom) found a significant interaction between Reference Transects and transects at risk of Material or Serious Environmental Harm and distance offshore ($F_{4,30}$ = 4.55, $p$ = 0.0059) during the April 2011 spring flood tide survey. The interaction indicates that although there were differences between the Reference Transects and transects at risk of Material or Serious Environmental Harm, the differences were restricted to certain distances. Subsequent *post hoc* tests found that the differences between Reference Transects and transects at risk of Material or Serious Environmental Harm were restricted to Distances A, C, D and E.

### 13.4.3 Water Column Profiles at Sites at risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

#### 13.4.3.1 East Coast of Barrow Island

##### 13.4.3.1.1 MOF1

Salinity ranged between 35.2 and 35.6 Practical Salinity Units (PSU) (Table 13-11). The lowest salinity was recorded in surface waters in September 2008 and bottom waters in October 2009, whilst the highest salinity was recorded in both surface and bottom waters in January 2008 and November 2009. Temperatures ranged from 21.4–29.9 °C. The lowest temperature was recorded in July 2009 in surface and bottom waters, whilst the highest temperature was recorded in March 2008 in surface waters. The lowest turbidity (8.8 NTU) was recorded in July 2008 in surface and bottom waters. A maximum turbidity of 11.7 NTU was recorded in November 2009 in bottom waters.

**Table 13-11 Surface (~1 m below) and Near-seabed (~0.5 m above) Physicochemical Water Quality Data from Vertical Profiles Undertaken at MOF1, MOF2 and MOF3 from January 2008 to November 2009**

| Month | MOF1 | | | | | | MOF2 | | | | | | MOF3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Salinity (PSU) | | Temperature (degrees C) | | Turbidity (NTU) | | Salinity (PSU) | | Temperature (degrees C) | | Turbidity (NTU) | | Salinity (PSU) | | Temperature (degrees C) | | Turbidity (NTU) | |
| | Near-surface | Near-seabed | Near-surface | Near-seabed | Near-surface | Near-seabed | Near-surface | Near-seabed | Near-surface | Near-seabed | Near-surface | Near-seabed | Near-surface | Near-seabed | Near-surface | Near-seabed | Near-surface | Near-seabed |
| Jan-08 | 35.6 | 35.6 | 28.9 | 28.9 | 9.8 | 10.3 | - | - | - | - | - | - | 35.4 | 35.5 | 29.0 | 28.8 | 9.8 | 10.3 |
| Mar-08 | 35.4 | 35.4 | 29.9 | 29.8 | - | - | - | - | - | - | - | - | 35.4 | 35.4 | 29.8 | 29.8 | - | - |
| Jul-08 | 35.4 | 35.4 | 22.2 | 22.2 | 8.8 | 8.8 | - | - | - | - | - | - | - | - | - | - | - | - |
| Sep-08 | 35.2 | 35.3 | 23.6 | 23.6 | 10.3 | 10.7 | 35.4 | 35.4 | 23.6 | 23.3 | 10.3 | 10.3 | 35.4 | 35.4 | 22.8 | 22.8 | 10.3 | 10.3 |
| Oct-08 | 35.4 | 35.3 | 24.1 | 24.0 | 10.3 | 10.7 | - | - | - | - | - | - | 35.2 | 35.2 | 23.9 | 23.9 | 10.7 | 10.7 |
| Jun-09 | - | - | - | - | - | - | - | - | - | - | - | - | 35.5 | 35.5 | 24.1 | 24.1 | 9.8 | 10.7 |
| Jul-09 | 35.3 | 35.3 | 21.4 | 21.4 | 10.0 | 10.3 | - | - | - | - | - | - | 35.3 | 35.3 | 21.4 | 21.4 | 9.8 | 10.3 |
| Sep-09 | - | - | - | - | - | - | 35.4 | 35.4 | 22.3 | 22.3 | 9.8 | 9.3 | 35.4 | 35.5 | 22.4 | 22.2 | 9.3 | 9.8 |
| Oct-09 | 35.3 | 35.2 | 25.6 | 25.3 | 10.7 | 10.3 | - | - | - | - | - | - | - | - | - | - | - | - |
| Nov-09 | 35.6 | 35.6 | 27.6 | 27.1 | 11.2 | 11.7 | - | - | - | - | - | - | 35.5 | 35.5 | 26.2 | 26.2 | 10.7 | 10.3 |

#### 13.4.3.1.2 MOF2

Salinity, temperature and turbidity measurements at MOF2 were available only for September 2008 and September 2009 (Table 13-11). The salinity was the same in surface and bottom waters on each sampling occasion (35.4 PSU). Turbidity was 10.3 NTU in September 2008 in surface and bottom waters, while in September 2009, 9.8 NTU and 9.3 NTU were recorded at surface and bottom waters respectively. Temperature varied from 22.3 °C in surface and bottom waters in September 2009 to 23.6 °C in surface waters in September 2008.

#### 13.4.3.1.3 MOF3

Salinity varied slightly between 35.2 and 35.5 PSU. The lowest salinity was recorded in October 2008 in surface and bottom waters (Table 13-11). The highest salinity was recorded in January 2008 and September 2009 in bottom waters, and in June and November 2009 in both surface and bottom waters. Temperatures recorded in surface and bottom waters ranged from 21.4 °C in July 2009 to 29.8 °C in March 2008. A minimum turbidity of 9.3 NTU was recorded in surface waters September 2009. A maximum turbidity of 10.7 NTU was recorded in surface and bottom waters in October 2008, bottom waters in June 2009, and surface waters in November 2009.

### 13.4.3.2 Mainland End of the DomGas Pipeline Route

#### 13.4.3.2.1 Turbidity

*13.4.3.2.1.1 Dry Season*

Turbidity during the October 2010 neap ebb tide survey (Figure 13-14) generally fell below 10 NTU for all transects at risk of Material or Serious Environment Harm (Transects 2, 3 and 4), with the exception of the inshore sites (WQ16 and WQ17, ~5–30 NTU) of Transect 4, and in some near-bottom waters (e.g. WQ13 on Transect 3).

Higher turbidity was recorded during the October 2010 spring flood tide survey (Figure 13-15) for all transects at risk of Material or Serious Environment Harm (Transects 2, 3 and 4); with turbidity typically below 20 NTU. However, much higher turbidity was recorded in the inshore sections of Transects 2, 3 and 4 (up to 80.2 NTU at WQ16 [Transect 4]). The replicate transect (Transect 3; Figure 13-16) data collected during the dry season spring ebb tide were lower in turbidity than during the spring flood tide, and in general turbidity was below 10 NTU.

Cross-shore change in turbidity was most pronounced during the spring tide survey, with higher turbidity inshore, decreasing offshore. The higher turbidity at Transects 3 and 4 was probably attributable to their location adjacent to large tidal creeks and the widest expanse of intertidal flats in the study area.

Near-surface and near-bottom turbidity (Figure 13-17) was markedly higher at Transects 3 and 4 (1.7–80.2 NTU), particularly at the inshore sites, compared to Transect 2 and Reference Transects 1 and 5 (1.0–22.6 NTU), during the spring flood tide survey. However, Transects 3 (3.2–8.6 NTU) and Reference Transect 5 (1.5–4.3 NTU) were relatively similar during the spring ebb tide survey, and Transect 4 (0.6–8.3 NTU) was only slightly higher than all other transects (0.4–2.8 NTU) during the neap ebb tide survey.

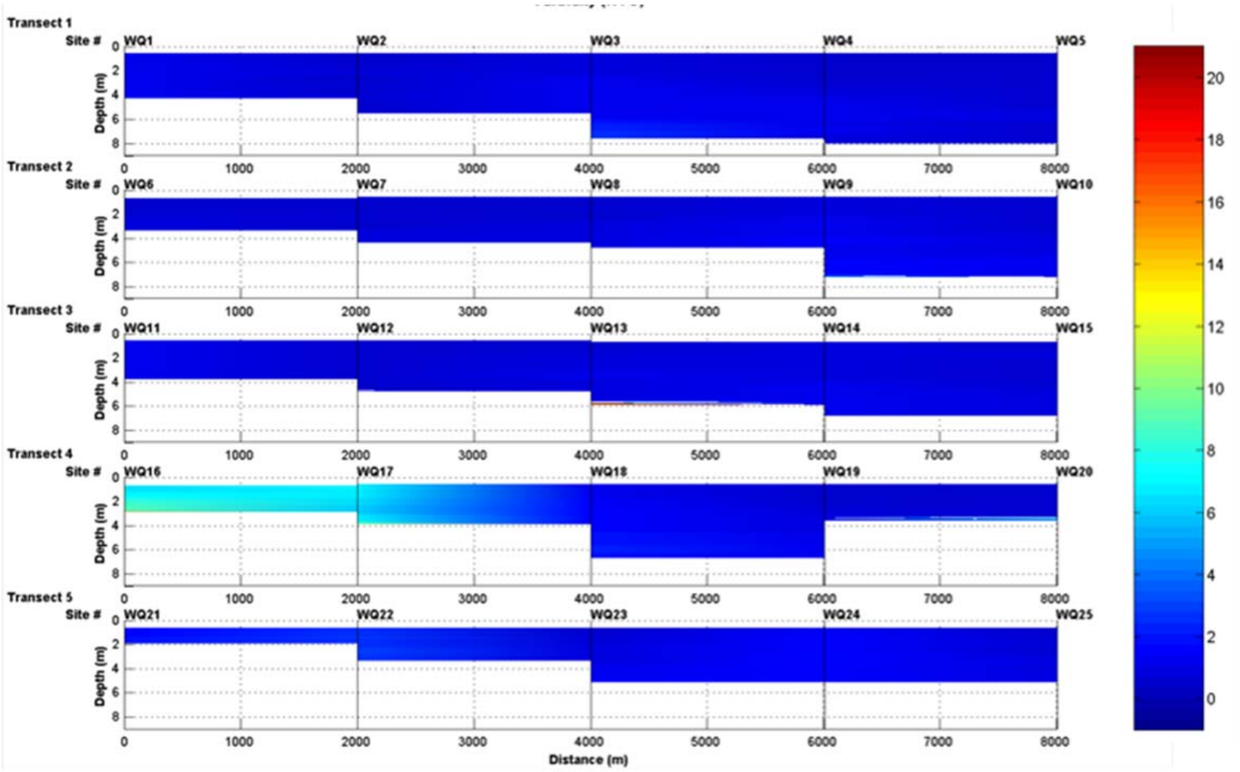


**Figure 13-14 Turbidity Profiles across the Water Quality Transects during the October 2010 Dry Season Neap (ebb) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm. Colour scale restricted to 20 NTU to show resolution at the lower end of the scale, where most values occur.*

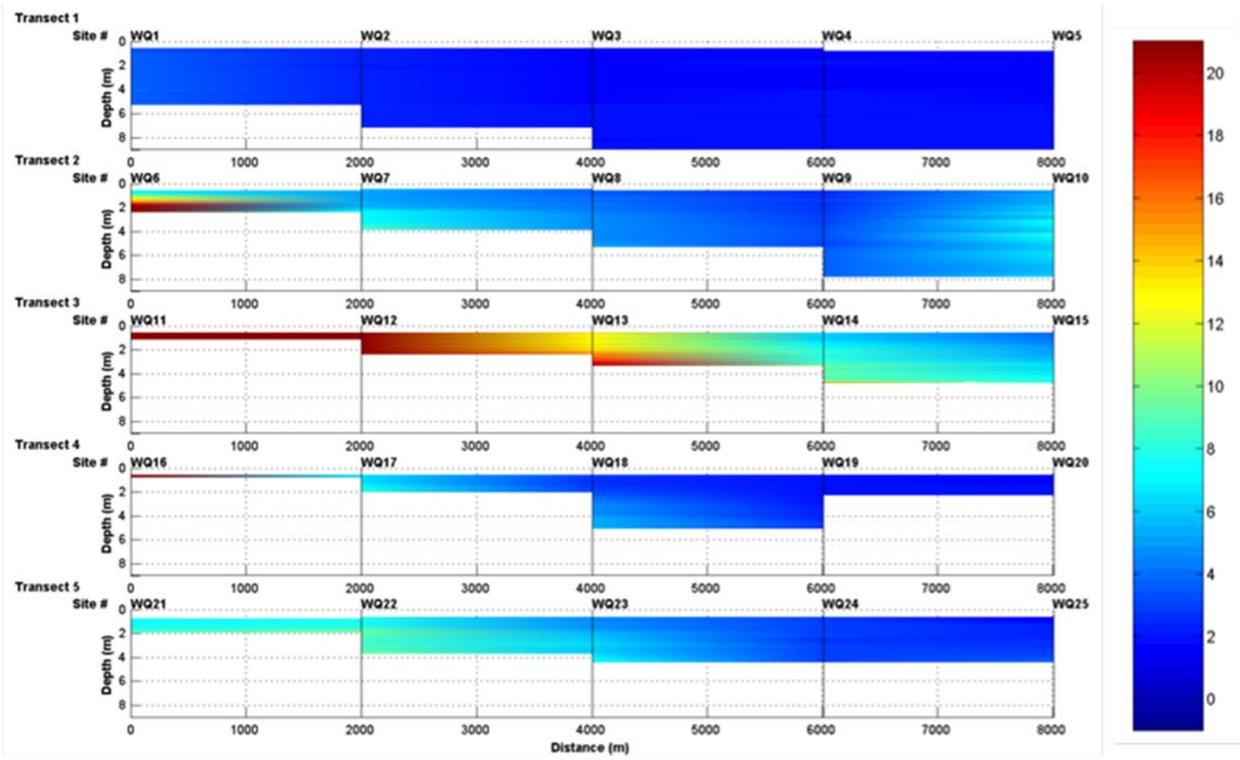


**Figure 13-15 Turbidity Profiles across the Water Quality Transects during the October 2010 Dry Season Spring (flood) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm. Colour scale restricted to 20 NTU to show resolution at the lower end of the scale, where most values occur.*

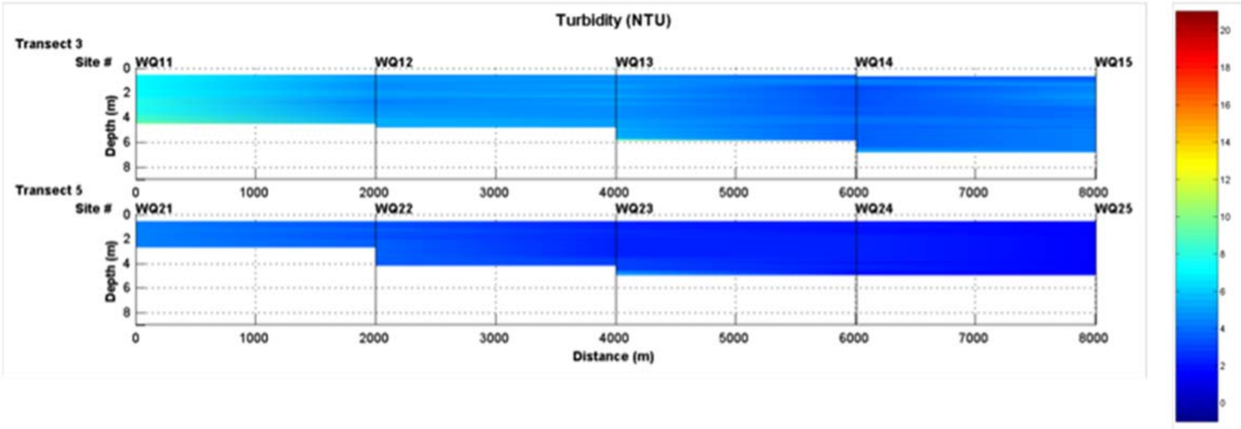


**Figure 13-16 Turbidity Profiles across the Water Quality Transects during the October 2010 Dry Season Spring (ebb) Tides**

*Note: Transect 5 is a Reference Transect, Transect 3 is at risk of Material or Serious Environmental Harm. Colour scale restricted to 20 NTU to show resolution at the lower end of the scale, where most values occur.*

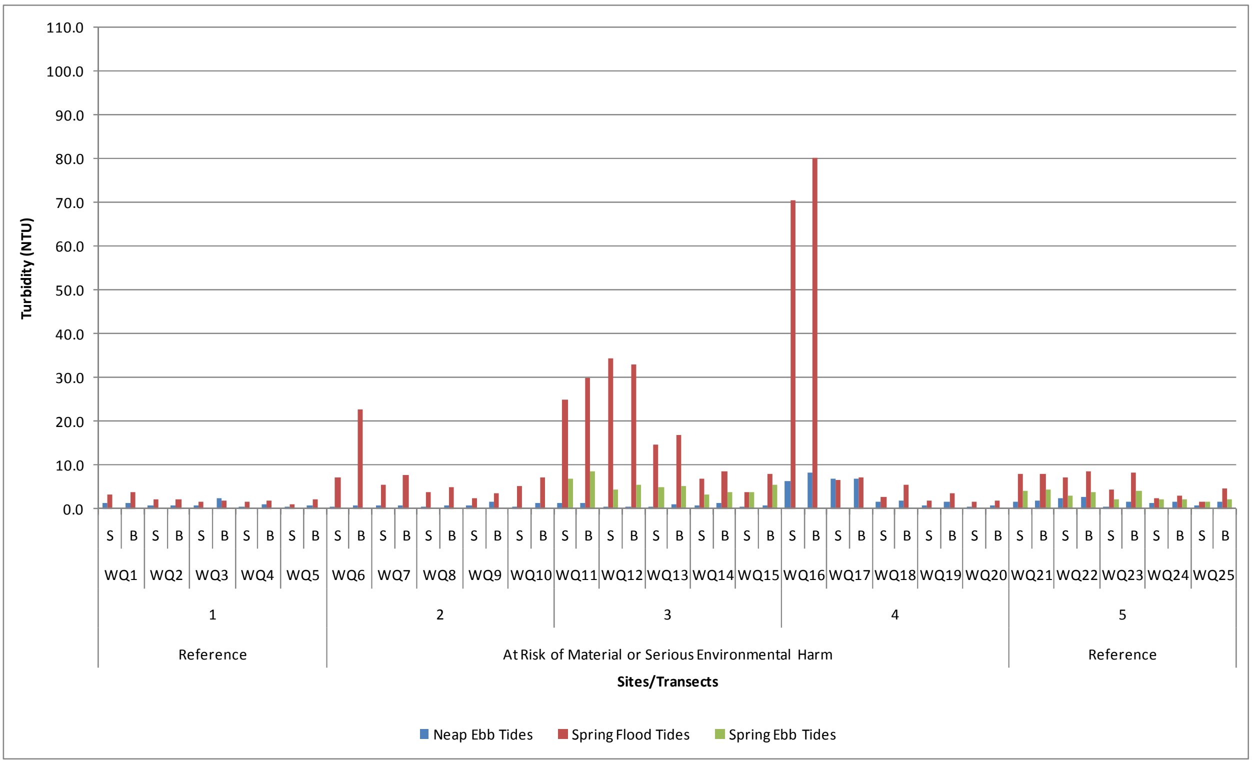


**Figure 13-17 Near-surface and Near-bottom Turbidity at Transects 1 to 5 during the October 2010 Dry Season Survey**

*Note: Turbidity values used for plotting were extracted from the profile at 0.5 m from the surface and 0.5 m from the bottom; where multiple turbidity readings were available, the value was averaged. S = Near-surface, B = Near-bottom.*

**Table 13-12 Summary of Results of Statistical Analyses for Turbidity during the October 2010 Dry Season Survey**

| Analysis | Summary |
|---|---|
| Neap ebb tide | Turbidity did not differ significantly with distance offshore (likely due to the lack of consistent trends between transects), or between near-surface and near-bottom, but differed significantly between transects ($F_{4,40}$ = 5.48, $p$ = 0.0009) during neap tides. There were no significant differences between Transects 4 and 5, and no significant differences between Transects 1, 2 and 3. Transects 4 and 5 were significantly different to Transects 1, 2 and 3. |
| Spring flood tide | Turbidity was significantly different with distance offshore ($F_{4,40}$ = 4.08, $p$ = 0.0051), but did not differ between transects or between near-surface and near-bottom. Inshore sites (A) generally had higher turbidity than offshore sites (D and E). Turbidity at distance A was statistically similar to B and C, but different from D and E. Turbidity at distances B, C, D and E were statistically similar. |
| Spring tides ebb vs flood | The 2-factor PERMANOVA identified significant differences in turbidity between spring ebb and flood tides ($F_{1,32}$ = 15.26, $p$ = 0.0002) and transects ($F_{1,32}$ = 13.617, $p$ = 0.0005). Turbidity was greater at Transect 3 relative to Transect 5 and higher during flood tides relative to ebb tides. |

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

### *13.4.3.2.1.2 Wet Season*

Turbidity during the April 2011 neap ebb tide survey (Figure 13-18) fell below 10 NTU for all transects at risk of Material or Serious Environment Harm (Transects 2, 3 and 4). Turbidity data collected from the repeated transect (Transect 3; Figure 13-19) during the neap flood tide were similarly low, falling below 10 NTU across all sites. Slight cross-shore and depth gradients were evident, with elevated turbidity at inshore sites, increasing with depth.

Turbidity during the April 2011 spring flood tide survey (Figure 13-20) generally fell below 10 NTU for all transects at risk of Material or Serious Environment Harm (Transects 2, 3 and 4), with the exception of some inshore sites (WQ11 [Transect 3], WQ21 and WQ22 [Transect 4]) and in some bottom waters. Turbidity data collected from the repeated transect (Transect 3; Figure 13-21) during the spring ebb tide were lower in turbidity at the inshore sites, and generally fell below 10 NTU at all other sites. Cross-shore and depth gradients were evident, with elevated turbidity at inshore sites, increasing with depth (Table 13-13).

Cross-shore change in turbidity was most pronounced during the April 2011 spring tide survey, with higher turbidity inshore, decreasing offshore (particularly at Transects 3 during the flood tide survey). However, overall turbidity was low across all sites and tide cycles.

Near-surface and near-bottom turbidity (Figure 13-22) in the April 2011 survey was relatively low across all sites and tidal cycles. The highest turbidity readings were recorded at inshore sites (WQ11 [Transect 3], WQ21, and WQ22 [Transect 4]) during the spring flood tide survey.

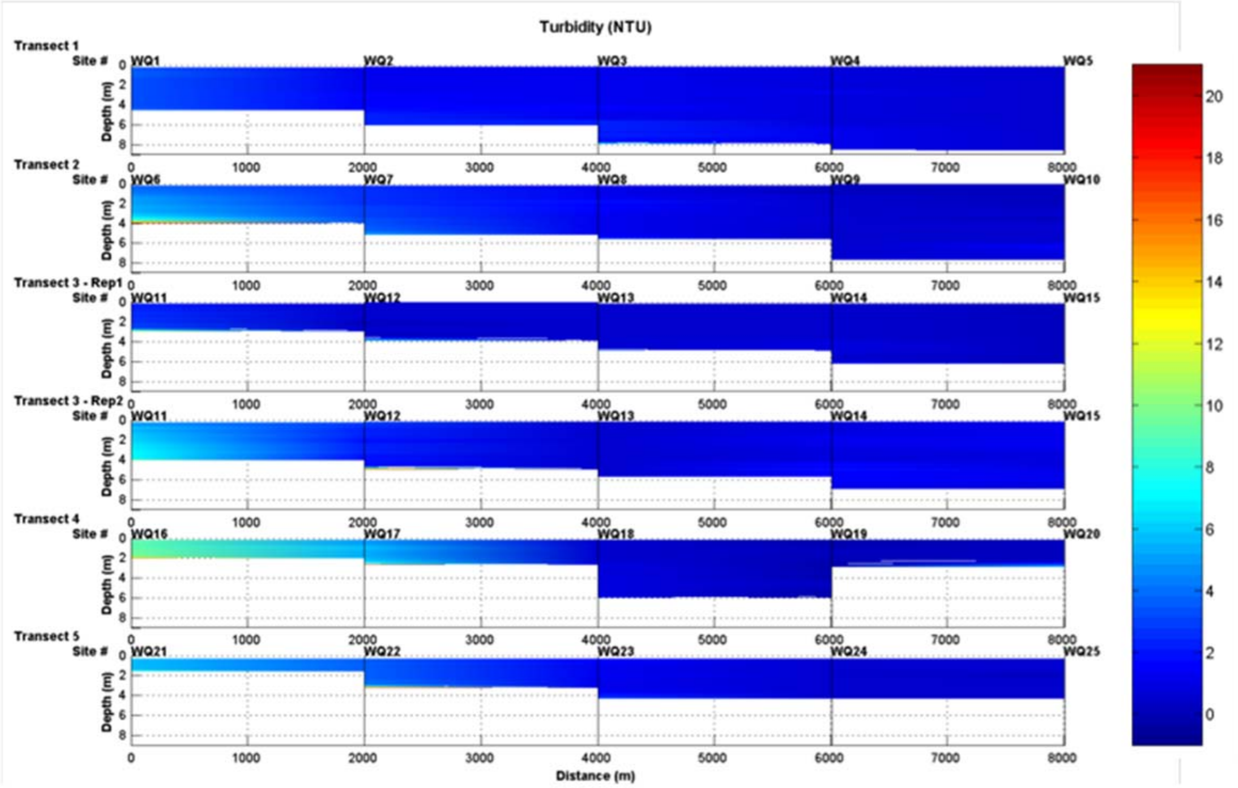


**Figure 13-18 Turbidity Profiles across the Water Quality Transects during April 2011 Wet Season Neap (ebb) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm. Colour scale restricted to 20 NTU to show resolution at the lower end of the scale, where most values occur.*

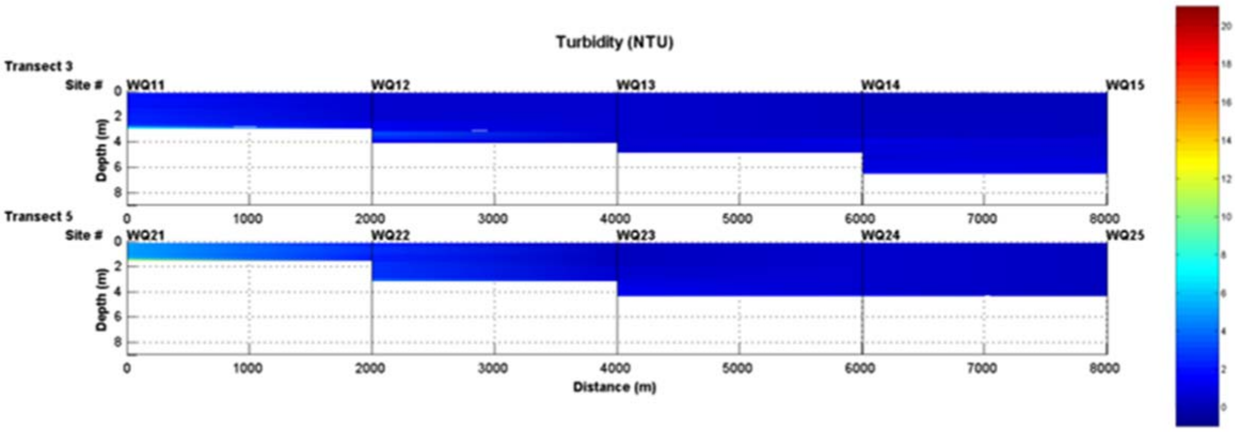


**Figure 13-19 Turbidity Profiles across the Water Quality Transects during April 2011 Wet Season Neap (flood) Tides**

*Note: Transect 5 is a Reference Transect, Transect 3 is at risk of Material or Serious Environmental Harm. Colour scale has been restricted to 20 NTU to show resolution at the lower end of the scale, where most values occur.*

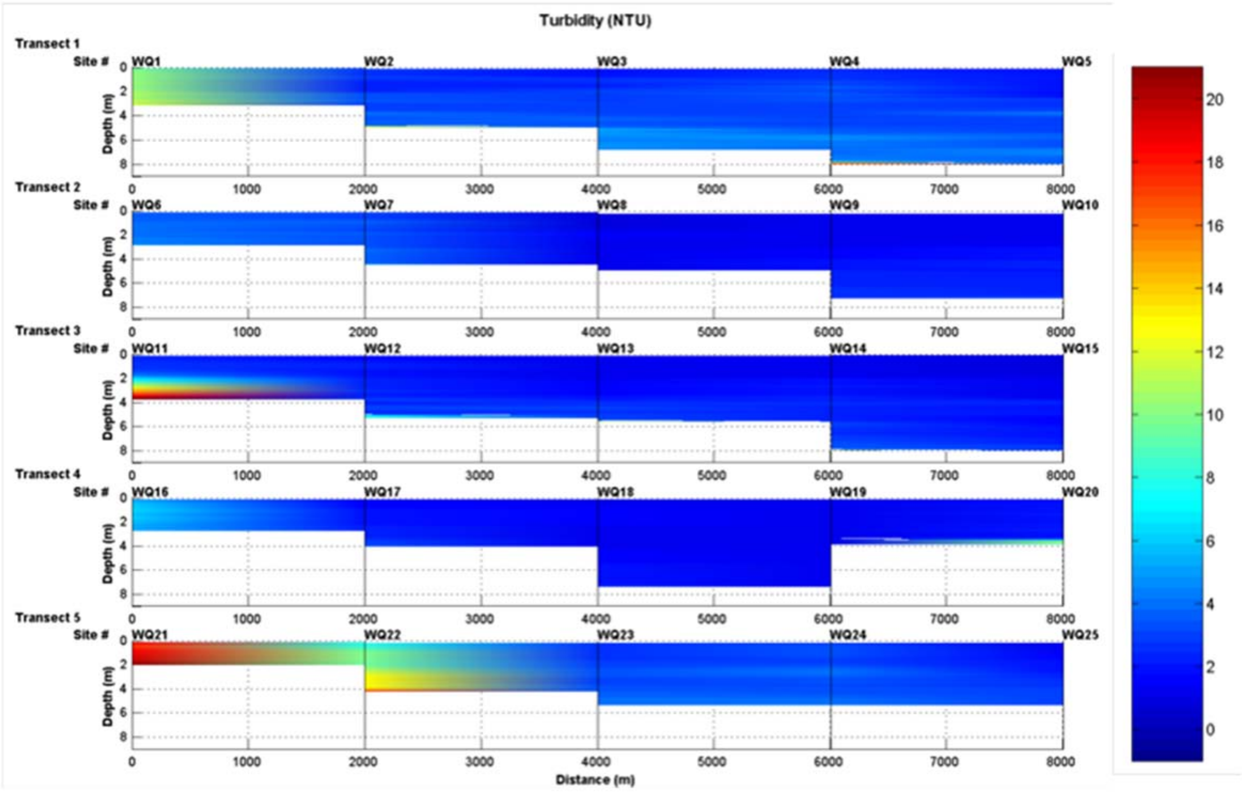


**Figure 13-20 Turbidity Profiles across the Water Quality Transects during April 2011 Wet Season Spring (flood) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm. Colour scale restricted to 20 NTU to show resolution at the lower end of the scale, where most values occur.*

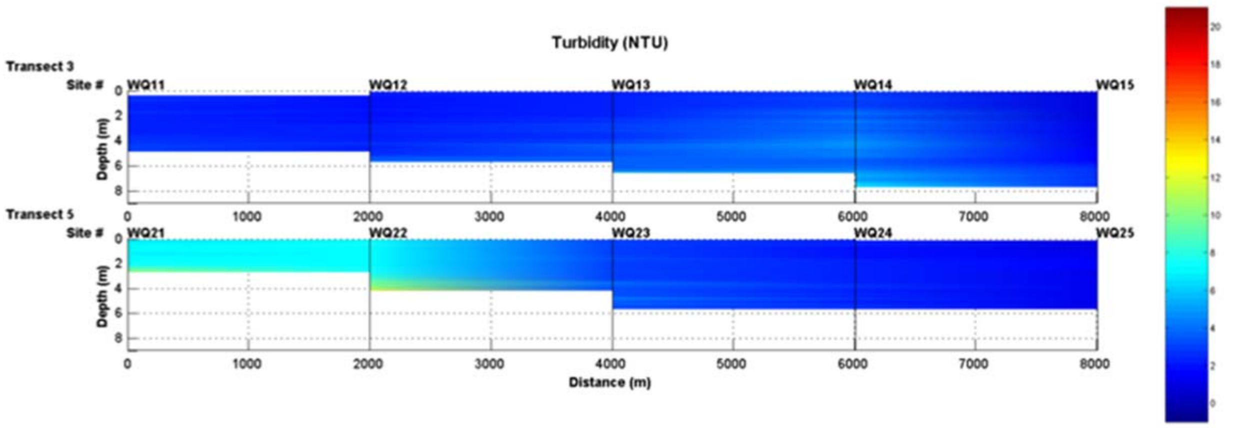


**Figure 13-21 Turbidity Profiles across the Water Quality Transects during April 2011 Wet Season Spring (ebb) Tides**

*Note: Transect 5 is a Reference Transect, Transect 3 is at risk of Material or Serious Environmental Harm. Colour scale restricted to 20 NTU to show resolution at the lower end of the scale, where most values occur.*

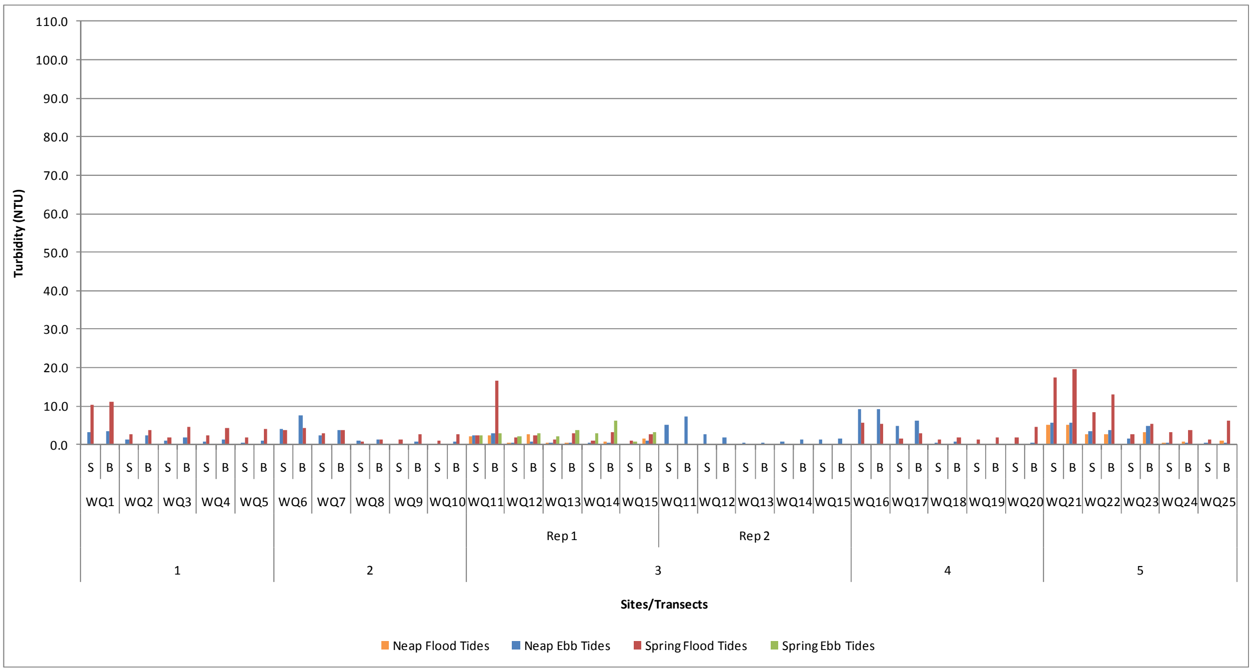


**Figure 13-22 Near-surface and Near-bottom Turbidity at Transects 1 to 5 during the April 2011 Wet Season Survey**

*Note: Turbidity values used for plotting were extracted from the profile at 0.5 m from the surface and 0.5 m from the bottom; where multiple turbidity readings were available, the value was averaged. S = Near-surface, B = Near-bottom.*

**Table 13-13 Summary of Results of Statistical Analyses for Turbidity during the April 2011 Wet Season Survey**

| Analysis | Summary |
|---|---|
| Neap ebb tide | Turbidity did not differ between transects, but did differ with distance offshore ($F_{4,38}$ = 14.72, *p* = 0.0001). *Post hoc* tests identified the presence of an inshore to offshore gradient with distance A (i.e. closest to shore) being significantly different to all other distances. Differences were also detected between distance B and E, and C and E.<br>No significant differences were detected between depths; i.e. between near-surface and near-bottom. |
| Spring flood tide | Turbidity differed significantly between transects during spring tides ($F_{4,40}$ = 3.22, *p* = 0.0199). *Post hoc* tests identified that Transect 2 differed from Transect 1 and Transect 4, and Transect 4 differed from Transect 5. The 2-factor PERMANOVA applied to distance offshore and depth identified that both factors were significant. Turbidity differed between near-surface and near-bottom ($F_{1,40}$ = 4.83, *p* = 0.0358) and Distance A was different to all other distances offshore ($F_{4,40}$ = 8.10, *p* = 0.0003). The non-significant interaction term between depth and distance offshore, indicated that the differences between near-surface and near-bottom were consistent across distances; i.e. differences were not restricted to certain distances offshore. |
| Neap tides<br>ebb vs flood | The 3-factor PERMANOVA applied to tide, depth and transect identified no significant differences between tide or depth. Differences were detected between Transects 3 and 5 ($F_{1,32}$ = 6.50, *p* = 0.0157). |
| Spring tides<br>ebb vs flood | The 3-factor PERMANOVA applied to tide, depth and transect identified no significant differences between tide or depth. Differences were detected between Transects 3 and 5 ($F_{1,32}$ = 5.18, *p* = 0.0269). |
| Neap day-to-day differences | The 2-factor PERMANOVA applied to data sampled at Transect 3 on 12 and 15 April identified no significant differences between the day of sampling or depth. |

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

### 13.4.3.2.2 Water Temperature

#### *13.4.3.2.2.1 Dry Season*

Water temperature during the October 2010 neap ebb tide survey (Figure 13-23) was variable both alongshore and cross-shore for all transects at risk of Material or Serious Environment Harm (Transects 2, 3 and 4). Inshore waters were generally warmer than offshore waters, and there was a generally warming trend moving north-east (Transect 2 to Transect 4). Temperature stratification was evident along Transect 2, with a warmer surface layer extending across the whole transect. The temperature range for all transects at risk of Material or Serious Environment Harm for the October 2010 neap tide survey was 24.78–26.27 °C.

Warmer waters overall were recorded during the October 2010 spring (flood and ebb) tide surveys (Figure 13-24 and Figure 13-25) for all transects at risk of Material or Serious Environment Harm; however, some much cooler waters were recorded at the innermost site of Transect 3. During both the neap ebb and spring ebb surveys, inshore waters were generally warmer than offshore, but during the spring flood tide, inshore waters were cooler or relatively uniform along the transect. The temperature range for all transects at risk of Material or Serious Environment Harm for the October 2010 spring tide survey was 22.51–26.39 °C.

The temperature profiles indicated that water temperature was influenced by the tidal cycle (ebb vs flood) and also by outflows from tidal creeks. This was particularly evident at Transects 3 and 4, which were directly adjacent to large tidal creeks, and may explain the stratification evident at Transect 2.

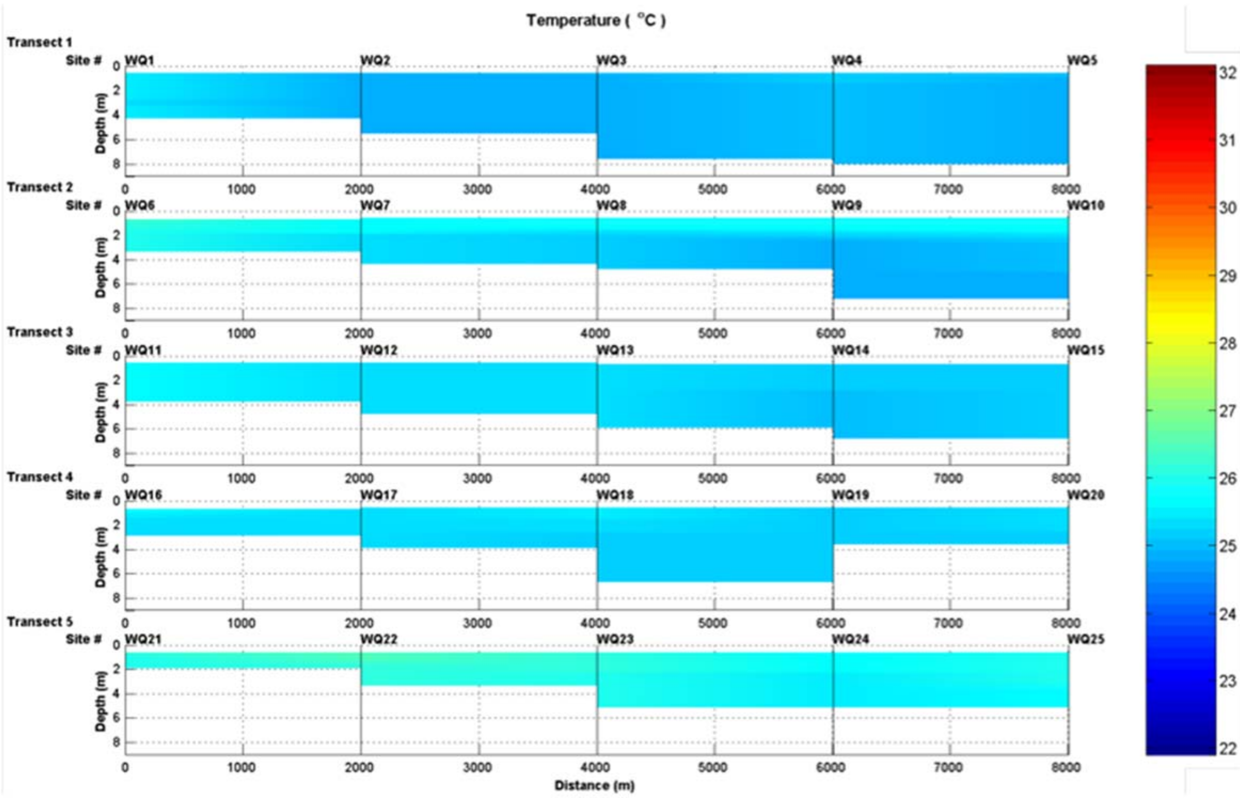


**Figure 13-23 Temperature Profiles across the Water Quality Transects during October 2010 Dry Season Neap (ebb) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

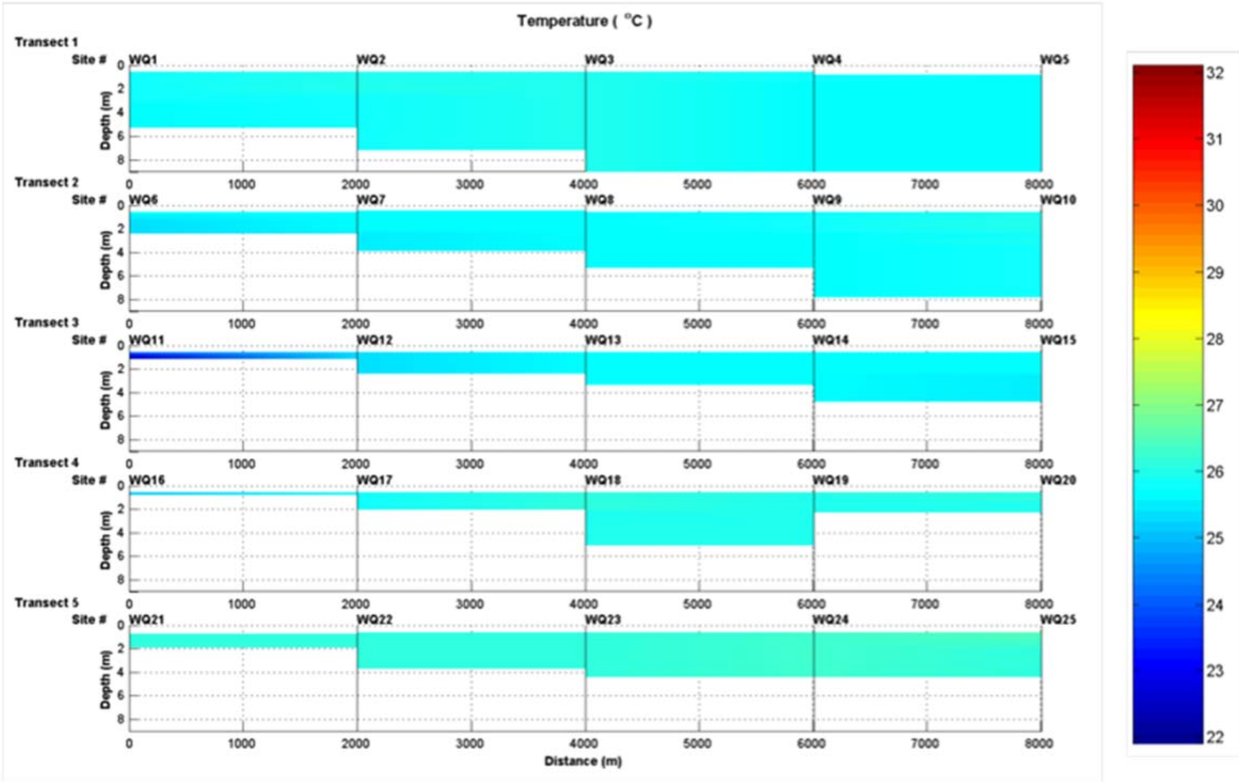


**Figure 13-24 Temperature Profiles across the Water Quality Transects during October 2010 Dry Season Spring (flood) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

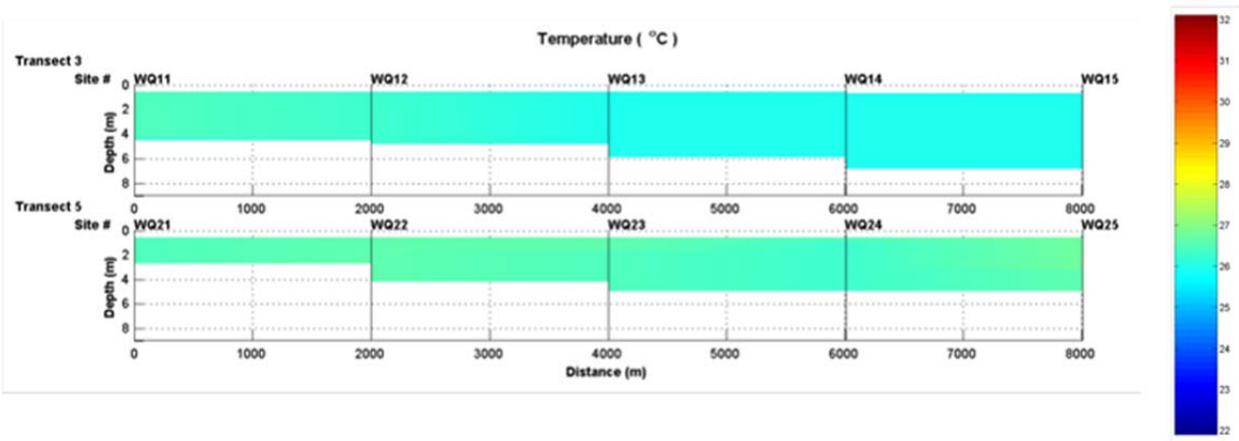


**Figure 13-25 Temperature Profiles across the Water Quality Transects during October 2010 Dry Season Spring (ebb) Tides**

*Note: Transect 5 is a Reference Transect, Transect 3 is at risk of Material or Serious Environmental Harm.*

### *13.4.3.2.2.2 Wet Season*

Water temperature during the April 2011 neap ebb tide survey (Figure 13-26) was relatively uniform both alongshore and cross-shore for all transects at risk of Material or Serious Environment Harm (Transects 2, 3 and 4), and the overall temperature range was relatively small (27.90–29.64 °C). The largest cross-shore change was recorded at Transect 4, where the offshore site (WQ20) was cooler than the rest of the Transect. Transect 2 exhibited slight stratification, with a warmer surface layer extending across the whole transect (as was also evident in the dry season neap ebb tide data). Temperature data collected from the repeated transect (Transect 3; Figure 13-27) during the neap flood tide were warmer than the transect surveyed earlier the same day during the neap ebb tide (likely due to warming over the day). Slight stratification was evident in the offshore sites of Transect 3.

Greater variability overall was evident during the April 2011 spring (flood and ebb) tide surveys (Figure 13-28 and Figure 13-29) for all transects at risk of Material or Serious Environment Harm, although overall the temperature range was small (28.57–29.45 °C). Slight stratification was evident at Transect 3 during flood tide sampling. Cross-shore differences between profiles do not follow a particular trend, and were small variations that were likely related to air temperature variations over different times and days of sampling.

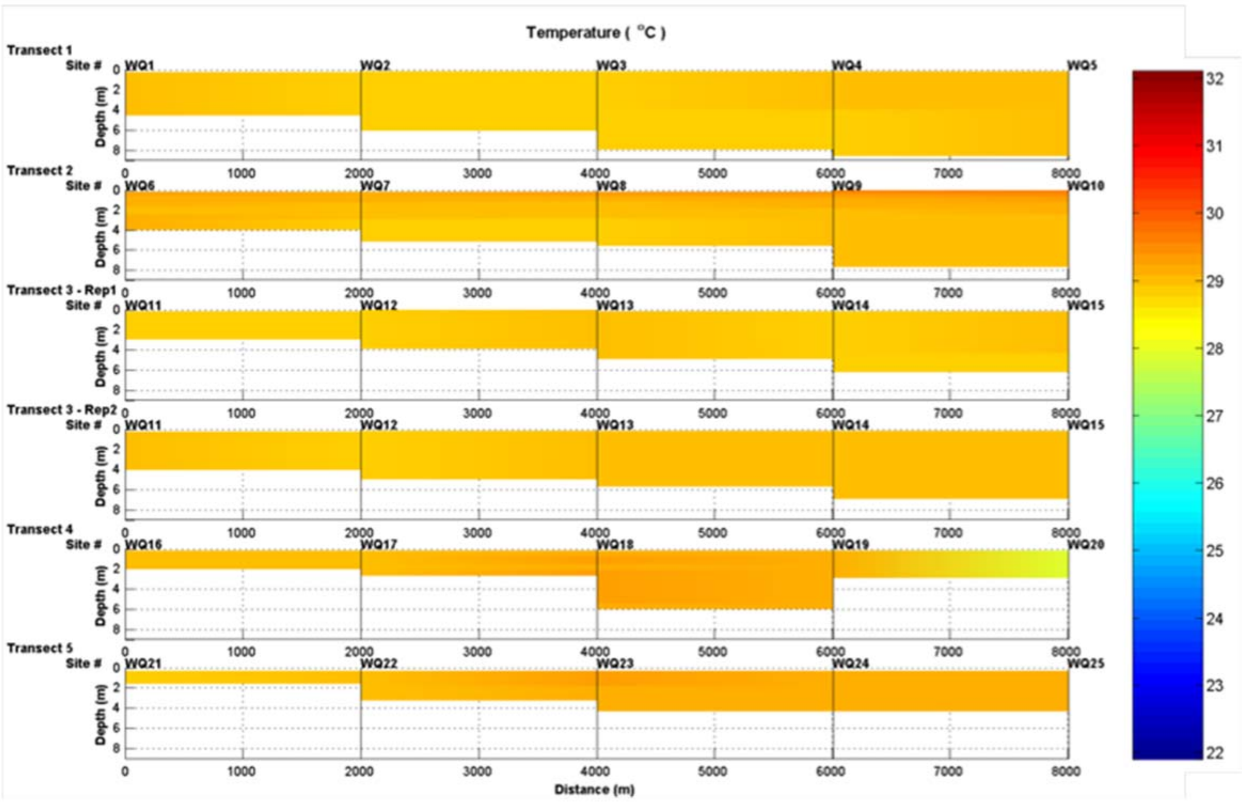


**Figure 13-26 Temperature Profiles across the Water Quality Transects during April 2011 Wet Season Neap (ebb) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

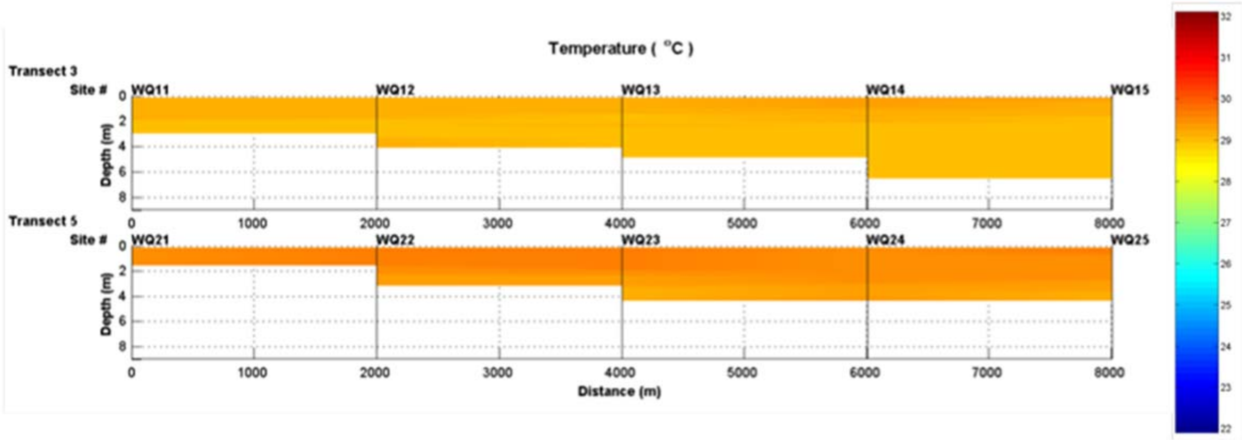


**Figure 13-27 Temperature Profiles across the Water Quality Transects during April 2011 Wet Season Neap (flood) Tides**

*Note: Transect 5 is a Reference Transect, Transect 3 is at risk of Material or Serious Environmental Harm.*

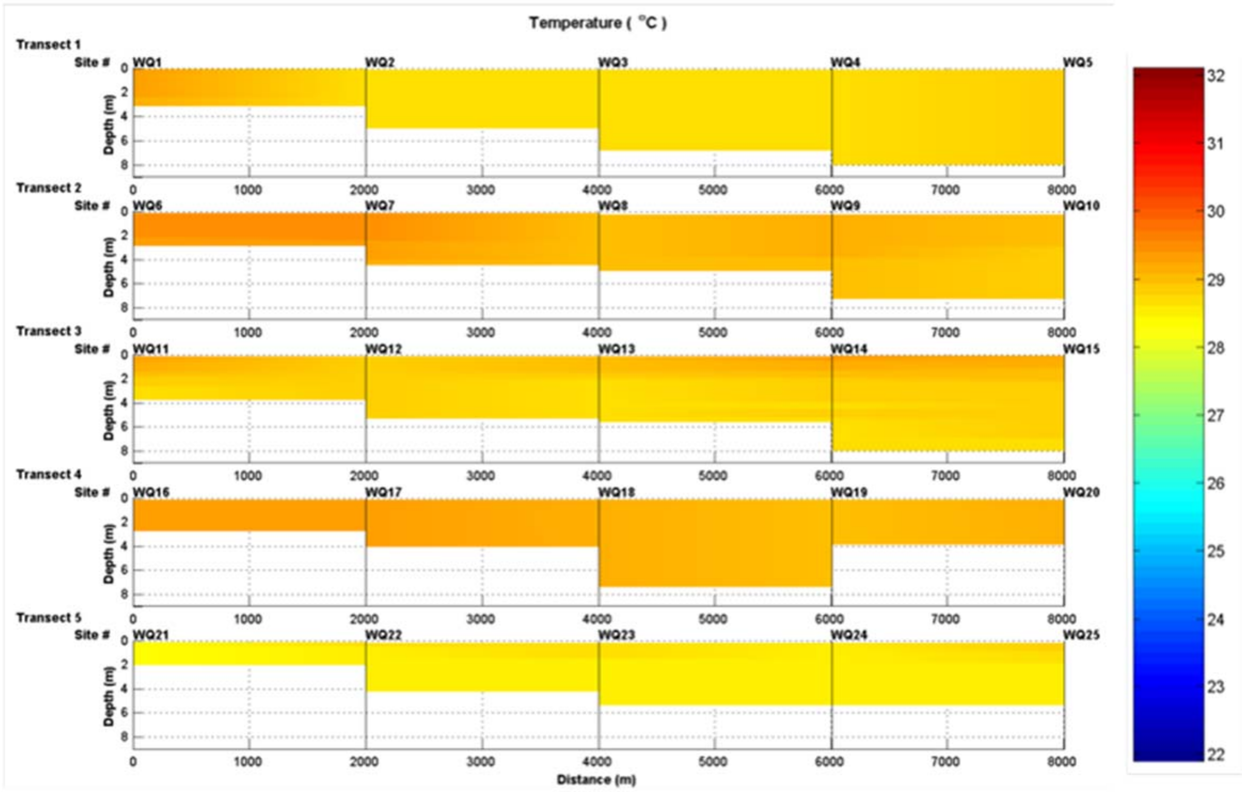


**Figure 13-28 Temperature Profiles across the Water Quality Transects during April 2011 Wet Season Spring (flood) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

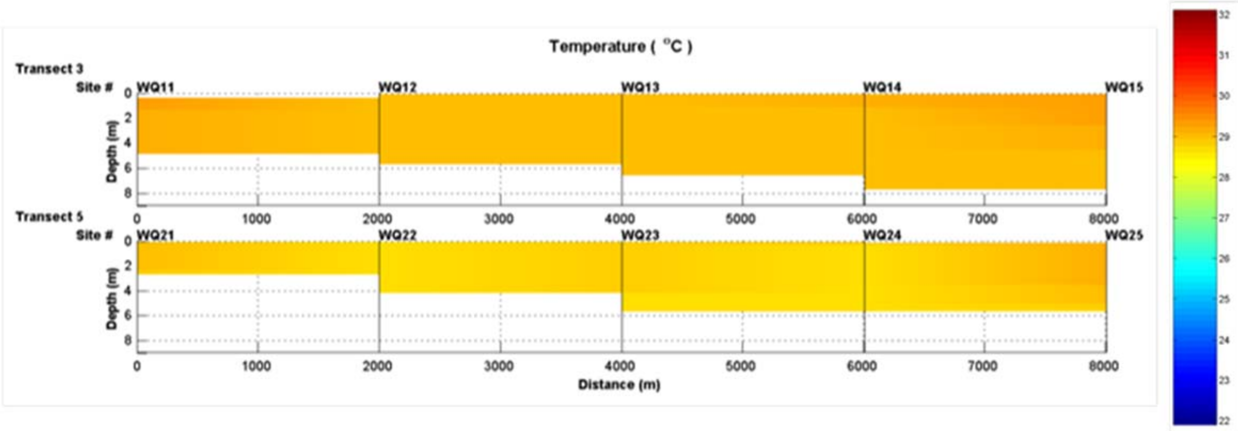


**Figure 13-29 Temperature Profiles across the Water Quality Transects during April 2011 Wet Season Spring (ebb) Tides**

*Note: Transect 5 is a Reference Transect, Transect 3 is at risk of Material or Serious Environmental Harm.*

#### 13.4.3.2.3 Salinity

##### *13.4.3.2.3.1 Dry Season*

Salinity during the October 2010 neap ebb tide survey (Figure 13-30) exhibited some alongshore and cross-shore gradients for all transects at risk of Material or Serious Environment Harm (Transects 2, 3 and 4), with a range of 33.75–35.93 ppt. Transects 2 and 3 had the most pronounced cross-shore gradients; Transect 2 had lower salinity inshore increasing offshore, while Transect 3 had higher salinity inshore than offshore. Two of the profiles (WQ7 [Transect 2] and WQ13 [Transect 3]) showed slightly lower salinities (~34 ppt) with an increasing trend with depth. As there was no obvious explanation for this trend, there may have been a problem with the salinity probe on the YSI at these sites, and results at these two sites should be interpreted with caution.

Higher salinities overall were recorded during the October 2010 spring (flood and ebb) tide surveys (Figure 13-31 and Figure 13-32) for all transects at risk of Material or Serious Environment Harm, with a range of 35.62–44.15 ppt. Cross-shore gradients were evident at Transect 3 during both the spring flood and spring ebb tide survey, with higher salinity inshore than offshore (Figure 13-31 and Figure 13-32). Particularly high salinities were evident at WQ16 in Transect 4, where the water was very shallow (<1 m). The spring/neap tidal cycle appears to be a significant driving force of salinity fluctuations, particularly for the northern transects.

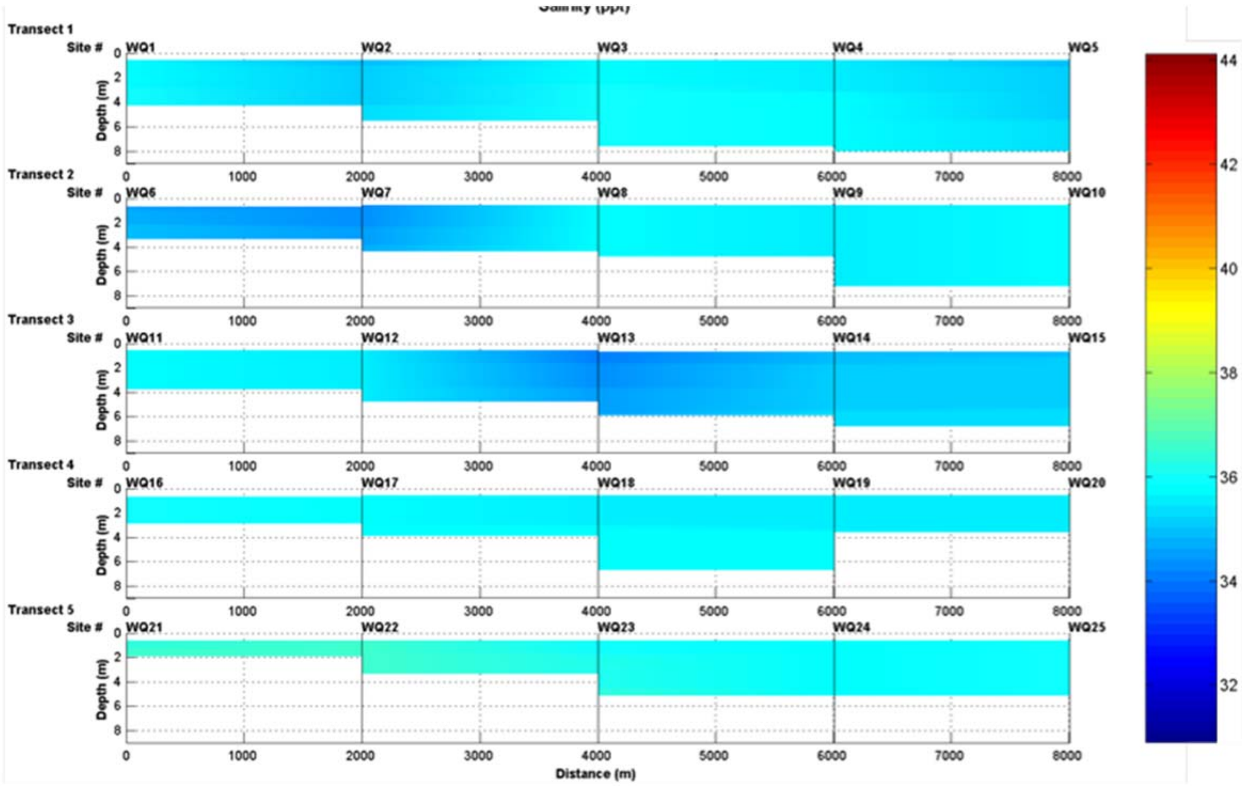


**Figure 13-30 Salinity Profiles across the Water Quality Transects during October 2010 Dry Season Neap (ebb) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

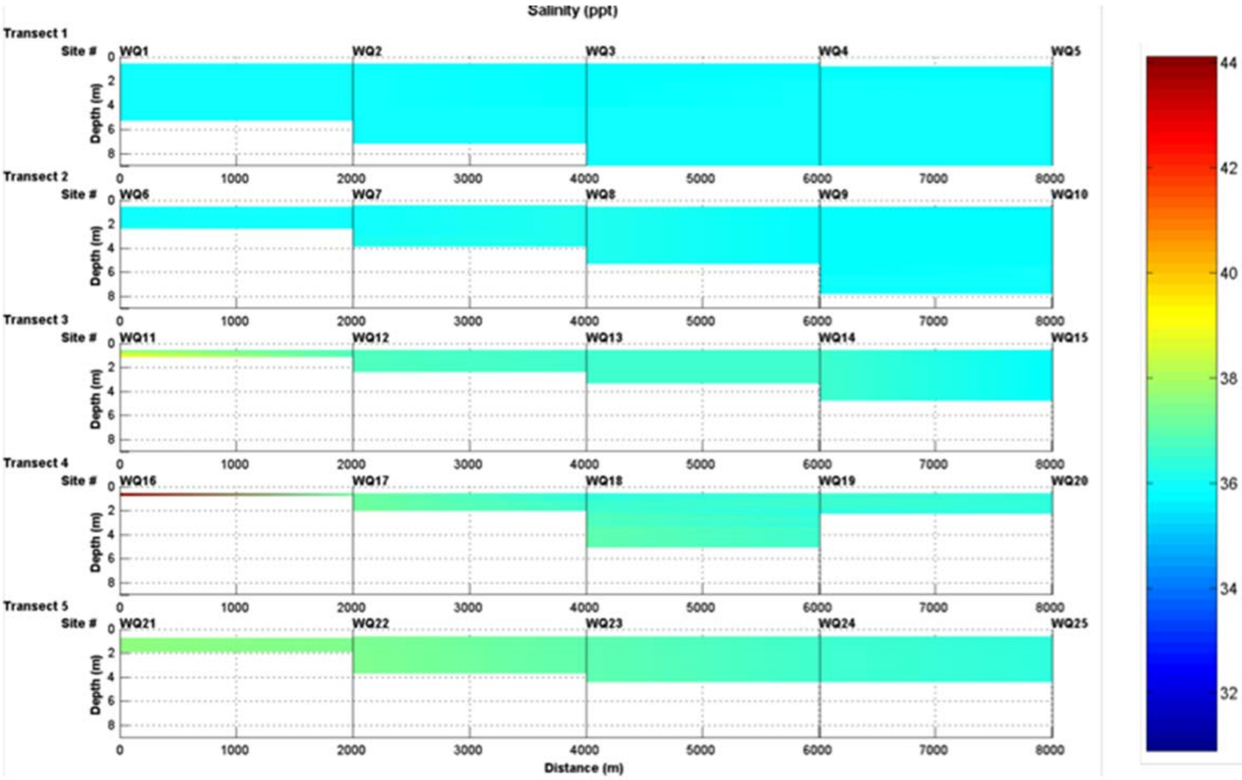


**Figure 13-31 Salinity Profiles across the Water Quality Transects during October 2010 Dry Season Spring (flood) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

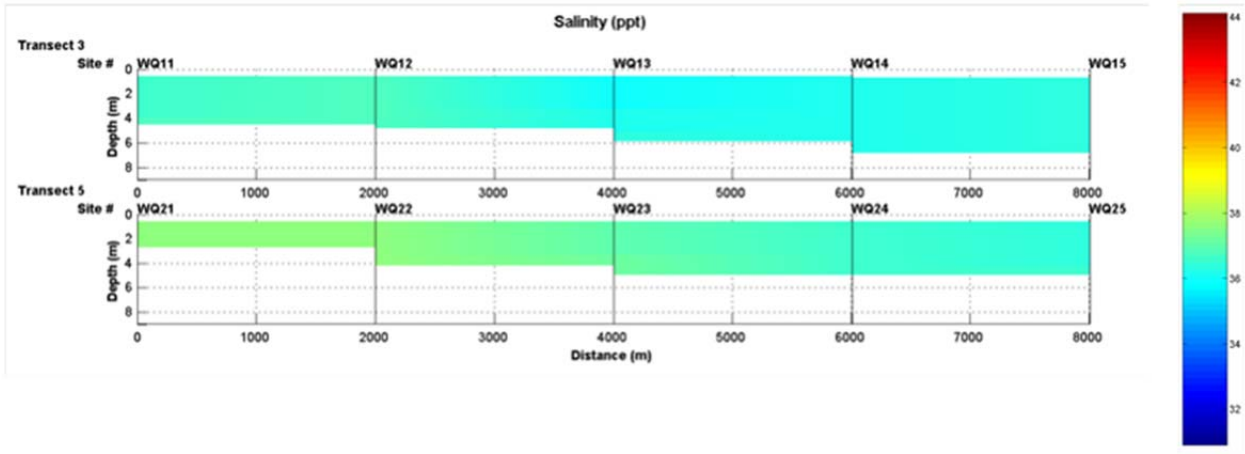


**Figure 13-32 Salinity Profiles across the Water Quality Transects during October 2010 Dry Season Spring (ebb) Tides**

*Note: Transect 5 is a Reference Transect, Transect 3 is at risk of Material or Serious Environmental Harm.*

### *13.4.3.2.3.2 Wet Season*

Salinity during the April 2011 neap ebb tide survey (Figure 13-33) was slightly variable alongshore and cross-shore for all transects at risk of Material or Serious Environment Harm (Transects 2, 3 and 4), with a range of 34.91–35.92 ppt. Salinity was slightly lower inshore, particularly at those Transects at risk of Material or Serious Environmental Harm. Transect 3 had slightly lower salinity when sampled for the second time during the neap ebb tide (Figure 13-33), and salinity measured at Transect 3 during the neap flood tide survey (Figure 13-34) showed little change from the transect sampled earlier in the day during ebb tides.

Salinity during the April 2011 spring flood tide survey (Figure 13-35) was slightly variable alongshore and cross-shore for all transects at risk of Material or Serious Environment Harm, with a range of 34.17–35.87 ppt. Salinity was lower inshore, particularly at transects at risk of Material or Serious Environmental Harm. Salinity measured at Transect 3 during the spring ebb tide survey (Figure 13-36) showed little change from the transect sampled earlier in the day during spring flood tide; however, salinity appeared to increase inshore at both transects (i.e. WQ11).


**Figure 13-33 Salinity Profiles across the Water Quality Transects during April 2011 Wet Season Neap (ebb) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

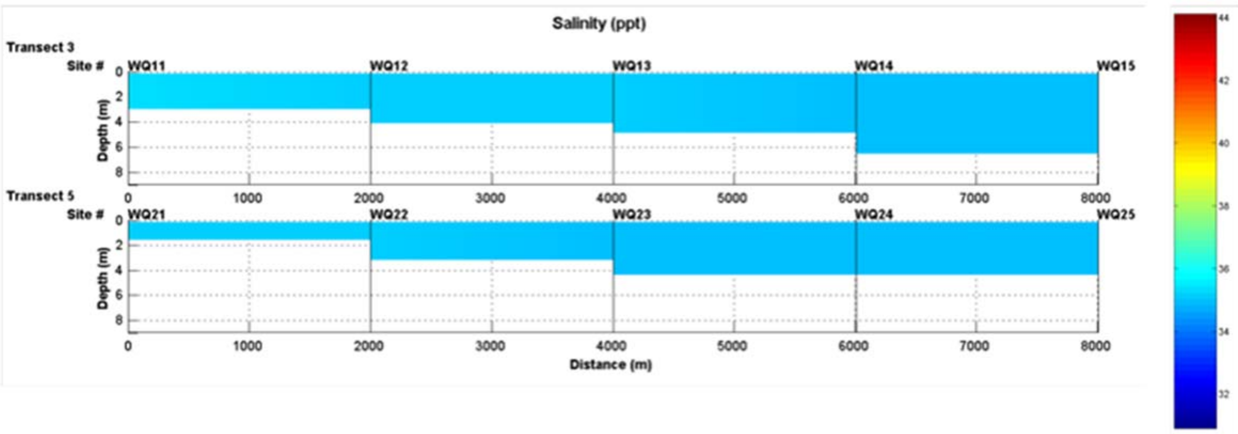


**Figure 13-34 Salinity Profiles across the Water Quality Transects during April 2011 Wet Season Neap (flood) Tides**

*Note: Transect 5 is a Reference Transect, Transect 3 is at risk of Material or Serious Environmental Harm.*

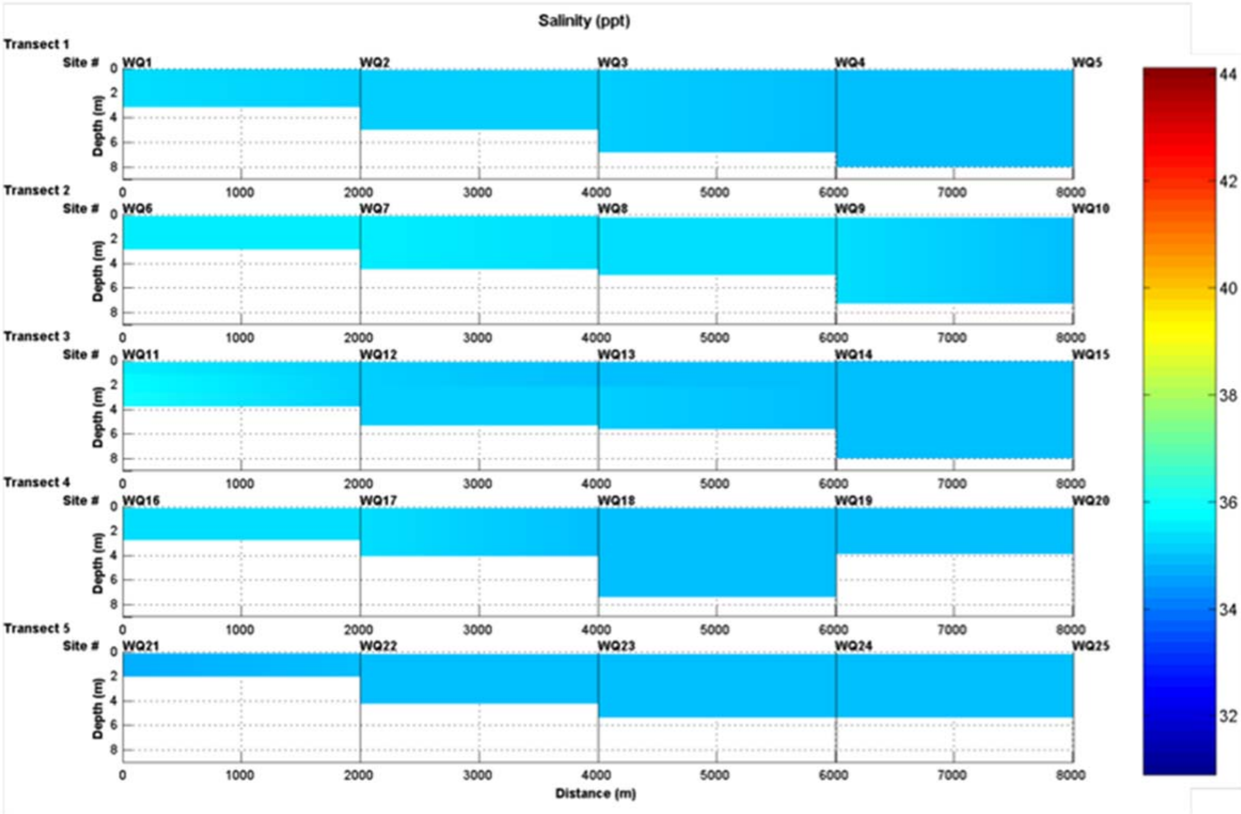


**Figure 13-35 Salinity Profiles across the Water Quality Transects during April 2011 Wet Season Spring (flood) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm.*

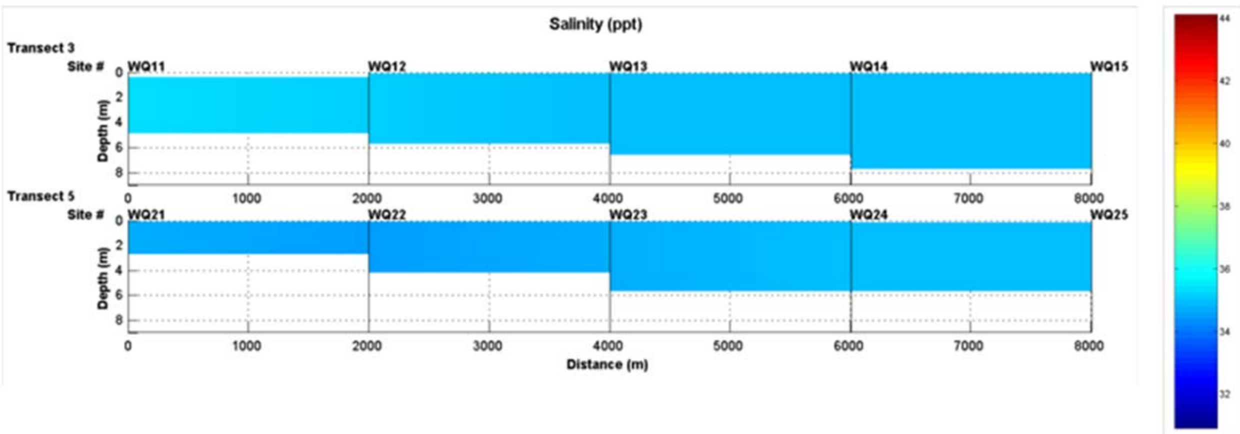


**Figure 13-36 Salinity Profiles across the Water Quality Transects during April 2011 Wet Season Spring (ebb) Tides**

*Note: Transect 5 is a Reference Transect, Transect 3 is at risk of Material or Serious Environmental Harm.*

### 13.4.4 Water Column Profiles at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Facilities

#### 13.4.4.1 East Coast of Barrow Island

##### 13.4.4.1.1 LNG3

Salinity ranged from 35.1 to 35.6 PSU (Table 13-14). The lowest salinity was recorded in surface waters in March and May 2008. The highest salinity was recorded in bottom waters in June and August 2009. A minimum temperature of 21.3 °C was recorded in August 2009 in bottom waters, and a maximum temperature of 30.3 °C was recorded in March 2008 in surface waters. The highest temperature in bottom waters was 29.9 °C, also recorded in March 2008. A minimum turbidity of 8.8 NTU was recorded in July 2008 in surface and bottom waters, and August 2009 in surface waters. A maximum turbidity of 11.7 NTU was recorded in November 2008 in bottom waters.

##### 13.4.4.1.2 Dugong Reef (DUG)

Salinity ranged from 35.2 to 35.6 PSU, with the lowest recorded in May 2008 in bottom waters and the highest recorded in November 2008 in surface and bottom waters. The lowest temperature was 21.9 °C, which was recorded in September 2009 in bottom waters. A maximum temperature of 30.7 °C was recorded in surface waters in January 2008. Turbidity ranged from 9.8–11.7 NTU, with the lowest recorded in January, May and September 2008 and September 2009 in bottom waters, and May 2008 and September 2009 in surface waters. The highest turbidity was recorded in November 2008 in surface and bottom waters.

**Table 13-14 Surface (~1 m below) and Near-seabed (~0.5 m above) Physicochemical Water Quality Data from Vertical Profiles Undertaken at LNG3 and DUG from January 2008 to November 2009**

| Month | LNG3 | | | | | | DUG | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Salinity (PSU) | | Temperature (degrees C) | | Turbidity (NTU) | | Salinity (PSU) | | Temperature (degrees C) | | Turbidity (NTU) | |
| | Near-surface | Near-seabed | Near-surface | Near-seabed | Near-surface | Near-seabed | Near-surface | Near-seabed | Near-surface | Near-seabed | Near-surface | Near-seabed |
| Jan-08 | 35.4 | 35.4 | 28.9 | 28.8 | 9.3 | 9.8 | 35.4 | 35.4 | 30.7 | 29.0 | 10.3 | 9.8 |
| Mar-08 | 35.1 | 35.2 | 30.3 | 29.9 | - | - | 35.3 | 35.3 | 29.8 | 29.6 | - | - |
| May-08 | 35.1 | 35.2 | 28.7 | 28.5 | 9.8 | 10.3 | 35.3 | 35.2 | 25.4 | 25.4 | 9.8 | 9.8 |
| Jun-08 | 35.3 | 35.3 | 23.0 | 22.7 | 9.8 | 9.8 | - | - | - | - | - | - |
| Jul-08 | 35.4 | 35.4 | 22.2 | 22.2 | 8.8 | 8.8 | - | - | - | - | - | - |
| Sep-08 | 35.3 | 35.3 | 23.6 | 23.2 | 10.7 | 10.3 | 35.3 | 35.3 | 23.5 | 23.4 | 10.3 | 9.8 |
| Oct-08 | - | - | - | - | - | - | - | - | - | - | - | - |
| Nov-08 | 35.5 | 35.5 | 24.6 | 24.3 | 11.2 | 11.7 | 35.6 | 35.6 | 24.1 | 23.8 | 11.7 | 11.7 |
| Jun-09 | 35.5 | 35.6 | 24.1 | 24.0 | 9.8 | 10.3 | - | - | - | - | - | - |
| Jul-09 | - | - | - | - | - | - | 35.3 | 35.3 | 22.2 | 22.2 | 10.7 | 10.3 |
| Aug-09 | 35.5 | 35.6 | 21.6 | 21.3 | 8.8 | 9.8 | - | - | - | - | - | - |
| Sep-09 | 35.4 | 35.4 | 22.4 | 22.3 | 9.8 | 9.8 | 35.5 | 35.5 | 22.0 | 21.9 | 9.8 | 9.8 |

### 13.4.4.2 Mainland End of Domestic Gas Pipeline Route

#### 13.4.4.2.1 Turbidity

##### *13.4.4.2.1.1 Dry Season*

Turbidity during the October 2010 neap ebb tide survey (Figure 13-14) generally fell below 10 NTU for Reference Transects 1 and 5. Higher turbidity was recorded during the October 2010 spring flood tide survey (Figure 13-15); however, in general, turbidity remained below 20 NTU for Reference Transects 1 and 5. Turbidity data collected from the repeated transect (Reference Transect 5; Figure 13-16) during the October 2010 spring ebb tide were lower in turbidity than during the spring flood tide, and, in general, turbidity was below 10 NTU.

In general, during both neap and spring tide surveys, turbidity was higher at Transects 2 to 4 (neap: 0.3–88.6 NTU, spring: 1.6–81.5 NTU) than at Reference Transects 1 and 5 (neap: 0.4–5.4 NTU, spring: 1.0–13.1 NTU). Cross-shore change in turbidity was most pronounced during the spring tide survey, with higher turbidity inshore, decreasing offshore.

Results from statistical tests on all factors apart from ‘Area’ (i.e. ‘Distance’, ‘Transect’, ‘Depth’, ‘Tide’ and ‘Day’ [see Section 13.3.5.2.2]) are summarised in Table 13-12. Results from PERMANOVA tests for the difference between Reference Transects and transects at risk of Material or Serious Environmental Harm are summarised below:

- there was no significant difference in turbidity between the Reference Transects and the transects at risk of Material or Serious Environmental Harm during the October 2010 neap ebb tide survey
- there was a significant difference in turbidity between the Reference Transects and transects at risk of Material or Serious Environmental Harm ($F_{1,30}$ = 7.46, $p$ = 0.0073) during the October 2010 spring flood tide survey.

##### *13.4.4.2.1.2 Wet Season*

Turbidity for Reference Transects 1 and 5 during the April 2011 neap ebb tide survey (Figure 13-18) typically fell below 10 NTU. Turbidity data collected from the repeated transect (Reference Transect 5; Figure 13-19) during the neap flood tide were similarly low, with turbidity below 10 NTU.

Turbidity during the April 2011 spring flood tide survey (Figure 13-20) generally fell below 10 NTU for Reference Transect 1 and 5, with the exception of some inshore sites (e.g. WQ21 and WQ22 [Reference Transect 5]) and in some bottom waters. Data collected from the repeated transect (Reference Transect 5; Figure 13-21) during the spring ebb tide recorded lower turbidity at the inshore sites, and generally fell below 10 NTU at all other sites.

Cross-shore change in turbidity was most pronounced during the April 2011 spring tide survey, with higher turbidity inshore, decreasing offshore (particularly at Reference Transect 5 during the flood survey). However, overall turbidity was low across all sites and tide cycles.

Near-surface and near-bottom turbidity (Figure 13-22) during the April 2011 survey was relatively low for Reference Transects 1 and 5 during all tidal cycles. The highest turbidity readings were recorded at inshore sites (e.g. WQ21 and WQ22 [Reference Transect 5]) during the spring flood tide survey.

Results from statistical tests on all factors apart from ‘Area’ (i.e. ‘Distance’, ‘Transect’, ‘Depth’, ‘Tide’ and ‘Day’ [see Section 13.3.5.2.2]) are summarised in Table 13-13. Results from PERMANOVA tests for the difference between Reference Transects and transects at risk of Material or Serious Environmental Harm are summarised below:

- there was no significant difference in turbidity between the Reference Transects and transects at risk of Material or Serious Environmental Harm during the October 2010 neap ebb tide survey

- the 3-factor PERMANOVA applied to Reference Transects and transects at risk of Material or Serious Environmental Harm, distance offshore and depth (near-surface/near-bottom) identified a significant interaction between Reference Transects and transects at risk of Material or Serious Environmental Harm and distance offshore ($F_{4,30} = 2.81$, $p = 0.0428$). The interaction indicated that although there were differences between the Reference Transects and transects at risk of Material or Serious Environmental Harm, the differences were restricted to certain distances. Subsequent *post hoc* tests identified that the differences between Reference Transects and transects at risk of Material or Serious Environmental Harm were restricted to Distances A, C and D.

#### 13.4.4.2.2 Temperature

##### *13.4.4.2.2.1 Dry Season*

Water temperature during the October 2010 neap ebb tide survey (Figure 13-23) was variable both alongshore and cross-shore for Reference Transects 1 and 5. Inshore waters were generally warmer than offshore waters, and there was a generally warming trend moving north-east (Transect 1 to Transect 5). The temperature range for Reference Transects 1 and 5 for the October 2010 neap tide survey was 24.76–26.44 °C.

Warmer waters overall were recorded during the October 2010 spring (flood and ebb) tide surveys (Figure 13-24 and Figure 13-25) for Reference Transects 1 and 5. During both the neap ebb and spring ebb surveys, inshore waters were generally warmer inshore than offshore, but during the spring flood tide, inshore waters were cooler inshore or relatively uniform along the transect. The temperature range for Reference Transects 1 and 5 during the October 2010 spring tide survey was 25.66–26.73 °C.

##### *13.4.4.2.2.2 Wet Season*

Water temperature during the April 2011 neap ebb tide survey (Figure 13-26) was relatively uniform both alongshore and cross-shore for Reference Transects 1 and 5, and the overall temperature range was relatively small (28.86–29.71 °C). The temperature data from the repeated transect (Reference Transect 5; Figure 13-27) during neap flood tide were warmer than the temperatures recorded earlier the same day during the neap ebb tide (likely due to warming over the day).

Greater variability overall was evident during the April 2011 spring (flood and ebb) tide surveys (Figure 13-28 and Figure 13-29) for Reference Transects 1 and 5, although overall the temperature range was small (28.34–29.32 °C). Waters were generally warmer inshore, with the exception of Reference Transect 5 during the spring flood tide. Cross-shore differences between profiles do not follow a particular trend, and were small variations that were likely related to air temperature variations over different times and days of sampling.

#### 13.4.4.2.3 Salinity

##### *13.4.4.2.3.1 Dry Season*

Salinity during the October 2010 neap ebb tide survey (Figure 13-30) exhibited some alongshore and cross-shore gradients for Reference Transects 1 and 5, with a range of 34.99–36.51 ppt. Reference Transect 5 had a more pronounced cross-shore gradient; with higher salinity inshore.

Higher salinities overall were recorded during the October 2010 spring (flood and ebb) tide surveys (Figure 13-31 and Figure 13-32) for Reference Transects 1 and 5, with a range of 35.76–37.70 ppt. Cross-shore gradients were again evident at Reference Transect 5 during both the flood and ebb survey. The spring/neap tidal cycle appears to be a significant driving force of salinity fluctuations, particularly for the northern transects.

##### *13.4.4.2.3.2 Wet Season*

Salinity during the April 2011 neap ebb tide survey (Figure 13-33) was slightly variable alongshore and cross-shore for Reference Transects 1 and 5, with a range of 34.89–35.31 ppt.

Salinity measured at Reference Transect 5 during the neap flood tide survey (Figure 13-34) showed little change from the transect sampled earlier in the day during the neap ebb tide.

Salinity during the April 2011 spring flood tide survey (Figure 13-35) was slightly variable alongshore and cross-shore for Reference Transects 1 and 5, with a range of 34.59–35.27 ppt. However, Reference Transect 1 had lower salinity inshore, while salinity at Reference Transect 5 was slightly higher inshore. Salinity measured at Reference Transect 5 during the spring ebb tide survey (Figure 13-36) showed little change from the transect sampled earlier in the day during spring flood tides; however, salinity appeared to increase inshore (i.e. WQ21).

### 13.4.5 Summary Description of Water Quality during the February 2011 Wet Season (post-cyclone) Survey

#### 13.4.5.1 Light Attenuation

Light attenuation measured during the February 2011 (post-cyclone) survey (Figure 13-37) was higher than that measured during the April 2011 survey for all transects and tidal cycles (although February 2011 neap tide data were limited). This is likely to be related to weather conditions; in February, wind speeds were higher on average, squalls passed through frequently, and a severe tropical cyclone passed through the region approximately one week prior to the survey (Tropical Cyclone Bianca; Section 3.4.). During the April 2011 survey, the wind speeds were lower on average and the weather was fine.

Weather conditions may also contribute significantly to variations within a tidal survey period. Repetitions of Transect 3 across different sampling days during the February 2011 (post-cyclone) spring flood and April 2011 neap ebb survey indicated that turbidity readings can change significantly. Marked differences were apparent between Day 1 and Day 4 for February 2011 spring flood data for Transect 3, particularly at inshore sites (Figure 13-37), with fewer differences in the Day 1 and Day 4 for April 2011 neap ebb data (Figure 13-7).

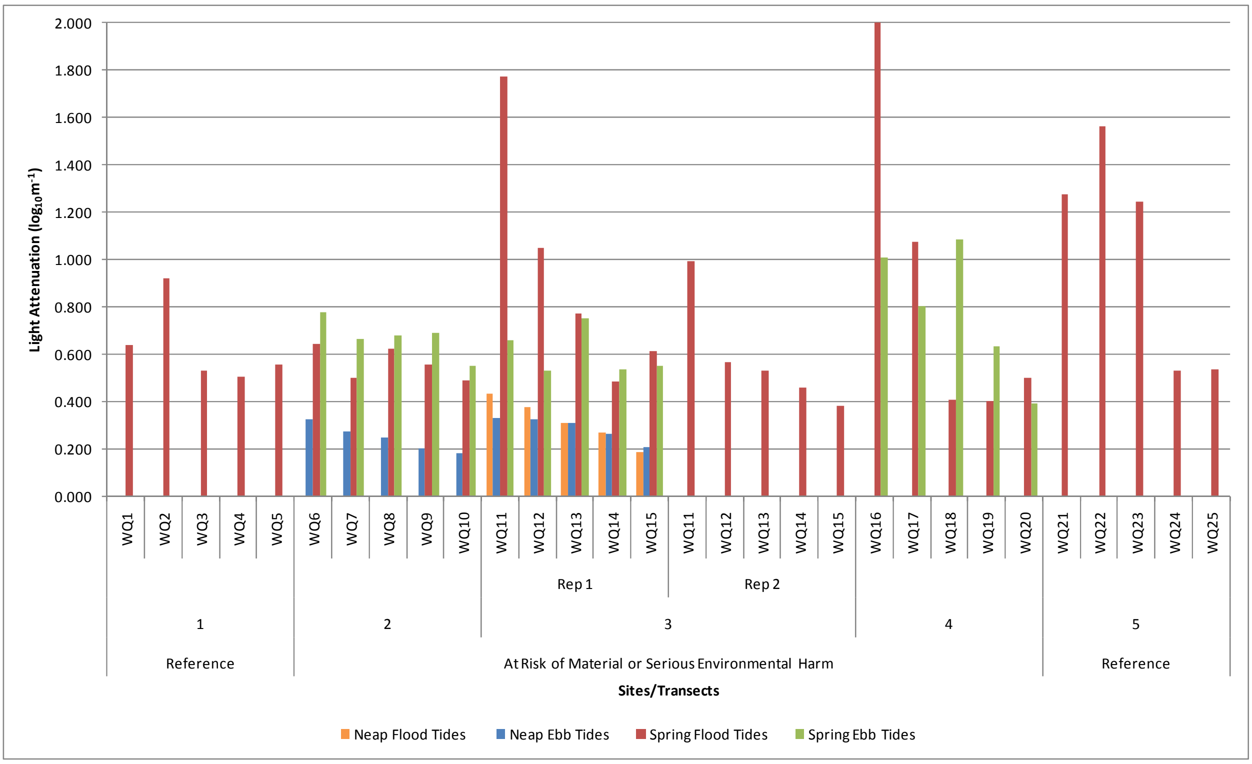


**Figure 13-37 Light Attenuation at Transects 1 to 5 during the February 2011 (post-cyclone) Wet Season Survey**

*Note: Figure has been cropped at 2.000 to show resolution in remaining data; WQ16, during spring flood, reached 4.5 $log_{10}$/m.*

### 13.4.5.2 Secchi Depth

In a similar trend to that described above for light attenuation, the Secchi depths recorded during the February 2011 (post-cyclone) survey (Figure 13-38) were markedly lower compared to the Secchi depths recorded during the April 2011 survey (Figure 13-9). Marked differences were again apparent between Day 1 and Day 4 for the February 2011 (post-cyclone conditions) spring flood survey at Transect 3 (Figure 13-38), compared to the day-to-day differences recorded during the April 2011 survey.

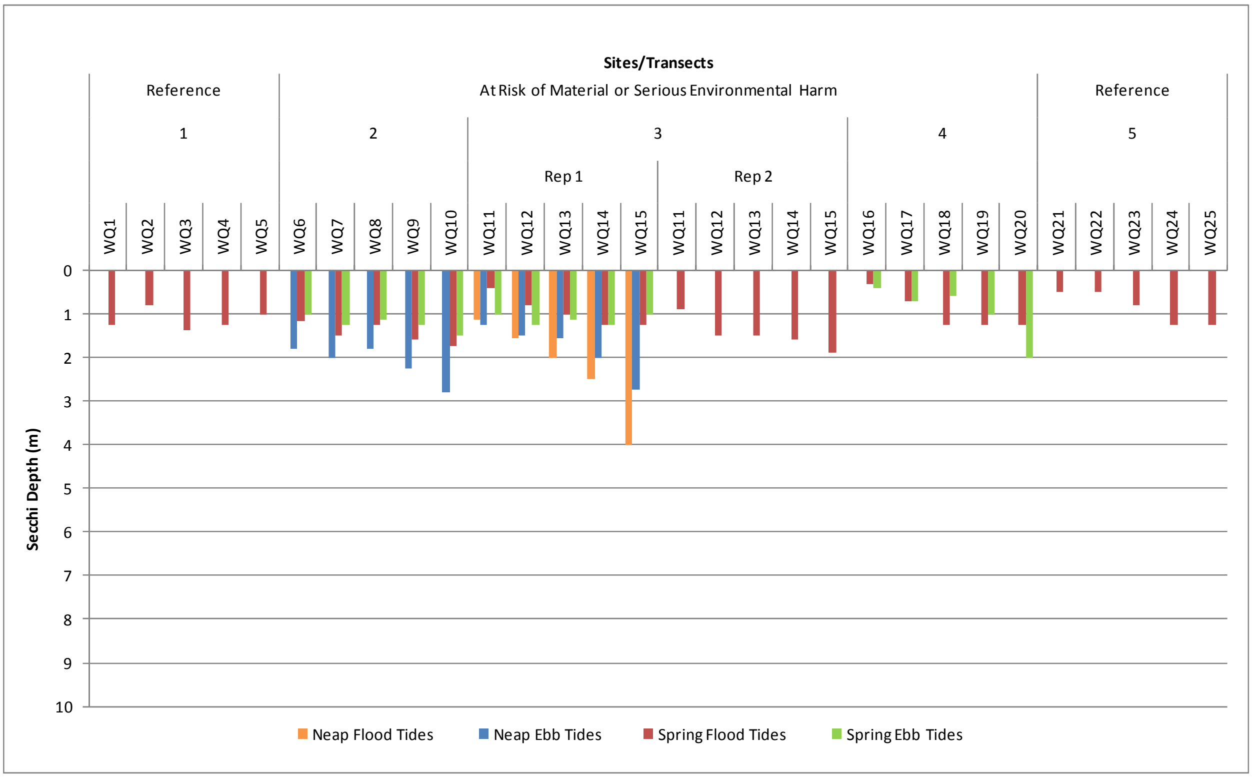


**Figure 13-38 Secchi Depth at Transects 1 to 5 during the February 2011 (post-cyclone) Wet Season Survey**

### 13.4.5.3 Total Suspended Solids

Similarly to light attenuation and Secchi depth, the TSS recorded during the February 2011 (post-cyclone) survey (Figure 13-39) were markedly higher compared to the TSS recorded during the April 2011 survey (Figure 13-11). Marked differences were again apparent between Day 1 and Day 4 for February 2011 (post-cyclone conditions) spring flood survey at Transect 3 (Figure 13-39), compared to the day-to-day differences recorded during the April 2011 survey.

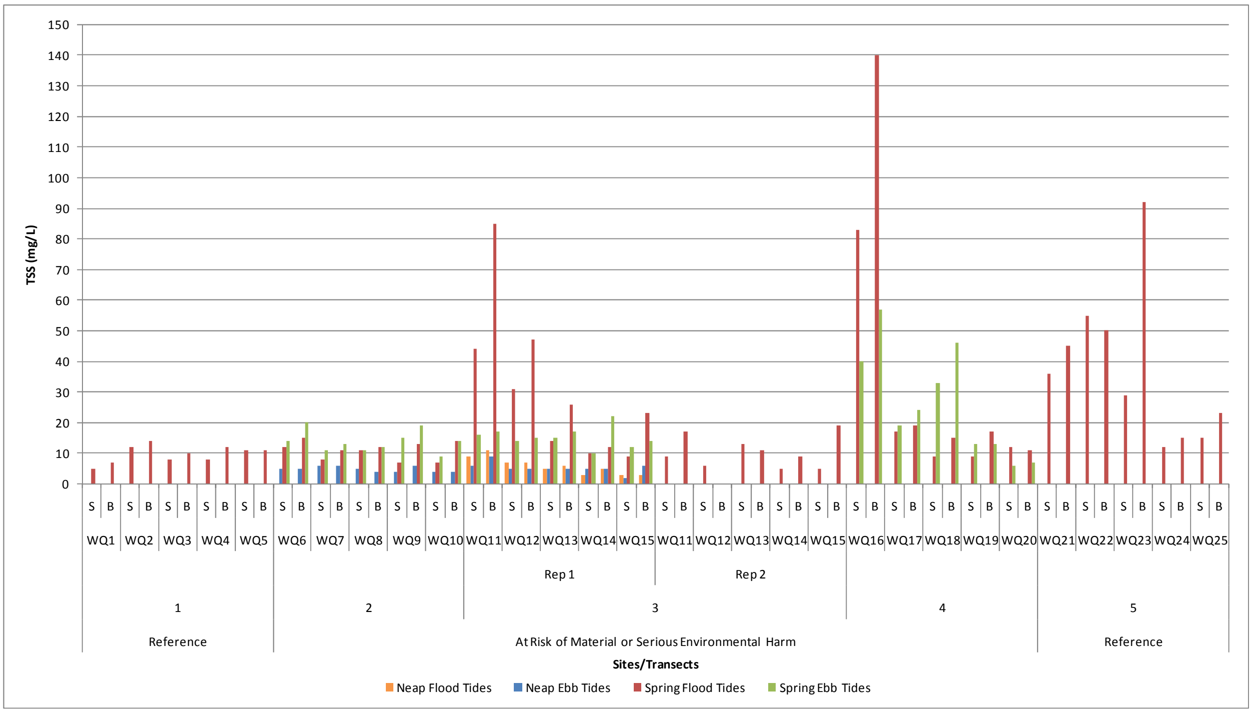


**Figure 13-39 Total Suspended Solids at Transects 1 to 5 during the February 2011 (post-cyclone) Wet Season Survey**

*Note: S = Near-surface, B = Near-bottom.*

#### 13.4.5.4 Turbidity

Turbidity during the February 2011 (post-cyclone) neap ebb tide survey was only collected at two transects (Transect 2 and Transect 3; Figure 13-40), and typically fell below 10 NTU. The one replicate transect (Transect 3; Figure 13-41) collected during the neap flood was similarly low, falling below 10 NTU. Both transects showed cross-shore and depth gradients in turbidity, increasing with depth, particularly inshore, and decreasing offshore.

Turbidity during the February 2011 (post-cyclone) spring flood tide survey (Figure 13-42) was variable both alongshore and cross-shore. Transects 3 and 4 and Reference Transect 5 showed high turbidity in inshore waters, but dropped below 20 NTU in offshore waters. Reference Transect 1 and Transect 2 were generally below 20 NTU across the entire transect. When the spring flood tide survey at Transect 3 was repeated on Day 4, turbidity was much lower across the transect than the spring flood tide survey on Day 1. All sites exhibited a depth gradient, increasing in turbidity with depth. The high variability in turbidity over the spring flood tide survey is likely related to the variable weather conditions during the survey period.

When Transects 2, 3 and 4 were repeated during the February 2011 (post-cyclone) spring ebb tide survey (Figure 13-43), turbidity was slightly higher at Transect 2, but tended to be higher inshore during the flood tide survey and higher offshore during the ebb tide survey. Cross-shore change in turbidity was most pronounced during the spring tide survey, with higher turbidity inshore, decreasing offshore.

Near-surface and near-bottom turbidity (Figure 13-44) was markedly higher during the spring tide survey compared with the neap tide survey. Transects 3 and 4 and Reference Transect 5 were notably higher in turbidity than Reference Transect 1 and Transect 2, particularly at inshore sites.

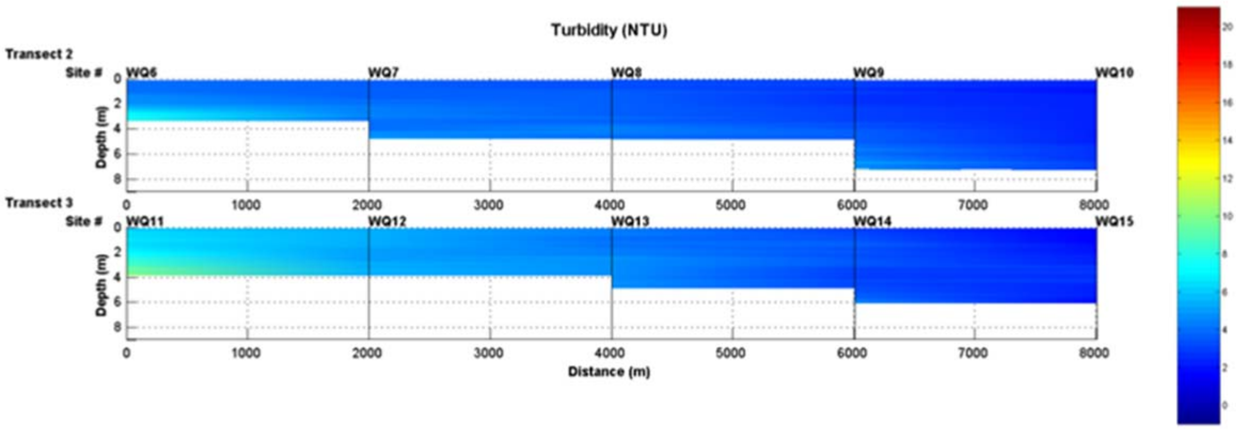


**Figure 13-40 Turbidity Profiles across the Water Quality Transects during February 2011 (post-cyclone) Wet Season Neap (ebb) Tides**

*Note: Transects 2 and 3 are at risk of Material or Serious Environmental Harm. Colour scale restricted to 20 NTU to show resolution at the lower end of the scale, where most values occur.*

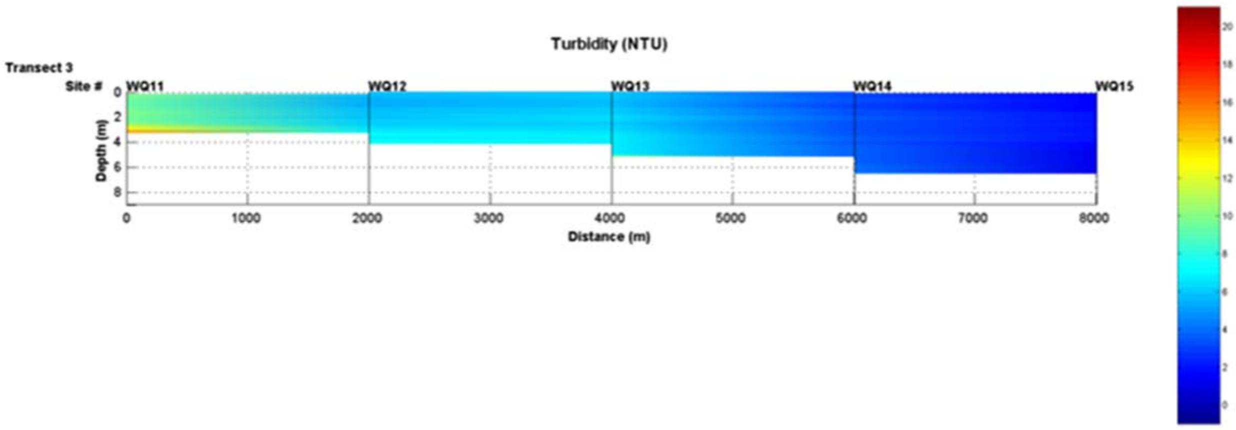


**Figure 13-41 Turbidity Profiles across the Water Quality Transect during February 2011 (post-cyclone) Wet Season Neap (flood) Tides**

*Note: Transect 3 is at risk of Material or Serious Environmental Harm. Colour scale restricted to 20 NTU to show resolution at the lower end of the scale, where most values occur.*

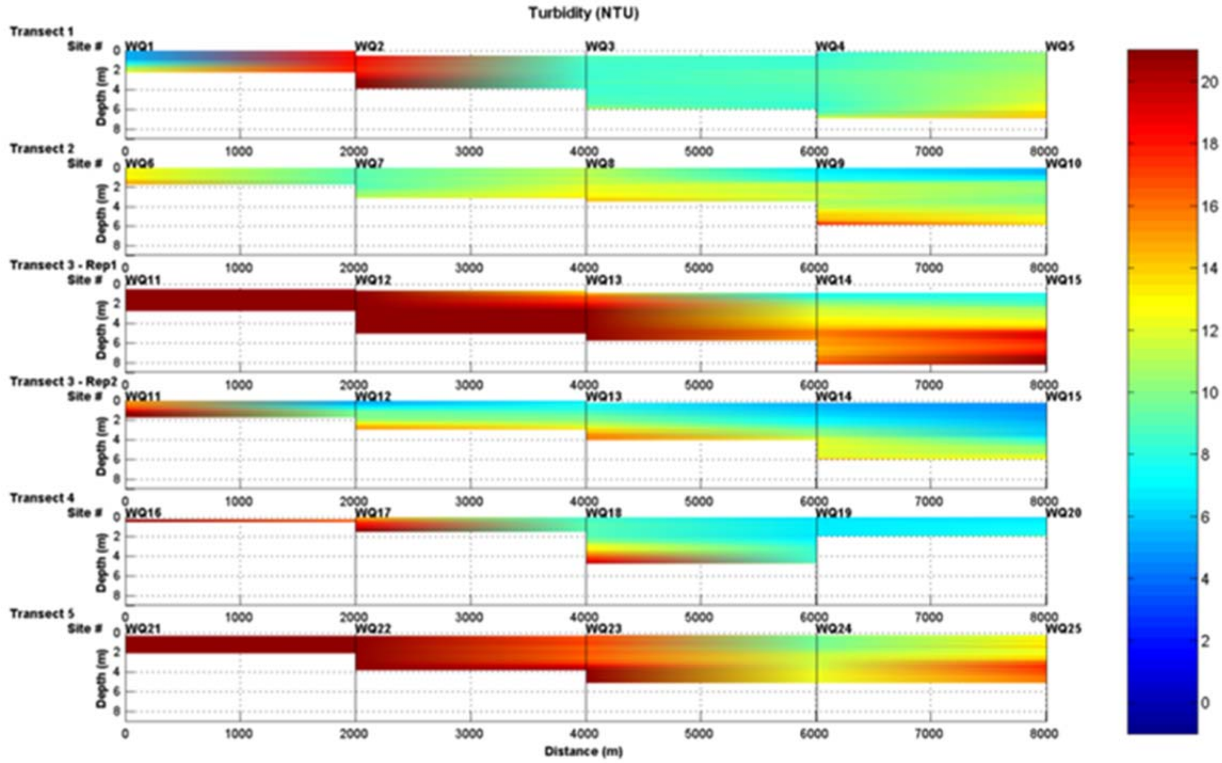


**Figure 13-42 Turbidity Profiles across the Water Quality Transects during February 2011 (post-cyclone) Wet Season Spring (flood) Tides**

*Note: Transects 1 and 5 are Reference Transects, Transects 2 to 4 are at risk of Material or Serious Environmental Harm. Colour scale restricted to 20 NTU to show resolution at the lower end of the scale, where most values occur.*

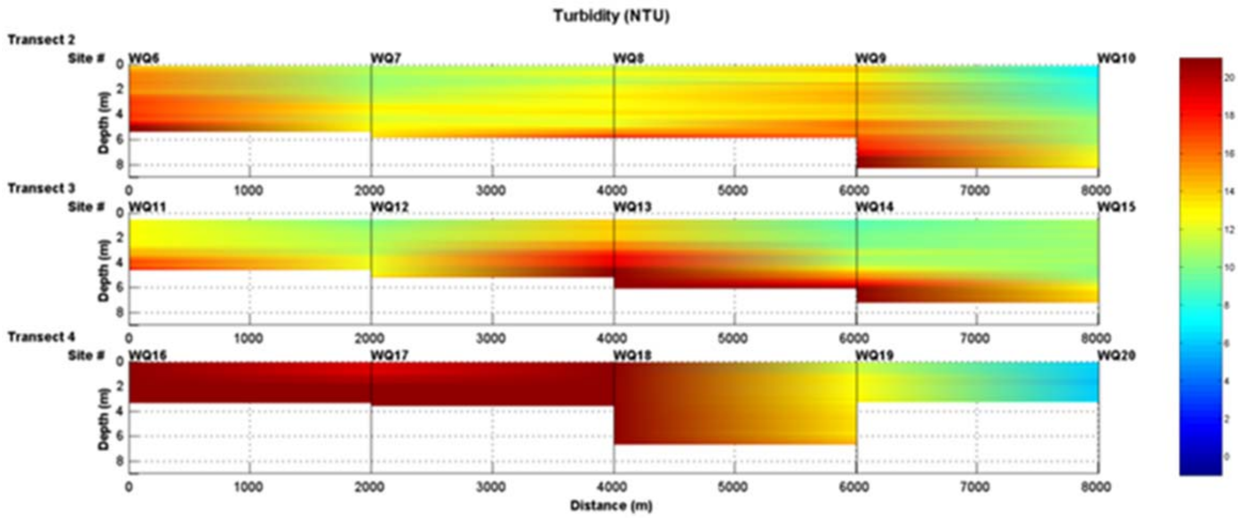


**Figure 13-43 Turbidity Profiles across the Water Quality Transects during February 2011 (post-cyclone) Wet Season Spring (ebb) Tides**

*Note: Transects 2 to 4 are at risk of Material or Serious Environmental Harm. Colour scale restricted to 20 NTU to show resolution at the lower end of the scale, where most values occur.*

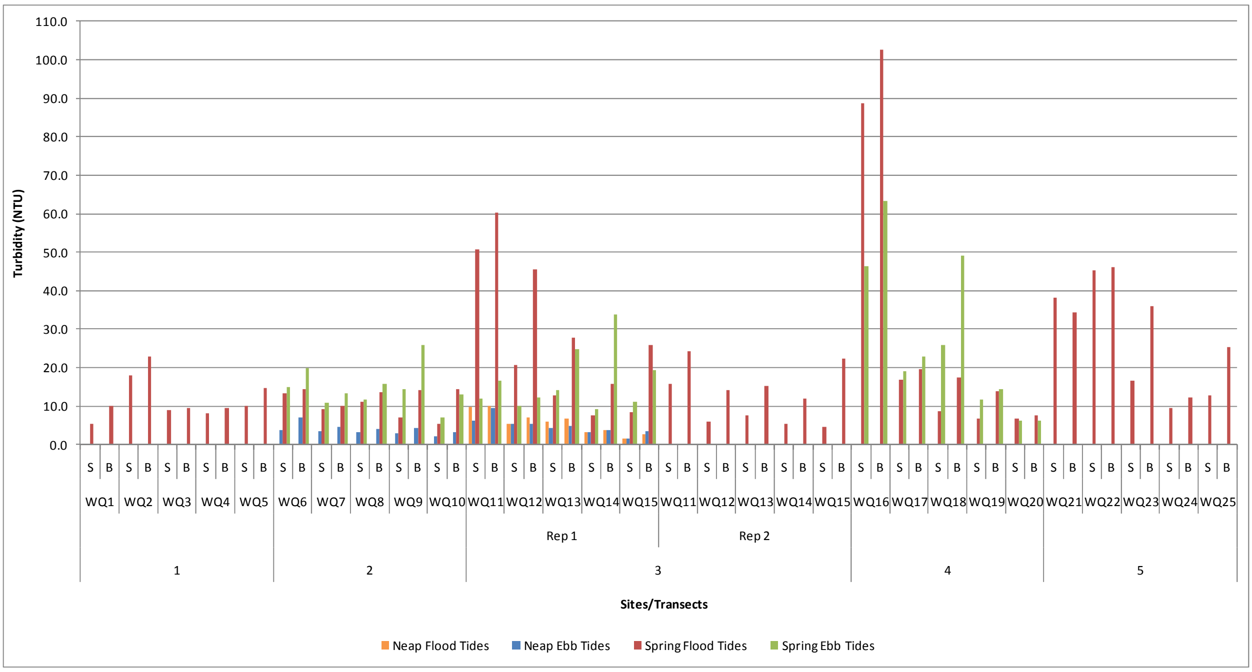


**Figure 13-44 Near-surface and Near-bottom Turbidity at Transects 1 to 5 during the February 2011 (post-cyclone) Wet Season Survey**

*Note: Turbidity values used for plotting were extracted from the profile at 0.5 m from the surface and 0.5 m from the bottom; where multiple turbidity readings were available, the value was averaged. S = Near-surface, B = Near-bottom.*

## 13.4.6 Correlations in Water Quality Parameters for the Mainland End of the DomGas Pipeline Route

### 13.4.6.1 Light Attenuation and Secchi Depth

LAC data and Secchi depth data were used to generate site-specific correlations. Secchi depth data that were equal to the water depth (i.e. 'plus' readings) were not included. LAC and Secchi depth were plotted in Microsoft Excel and a power trendline was added to calculate the correlation.

#### 13.4.6.1.1 Dry Season

The $R^2$ values for the correlations for neap ebb tides, spring flood tides, spring ebb tides and all data during the October 2010 survey were 0.88, 0.55, 0.82 and 0.59 respectively, indicating Secchi depth provided a good to fair approximation of light attenuation on a tide-specific basis, and a fair approximation when the data were combined.

#### 13.4.6.1.2 Wet Season

The $R^2$ values for the correlations for neap flood tides, neap ebb tides, spring flood tides, spring ebb tides and all data for the February 2011 (post-cyclone) survey were 0.99, 0.80, 0.88, 0.75 and 0.85 respectively. The $R^2$ values for the April 2011 survey were 0.97, 0.74, 0.9, 0.73 and 0.80, respectively. These values indicate that Secchi depth provided a good approximation of light attenuation, both on a tide-specific basis and when the data were combined.

#### 13.4.6.1.3 All Data

The $R^2$ values for the correlations for all neap flood tides, all neap ebb tides, all spring flood tides, all spring ebb tides and for all baseline data (Figure 13-45) collected over the surveys were 0.97, 0.81, 0.75, 0.84 and 0.81 respectively. These values indicate that Secchi depth provided a good approximation of light attenuation, both on a tide-specific basis and when the data were combined.

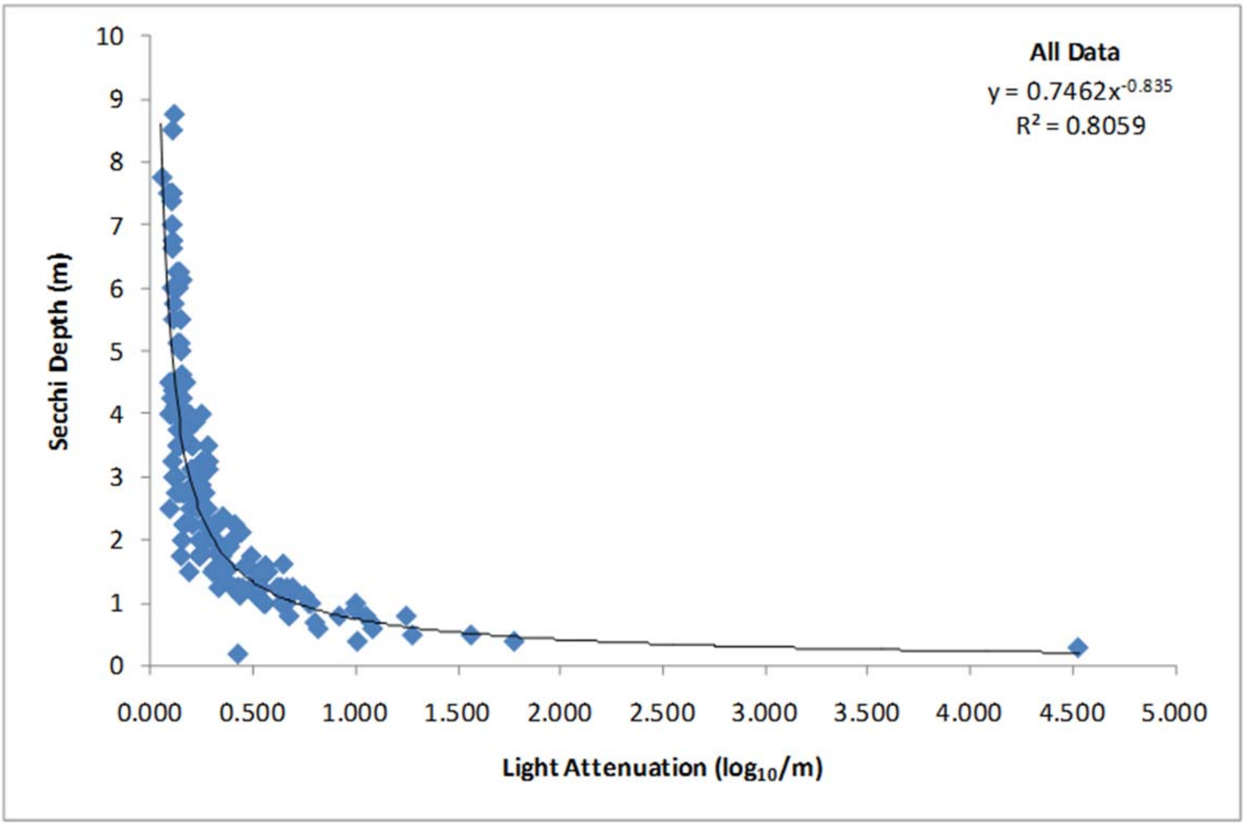


**Figure 13-45 Correlation of Light Attenuation vs Secchi Depth for all Baseline Data**

#### 13.4.6.2 TSS and Turbidity

The TSS and turbidity data were used to generate site-specific correlations. The data were plotted in Microsoft Excel and a linear trendline was added to calculate the correlation.

##### 13.4.6.2.1 Dry Season

The $R^2$ values for the correlations for neap ebb tides, spring flood tides, spring ebb tides and all data for the October 2010 survey were 0.89, 0.87, 0.89, and 0.88, respectively, indicating turbidity provided a good and consistent approximation of TSS concentrations, for both tide-specific and combined data. For the neap ebb tides, one significant outlier was removed—TSS at WQ1 (Reference Transect 1) was very high relative to turbidity and therefore there may have been a degree of error associated with this result.

##### 13.4.6.2.2 Wet Season

The $R^2$ values for the correlations for neap flood tides, neap ebb tides, spring flood tides, spring ebb tides and all data for the February 2011 (post-cyclone) survey were 0.89, 0.57, 0.86, 0.92, and 0.87 respectively. The $R^2$ values for the April 2011 survey were 0.75, 0.84, 0.90, 0.77, and 0.88 respectively. These values indicate that turbidity generally provides a good and relatively consistent approximation of TSS concentrations, for both tide-specific and combined data. For the neap ebb tides, two data pairs were removed—the turbidity profile at WQ19 (Transect 4) was unusually low. The YSI turbidity sensor may have malfunctioned for this profile, and therefore both the near-surface and near-bottom values for WQ19 were removed from the correlation.

##### 13.4.6.2.3 All Data

The $R^2$ values for the correlations for all neap flood tides, all neap ebb tides, all spring flood tides, all spring ebb tides and for all baseline data (Figure 13-46) collected over the surveys were 0.91, 0.83, 0.88, 0.95, and 0.89 respectively. These values indicate that turbidity provided a good and consistent approximation of TSS, both on a tide-specific basis and when the data were combined.

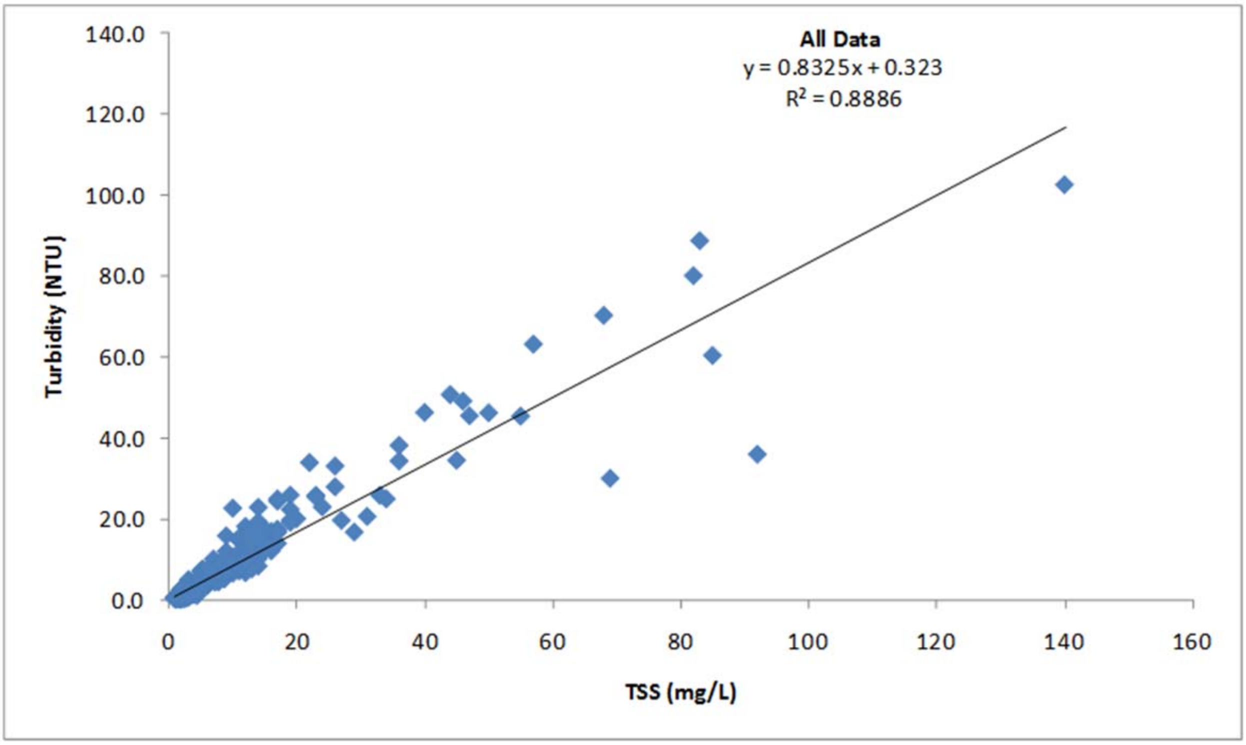


**Figure 13-46 Correlation of TSS Concentration vs Turbidity for all Baseline Data**

## 13.5 Discussion and Conclusions

### 13.5.1 East Coast of Barrow Island

In summary, the results from the baseline water quality (light and turbidity) monitoring program indicate that in the waters around Barrow Island, turbidity and concentrations of suspended sediments were generally low (<5 mg/L) and indicative of clear water environments (Chevron Australia 2013a).

At most sites, wave activity was significant in contributing to local resuspension of sediments, resulting in elevated turbidity and suspended sediment concentrations. In winter, easterly winds can generate wind seas that propagate into the east coast of Barrow Island. Thus, at the majority of the sites, there was a measurable effect on water quality, with suspended sediment concentrations generally higher during winter when easterly winds were more common. Extreme weather events, such as tropical cyclones, also had a strong influence on water quality. Short periods of elevated suspended sediment concentrations, reduced light levels and elevated light attenuation as a consequence of increased turbidity in the water column, coincided with the passage of tropical cyclones.

Water column profiles consistently demonstrate that the water column was well mixed with little evidence of stratification, indicative of an offshore environment with limited influence from surface water run-off and groundwater inflow, combined with good flushing and mixing by tidal and atmospheric forcing.

Seabed light levels were primarily influenced by depth and there were seasonal patterns in the daily average light levels at most sites, with summer values generally higher than winter. The Marine Baseline Program indicates that there is considerable variability, with water quality and sediment deposition varying markedly between sites close to each other and sites responding dissimilarly to the same hydrodynamic conditions (e.g. waves). Seasonal patterns, such as higher light levels in summer than in winter, were also more evident at some sites than others. Similarly, the influence of environmental parameters on water quality also varied over relatively small spatial scales.

### 13.5.2 Mainland End of Domestic Gas Pipeline Route

During the October 2010 dry season, February 2011 (post-cyclone) wet season, and April 2011 wet season surveys, water clarity was found to be influenced by tidal cycle, water depth, the presence of tidal creeks and shallow intertidal areas, distance offshore and weather.

Greater water clarity was typically recorded during neap and ebb tides (generally below ~10 NTU) compared to spring and flood tides (generally below ~20 NTU), with the lowest water clarity always associated with spring flood tide conditions. Spring tides are likely to result in lower water clarity due to larger water movements, higher sediment resuspension, shallower water depths, and greater outflows from tidal creeks. The timing of sampling of the flood tide (generally commencing just after lowest water) resulted in greater capacity for sediment resuspension and coincided with maximum outflow from tidal creeks. Within the study area, the effect of tidal outflows on water clarity was more pronounced at Transects 2, 3 and 4 (transects at risk of Material or Serious Environmental Harm) than at Reference Transects 1 and 5, as they were adjacent to large tidal creeks and wide tidal flats. Water clarity at WQ16, WQ17, WQ20 (Transect 4) and WQ22 (Reference Transect 5) could potentially also be influenced by the presence of small islands (Solitary Island, Passage Island) and shallow intertidal areas. However, the survey data does not show any strong or consistent links between the presence of islands or intertidal areas and water clarity.

Water clarity was lower inshore, increasing offshore for all surveys. Statistical analysis confirmed significant differences in water clarity between sites located inshore and sites located offshore. Although the strength of the offshore gradient varied in intensity, the sites closest to shore were generally different to all other sites.

Differences between near-surface and near-bottom turbidity and TSS samples were typically minor when compared against spatial, temporal and tidal cycle differences. Similarly temperature and salinity profiles showed waters in all surveys were typically well mixed, with tidal forces largely overriding any tendency to vertical stratification in temperature and/or salinity due to the differential heating of land and water.

Differences in water clarity between transects at risk of Material or Serious Environmental Harm and Reference Transects not at risk of Material or Serious Environmental Harm were less pronounced in the wet season surveys compared to the October 2010 dry season survey. Statistically significant differences between Reference Transects and transects at risk of Material or Serious Environmental Harm were confirmed only during spring tides in both the October 2010 dry season and April 2011 wet season surveys, but the pattern varied between seasons. During the October 2010 dry season survey, water clarity was lower at the transects at risk of Material or Serious Environmental Harm, largely due to lower water clarity at inshore sites at Transects 3 and 4. During the April 2011 wet season survey, water clarity was lower at Reference Transects, largely due to lower water clarity at inshore sites at Transect 5. It is likely that the differences between Reference Transects and transects at risk of Material or Serious Environmental Harm during spring tides were at least partly caused by the timing of water quality surveys, rather than fully representing any spatial differences in water clarity.

Weather was a key driver of water clarity, with severe and variable weather conditions (such as the wind, squalls, and tropical cyclone associated with the February 2011 wet season survey) resulting in lower and more variable water clarity. High winds and rainfall result in sediment resuspension and increased sediment loads from tidal creeks, as well as a well-mixed water column, generally resulting in lower water clarity.

# 14.0 Auditing, Reporting and Review

## 14.1 Auditing

### 14.1.1 Internal Auditing

Chevron Australia has prepared the internal ABU Compliance Assurance Process (Chevron Australia 2009) to manage compliance, and which it internally requires its employees, contractors, etc. to comply with. This Process is used to assess compliance of the Gorgon Gas Development and Jansz Feed Gas Pipeline against the requirements of Statement No. 800, Statement No. 769, and EPBC Reference: 2003/1294 and 2008/4178 where this is appropriate and reasonably practicable.

An internal Audit Schedule has been developed and is maintained for the Gorgon Gas Development and Jansz Feed Gas Pipeline (with input from the Engineering, Procurement and Construction Management [EPCM] Contractors) that includes audits of the Development's environmental performance and compliance with the Ministerial Conditions. A record of all internal audits and the audit outcomes is maintained. Actions arising from internal audits are tracked until their close-out.

Under EPBC Reference: 2003/1294 and 2008/4178, Condition 24 also requires that the person taking the action must maintain accurate records of activities associated with or relevant to the Conditions of approval and make them available on request by the Commonwealth (DotE). Such documents may be subject to audit by DotE and used to verify compliance with the conditions of approval.

Any document that is required to be implemented under this Report is to be made available to the relevant DPaW/DotE auditor.

### 14.1.2 External Auditing

Audits and/or inspections undertaken by external regulators are facilitated via the Gorgon Gas Development and Jansz Feed Gas Pipeline's Regulatory Approvals and Compliance Team. The findings of external regulatory audits are recorded and actions and/or recommendations are addressed and tracked. Chevron Australia may also undertake independent external auditing during the Gorgon Gas Development and Jansz Feed Gas Pipeline.

Under EPBC Reference: 2003/1294 and 2008/4178, Condition 23 also requires that upon the direction of the Minister, the person taking the action must ensure that an independent audit of compliance with the Conditions of approval is conducted and a report submitted to the Minister. The independent auditor must be approved by the Minister prior to the commencement of the audit. Audit criteria must be agreed to by the Minister and the audit report must address the criteria to the satisfaction of the Minister.

## 14.2 Reporting

### 14.2.1 Compliance Reporting

Condition 4 of Statement No. 800 and Condition 2 of EPBC Reference: 2003/1294 and 2008/4178 requires Chevron Australia to submit a Compliance Assessment Report annually to address the previous 12-month period.

### 14.2.2 Environmental Performance Reporting

Condition 5.1 of Statement No. 800 and Statement No. 769, and Condition 4 of EPBC Reference: 2003/1294 and 2008/4178 require that Chevron Australia submits an Environmental Performance Report to the Western Australian Minister for the Environment and to the Commonwealth (DotE), respectively, on an annual basis, for the previous 12-month period.

In addition, under Condition 5.3 of Statement No. 800 and Statement No. 769, and Condition 4.2 for EPBC Reference: 2003/1294 and 2008/4178, every five years from the date of the first annual Report, Chevron Australia shall submit to the Western Australian Minister for the Environment and to the Commonwealth Minister for Environment, an Environmental Performance Report covering the previous five-year period.

Specific details on the content of the Environmental Performance Report are defined in Condition 5.2 and Schedule 3 of Statement No. 800, Condition 5.2 of Statement No. 769, and Schedule 3 of EPBC Reference: 2003/1294 and 2008/4178.

The information in the Environmental Performance Report will also partly meet the requirements of Condition 3.7 of EPBC Reference: 2003/1294 and 2008/4178.

### 14.2.3 Routine Internal Reporting

The Gorgon Gas Development and Jansz Feed Gas Pipeline uses a number of routine internal reporting formats to effectively implement the requirements of this Report. Routine reporting is likely to include daily, weekly and/or monthly Health, Environment and Safety (HES) reports for specific scopes of work on the Development. These reports include information on a number of relevant environmental aspects, such as details of environmental incidents (if any), environmental statistics and records, records of environmental audits and inspections undertaken, status of environmental monitoring programs, tracking of environmental performance against performance indicators, targets and criteria, etc.

### 14.2.4 Incident Response and Reporting

Chevron Australia has prepared the ABU Emergency Management Process (Chevron Australia 2010d) and Incident Investigation and Reporting Process (Chevron Australia 2010e), which it internally requires its employees, contractors, etc. to follow in the event of environmental incidents. These processes are internally applied to environmental incidents identified in this Report, where this is appropriate and reasonably practicable.

The environmental incidents, reporting requirements and timing specific to this Report are provided in Table 14-1. Note that under Condition 3.2.7 of EPBC Reference: 2003/1294 and 2008/4178, Significant Impacts detected by the monitoring programs under this Report will follow protocols for reporting to the Commonwealth (DotE), whether or not the impact is caused by the Gorgon Gas Development.

**Table 14-1 Incident Reporting Requirements**

| Incident | Reporting to | Timing |
|---|---|---|
| Material or Serious Environmental Harm outside the Marine Disturbance Footprint | DPaW/DotE | Within 48 hours of detection or as soon as reasonably practicable |
| Significant Impact to a matter of National Environmental Significance | DotE | Within 48 hours of detection |

## 14.3 Review of this Plan

Chevron Australia is committed to conducting activities in an environmentally responsible manner and aims to implement best practice environmental management as part of a program of continuous improvement. This commitment to continuous improvement means Chevron Australia will review this Marine Baseline Report as required (e.g. in response to new information).

Reviews will address matters such as the overall design and effectiveness of the Report, progress in environmental performance, changes in environmental risks, changes in business conditions, and any relevant emerging environmental issues.

If the Report no longer meets the aims, objectives or requirements of the Report, if works are not appropriately covered by the Report, or measures are identified to improve the Report, Chevron Australia may submit an amendment or addendum to the Report to the Minister for approval under Condition 36 of Statement No. 800 and Condition 21 of Statement No. 769.

If Chevron Australia wishes to carry out an activity otherwise than in accordance with the Report, Chevron Australia will update the Report and submit it for approval by the Minister in accordance with Condition 25 of EPBC Reference: 2003/1294 and 2008/4178. The Commonwealth Minister may also direct Chevron Australia to revise the Report under Condition 26 of EPBC Reference: 2003/1294 and 2008/4178.

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# Appendix 1 Identification and Risk Assessment of Marine Matters of National Environmental Significance (NES)

# Appendix 2 Barrow Island Habitat Classification Scheme

| Physical Factors | | Biological Factors | | | Biological Factors | |
|---|---|---|---|---|---|---|
| **Relief** | **Substrate Type** | **Dominant Ecological Element** | **Dominant Taxa or physical descriptor** | **Cover** | **Sub-Dominant Taxa or physical descriptor** | **Cover** |
| R0 Flat/micro-ripples (<0.5m height) | S01 Sand | H01 **Macroalgae** | *Sargassum* | C0 Unknown density | *Sargassum* | C0 Unknown density |
| R1 Gently sloping (5 - 35 deg) | S02 Silt | | *Padina* | C1 Sparse (5-25%) | *Padina* | C1 Sparse (5-25%) |
| R2 Steeply sloping (35 - 70 deg) | S03 Mud | | *Caulerpa* | C2 Medium (25-75%) | *Caulerpa* | C2 Medium (25-75%) |
| R3 Vertical wall (70-90 deg) and caves/overhangs | S04 Gravel | | *Cladophora* | C3 Dense (> 75%) | *Cladophora* | C3 Dense (> 75%) |
| R4 Macro-ripples (>0.5m height) | S05 Rubble | | Mixed Rhodophyta | | Mixed Rhodophyta | |
| | S06 Consolidated rubble | | Mixed Chlorophyta | | Mixed Chlorophyta | |
| | S07 Limestone pavement | | Mixed Phaeophyceae | | Mixed Phaeophyceae | |
| | S08 Limestone pavement w/ shallow sand veneer | | Mixed turfing algae | | Mixed turfing algae | |
| | S09 Boulders | | Unidentified Rhodopyhta | | Unidentified Rhodopyhta | |
| | S10 Reef - low profile | | Unidentified Chlorophyta | | Unidentified Chlorophyta | |
| | S11 Reef - high profile | | Unidentified Phaeophyceae | | Unidentified Phaeophyceae | |
| | S12 Sand with Shell fragments | | Unidentified turfing algae | | Unidentified turfing algae | |
| | S13 Silt with Shell fragments | | Unidentified macroalgae | | Unidentified macroalgae | |
| | | H02 **Seagrass** | *Halophila* | C0 Unknown density | *Halophila* | C0 Unknown density |
| | | | *Heterzostera* | C1 Sparse (5-25%) | *Heterzostera* | C1 Sparse (5-25%) |
| | | | *Syringodium* | C2 Medium (25-75%) | *Syringodium* | C2 Medium (25-75%) |
| | | | *Thallasodendron* | C3 Dense (> 75%) | *Thallasodendron* | C3 Dense (> 75%) |
| | | | Unidentified seagrass | | Unidentified seagrass | |
| | | H03 **Non-coral benthic invertebrates** | Crinoids (sea, brittle and feather stars) | Present | Crinoids (sea stars, brittle and feather stars) | Present |
| | | | Sea pens, whips and fans | | Sea pens, whips and fans | |
| | | | Gorgonians | | Gorgonians | |
| | | | Sea Urchins | | Sea Urchins | |
| | | | Sponges | | Sponges | |
| | | | Ascidians | | Ascidians | |
| | | | Holothurians | | Holothurians | |
| | | | Bivalaves | | Bivalaves | |
| | | | Bryozoans | | Bryozoans | |
| | | H04 **Coral - hard and soft** | A *Acropora* | C2 Medium (10-50%) | *Acropora* | C0 Unknown density |
| | | | P Coral bombora - *Porites* | C3 Dense (51-75%) | Coral bombora - *Porites* | C1 Sparse (<10%) |
| | | | N Coral bombora - non-*Porites* | CV Very Dense (>75%) | Coral bombora - non-*Porites* | |
| | | | I Bombora - invert/macroalgae dominated | | Bombora - invert/macroalgae dominated | |
| | | | M Mixed coral community | | Mixed coral community | |
| | | H05 **Mangroves** | *Avicennia* | Present | *Avicennia* | Present |
| | | | *Rhizophora* | | *Rhizophora* | |
| | | | *Ceriops* | | *Ceriops* | |
| | | | *Brugeiera* | | *Brugeiera* | |
| | | | *Aegialitis* | | *Aegialitis* | |
| | | | *Aegiceras* | | *Aegiceras* | |
| | | | *Acanthus* | | *Acanthus* | |
| | | | Unidentified mangrove | | Unidentified mangrove | |
| | | H06 **Unvegetated** | Undisturbed flat | C0 Unknown density | Undisturbed flat | C0 Unknown density |
| | | | Undisturbed micro-ripples (<0.5m height) | C1 Sparse (5-25%) | Undisturbed micro-ripples (<0.5m height) | C1 Sparse (5-25%) |
| | | | Bioturbated (mounds and burrows) | C2 Medium (25-75%) | Bioturbated (mounds and burrows) | C2 Medium (25-75%) |
| | | | Drift macroalgae | C3 Dense (> 75%) | Drift macroalgae | C3 Dense (> 75%) |
| | | | Drift seagrass | C4 Bare | Drift seagrass | C4 Bare |

# Appendix 3 Coral Species Lists for the Mainland End of the Domestic Gas Pipeline Route from the Rapid Visual Assessment Surveys

## Site CI1

| Family | Hard Coral Species | Abundance Category |
|---|---|---|
| Dendrophylliidae | *Turbinaria mesenterina* (Lamarck, 1816) | 5 |
| Faviidae | *Favites abdita* (Ellis and Solander, 1786) | 4 |
| Faviidae | *Platygyra daedalea* (Ellis and Solander, 1786) | 4 |
| Dendrophylliidae | *Turbinaria peltata* (Esper, 1794) | 4 |
| Faviidae | *Cyphastrea microphthalma* (Lamarck, 1816) | 4 |
| Mussidae | *Acanthastrea hemprichii* (Ehrenberg, 1834) | 3 |
| Poritidae | *Goniopora tenuidens* (Quelch, 1886) | 3 |
| Faviidae | *Barabattoia amicorum* (Milne Edwards and Haime, 1850) | 3 |
| Faviidae | *Favia pallida* (Dana, 1846) | 3 |
| Faviidae | *Favites complanata* (Ehrenberg, 1834) | 3 |
| Faviidae | *Favites pentagona* (Esper, 1794) | 3 |
| Faviidae | *Goniastrea aspera* Verrill, 1905 | 3 |
| Faviidae | *Montastrea curta* (Dana, 1846) | 3 |
| Acroporidae | *Montipora crassituberculata* Bernard, 1897 | 3 |
| Faviidae | *Moseleya latistellata* Quelch, 1884 | 3 |
| Poritidae | *Porites annae* Crossland, 1952 | 3 |
| Poritidae | *Porites lobata* Dana, 1846 | 3 |
| Siderastreidae | *Psammocora superficialis* Gardiner, 1898 | 3 |
| Dendrophylliidae | *Turbinaria bifrons* Brüggemann, 1877 | 3 |
| Dendrophylliidae | *Turbinaria reniformis* Bernard, 1896 | 3 |
| Acroporidae | *Acropora bushyensis* Veron and Wallace, 1984 | 2 |
| Euphyllidae | *Euphyllia ancora* Veron and Pichon, 1979 | 2 |
| Faviidae | *Favia matthaii* Vaughan, 1918 | 2 |
| Faviidae | *Favia speciosa* Dana, 1846 | 2 |
| Faviidae | *Favites halicora* (Ehrenberg, 1834) | 2 |
| Poritidae | *Goniopora minor* Crossland, 1952 | 2 |
| Poritidae | *Goniopora lobata* Milne Edwards and Haime, 1860 | 2 |
| Faviidae | *Montastrea valencinessi* (Milne Edwards and Haime, 1848) | 2 |
| Acroporidae | *Montipora digitata* (Dana, 1846) | 2 |
| Alcyoniidae | *Sinularia* sp. | 2 |
| Alcyoniidae | *Lobophytum* sp. | 2 |
| Alcyoniidae | *Sarcophyton ehrenbergi* von Marenzellar, 1886 | 2 |
| Mussidae | *Acanthastrea echinata* (Dana, 1846) | 1 |
| Acroporidae | *Astreopora myriophthalma* (Lamarck, 1816) | 1 |
| Faviidae | *Cyphastrea serailia* (Forskål, 1775) | 1 |
| Dendrophylliidae | *Duncanopsammia axifugia* (Milne Edwards and Haime, 1848) | 1 |
| Faviidae | *Favia favus* (Forskål, 1775) | 1 |
| Faviidae | *Favia veroni* Moll and Borel-Best, 1984 | 1 |
| Faviidae | *Favites micropentagona* Veron, 2000 | 1 |
| Faviidae | *Goniastrea pectinata* (Ehrenberg, 1834) | 1 |

| Family | Hard Coral Species | Abundance Category |
|---|---|---|
| Poritidae | *Goniopora djboutiensis* Vaughan, 1907 | 1 |
| Poritidae | *Goniopora stokesi* Milne Edwards and Haime, 1851 | 1 |
| Acroporidae | *Isopora brueggemanni* (Brook, 1893) | 1 |
| Acroporidae | juvenile *Acropora* unid. sp. | 1 |
| Faviidae | *Leptastrea pruinosa* Crossland, 1952 | 1 |
| Mussidae | *Lobophyllia hemprichii* (Ehrenberg, 1834) | 1 |
| Merulinidae | *Merulina ampliata* (Ellis and Solander, 1786) | 1 |
| Acroporidae | *Montipora capricornis* Veron 1985 | 1 |
| Acroporidae | *Montipora undata* Bernard 1897 | 1 |
| Faviidae | *Platygyra pini* Chevalier, 1975 | 1 |
| Faviidae | *Platygyra sinensis* (Milne Edwards and Haime, 1849) | 1 |
| Ellisellidae | *Juncella* sp. | 1 |

*Note: Soft corals in blue font.*

### Site CI2

| Family | Hard Coral Species | Abundance Category |
|---|---|---|
| Alcyoniidae | *Sinularia* sp. | 5 |
| Faviidae | *Platygyra daedalea* (Ellis and Solander, 1786) | 4 |
| Dendrophylliidae | *Turbinaria mesenterina* (Lamarck, 1816) | 4 |
| Dendrophylliidae | *Turbinaria peltata* (Esper, 1794) | 4 |
| Ellisellidae | *Juncella* sp. | 4 |
| Faviidae | *Cyphastrea microphthalma* (Lamarck, 1816) | 3 |
| Pectiniidae | *Echinophyllia aspera* (Ellis and Solander, 1788) | 3 |
| Pectiniidae | *Echinophyllia orpheensis* Veron and Pichon, 1980 | 3 |
| Faviidae | *Favia pallida* (Dana, 1846) | 3 |
| Faviidae | *Favites abdita* (Ellis and Solander, 1786) | 3 |
| Faviidae | *Favites pentagona* (Esper, 1794) | 3 |
| Faviidae | *Goniastrea aspera* Verrill, 1905 | 3 |
| Poritidae | *Goniopora djboutiensis* Vaughan, 1907 | 3 |
| Poritidae | *Goniopora minor* Crossland, 1952 | 3 |
| Merulinidae | *Hydnophora exesa* (Pallas, 1766) | 3 |
| Faviidae | *Moseleya latistellata* Quelch, 1884 | 3 |
| Faviidae | *Barabattoia amicorum* (Milne, Edwards and Haime, 1850) | 3 |
| Siderasteridae | *Psammocora superficialis* Gardiner, 1898 | 3 |
| Dendrophylliidae | *Turbinaria bifrons* Brüggemann, 1877 | 3 |
| Anthothelidae | *Alertigorgia mjobergi* (Broch 1916) | 3 |
| Plexauridae | *Paraplexuria* sp. | 3 |
| Poritidae | *Goniopora norfolkensis* Veron and Pichon, 1982 | 2 |
| Faviidae | *Montastrea curta* (Dana, 1846) | 2 |
| Acroporidae | *Montipora capricornis* Veron 1985 | 2 |
| Pectiniidae | *Mycedium elephantotus* (Pallas, 1766) | 2 |
| Poritidae | *Porites lichen* Dana, 1846 | 2 |
| Dendrophylliidae | *Turbinaria reniformis* Bernard, 1896 | 2 |
| Mussidae | *Acanthastrea hemprichii* (Ehrenberg, 1834) | 1 |

| Family | Hard Coral Species | Abundance Category |
|---|---|---|
| Mussidae | *Acanthastrea hillae* Wells, 1955 | 1 |
| Acroporidae | *Astreopora myriophthalma* (Lamarck, 1816) | 1 |
| Faviidae | *Cyphastrea serailia* (Forskål, 1775) | 1 |
| Euphyllidae | *Euphyllia ancora* Veron and Pichon, 1979 | 1 |
| Faviidae | *Favia favus* (Forskål, 1775) | 1 |
| Faviidae | *Favia matthaii* Vaughan, 1918 | 1 |
| Faviidae | *Favia speciosa* Dana, 1846 | 1 |
| Faviidae | *Favites complanata* (Ehrenberg, 1834) | 1 |
| Faviidae | *Favites halicora* (Ehrenberg, 1834) | 1 |
| Faviidae | *Favites micropentagona* Veron, 2000 | 1 |
| Faviidae | *Favites paraflexuosa* Veron, 2000 | 1 |
| Poritidae | *Goniopora stutchburyi* Wells, 1955 | 1 |
| Poritidae | *Goniopora lobata* Milne Edwards and Haime, 1860 | 1 |
| Mussidae | *Lobophyllia hemprichii* (Ehrenberg, 1834) | 1 |
| Merulinidae | *Merulina ampliata* (Ellis and Solander, 1786) | 1 |
| Faviidae | *Montastrea valencinessi* (Milne Edwards and Haime, 1848) | 1 |
| Acroporidae | *Montipora crassituberculata* Bernard, 1897 | 1 |
| Acroporidae | *Montipora mollis* Bernard, 1897 | 1 |
| Pocilloporidae | *Pocillopora damicornis* (Linnaeus, 1758) | 1 |
| Siderasteridae | *Pseudosiderastrea tayami* Yabe and Sugiyama, 1935 | 1 |
| Dendrophylliidae | *Turbinaria radicalis* Bernard, 1896 | 1 |
| Subergorgiidae | *Subergorgia suberosa* (Pallas, 1766) | 1 |
| Nephtheidae | *Capnella* cf. *fungiaformis* (Kukenthal, 1903) | 1 |
| Nephtheidae | *Dendronephthya* sp. | 1 |
| Nephtheidae | *Nepthea* sp. | 1 |

*Note: Soft corals in blue font.*

### Site CR1

| Family | Hard Coral Species | Abundance Scale |
|---|---|---|
| Dendrophylliidae | *Turbinaria mesenterina* (Lamarck, 1816) | 5 |
| Faviidae | *Platygyra daedalea* (Ellis and Solander, 1786) | 4 |
| Poritidae | *Porites lobata* Dana, 1846 | 4 |
| Mussidae | *Acanthastrea hemprichii* (Ehrenberg, 1834) | 3 |
| Acroporidae | *Acropora bushyensis* Veron and Wallace, 1984 | 3 |
| Acroporidae | *Astreopora myriophthalma* (Lamarck, 1816) | 3 |
| Faviidae | *Cyphastrea microphthalma* (Lamarck, 1816) | 3 |
| Pectiniidae | *Echinophyllia orpheensis* Veron and Pichon, 1980 | 3 |
| Faviidae | *Favia favus* (Forskål, 1775) | 3 |
| Faviidae | *Favia speciosa* Dana, 1846 | 3 |
| Faviidae | *Favites abdita* (Ellis and Solander, 1786) | 3 |
| Faviidae | *Favites halicora* (Ehrenberg, 1834) | 3 |
| Faviidae | *Favites pentagona* (Esper, 1794) | 3 |
| Oculinidae | *Galaxea astreata* (Lamarck, 1816) | 3 |
| Poritidae | *Goniopora lobata* Milne Edwards and Haime, 1860 | 3 |
| Poritidae | *Goniopora stutchburyi* Wells, 1955 | 3 |

| Family | Hard Coral Species | Abundance Scale |
|---|---|---|
| Poritidae | *Goniopora tenuidens* (Quelch, 1886) | 3 |
| Merulinidae | *Hydnophora exesa* (Pallas, 1766) | 3 |
| Mussidae | *Lobophyllia hemprichii* (Ehrenberg, 1834) | 3 |
| Acroporidae | *Montipora crassituberculata* Bernard, 1897 | 3 |
| Pectiniidae | *Mycedium elephantotus* (Pallas, 1766) | 3 |
| Faviidae | *Platygyra lamellina* (Ehrenberg, 1834) | 3 |
| Siderasteridae | *Psammocora superficialis* Gardiner, 1898 | 3 |
| Dendrophylliidae | *Turbinaria bifrons* Brüggemann, 1877 | 3 |
| Dendrophylliidae | *Turbinaria peltata* (Esper, 1794) | 3 |
| Dendrophylliidae | *Turbinaria reniformis* Bernard, 1896 | 3 |
| Alcyoniidae | *Sinularia* sp. | 3 |
| Alcyoniidae | *Sarcophytum ehrenbergi* von Marenzellar, 1886 | 3 |
| Acroporidae | *Acropora millepora* (Ehrenberg, 1834) | 2 |
| Faviidae | *Cyphastrea chalcidium* (Forskål, 1775) | 2 |
| Faviidae | *Favia pallida* (Dana, 1846) | 2 |
| Faviidae | *Favia rotumana* (Gardiner, 1899) | 2 |
| Faviidae | *Favites complanata* (Ehrenberg, 1834) | 2 |
| Faviidae | *Favites flexuosa* (Dana, 1846) | 2 |
| Poritidae | *Goniopora stokesi* Milne Edwards and Haime, 1851 | 2 |
| Merulinidae | *Merulina ampliata* (Ellis and Solander, 1786) | 2 |
| Faviidae | *Moseleya latistellata* Quelch, 1884 | 2 |
| Faviidae | *Platygyra pini* Chevalier, 1975 | 2 |
| Fungiidae | *Podabacia crustacea* (Pallas, 1766) | 2 |
| Alcyoniidae | *Lobophytum* sp. | 2 |
| Acroporidae | *Acropora divaricata* (Dana, 1846) | 1 |
| Acroporidae | *Acropora latistella* (Brook, 1891) | 1 |
| Acroporidae | *Acropora muricata* (Linnaeus, 1758) | 1 |
| Acroporidae | *Acropora pulchra* (Brook, 1891) | 1 |
| Acroporidae | *Acropora robusta* (Dana, 1846) | 1 |
| Acroporidae | *Astreopora gracilis* Bernard, 1896 | 1 |
| Faviidae | *Barabattoia amicorum* (Milne Edwards and Haime, 1850) | 1 |
| Siderasteridae | *Coscinaraea columna* (Dana, 1846) | 1 |
| Dendrophylliidae | *Duncanopsammia axifugia* (Milne Edwards and Haime, 1848) | 1 |
| Pectiniidae | *Echinophyllia aspera* (Ellis and Solander, 1788) | 1 |
| Euphyllidae | *Euphyllia ancora* Veron and Pichon, 1979 | 1 |
| Faviidae | *Favia helianthoides* Wells, 1954 | 1 |
| Faviidae | *Favites micropentagona* | 1 |
| Fungiidae | *Fungia fungites* (Linneaus, 1758) | 1 |
| Fungiidae | *Lithophyllon undulatum* Rehberg, 1892 | 1 |
| Faviidae | *Goniastrea aspera* Verrill, 1905 | 1 |
| Faviidae | *Goniastrea edwardsi* Chevalier, 1971 | 1 |
| Faviidae | *Goniastrea pectinata* (Ehrenberg, 1834) | 1 |
| Faviidae | *Goniastrea retiformis* (Lamarck, 1816) | 1 |
| Merulinidae | *Hydnophora grandis* Gardiner, 1904 | 1 |
| Faviidae | *Leptastrea purpurea* (Dana, 1846) | 1 |
| Mussidae | *Lobophyllia corymbosa* (Forskål, 1775) | 1 |
| Faviidae | *Montastrea curta* (Dana, 1846) | 1 |

| Family | Hard Coral Species | Abundance Scale |
|---|---|---|
| Faviidae | *Montastrea valencinessi* (Milne Edwards and Haime, 1848) | 1 |
| Acroporidae | *Montipora monasteriata* (Forskäl, 1775) | 1 |
| Acroporidae | *Montipora turgescens* Bernard, 1897 | 1 |
| Faviidae | *Oulophyllia crispa* (Lamarck, 1816) | 1 |
| Agariciidae | *Pavona decussata* (Dana, 1846) | 1 |
| Euphyllidae | *Physogyra lichtensteini* (Milne Edwards and Haime, 1851) | 1 |
| Faviidae | *Platygyra sinensis* (Milne Edwards and Haime, 1849) | 1 |
| Faviidae | *Plesiastrea versipora* (Lamarck, 1816) | 1 |
| Poritidae | *Porites annae* Crossland, 1952 | 1 |
| Poritidae | *Porites lutea* Milne Edwards & Haime, 1851 | 1 |
| Poritidae | *Porites solida* (Forskål, 1775) | 1 |
| Siderasteridae | *Psammocora nierstraszi* van der host, 1921 | 1 |
| Siderasteridae | *Psammocora profundacella* Gardiner, 1898 | 1 |
| Mussidae | *Symphyllia radians Milne* Edwards and Haime, 1849 | 1 |
| Ellisellidae | *Juncella* sp. | 1 |

*Note: Soft corals in blue font.*

## Site CR2

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Faviidae | *Favites complanata* (Ehrenberg, 1834) | 4 |
| Mussidae | *Lobophyllia hemprichii* (Ehrenberg, 1834) | 4 |
| Faviidae | *Platygyra daedalea* (Ellis and Solander, 1786) | 4 |
| Dendrophylliidae | *Turbinaria mesenterina* (Lamarck, 1816) | 4 |
| Mussidae | *Acanthastrea hemprichii* (Ehrenberg, 1834) | 3 |
| Pectiniidae | *Echinophyllia orpheensis* Veron and Pichon, 1980 | 3 |
| Faviidae | *Favia favus* (Forskål, 1775) | 3 |
| Faviidae | *Favia pallida* (Dana, 1846) | 3 |
| Faviidae | *Favia speciosa* Dana, 1846 | 3 |
| Faviidae | *Favites abdita* (Ellis and Solander, 1786) | 3 |
| Faviidae | *Favites flexuosa* (Dana, 1846) | 3 |
| Faviidae | *Favites halicora* (Ehrenberg, 1834) | 3 |
| Faviidae | *Goniastrea pectinata* (Ehrenberg, 1834) | 3 |
| Poritidae | *Goniopora lobata* Milne Edwards and Haime, 1860 | 3 |
| Merulinidae | *Hydnophora exesa* (Pallas, 1766) | 3 |
| Merulinidae | *Merulina ampliata* (Ellis and Solander, 1786) | 3 |
| Milleporidae | *Millepora* spp. | 3 |
| Faviidae | *Montastrea curta* (Dana, 1846) | 3 |
| Acroporidae | *Montipora crassituberculata* Bernard, 1897 | 3 |
| Pectiniidae | *Mycedium elephantotus* (Pallas, 1766) | 3 |
| Faviidae | *Platygyra lamellina* (Ehrenberg, 1834) | 3 |
| Fungiidae | *Podabacia crustacea* (Pallas, 1766) | 3 |
| Poritidae | *Porites lobata* Dana, 1846 | 3 |
| Dendrophylliidae | *Turbinaria bifrons* Brüggemann, 1877 | 3 |
| Dendrophylliidae | *Turbinaria reniformis* Bernard, 1896 | 3 |
| Alcyoniidae | *Lobophytum* sp. | 3 |

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Acroporidae | *Acropora bushyensis* Veron and Wallace, 1984 | 2 |
| Acroporidae | *Acropora humilis* (Dana, 1846) | 2 |
| Acroporidae | *Astreopora myriophthalma* (Lamarck, 1816) | 2 |
| Faviidae | *Cyphastrea microphthalma* (Lamarck, 1816) | 2 |
| Euphyllidae | *Euphyllia ancora* Veron and Pichon, 1979 | 2 |
| Faviidae | *Favia rotundata* Veron, Pichon & Wijsman-Best, 1972 | 2 |
| Fungiidae | *Fungia fungites* (Linneaus, 1758) | 2 |
| Oculinidae | *Galaxea fascicularis* (Linnaeus, 1767) | 2 |
| Faviidae | *Goniastrea favulus* (Dana, 1846) | 2 |
| Poritidae | *Goniopora minor* Crossland, 1952 | 2 |
| Merulinidae | *Hydnophora pilosa* Veron, 1985 | 2 |
| Faviidae | *Leptastrea transversa* Klunzinger, 1879 | 2 |
| Faviidae | *Leptoria phrygia* (Ellis and Solander, 1786) | 2 |
| Mussidae | *Lobophyllia corymbosa* (Forskål, 1775) | 2 |
| Merulinidae | *Merulina scabricula* Dana, 1846 | 2 |
| Acroporidae | *Montipora turgescens* Bernard, 1897 | 2 |
| Faviidae | *Moseleya latistellata* Quelch, 1884 | 2 |
| Faviidae | *Oulophyllia crispa* (Lamarck, 1816) | 2 |
| Pocilloporidae | *Pocillopora damicornis* (Linnaeus, 1758) | 2 |
| Poritidae | *Porites cylindrica* Dana, 1846 | 2 |
| Poritidae | *Porites lutea* Milne Edwards & Haime, 1851 | 2 |
| Siderasteridae | *Psammocora profundacella* Gardiner, 1898 | 2 |
| Dendrophylliidae | *Tubastrea* sp. | 2 |
| Alcyoniidae | *Sinularia* sp. | 2 |
| Mussidae | *Acanthastrea echinata* (Dana, 1846) | 1 |
| Acroporidae | *Acropora divaricata* (Dana, 1846) | 1 |
| Acroporidae | *Acropora millepora* (Ehrenberg, 1834) | 1 |
| Poritidae | *Alveopora fenestrata* (Lamarck, 1816) | 1 |
| Acroporidae | *Astreopora gracilis* Bernard, 1896 | 1 |
| Faviidae | *Barabattoia amicorum* (Milne Edwards and Haime, 1850) | 1 |
| Faviidae | *Caulastrea curvata* Wijsmann-Best, 1972 | 1 |
| Dendrophylliidae | *Duncanopsammia axifugia* (Milne Edwards and Haime, 1848) | 1 |
| Euphyllidae | *Euphyllia glabrescens* (Chamisso and Eysenhardt, 1821) | 1 |
| Faviidae | *Favia matthaii* Vaughan, 1918 | 1 |
| Faviidae | *Favites pentagona* (Esper, 1794) | 1 |
| Faviidae | *Goniastrea aspera* Verrill, 1905 | 1 |
| Faviidae | *Goniastrea retiformis* (Lamarck, 1816) | 1 |
| Poritidae | *Goniopora norfolkensis* Veron and Pichon, 1982 | 1 |
| Poritidae | *Goniopora somaliensis* Vaughan, 1907 | 1 |
| Poritidae | *Goniopora tenuidens* (Quelch, 1886) | 1 |
| Merulinidae | *Hydnophora rigida* (Dana, 1846) | 1 |
| Faviidae | *Leptastrea purpurea* (Dana, 1846) | 1 |
| Fungiidae | *Lithophyllon undulatum* Rehberg, 1892 | 1 |
| Faviidae | *Montastrea colemani* Veron, 2000 | 1 |
| Faviidae | *Montastrea valencinessi* (Milne Edwards and Haime, 1848) | 1 |
| Acroporidae | *Montipora efflorescens* Bernard, 1897 | 1 |
| Acroporidae | *Montipora stellata* Bernard, 1897 | 1 |

| Coral Family | Coral Species | Abundance Scale |
|---|---|---|
| Acroporidae | *Montipora undata* Bernard, 1897 | 1 |
| Faviidae | *Oulophyllia bennettae* (Veron & Pichon, 1977) | 1 |
| Pectiniidae | *Oxypora lacera* Verrill, 1864 | 1 |
| Agariciidae | *Pavona clavus* (Dana, 1846) | 1 |
| Agariciidae | *Pavona varians* Verrill, 1864 | 1 |
| Pectiniidae | *Pectinia lactuca* (Pallas, 1766) | 1 |
| Faviidae | *Platygyra pini* Chevalier, 1975 | 1 |
| Siderasteridae | *Psammocora superficialis* Gardiner, 1898 | 1 |
| Dendrophylliidae | *Turbinaria peltata (*Esper, 1794) | 1 |
| Nephtheidae | *Dendronepthea* sp. | 1 |
| Alcyoniidae | *Sarcophytum ehrenbergi* von Marenzellar, 1886 | 1 |

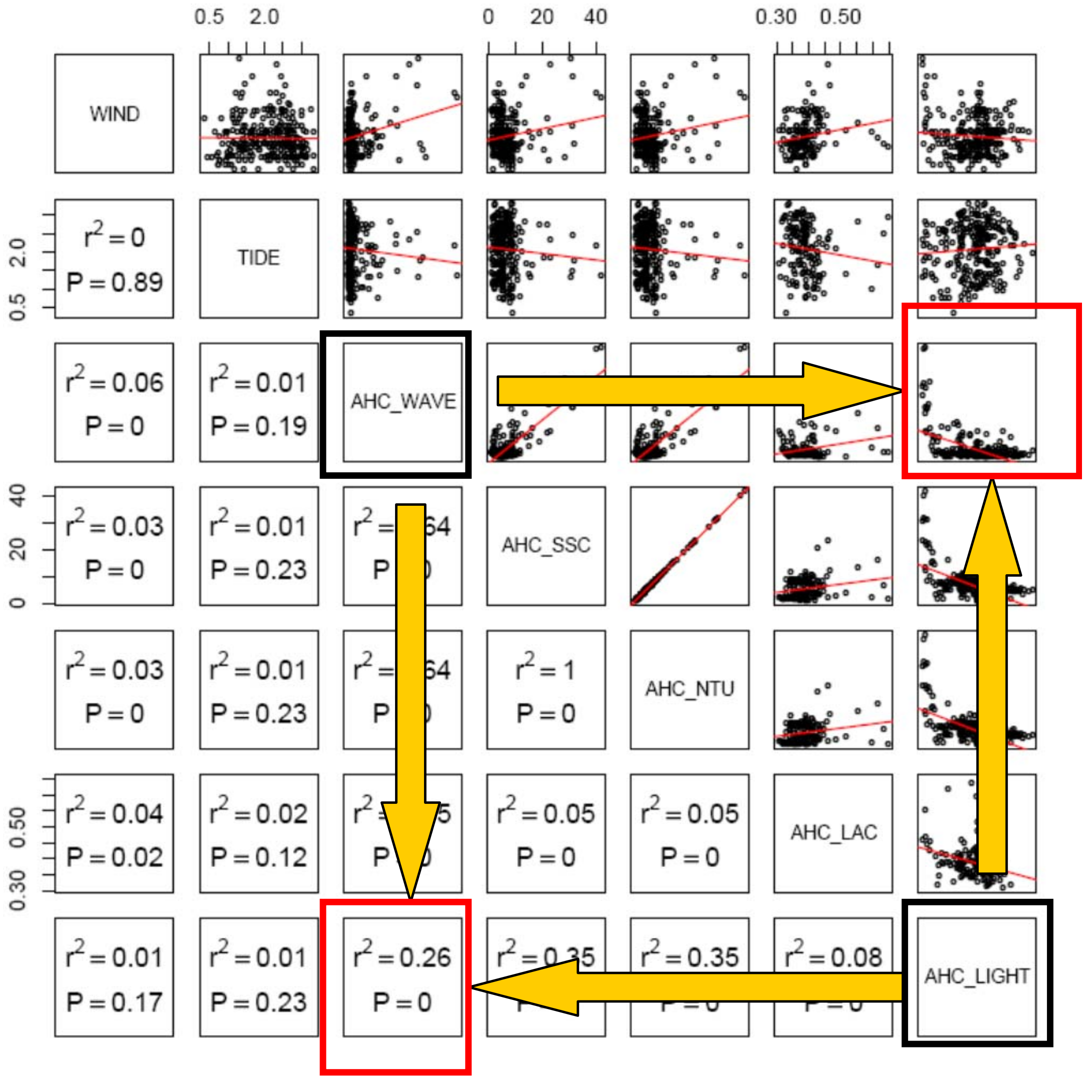
*Note: Soft corals in blue font.*

# Appendix 4 Water Quality Scatter Plots

Note: These figures show a matrix of correlations for seven different variables. The corresponding correlations and scatter plots of any pair of variables can be found at the intersection of the rows and columns that stem from those variables. For example, in the example figure below, the scatter plot and associated statistic between the variables wave height and light at site AHC (black boxes) can be viewed by looking at the intersection (follow orange arrows) of the rows and columns (red boxes).

Environmental variables: Tide – Greatest daily tidal movement; Wind – Median of the 30-minute maximum wind speed; WAVE – Daily median of 10-minute wave height.

Water quality variables (measured or estimated with LTD loggers): SSC – Daily median Suspended Sediment Concentration; NTU – Daily median turbidity (Nephelometric Turbidity Units); LAC – Daily Light Attenuation Coefficient; Light – median of daily midday light.



## Site MOF1

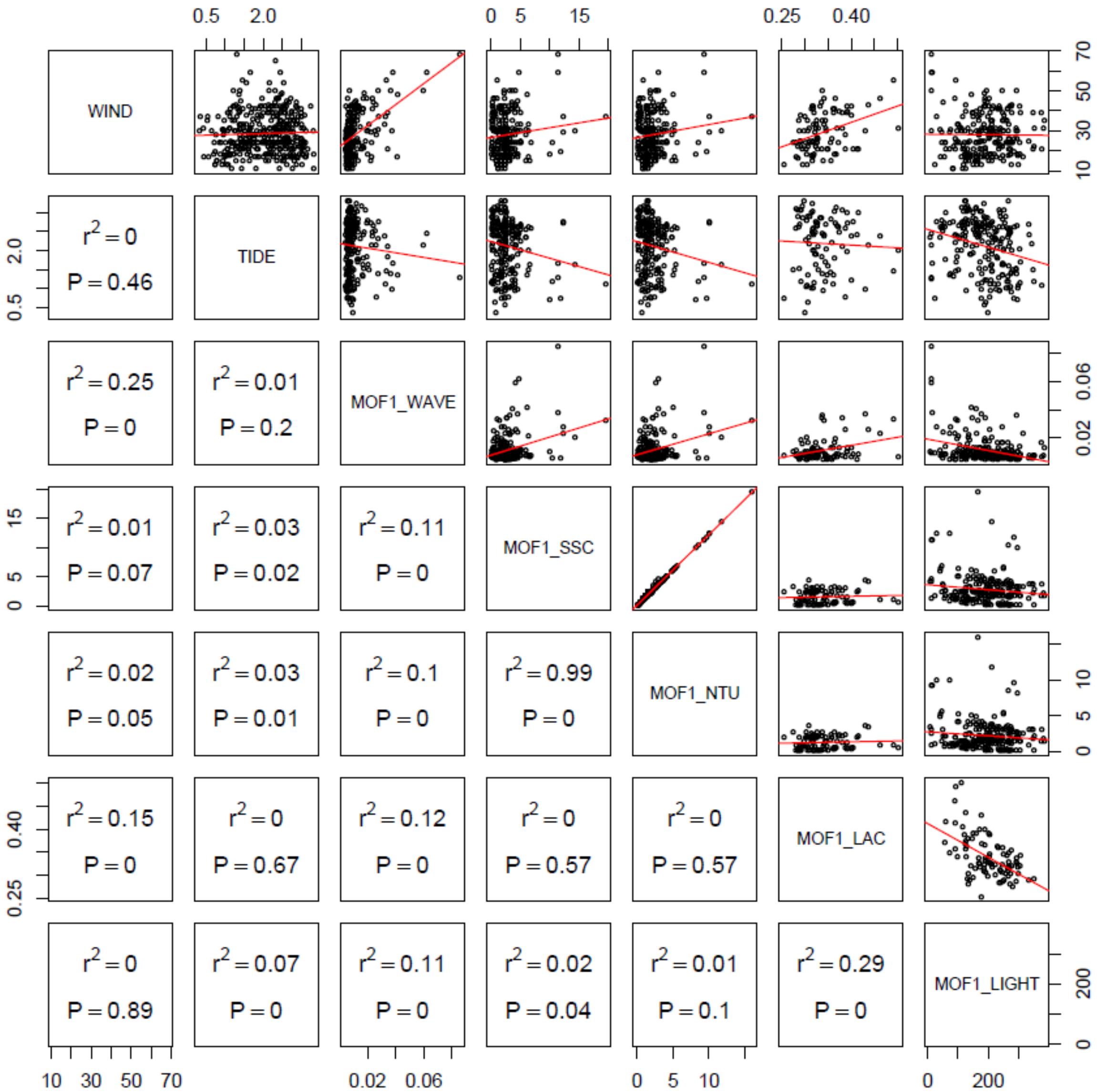



**Figure 1: Relationship During the Summer Period Between Environmental and Water Quality Variables at MOF1 (Scatter Plot with Trend Line, Pearson's $R^2$ and Level of Significance; *P* = 0 is Equivalent to *P*<0.005)**

*Note: Data for the summer period is represented from 6 December 2007 – 25 April 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 21 November 2009.*

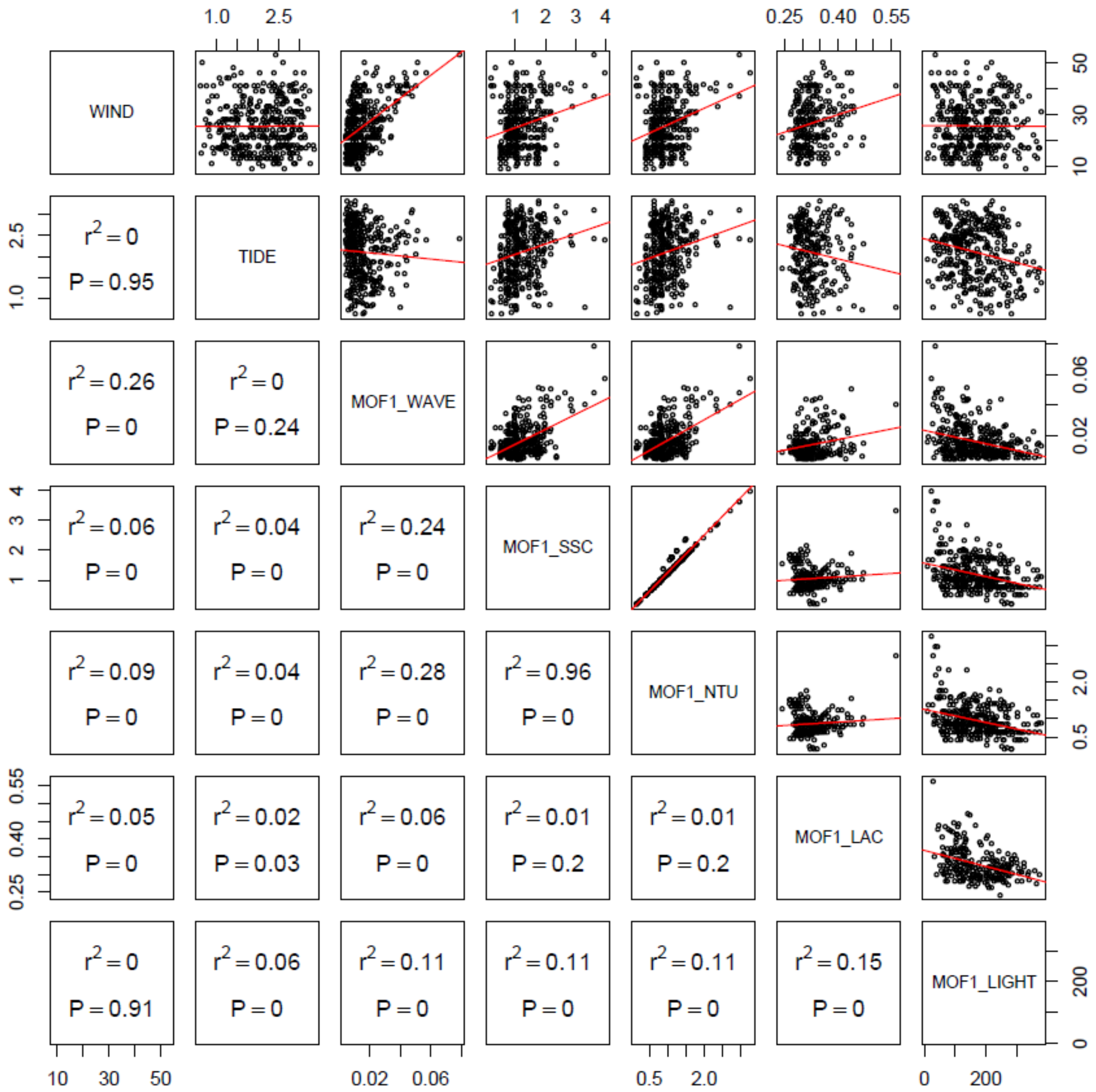



**Figure 2: Relationship During the Winter Period Between Environmental and Water Quality Variables at MOF1 (Scatter Plot with Trend Line, Pearson's $R^2$ and Level of Significance; *P* = 0 is Equivalent to *P*<0.005)**

*Note: Data for the winter period is represented from 5 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.*

## Site MOF2

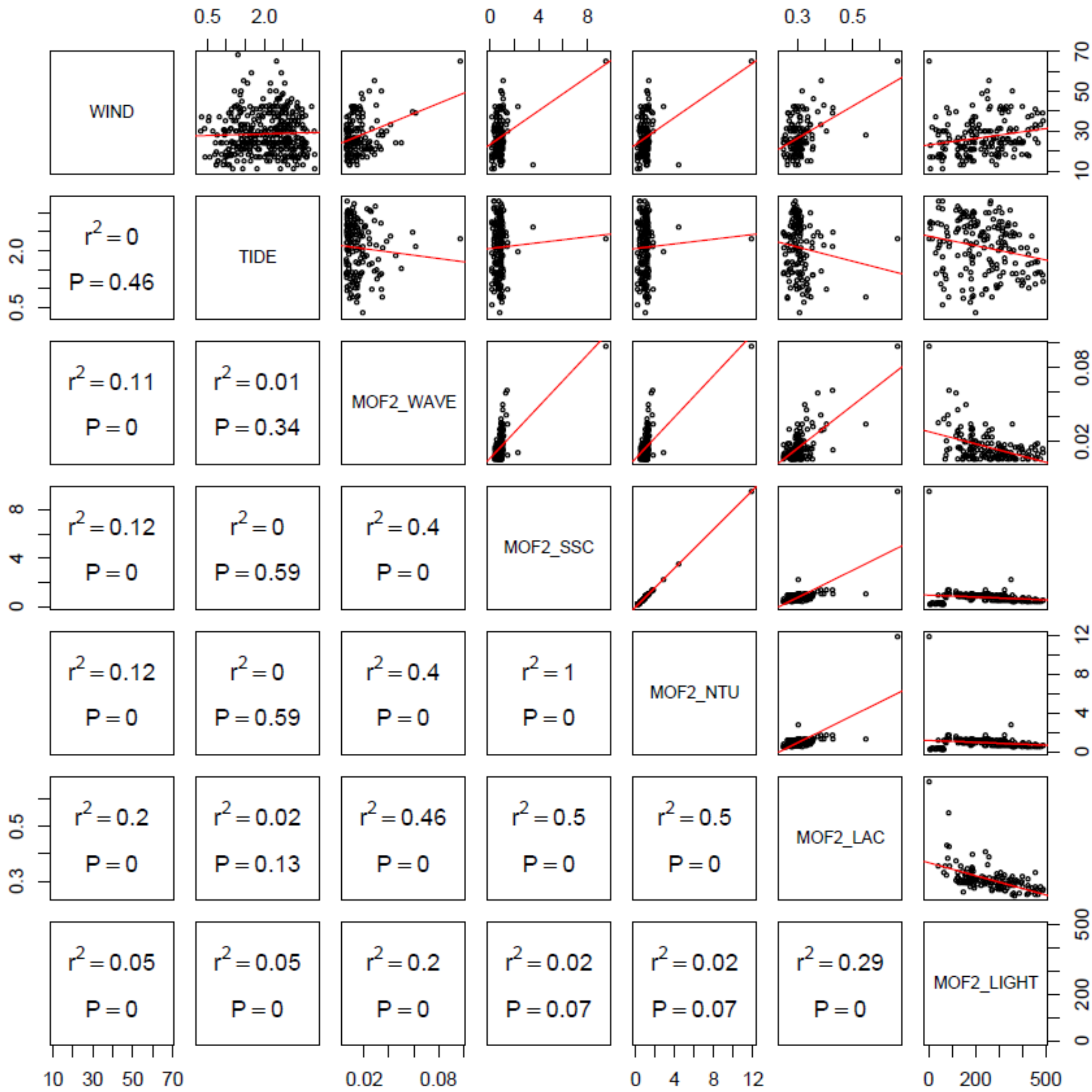



**Figure 3: Relationship During the Summer Period Between Environmental and Water Quality Variables at MOF2 (Scatter Plot with Trend Line, Pearson's $R^2$ and Level of Significance; *P* = 0 is Equivalent to *P*<0.005)**

*Note: Data for the summer period is represented from 2 April – 24 April 2008 and 1 November 2008 – 30 April 2009.*

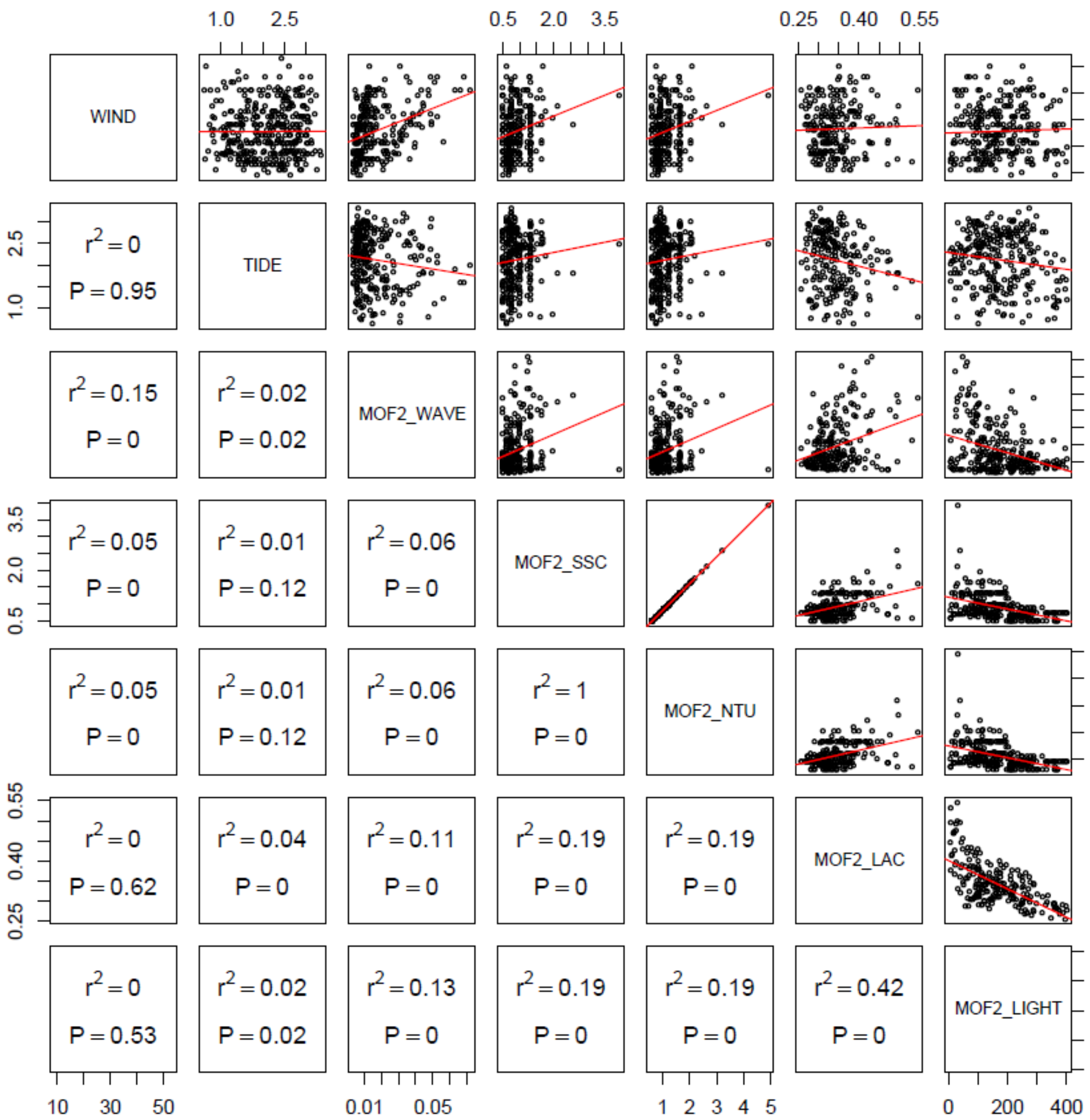



**Figure 4: Relationship During the Winter Period Between Environmental and Water Quality Variables at MOF2 (Scatter Plot with Trend Line, Pearson's $R^2$ and Level of Significance; *P* = 0 is Equivalent to *P*<0.005)**

*Note: Data for the winter period is represented from 15 July 2008 – 31 October 2008 and 1 May 2009 – 11 October 2009.*

## Site MOF3

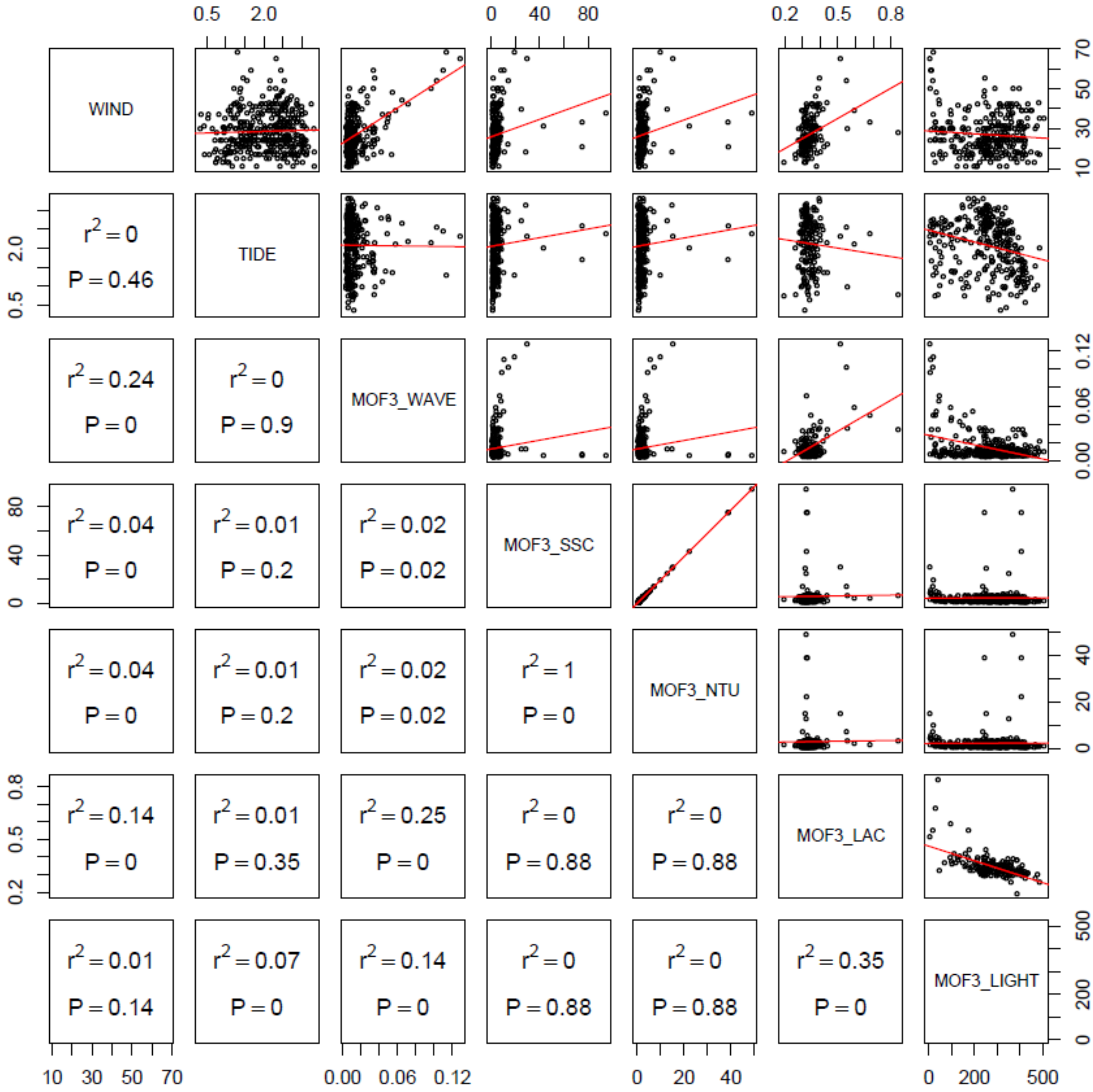



**Figure 5: Relationship During the Summer Period Between Environmental and Water Quality Variables at MOF3 (Scatter Plot with Trend Line, Pearson's $R^2$ and Level of Significance; *P* = 0 is Equivalent to *P*<0.005)**

*Note: Data for the summer period is represented from 6 December 2007 – 30 April 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 5 November 2009.*

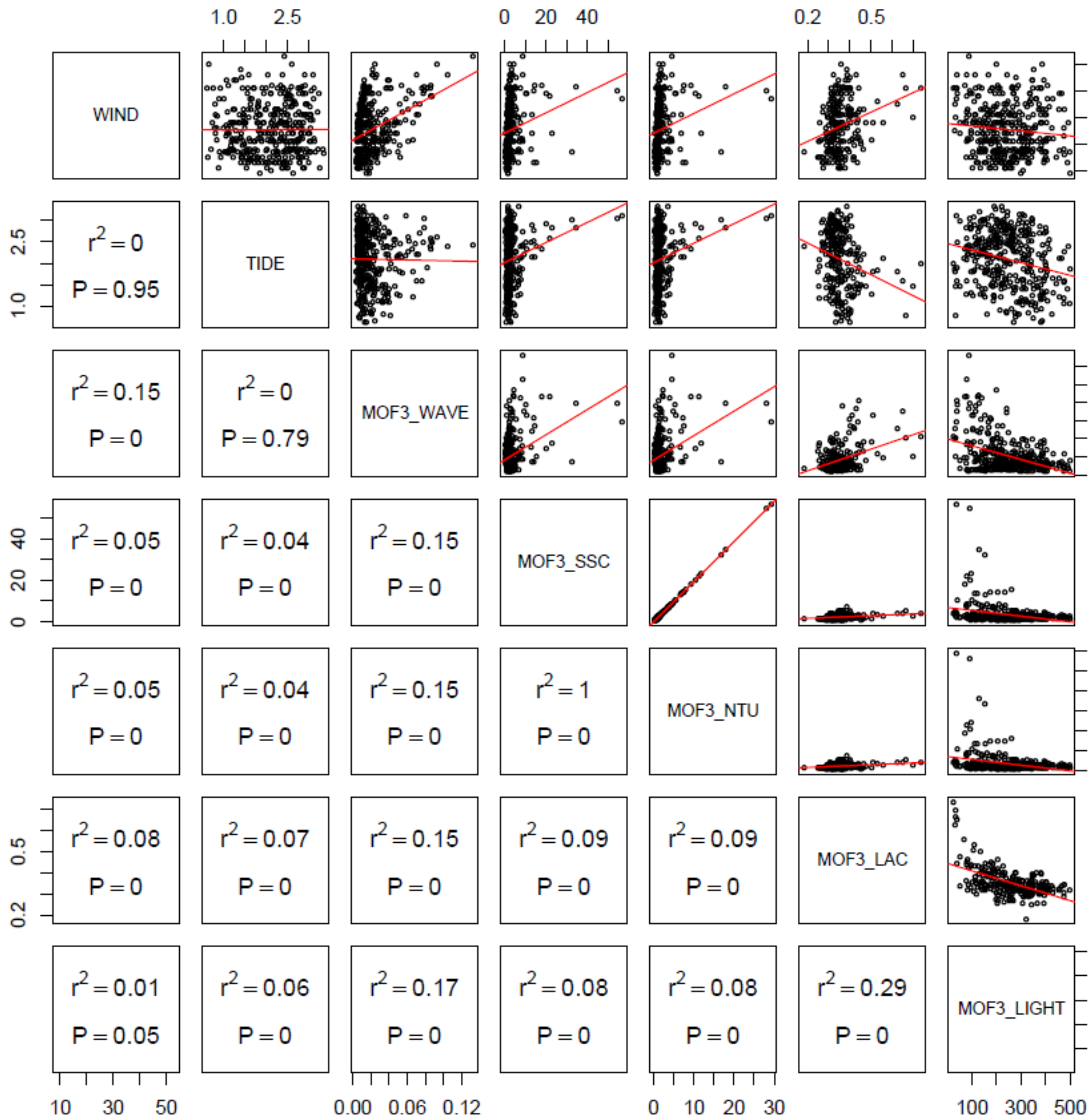



**Figure 6: Relationship During the Winter Period Between Environmental and Water Quality Variables at MOF3 (Scatter Plot with Trend Line, Pearson's $R^2$ and Level of Significance; *P* = 0 is Equivalent to *P*<0.005)**

*Note: Data for the winter period is represented from 1 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.*

## Site LNG3

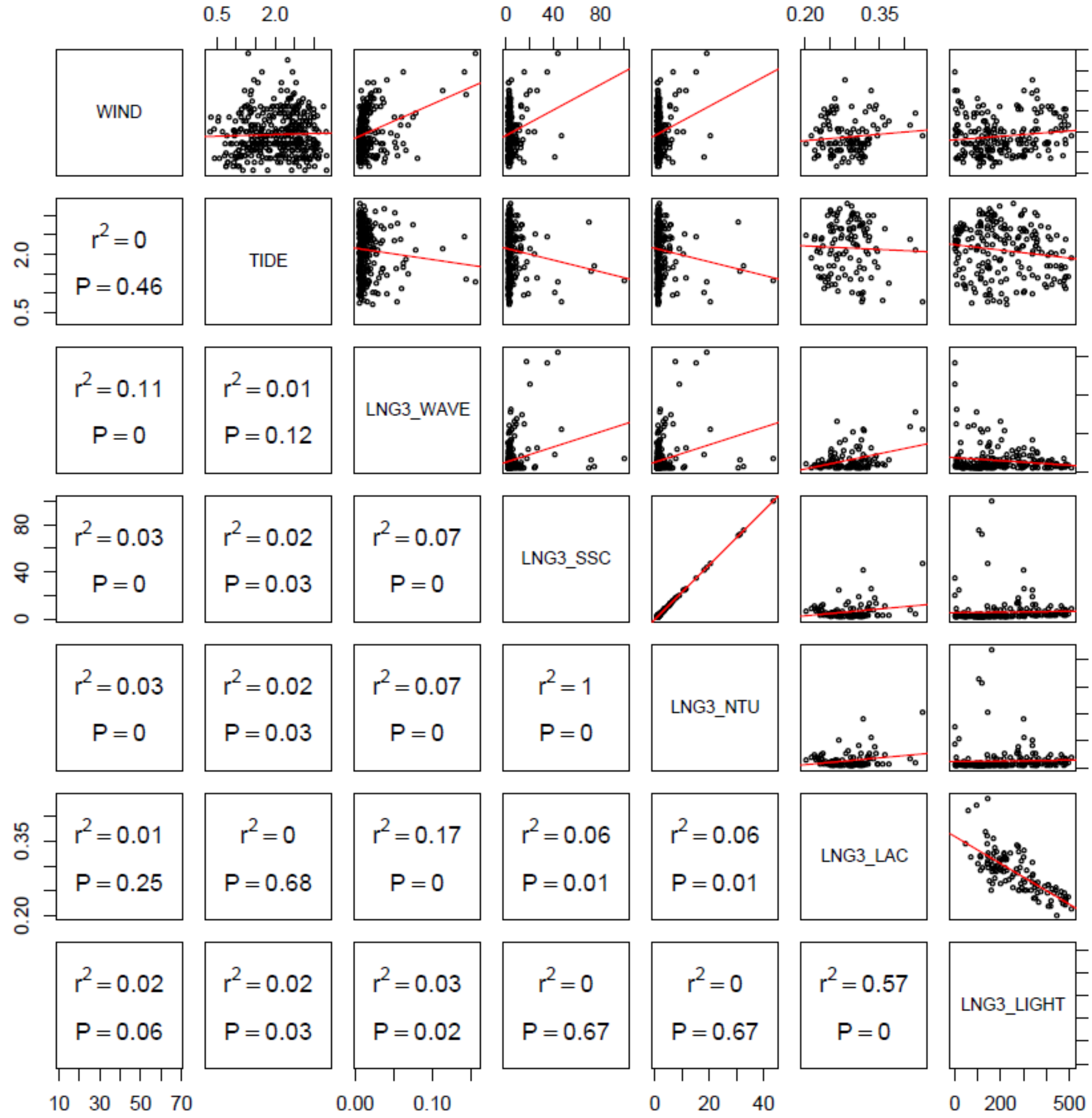



**Figure 7: Relationship During the Summer Period Between Environmental and Water Quality Variables at LNG3 (Scatter Plot with Trend Line, Pearson's $R^2$ and Level of Significance; *P* = 0 is Equivalent to *P*<0.005)**

*Note: Data for the summer period is represented from 5 December 2007 – 29 March 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 28 January 2010.*

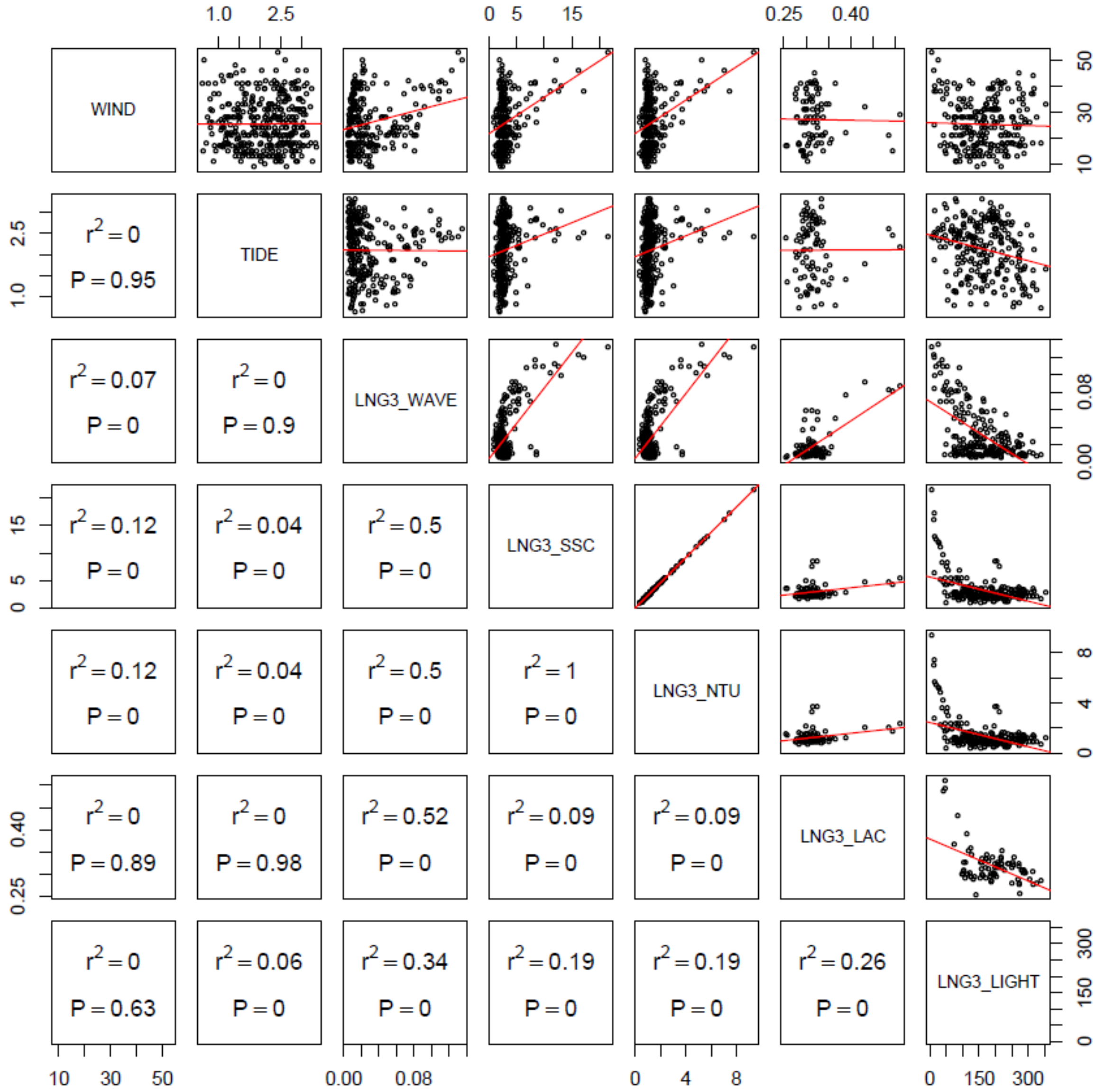



**Figure 8: Relationship During the Winter Period Between Environmental and Water Quality Variables at LNG3 (Scatter Plot with Trend Line, Pearson's $R^2$ and Level of Significance; *P* = 0 is Equivalent to *P*<0.005)**

*Note: Data for the winter period is represented from 4 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.*

## Site DUG

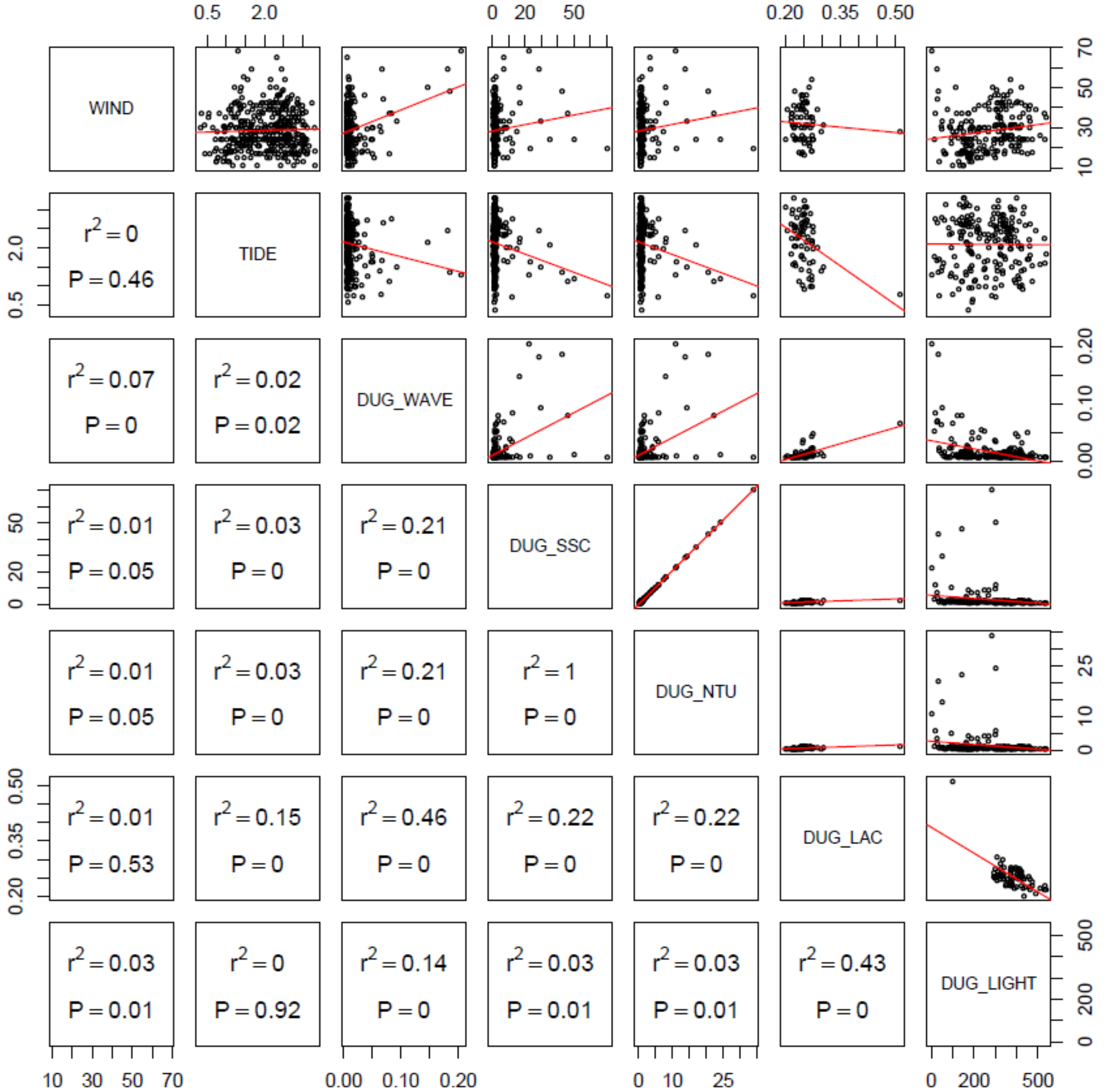



**Figure 9: Relationship During the Summer Period Between Environmental and Water Quality Variables at Dugong Reef (DUG) (Scatter Plot with Trend Line, Pearson's $R^2$ and Level of Significance; *P* = 0 is Equivalent to *P*<0.005)**

*Note: Data for the summer period is represented from 4 December 2007 – 25 April 2008, 1 November 2008 – 30 April 2009, and 1 November 2009 – 23 December 2009.*

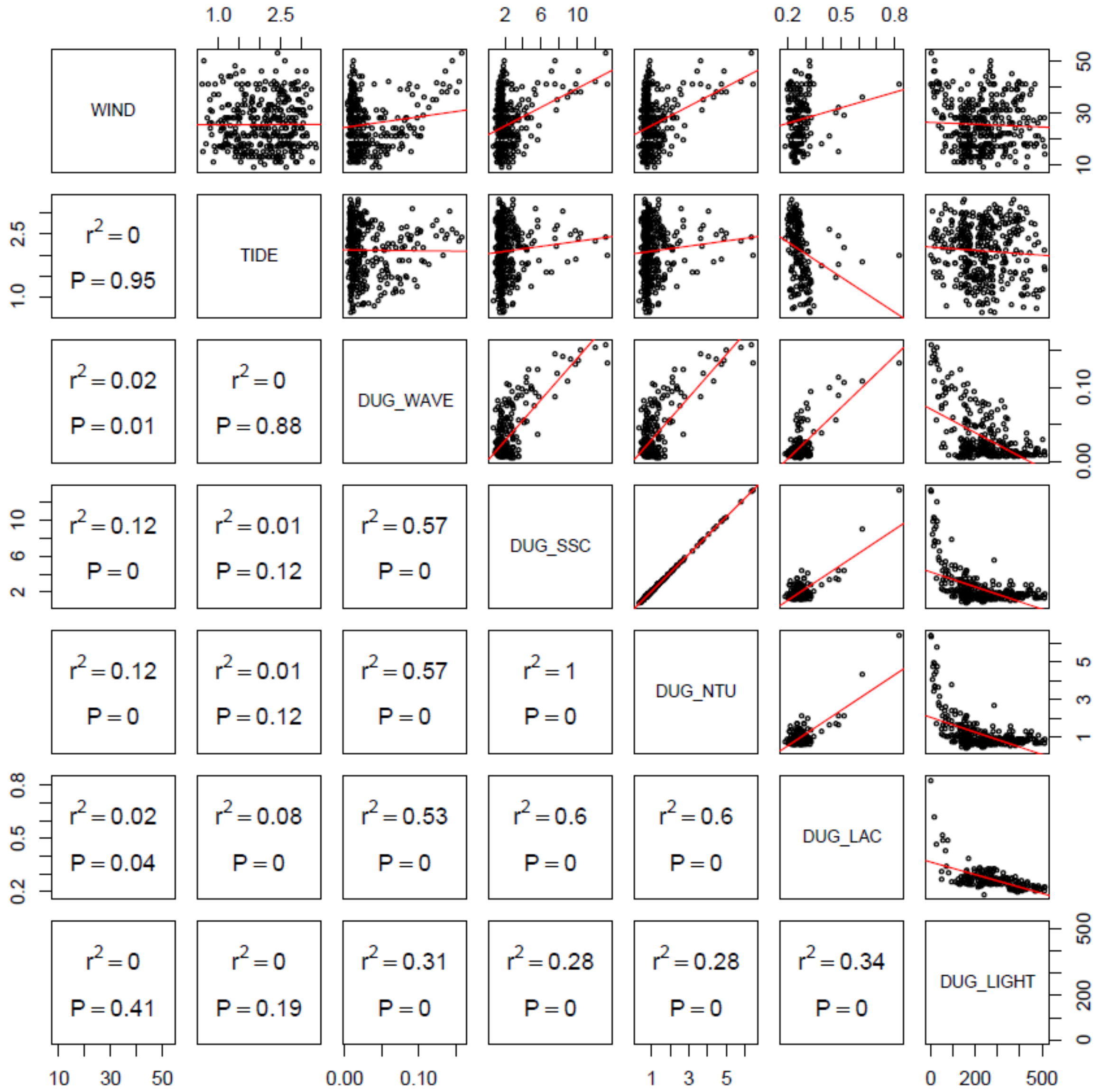



**Figure 10: Relationship During the Winter Period Between Environmental and Water Quality Variables at Dugong Reef (DUG) (Scatter Plot with Trend Line, Pearson's $R^2$ and Level of Significance; *P* = 0 is Equivalent to *P*<0.005)**

*Note: Data for the winter period is represented from 1 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.*