Appendix C-5

Nearshore benthic habitat modelling and mapping, James Price Point
NEARSHORE BENTHIC HABITAT MODELLING AND MAPPING, JAMES PRICE POINT

- Rev 3
- 8 July 2010
Browse Kimberley LNG Precinct

NEARSHORE BENTHIC HABITAT MODELLING AND MAPPING,
JAMES PRICE POINT

- Rev 3
- 8 July 2010

Sinclair Knight Merz
ABN 37 001 024 095
11th Floor, Durack Centre
263 Adelaide Terrace
PO Box H615
Perth WA 6001 Australia
Tel: +61 8 9469 4400
Fax: +61 8 9469 4488
Web: www.skmconsulting.com

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Executive Summary

Woodside Energy Ltd (WEL), as operator of the Browse Development Joint Venture (JV) Partners, is progressing the Browse Liquefied Natural Gas (LNG) development that is based on the recovery of hydrocarbons from the Browse Basin, located approximately 425 km north of Broome, Western Australia. The downstream components of the Browse LNG Development are proposed to be located at a Kimberley-based Liquefied Natural Gas (LNG) Precinct.

As part of the baseline biological and physical studies and investigations program identified in the ‘Scope of Strategic Assessment’ document prepared by DSD (2009), an assessment of the nearshore benthic habitat was considered necessary. The aim of this study is to assess and map the distribution of Benthic Primary Producer Habitat (BPPH) and other benthic marine habitats offshore from the James Price Point coastal area to assist in future impact prediction and assessment in accordance with Environmental Assessment Guidelines No.3 (EPA, 2009).

The marine benthic biota within the Kimberley region are largely unknown and the need for increased and ongoing research to develop inventories to describe and map areas of significant habitat and sensitivity has been identified (Wood and Mills, 2008). A marine benthic community survey was undertaken in June 2008 at four potential LNG precinct locations, including James Price Point (Fry et al., 2008). The information collected and analysed by Fry et al. (2008) provided broad scale video transect data on the distribution and composition of the benthic habitats present within the areas surveyed. However, to allow a more thorough and rigorous evaluation of the potential environmental impact that the development of the LNG Precinct may have on BPPH, and to address the requirements of Environmental Assessment Guidelines No.3 (EPA, 2009), further investigation was required to accurately map the extent of BPPH at finer spatial scales.

In May 2009, Fugro LADS Corporation (FLC) undertook a Laser Airborne Depth Survey (LADS) to acquire reliable and accurate bathymetric data (Fugro, 2009). LADS data were collected across the region, from north of Coulomb Point to Cape Boileau in the south. Using this baseline high resolution bathymetry data, an additional towed video survey of benthic habitats was undertaken in November 2009 (SKM, 2009a) to validate topographic features identified and the biota present in areas not previously surveyed by Fry et al. (2008).

The habitat data from video collected in the field in 2008 and 2009 (Fry et al., 2008; SKM, 2009a) were classified and regression models were developed to define the relationships between the observed habitat distribution (from the towed video) and a series of environmental data, principally derived from the LADS bathymetry. From these modelled relationships, maps were developed predicting the distribution (based on a minimum of 5% coverage) of biota, substrate and combined habitat classes across an area centred on James Price Point. Specifically, the distribution of Hard Substrate, Sediment, and sediment obscured hard substrate, Hard Coral, Soft Coral, Algae (Canopy
Algae and Small Algae) and Sessile Invertebrates were mapped. Attempts to model the distribution of Seagrass were unsuccessful due to the low observed prevalence and the highly variable temporal distribution observed during 2008 and 2009. Seagrass distribution has been mapped based on the observed distribution along the survey transects from 2008 and 2009.

For those substrate and biota classes observed with sufficient prevalence to be modelled, the modelling was able to accurately predict the probable distribution with a high degree of confidence, with correct classification rates ranging from 75-96%. The correct classification rate for all modelled Benthic Primary Producers (BPP) classes was above 83%. The modelling identified that sediment substrate covered most of the area (either sediment or sediment obscured hard substrate).

Biota was largely present as mixed mosaics and these were more likely to be found in areas of topographic complexity. Algae and Sessile Invertebrates had the most extensive predicted distribution of the biota classes modelled, typically occurring in areas of low topographic complexity, while Seagrass had the most restricted range. BPP occurring on hard substrate were found extensively in the north of the study area, adjacent to Coulomb Point, while the area in the vicinity of James Price Point was found to have the lowest coverage of BPP. A mixed mosaic of biota consisting of hard corals, algae, soft corals, seagrass and sessile invertebrates was found across the surveyed area, however sediment substrates dominated the offshore region in waters deeper than 10 metres.

Hard coral communities were small and not well developed in the James Price Point coastal area suggesting they are exposed to periodic natural disturbances. The modelled distribution of Hard Coral cover illustrated that coverage rarely exceeded 10%, unlike other areas of the Kimberley, such as the Maret Islands, that have high coral coverage and diversity. Hard coral colonies typically co-occurred with other biota types, such as algae, sessile invertebrates and soft coral. In some instances, seagrasses such as *Halophila* spp. were found growing amongst hard coral communities in inter-reefal sand patches. Seagrass in the region appeared to be seasonally abundant, but patchy, with meadows of seagrass being highly seasonal (Masini *et al.*, 2009).

Non-BPP sessile invertebrates (including most sponges, sea whips, gorgonians, ascidians, sea pens and non photosynthesising soft corals), were the most extensive biota mapped throughout the study area. Non-BPP sessile invertebrates were typically found on hard substrates and in areas with sand obscured hard substrate. Previous research (Fry *et al.*, 2008) identified that sessile invertebrate communities, although highly diverse, were very patchy in distribution within the vicinity of James Price Point itself. The modelling and mapping in this study predicted the most extensive areas of sessile invertebrates were to the north and in deeper waters to the south, offshore from Quondong Point and Cape Boileau.
This study provides details on the distribution and extent of benthic habitats at a finer spatial scale, and with a greater degree of accuracy than previous studies. The habitats observed and mapped within the study area were indicative of the benthic habitats found across the wider region. It is concluded that the mapping products of this study provide the necessary information and detail required to make future quantitative assessments of the potential impact that any proposed development in the area could have on the nearshore benthic primary producer habitats of the James Price Point coastal area.
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# Nearshore Benthic Habitat Modelling and Mapping, James Price Point

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1. Introduction

1.1. Study purpose and context

The aim of this study is to assess and map the distribution of benthic habitat of the James Price Point coastal area (Figure 1). Woodside Energy Ltd (WEL), as operator of the Browse Development Joint Venture (JV) Partners, is progressing the Browse Liquefied Natural Gas (LNG) development that is based on the recovery of hydrocarbons from the Browse Basin, located approximately 425 km north of Broome, Western Australia. The downstream components of the Browse LNG Development are proposed to be located at a Kimberley-based Liquefied Natural Gas (LNG) Precinct. The LNG Precinct will involve the construction and operation of LNG processing facilities and associated infrastructure, including export facilities. The Department of State Development (DSD), as the Precinct Proponent, has identified James Price Point as the preferred location and is progressing a Strategic Assessment of the Precinct.

The marine benthic communities within the Kimberley region are largely unknown and the need for increased and ongoing research to develop inventories to describe and map areas of significant habitat and sensitivity have been identified (Wood and Mills, 2008). Additional research is considered necessary for developing conservation strategies, and to inform decision making around biodiversity conservation and Environmental Impact Assessment (EIA) for proposed developments (DEWHA, 2008). A detailed understanding of the existing marine environment will facilitate an accurate evaluation of potential environmental impacts likely to emanate from a proposed development in the coastal environment.

In line with this view, the ‘Scope of Strategic Assessment’ document prepared by DSD (2009) considered that an assessment of the nearshore benthic habitat was necessary. Such an assessment could provide baseline habitat information and assist in future assessments to determine any potential impact to, or loss of, BPPH in accordance with the level of detail stipulated within the EPA’s Environmental Assessment Guidelines No. 3, ‘Protection of Benthic Primary Producer Habitats in Western Australia’s Marine Environment’ (EPA, 2009).

1.2. Study Area and Approach

In May 2009, Fugro LADS Corporation (FLC) undertook a Laser Airborne Depth Survey (LADS) to acquire reliable and accurate bathymetric data (Fugro, 2009). LADS data were collected across the region, from north of Coulomb Point to Cape Boileau in the south (Figure 1). In addition to providing high resolution bathymetric data for engineering purposes, the data were also collected to support benthic habitat mapping and any dredging studies required as part of the Strategic Assessment.
The over-arching objective of this study was to map the distribution of marine benthic habitats across the spatial extent of the LADS data (Fugro, 2009) collected for the James Price Point coastal area, hereafter referred to as the ‘study area’.

The study area is bounded from the shoreline to approximately the 25 m depth contour (approximately 12.5 km offshore) and the total ocean area is approximately 500 km². James Price Point is located approximately 20 km north of Cape Boileau and 15 km south of Coulomb Point (Figure 1). The bathymetry in the area is generally less than 10 m water depth with limited vertical relief. Baseline water quality data collected between November 2009 and February 2010 indicate that water quality in the area is strongly influenced by tidal cycles and tidally driven sediment re-suspension can result in rapid and dramatic increases in turbidity (SKM, 2010). Similarly, logger data has shown that the amount of irradiance reaching the benthos (i.e. benthic light availability) can vary dramatically between sites where there is as little as three metres difference in depth.

Given the broad spatial extent for which baseline habitat information is required (i.e. full coverage maps for approximately 500 km²), the only practical means to produce detailed and accurate habitat maps is to undertake habitat modelling. Previous approaches for mapping the distribution of benthic marine habitats have typically involved generalising observations made at point locations to create indicative maps of habitats. The boundaries between the different habitat classes on such maps are arbitrary, often being placed equidistant between the points without considering the underlying seabed characteristics. Such approaches do not provide maps that reflect the actual distribution of habitats across an area, nor do they allow the accuracy of the maps to be quantified. Spatial interpolation is an alternative, more rigorous approach to produce full coverage maps which is also based on point locations, but it also incorporates the similarity of the observed distributions in space. However, over larger areas, the required density of points for accurate interpolation is rarely practicable and distances between point locations increase to a point where the interpolated boundaries do not reflect the underlying conditions. Consequently, interpolation is rarely suitable or reliable for large areas.

Unlike these approaches, habitat (statistical) modelling provides a more accurate representation of the observed distribution of the different habitat classes, and the accuracy of the models and the maps can be quantified and reported. Using a combination of high resolution bathymetric data and habitat distribution data (as observed from towed video) the models define the environmental conditions (physical characteristics of the seafloor) at which the different substrate and biota types are likely to occur. By defining these relationships, the models can be used to predict the probable occurrence of the different habitat classes across the entire area for which the environmental data (LADS data) is available. As predictions are based on defined statistical relationships, the distance between the sampled point locations is (essentially) irrelevant, as long as towed video has been taken across the full spatial extent and over the full range of environmental gradients present in the study area.
Figure 1 Location of the study area at James Price Point based on the extent of the bathymetric data collected by Fugro LADS Corporation in May 2009
Habitat modelling is an implementation of (species) distribution modelling for which there is an extensive body of literature (see reviews by Guisan and Zimmerman, 2000; Elith et al., 2006) and it has previously been used to model and map the distribution of benthic marine habitats for Parks Victoria (e.g. Holmes et al., 2007a, b, c, d and e) and details of the approach have been published in a peer reviewed journal by Holmes et al. (2008). This approach has also previously been applied for commercial purposes on several occasions (Sinclair Knight Merz, unpublished data).

Given the availability of the LADS data and observed biota information collected in previous video surveys (Fry et al., 2008) and specific towed video surveys (SKM, 2009a; 2009b), and the fact that it is the most rigorous and quantifiable method for mapping habitats over large areas, the habitat modelling approach was adopted for this study.

1.3. Study Objectives and Scope of Works

This study aimed to produce a detailed assessment and map of the benthic (subtidal) habitats, including benthic primary producer habitats (BPPH), located offshore of the James Price Point coastal area, satisfying the terms of reference outlined by the DSD for study DSF14.

To achieve this aim, the specific scope of works included:

- desktop literature review and assessment of existing information on the marine habitats of the James Price Point coastal area;
- review the existing LADS bathymetry data and prepare the data for habitat modelling;
- source, review and reclassify existing habitat information including the towed video footage collected as part of the DSD benthic habitat survey (Fry et al., 2008) and prepare the data for habitat modelling;
- incorporate additional towed video data collected after the LADS survey (SKM, 2009a; 2009b) and prepare the data for habitat modelling;
- develop and evaluate models to predict the distribution of the substrate and biota classes present in the study area;
- prepare maps showing the predicted distribution of the substrate and biota classes present and the distribution of aggregated habitat classes across the extent of the study area; and
- prepare a report that includes a description of the methods used to complete the modelling and mapping, as well as an assessment of the marine benthic habitats in the study area.

1.4. Review of Existing Habitat Data

This section provides a summary of all previous studies, surveys and literature concerning the habitat types known to exist within the James Price Point coastal area and regional surrounds. Of particular importance was a study undertaken by the CSIRO Marine and Atmospheric Research
CMAR division and the Australian Institute of Marine Science (AIMS), contracted through the Western Australian Marine Science Institute (WAMSI) in collaboration with the Western Australian Department of Environment and Conservation (DEC). The survey used a combination of towed video and dredge tows to undertake a rapid assessment of the marine benthic communities within the Kimberley region in June 2008 at four locations, namely Gourdon Bay, Quondong to Coulomb Point, Perpendicular Head and Packer Island (Fry et al., 2008) (Figure 2). It provided a comprehensive assessment and description of the habitat complexity and biodiversity at each of the locations. Based on the data collected, maps of the distribution of substratum and biohabitat were produced based on clustering analyses and Voronoi tessellations (reproduced in Figure 3 and Figure 4). When considering the mapped distributions of the substratum and biohabitat shown in these figures, it is important to do so in the context of how the maps were developed and the corresponding objectives that they were produced for. As stated on page 97 in Fry et al. (2008),

“It is worth noting that the clustering analyses and subsequent Voronoi tessellations are an extrapolation of distributions of aggregated substratum and benthic habitat groups from point composition data at a scale of about 1 to 1.5 km spacing. As such, it is not intended to describe or detect individual patches of each substratum or biohabitat type throughout the locations. This method is used to give an indication of the dominant substratum characteristics and benthic biohabitat communities that are most likely to occur.”

1.4.1. Habitat Types

Benthic habitats in the Kimberley region are characterised by the presence of mixed communities, typically consisting of complex habitats of hard coral and soft coral, interspersed among filter feeding communities such as ascidians, sponges and algae (Fry et al., 2008). The overall distribution of seagrass in the region is poorly documented but appears to be regionally represented. Similarly, macroalgae communities are common and well represented throughout the region.

Fry et al. (2008) found that the seabed was comprised mostly of sand with a mean percent coverage of 55% with extensive areas of sand waves (Figure 3). A range of complex, mixed habitats are known to exist within the James Price Point coastal area (study area) and regionally. The subtidal geomorphology and bathymetry of the Kimberley region provides both hard and soft substrate environments with distinct seabed features such as shoals and valleys which support a variety of biota types. Locally, relatively large patches of low relief reef structure were present from Quondong Point to James Price Point, and these were mostly in water less than 10 m deep. Smaller patches of high relief structures and rocky substrate exist further to the north of James Price Point. North of James Price Point the reef platform extends further offshore (to approximately 2 km) providing a sheltered lagoon and intertidal platform with pools and crevices supporting a variety of
benthic biota. Limited tracts of low relief reef are present in shallow waters in the south. Resuspension and deposition are common within the area due to the high tidal range and influence of periodic cyclones. As a consequence, low relief reefs often contain a transient, thin covering of sediment creating additional habitat for certain biota types.

Within the James Price Point coastal area, hard substrate supports a reef community of filter feeders, hard corals and macroalgae, while areas of shallow sandy sediment support seasonal seagrass and macroalgae (Figure 3 and Figure 4; Fry et al., 2008). Existing information on these biota types, as well as soft corals and other sessile invertebrates is summarised below for the James Price Point coastal area and Kimberley region.

1.4.2. Hard Coral

1.4.2.1. Kimberley Region

In comparison to other regions of Western Australia, such as Ningaloo Reef and the Dampier Archipelago, coral communities in the Kimberley region have not been extensively studied (Blakeway & Radford, 2005). The majority of information on hard coral in this region relates to offshore and fringing coral reef systems, such as those found at Ashmore and Cartier Islands, Seringapatam Reef, Scott Reef, Rowley Shoals, Buccaneer Archipelago and Maret Islands where studies have identified in excess of 280 species and 60 genera of scleractinian corals (Wells et al., 1995; INPEX, 2008; Masini et al., 2009) (Figure 2). However, other studies in the region (e.g. DEC, 2008) have identified that the number and diversity of coral colonies present on nearshore reefs is low, with habitats generally classified as algal-dominated reefs.
Figure 2 Regional map showing the locations of existing habitat information
Figure 3 Distribution of substrates produced by Fry et al. (2008) using clustering and Voronoi tessellation methods.
Figure 4 Distribution of biohabitats produced by Fry et al. (2008) using clustering and Voronoi tessellation methods.
The Dampier Peninsula contains areas of coral habitat, although at a broader scale they are not comparable in terms of regional significance to areas with typical reef building coral communities found elsewhere, such as at Scott or Ningaloo Reefs or Maret Islands (INPEX, 2008). Along the Dampier Peninsula, the extent of coral growth within the intertidal platforms is likely to be linked to the availability of suitable substrate for colonisation. Areas where the reefs are terraced often include sheltered rock pools and gutters, which may support coral growth. Shallow reef platforms are unlikely to support extensive coral growth due to frequent periods of desiccation during low tide.

Fry et al. (2008) found that mixed communities of hard coral were generally not well represented at any of the four locations surveyed, including the James Price Point coastal area. Coral patches were more abundant along the deeper transects (approximately 20 m) around the shoals at Gourdon Bay and in the shallows of the northern half of the Quondong to Coulomb Point location, where hard substrate was present. At Perpendicular Head and Packer Island, a greater abundance of hard rock or reef substrates, colonised by higher densities of Turbinaria sp. and other coral species were recorded, with coral growth mainly restricted to the shallow waters (less than 15 m water depth).

Twenty four hard corals were collected in samples from the Dampier Peninsula to Gourdon Bay, comprising of six families, 11 genera and 14 species (Irvine and Keesing, 2009). Eight species were collected at the Gourdon Bay location and four species at each of the other three locations (Quondong to Coulomb Point, Perpendicular Head and Parker Island). The most abundant species were Cycloseris cyclolites (31 colonies), Turbinaria reniformis (3 colonies) and Turbinaria patula (3 colonies) (Irvine and Keesing, 2009).

1.4.2.2. James Price Point Area

Fry et al. (2008) documented the presence of mixed subtidal communities with hard coral present in a few small patches or individual species in shallow water (less than 10 m) and these generally consisted of only a small number of species, with Turbinaria sp. and Acropora sp. being the most abundant. There were small patches of dense hard coral associated with high relief reef substrate inshore and north of Coulomb Point (Fry et al., 2008). These mixed communities typically consisted of complex habitats of hard coral and soft coral, interspersed among filter feeding organisms such as ascidians, sponges and algae, suggesting that in general, coral communities were not well developed in the James Price Point coastal area (Masini et al., 2009).

Similarly, the intertidal area was characterised by flat, sandy areas with relatively sparse, intermittent rocky substratum and reef platform which was exposed at low tide and therefore not suitable for the development of highly diverse or complex coral communities. This is a typical feature of intertidal reefs from Mermaid Sound (Western Australia) to Darwin (Northern Territory),
wherever large tidal ranges expose reefs on low tides. Identified genera included *Favites*, *Goniopora*, *Porites*, *Platygyra*, *Turbinaria* and *Acropora* (SKM, 2009c).

1.4.3. **Algae**

1.4.3.1. **Kimberley Region**

Canopy and turf algae were commonly found throughout the Kimberley region and along the Dampier Peninsula. From the Dampier Peninsula to Gourdon Bay, the green algae *Caulerpa* spp. and *Halimeda* spp. were most diverse with three species from each genera collected (Irvine & Keesing, 2009). The brown algae were represented by seven species belonging to the families Dictyotaceae and Sargassaceae. Several juvenile Sargassum plants (*Sargassum* sp.) were also collected in the samples. The red algae were the most diverse group among the collection, with 28 species recorded (Irvine and Keesing, 2009). Similarly, Walker (1996) documented *Sargassum* sp. along with rhizobenthic algae, such as *Halimeda*, *Avrainvillea* and *Udotea* (Chlorophyta) as the most abundant on subtidal reefs and within patches of sediment. According to Fry *et al.* (2008) green, red and brown macroalgae were common, but were mostly restricted to the shallow areas at Gourdon Bay, Perpendicular Head and Packer Island locations. Macroalgal habitat is well represented along the Dampier Peninsula and therefore unlikely to be of local importance.

1.4.3.2. **James Price Point Area**

Macroalgae were the most abundant benthic primary producer encountered during surveys by Fry *et al.* (2008) in the James Price Point coast area. This was largely driven by suitable hard substrate for algal growth between Quondong Point and Coulomb Point. Along the coast off Coulomb Point, there were extensive patches of *Sargassum* spp. in shallow water (5–10 m depth) and extending into the deep waters, almost to the seaward extent of the survey boundary. This represented more than 50% of the seabed along transects located off Coulomb Point. Other undifferentiated small algal species were common in shallow water on reef and rocky substratum (Fry *et al.*, 2008). In the deeper waters with flat sand substrate, green turf algae was the most dominant biota, with mean percent coverage ranging from 7 to 22%.

Large areas of green and brown turf algae were recorded from the intertidal areas of James Price Point by SKM (2009c). The majority of the species recorded were typical of those found along rocky shores in the region (WA Museum, 2008). Virtually all species recorded in the survey were previously known from the Broome area and Dampier Peninsula. Common intertidal genera include *Caulerpa*, *Codium*, *Cystoseira*, *Gracilaria*, *Padina*, *Portieria*, *Sargassum*, *Spatoglossum*, *Tricleocarpa* and *Ulva* (SKM, 2009c).
1.4.4. Seagrass

1.4.4.1. Kimberley Region

Seagrass habitats within the region have been generally found in shallow water (less than 20 m) near offshore reefs, shoals and the mainland (Fry et al., 2008). This has included both subtidal and intertidal sheltered environments, such as reef flats and large bays. Seagrasses were generally sparse, occurring in low abundance on sandy sediments (Semeniuk et al., 1982; Jones, 2004). Very limited information exists on the subtidal seagrass communities in the region with the majority of studies based on collections of individual voucher species from the intertidal zone (Walker, 1992; 1995; 1996; 1997 and Walker and Prince, 1987). Seagrass appears to be well represented regionally and is not specific to the James Price Point coastal area.

Seasonally abundant, subtidal seagrass communities were patchily distributed across large areas along the Dampier Peninsula. Twelve species were known to occur within north Western Australia’s tropical waters, 11 of which were recorded around the coastal margin of the Dampier Peninsula (Kenneally et al., 1996) and at intertidal sites in the Kimberley (Walker, 1992; 1995; 1996 and 1997). Fry et al. (2008) recorded sparse patches of Halophila sp. in the shallows at Perpendicular Head and Packer Island. Further south, at Gourdon Bay, mean seagrass coverage was considered sparse (average of 4%) (Fry et al., 2008). Eight species were identified from the southern Kimberley region, particularly around Sunday and Tallon Islands (Cape Leveque to Montgomery Reef) (Walker, 1995) (Figure 4). The most extensive seagrass meadows known for the Kimberley were documented from around Sunday and Tallon islands (Wells et al., 1995). Areas of seagrass in the central and northern Kimberley region (Buccaneer Archipelago in the south to Cambridge Gulf in the north) were not found to be as extensive or diverse as seagrass at the Sunday and Tallon Islands (Walker, 1996; 1997) (Figure 4).

The genera of seagrasses known within the region include Cymodocea, Enhalus, Halodule, Halophila Syringodium, Thalassia and Thalassodendron. Common species were Thalassia hemprichii, often covering 30-50% of the substratum, followed by Enhalus acoroides, Halophila ovalis, Halodule uninervis, Thalassodendron ciliatum and Halophila decipiens (Walker, 1992; 1995; 1996 and 1997; Huisman & Borowitzka, 2003; Kenneally et al., 1996). Thalassia hemprichii was associated with coral rubble at varying depths. Enhalus acoroides was typically found in deep fine sediment, usually on the upper part of the shore, often in front of mangroves (Walker, 1992; 1995; 1996 and 1997). The species H. ovalis often formed extensive beds with a large depth range and greater tolerance to exposed conditions, compared with other species of this genus (Edgar, 1997).

In mixed seagrass communities, where the substrate was fully exposed at low tide, Halodule uninervis was the dominant species and a rapid coloniser that played an important role in
maintaining seagrass habitat in areas of high disturbance (Kenneally et al., 1996; Waycott et al., 2004). Other species, such as *Thalassodendron ciliatum*, were located in areas with strong currents, growing directly on reef or coarse shell grit (Kenneally et al., 1996). *Halophila decipiens* was the most common seagrass found in deeper waters and was also common in reef and sandy habitats (Irvine and Keesing, 2009).

### 1.4.4.2. James Price Point Area

The James Price Point coastal area has been found to support seasonally abundant, subtidal seagrass communities consisting mainly of *Halophila* sp. in waters approximately 10 m deep (Fry et al., 2008). Seagrasses were usually sparse, patchily distributed and generally interspersed with other habitats on sand areas between reef patches, and the mean percent cover of seagrass was less than 6% (Fry et al., 2008). Seagrass was largely restricted to the flat sand areas to the south of Coulomb Point within the 5–10 m depth contours. Some small patches were also recorded further south between James Price Point and Quondong Point. Based on observations from the towed video, seagrass was observed to occur in waters ranging from 4 m to 18 m deep (MSL).

Unpublished work completed by DEC and AIMS in the James Price Point coastal area during November 2007 found areas of dense seagrass with high biomass. Repeat surveys undertaken in April 2008 at the same locations found no seagrass, while further sampling during June 2008 and December 2008 found seagrass had re-established, with prolific seed production observed in *Halophila* sp. suggesting these communities were seasonally abundant (Masini et al., 2009).

### 1.4.5. Soft Corals and other Sessile Marine Invertebrates

#### 1.4.5.1. Kimberley Region

Invertebrates have been collected throughout the Kimberley region by the WA Museum (WAM) since the late 1980’s. Surveys of intertidal and subtidal invertebrates were conducted in 1992 (Morgan, 1992) and 1995 (Hanley, 1995; Wells et al., 1995) along the Kimberley coast from Broome in the south to Wyndham in the north. Communities were generally associated with stable hard substrate, overlain by sand veneers in areas of sloping bathymetry where light availability was limiting for hard corals (Masini et al., 2009).

A diverse range of invertebrate epifauna have been documented from subtidal filter feeding communities including sponges, soft corals, bryozoans, anemones, hydroids and ascidians. The diversity and abundance of these sessile fauna are dependent on a range of variables, including the availability of suitable substrate and the level of exposure.

Sea pens, ascidians and hydroids were among the most widespread groups at both Perpendicular Head and Packer Island. Fry et al. (2008) found ascidians to be common in Gourdon Bay, with a
wide distribution throughout most of the survey location, especially within sponge and whip
gardens. Ascidian conical species were relatively abundant and three genera *Aplidium*, *Didemnum*
and *Pseudodistoma* represented the majority identified in epi-benthic dredge sled samples collected
(Irvine & Keesing 2009). These genera are widespread throughout Australia and species from these
genera are found in most tropical and temperate waters. The most common solitary ascidians were
the genera *Polycarpa* and *Phallusia*. There were dense patches of bryozoans in the north east of the
survey location; these were attached to patches of dead sea whips. At Packer Island it was noted
that sea pens generally inhabited the flat sandy patches in the deeper water transects where the
currents were quite strong (Fry et al., 2008). The diversity of sessile marine invertebrates at
Perpendicular Head was relatively high compared to other biota (Fry et al., 2008), and Irvine and
Keesing (2009) recorded 52 species of the class Demospongia from 18 families during epi-benthic
dredge sled samples. Of the identified taxa, the greatest sponge diversity was recorded at the
Quondong to Coulomb Point location (52 species). This was followed by the Packer Island location
(25 species) and Gourdon Bay location (23 species), with only 11 species recorded at the
Perpendicular Head location.

The crinoids species in dredge sled samples were generally typical of crinoid communities seen in
the northern WA region and there were three families represented by eight genera and fourteen
species (Irvine & Keesing, 2009). Nine of these species were from the family Comasteridae,
including two from the genus *Comatula*. The diversity of crinoids was greatest at the Gourdon Bay
location (11 species) compared to the other three locations (six at Packer Island, five at Quondong
to Coulomb Point and 4 at Perpendicular Head).

1.4.5.2. James Price Point Area

Along the patches of low relief reef at James Price Point, sparse to medium (2–16%) densities of
soft corals, sponges, gorgonians and whips were identified. According to Fry et al. (2008) these
communities were very patchy and most common among the fine sand substrates where they were
attached to hard substrates just below a thin sand layer. The filter feeding communities were
dominated by sponges, followed by whips and gorgonians. Soft corals were recorded within each
location, however their abundance was generally low and variable. There were some isolated
medium to dense patches of Alcyonacea at Coulomb Point. Sites with higher proportions of low or
high relief reef in deeper waters were strongly associated with mixed filter feeding communities,
including sponges, gorgonians, sea whips and Alcyonaceans.

1.5. Summary of existing habitat information

The benthic habitats found within the study area were consistent with, and further represented by,
the habitats found across the wider region. Based on the existing information, there were no
habitats found within the study area that were not found in the same or better condition to the north
and south of the study area. The area was dominated by sediment substrate and there were few areas occupied by a single biota type. Both sediment and hard substrate were observed to have, in general, low coverage of different mosaics of biota types.

The existing information provides a broad scale overview on the distribution and composition of the benthic habitats present, but fine scale distributions and extents of habitat composition remain undefined. To enable a thorough and rigorous evaluation of the potential impact the development of the LNG Precinct may have on BPPH, and to address the requirements of Environmental Assessment Guidelines No. 3 (EPA, 2009), further investigations are required to accurately map and quantify the distribution of these BPPH at finer spatial scales.
2. Methods

2.1. Overview

The distribution and spatial extent of the benthic habitats found in the study area were modelled and predicted using a combination of high resolution bathymetry data and towed video data. Models were developed to define the relationships between the observed habitat distribution (from the towed video) and a series of environmental data that quantify the characteristics of the seabed (‘predictor’ variables: bathymetry and derived data). From these relationships, the distribution of different substrate types (Hard Substrate and Sediment) and benthic biota (Hard Coral, Soft Coral, Algae, including Canopy Algae and Small Algae, and Sessile Invertebrates) were predicted and mapped across the entire area for which the environmental data exists. The distribution of Sediment Obscured Hard Substrate was also mapped by combining the predicted distribution of the Hard Substrate and Sediment class maps. Attempts to model Seagrass distribution were made, but due to the limited prevalence (<5% occurrence) across the study area and the highly variable distribution of seagrass recorded in the two towed video datasets, Seagrass distribution could not be accurately modelled. Seagrass mapping methods are discussed in Section 2.6.

The key phases of this process included:

1) Bathymetry data collection and development of modelling inputs;
2) Towed video data collection and classification of habitats;
3) Modelling substrate and biota distributions, including validating the models and evaluating the predictive accuracy; and
4) Mapping the predicted distribution of substrates and biota across the study area.

These key phases are outlined in detail below, along with the limitations and assumptions of the modelling and mapping methods used.

2.2. Bathymetric Data Collection and Processing

High resolution bathymetry and reflectivity data were collected by Fugro LADS Corporation (FLC) under contract to WEL during May 2009 (Fugro, 2009). The hydrographic survey was undertaken using the LADS Mk II Bathymetric LiDAR (Light Detection and Ranging) system which was operated from a dedicated Dash-8 202 series aircraft. Approximately 500 km² of bathymetric data and 35 km² of topographic data were collected at 5 x 5 m laser spot spacing with a swath width of 240 m. The main sounding lines were flown at 220 m spacing to provide 100% coverage of the seabed.
Fugro (2009) determined that International Hydrographic Organisation (IHO) Order 1 Survey Standards for horizontal and vertical accuracy were achieved for data to at least the 18 m depth contour. Unfortunately, turbidity and poor water clarity affected data collection and a large area in deeper water to the south-west of James Price Point remains unsurveyed (Figure 1).

These data were supplied to WEL and subsequently processed by WEL to produce a 6 x 6 m bathymetry dataset (Rev 0) that was provided to the Consolidated Environmental Services (CES). The relative reflectivity data collected during the survey, which is a measure of the amount of energy reflected from the seabed during a single pulse of the laser scanner (Fugro, 2009), was also provided to CES. Upon reviewing these data, it was apparent that there was considerable artefact in the data which presented as straight lines running in a north-south direction. Based on the regular nature of this artefact, it is believed that it was the result of poor ‘matching’ of the bathymetry data between the overlapping flight lines. These lines act to create artificially ridges in the dataset which will be carried over when deriving secondary datasets (detailed below) and therefore, carried into the modelling and thus the predictions and final mapping. The impact that this artefact has on the final maps is discussed in Section 3.3.

2.2.1. Environmental Data Derived from Bathymetry

A series of secondary datasets that quantify the topographic complexity and characteristics of the seabed in the local neighbourhood, were derived from the bathymetry data using ArcGIS 9.3 (ESRI, 2009). These variables have been shown to be correlated with the distribution of different substrate and biota categories (e.g. Holmes et al., 2008) and can be used as indirect predictors of substrate and biota presence. Any artefact in the bathymetry data, e.g. the regular artefact seen in this dataset, will be perpetuated into the derived datasets, which may influence the ability of the models to define relationships between observed distributions and the derived variables.

The secondary datasets derived from the bathymetry data are listed in Table 2-1 and include slope, aspect and rugosity (surface area and surface area ratio). In addition, a number of variables were calculated that describe variation in bathymetry over different neighbourhood areas (circular kernels) with radii ranging from six to 62 m. These included standard deviation, range (maximum minus minimum bathymetry), Moran’s I (a measure of spatial autocorrelation calculated on the residual values after a linear trend has been removed from the depth data) and hypsometric index (a measure of topographic complexity). The larger neighbourhoods incorporate seabed features from further away and thus provide a more general trend of the seabed features. In an effort to ‘fill in’ the area of missing bathymetry data (a consequence of turbidity during data collection), different interpolation techniques were applied using ArcGIS 9.3 (ESRI, 2009). Various implementations of both spline and kriging interpolation methods were developed, although they were unable to provide an accurate representation of the bathymetry in the area. The poor interpolation was primarily due to the large extent of the missing data area and as a consequence, it would not be
possible to use the developed models to map the distribution of the different benthic habitats in that particular area.

- **Table 2-1 Secondary datasets included as environmental variables in the modelling**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Acronym</th>
</tr>
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<tbody>
<tr>
<td>Absolute depth residual</td>
<td>absdpthres</td>
</tr>
<tr>
<td>Aspect</td>
<td>aspect</td>
</tr>
<tr>
<td>Bathymetry</td>
<td>bathy</td>
</tr>
<tr>
<td>Relative reflectivity</td>
<td>bath.reflect</td>
</tr>
<tr>
<td>Curvature</td>
<td>curv</td>
</tr>
<tr>
<td>Hypsometric index</td>
<td>Hyp*</td>
</tr>
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<td>Moran’s I residual</td>
<td>moranRes*</td>
</tr>
<tr>
<td>Plan Curvature</td>
<td>plcurv</td>
</tr>
<tr>
<td>Profile Curvature</td>
<td>prcurv</td>
</tr>
<tr>
<td>Range</td>
<td>rng*</td>
</tr>
<tr>
<td>Slope</td>
<td>slope</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>stdev*</td>
</tr>
<tr>
<td>Rugosity surface area</td>
<td>surfarea</td>
</tr>
<tr>
<td>Rugosity surface area ratio</td>
<td>surfratio</td>
</tr>
<tr>
<td>Topographic position index</td>
<td>tpi1**</td>
</tr>
<tr>
<td>Topographic position index</td>
<td>tpi2**</td>
</tr>
<tr>
<td>Topographic position index</td>
<td>tpi3**</td>
</tr>
<tr>
<td>Reflectivity</td>
<td>reflect</td>
</tr>
</tbody>
</table>

*Calculated for a local neighbourhood radius of: 6, 16, 24, 32, 44 and 62 m

**Calculated for annulus neighbourhood sizes (internal and external cell radii) of v1 = 2 cells and 5 cells, v2 = 3 cells and 6 cells, v3 = 5 cells and 8 cells

2.2.2. **Towed video survey completed in 2008 by Fry et al. (2008)**

An extensive towed video survey was undertaken by CSIRO, AIMS and DEC under contract to WAMSI during June 2008 (Fry et al., 2008). While undertaken prior to the collection of the high resolution bathymetry data, the use of a stratified sampling design ensured that the spatial extent and the majority of environmental conditions present in the study area were surveyed (see Fry et al., 2008). The GPS location of the vessel towing the video system was recorded and used to geo-reference the location of the habitats observed on the video in ‘real time’ by Fry et al. (2008). Video footage from 201 x 500 m long completed transects were made available to CES for this study (Figure 5).
Figure 5 Location of the towed video transects surveyed by Fry et al. (2008)
2.2.3. **Towed video surveys completed in 2009 by SKM (2009a; 2009b)**

As part of the baseline biological studies and investigations program for the LNG Precinct, WEL required an assessment of the distribution of seagrass habitat during the wet season (November to April), for comparison with data from the dry season (May to October) collected by Fry *et al.* (2008). To allow this assessment to be undertaken, a subtidal towed video survey was conducted from November 23\textsuperscript{rd} to 29\textsuperscript{th} 2009 (SKM, 2009a). Previous video footage (Fry *et al*., 2008), LADS data and preliminary habitat modelling results (based on towed video data collected by Fry *et al*., 2008) were used to select possible sites to video, including seagrass as well as a range of other habitat types.

In total, 161 video transects (Figure 6) were completed (representing 150 individual transect sites, some with replicates), by towing a high-resolution video camera from a vessel, along the seafloor (Figure 7). Transects were generally between 300 and 500 m long. The towed video camera was controlled remotely from the vessel and displayed on a monitor onboard, in relation to navigation software showing the vessel position (Figure 8). The video footage was geo-referenced with latitude and longitude coordinates using a Furuno GP-37 differential global positioning system (DGPS). The video and audio tracks were encoded with the GPS position (one GPS encoding per second) and recorded to a portable hard drive recorder.

The video footage from this survey (SKM, 2009a) was classified (see Section 2.2.4 below) and used as input into the habitat modelling process for this study (see Section 2.3). In addition to the seagrass towed video survey, 13 towed video transects were obtained on the 11\textsuperscript{th} December, 2009 as part of a heritage survey of seafloor characteristics in the James Price Point area (SKM, 2009b). These video transects were also classified and included as inputs into the habitat modelling for this study (see Section 2.2.4).

For all surveys, video data was not collected from within current pearl leases due to access restrictions and consequently, there was no opportunity to determine the habitats that existed in these areas.
Figure 6 Location of the towed video transects surveyed by SKM (SKM 2009a, 2009b)
- **Figure 7** Towed video camera unit

- **Figure 8** Equipment set up within the vessel wheelhouse showing camera view and sampling plan
2.2.4. Classification of video using a consistent Habitat Classification Scheme

The habitat observed from the towed video footage collected in June 2008 survey was originally classified in real-time as the footage was collected (Fry et al., 2008). This towed video footage was subsequently re-classified as part of this study to ensure consistency between observers and to allow a more detailed classification of the habitats for use in the modelling for each second of video footage. A custom visual basic interface was used to assign a habitat classification to the corresponding geo-referenced video data in a spreadsheet during video play back. A classification was assigned to each unique GPS coordinate that corresponded to a second of video footage. Towed video footage collected in 2009 (SKM, 2009a; 2009b) was classified using the same methods.

All habitats observed in the video footage were classified according to the combination of substrate and biota types present (see Appendix A and Appendix B for definitions). Biota included all forms of macro-biota, excluding microscopic biota such as bacteria, microalgae and microphytobenthos (MPB). Microphytobenthos can be surveyed and classified accurately using the methods described in this study. However, MPB was not classified or modelled since it was assumed to be present wherever there was available sand substrate. The highly ephemeral and opportunistic nature of MPB makes it difficult to accurately define the distribution and extent.

A biota type was included in the classification if it covered an area greater than or equal to 5% of the substrate over a 5m distance. Seagrass and Hard Coral were classified if they were observed with a cover greater than 1%. More than one biota type could be recorded as present at a location. For the purposes of the final habitat mapping these combined biota were represented as a mixed habitat class. Substrate types classified were ‘Hard Substrate’ (e.g. consolidated limestone ridge), ‘Sediment’ and ‘Sediment Obscured Hard Substrate’. Biota was classified initially into 18 broad biota groups, based on morphological characteristics (Table 2-2). Examples of the biota typically found in each Morphological Group are also listed in Table 2-2. The Morphological Groups were further grouped into 7 main biota types including ‘Hard Coral’, ‘Soft Coral (BPP)’, ‘Small Algae’, ‘Canopy Algae’, ‘Turf Algae’, ‘Seagrass’ and ‘Sessile Invertebrates’. Throughout this document, the use of capital letters will be used to denote that it is a habitat class that is being discussed, as opposed to general comments about substrate and/or biota types.

Using the classified data, a table detailing the presence (1) and absence (0) of each biota and substrate type at each GPS coordinate (site) was developed for all 2008 and 2009 data. A presence was recorded if a habitat class was observed to have a percent cover of 5% or greater over a 5 m distance along a transect. All data were stored in a Microsoft Access database for error and quality control checking before use in the modelling.
# Table 2-2 Main biota groups classified and typical life forms present in each group

<table>
<thead>
<tr>
<th>Biota group</th>
<th>Morphological group</th>
<th>Typical taxonomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abiotic</td>
<td>Abiotic</td>
<td>Sand substrate (particles &lt; 64 mm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rock substrate (particles &gt; 64 mm)</td>
</tr>
<tr>
<td>Canopy Algae (&gt;20cm)</td>
<td>Canopy Algae</td>
<td>Sargassum spp.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Large algae (&gt; 20 cm)</td>
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<tr>
<td>Small Algae (&lt;20cm)</td>
<td>Brown small</td>
<td>Small brown algae (&lt; 20 cm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dictyota spp.</td>
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<tr>
<td></td>
<td>Brown lobed</td>
<td>Padina spp.</td>
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<td></td>
<td></td>
<td>Lobophora spp.</td>
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<tr>
<td></td>
<td>Green algae</td>
<td>Small green algae (&lt; 20 cm)</td>
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<tr>
<td></td>
<td></td>
<td>Caulerpa spp.</td>
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<td></td>
<td></td>
<td>Halimeda spp.</td>
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<td></td>
<td>Red small</td>
<td>Small red algae (&lt; 20 cm)</td>
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<tr>
<td>Turf algae *</td>
<td>Turf algae</td>
<td>Turf algae (filamentous algae &lt; 20 mm)</td>
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<tr>
<td>Hard Coral</td>
<td>Branching; Digitate</td>
<td>Acropora spp.</td>
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<tr>
<td></td>
<td>Foliose</td>
<td>Turbinaria spp.</td>
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<td>Favid</td>
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<td>Sub-massive</td>
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<td></td>
<td>Encrusting</td>
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<td></td>
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<td>Halophila</td>
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<td>Sessile Invertebrates (non-BPP)</td>
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<tr>
<td></td>
<td>Scleraxonia group</td>
<td>Gorgonian fan</td>
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<tr>
<td></td>
<td>Sea whips</td>
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<tr>
<td></td>
<td>Soft Coral (non-BPP)</td>
<td>Dendronephtya sp</td>
</tr>
<tr>
<td></td>
<td>Milleporiidae</td>
<td>Millepora sp</td>
</tr>
<tr>
<td></td>
<td>Sponge</td>
<td>Sponge</td>
</tr>
</tbody>
</table>

Note: Turf algae was not modelled in this study

The classification scheme has been developed by SKM (Brayford et al., 2008) but is also consistent with the National Intertidal / Subtidal Benthic (NISB) Habitat Classification Scheme (Mount et al., 2007) and those used during similar habitat modelling studies (e.g. Holmes et al., 2007). As the classification scheme is hierarchical, it can be used to combine data collected from a number of sources and at different scales of resolution. While only details of the primary biota groups and substrate types were of interest in this specific study, the scheme caters for detailed taxonomic data.
of biota to be collected in the same format and nested within the higher groups (e.g. fine scale classification at lower taxonomic levels, such as family or species, can be nested within higher groups, such as seagrass or algae). The advantage of this approach is that all recorded data can be easily aggregated to the level for which there are sufficient numbers of observations required to undertake modelling. For example, not all Hard Coral morphologies (massive, sub-massive, foliose or digitate) had sufficient number of presence observations to model the distribution of each morphology type separately. All morphologies can be aggregated and modelled together.

2.2.5. Classification of cover

Where Seagrass and Hard Coral cover were present, the percent coverage of these types was recorded within the categories: 1-5%; 5-10%; 10-25%; 25-50%; 50-75%; and 75-100%. Seagrass cover was categorised for both the 2008 and 2009 data, but Hard Coral cover was only determined from the 2009 data.

To improve the confidence in the qualitative analysis of the video footage, subsamples of the video transects were quantitatively analysed to calibrate the analysts’ Hard Coral cover classifications (Appendix C). The aim of the calibration was to detect if predetermined percent cover classes could be consistently and accurately identified from the video footage by two video analysts (referred to as MS1 and MS2). The process ensured that cover was not being routinely over or underestimated by the video analysts. For Hard Coral cover that had been classified as 1-5%, quantitative analysis determined the mean cover to be 1.2% (Appendix C). This result provides confidence that the classifications of cover assigned are representative of the actual coverage that was present.

2.3. Modelling Substrate and Biota Distributions

2.3.1. Overall modelling approach

The multi-stage process to model and map substrate and biota types is summarised in Figure 9. The modelling involves defining relationships between the observed biota distribution (classified video data) and the environmental data (bathymetry and derived data) using Classification and Regression Tree (CART) models (Breiman et al., 1984). CARTs use binary partitioning of the predictor variables to differentiate between the presence and absence of the biota being modelled (e.g. if depth > 10 m and < 25 m, with slope > 5, then class A = present, else class A = absent). They are particularly well suited to modelling categorical data and their non-parametric approach is well suited to modelling the complex relationships that often exist in ecological datasets (De’ath and Fabricius, 2000). CARTs also allow interacting predictor variables to be modelled in the same process, and each variable can be used more than once in each model.
For those habitat classes, substrate and biota classes that have been observed with prevalence greater than 5% (number of presence observations/total number of observations), separate models are developed using a ‘training’ data set which comprises 75% of the observed classified video data and environmental data. The remaining 25% of data is withhold from the model development and is used to evaluate model accuracy (testing data). The use of training and testing data provides a more independent validation of the accuracy of the models compared to evaluating accuracy using the same data that was used to develop the models. Data are randomly allocated to training and testing datasets while maintaining prevalence ratios (presence: absence) between the training and testing datasets.

Using the relationships defined by the model, the probable occurrence of the different biota and substrate classes (between 0 and 1) is converted into predicted presence/absence distributions and then mapped across the entire extent of the environmental data (e.g. the LADS bathymetry data). As the original habitat classification defined a presence if a habitat class had coverage of 5% or greater, predicted presences also indicate a minimum coverage of 5% is likely. The final step is to evaluate the accuracy of the model predictions by comparing the predicted values (from the training data) with the observed values from the testing data that was withheld from the model development.

- **Figure 9** Summary of the process used to model and classify substrate and benthic biota types (from SKM, 2008)
2.3.2. Development of Models

Once the habitat data (dependent data) has been developed, the geo-referenced location of each habitat observation is used to interrogate the environmental data (independent data) to derive the coincident environmental characteristics that occur at each location and thus produce the final dataset for modelling.

The combined dataset was split into the training and testing data and the models developed using the SPLUS statistical program, version 8.0 (Insightful Corporation, 2007). All classification models will group the data and can produce large, complex trees. However, a highly detailed tree may be very specific to the data used to develop it, but may not be very good at classifying beyond the training data. Similarly, a less complex tree may be considered highly general, thereby rendering the prediction meaningless. Trees are typically ‘grown’ to a certain size and then ‘pruned’ to avoid over-fitting the data and the production of redundant branches or splits that provide no further information.

In this study, 10-fold cross validation was used to determine misclassification rates for different size trees to identify the most appropriate tree size for each modelled class. With this approach, the final tree was one that minimised misclassification errors, but that was still able to accurately predict distribution in locations where no video data were available. The final model was then applied to the full extent of the environmental variables to predict the distribution of each class across the area. The accuracy of the prediction was subsequently assessed.

2.3.3. Evaluating Predictive Accuracy

The predictive performance of each model was assessed by comparing the predicted values to the observed (known) substrate and biota data for the testing data. Predictive accuracy was evaluated in two ways and provided a measure of reliability or a degree of confidence for the mapped results. Firstly, the ability of the model to discriminate between presence and absence states was determined by calculating the area under the curve (AUC) of receiver-operating characteristic plots (ROC plots) (Hanley and McNeil, 1982, Fielding and Bell, 1997).

An AUC value of 1 indicates that the model can discriminate perfectly between presences and absences. That is, when a class was observed to be present, the corresponding predicted probability of occurrence for that observation will be higher than the predicted probability of occurrence for an absence observation 100% of the time. A score of 0.5 indicates a discriminatory ability no better than by chance alone, i.e. that a presence observation will only have a probability of occurrence greater than an absence observation 50% of the time. AUC values > 0.8 are considered high, 0.7–0.8 acceptable and < 0.5 are considered not to be good at discriminating (Hosmer and Lemeshow, 2000). The ROC AUC software program (Schroeder, 2004) was used to calculate ROC curves and corresponding AUC values to assess the accuracy of all substrate and biota classifications.
The second measure of predictive performance was to calculate the correct classification rate (CCR) to evaluate how accurately the models correctly predicted the observed presences and absences (percentage of correct predictions). For example, a correct classification rate of 80% indicates that the model correctly predicted the observed value (presence or absence) 80% of the time. In order to calculate CCR, a threshold or cut-off value must be determined to convert the predicted probability of occurrence determined by the model (ranging between 0 and 1) into either a presence or an absence value. The commonly used 0.5 cut-off, above which presence is assigned and below absence, does not take into account any misclassifications that may occur. ROC analysis takes into account the accuracy or predictive ability according to the cut-off and the point along the ROC curve that avoided extreme over or underestimation of presence/absence predictions (p-kappa) was chosen as the cut-off to map the results for each substrate and biota type.

2.4. Mapping the Predicted Distribution of Substrates and Biota across the Study Area

Based on the final tree models, continuous predictive maps were developed across the extent of the LADS data using a custom script developed by SKM. This script applies the final classification tree model to the bathymetry and derived datasets for the entire area, assembling a final prediction surface, with each cell having a probability of occurrence value between 0 and 1.

Final maps showing the predicted distribution (presence and absence) of each of the different substrate and biota classes individually and the combined substrate classes were created by applying the p-kappa threshold to the predicted probability of occurrence values. Maps based on the combinations of biota and substrate classes were also produced to visualise spatial overlaps between habitat classes throughout the study area. All resulting maps were full coverage to spatial resolution of 6 x 6 m. The final map represents the presence of biota with coverage of 5% or greater.
2.5. Model and Mapping Limitations

The model is used as a predictive tool to support assessment and decision making. It is important to consider that no model can ever replicate the complexities of the natural system and the accuracy of any model is directly related to the quality and accuracy of the data used in its development. The extent and range of the collected ground truthing data will not only influence the models developed (the relationships that the models define), but will also influence the assessment of model accuracy.

As the CES has developed models using data provided by third parties, there is limited ability to evaluate the accuracy of these data and to make comment on how this may influence the models developed and the final mapping outputs. The raw bathymetry data was not made available to the CES and as a result, there was no capacity to make any correction to the data despite there being artefacts evident in both the bathymetry and reflectivity data (e.g. along the flight lines). Similarly, the geo-referencing of the towed video survey has no measure of spatial accuracy and based on the methods used (Fry et al., 2008) it is likely that there will be inaccuracies surrounding the assignment of environmental conditions to the classified habitat data used to develop the models in this study. The consequences of this will be that the habitat-environment relationships defined by the models, and which form the basis for the predictive mapping, may be less accurate. There is no way of determining the level of influence that these issues may have on the final accuracy of the models or the mapping output, but it is likely that result would be that more general relationships are defined between the observed distributions and the corresponding environmental characteristics. The consequence of this is that overall model accuracy could be reduced and the distribution of biota classes may be predicted to occur over a wider range of environmental conditions than actually occurs.

The justification for combining data collected at different times (data from June 2008 and data from November 2009) is that the objective was to predict and map the likely distribution of habitats across the study area, irrespective of time. To this end, the time of year that the habitat class was observed over a set of environmental conditions is, to a large extent, irrelevant. What is important is that it was found over those conditions, and that is what the model will ‘use’ to define the relationships between observed distribution and environmental characteristics. The result is that the models and predictions will be more robust and representative of the probable distribution of the different habitat classes through time (2008 and 2009), compared to models derived from data collected at a single point in time. However, it should be noted that as the distribution of some biota types is highly variable over time and thus, the predicted and mapped presence of a habitat class does not guarantee that it will be present either currently, or on any future occasion. It only indicates that the combined environmental characteristics at that location are likely to be suitable for that habitat class.
As the pearl lease areas could not be accessed for sampling, no ground truthing could be undertaken in these areas and thus we have limited ability to determine the accuracy of the predicted distribution in these areas. As the distribution of habitats in these areas may have been altered as a result of pearling activities the benthic habitats in areas within existing pearling leases have not been mapped.

2.6. Modelling and mapping of Seagrass

In order to be able to develop robust models for predicting distributions, the habitat class must have been observed with sufficient prevalence (at least 5%). Models developed for habitat classes that were observed with lower prevalence will not be robust as there would be insufficient presence data to train the models. In essence, the model would be trained to predict where that biota class would not be found and it would have extremely poor ability to predict presences.

During both the 2008 and 2009 surveys, Seagrass was observed with lower prevalence than 5% (3.4% in 2008 and 4.8% in 2009). An attempt to model Seagrass distribution was made using the approach described above. However, due to the very low prevalence across the study area and the highly variable temporal distribution observed between the 2008 and 2009 surveys, the models were unable to define robust relationships between the environmental characteristics and the observed distribution and were unable to explain much of the variation in the observed distribution. Attempts to model the observed distribution of Seagrass in 2008 and 2009 separately were no more successful and demonstrated that the relationships between the 2008 observed distribution and the environmental characteristics differed to the relationships defined using the 2009 observed distribution. No consistent relationships between the observed distribution and the environmental characteristics were derived when using different data, indicating that there was a poor association between the observed Seagrass distribution and the environmental characteristics used as predictor variables.

Seagrass was the only habitat class that suffered this problem with models for other habitat types being relatively consistent across the two sampling periods.

While not conducive to modelling distribution, this result did highlight the highly variable nature of Seagrass distribution in the James Price Point coastal area. It also indicated that the spatial and temporal variability of Seagrass distribution is less influenced by the environmental characteristics used in this study (e.g. bathymetry and topographic complexity), but more driven by other factors, perhaps seed dispersal or benthic light availability. The conclusion drawn was that there could be no confidence in the maps of Seagrass distribution that would be developed from the model predictions. If predictions of probable Seagrass distribution were made, the model would predict the distribution of absences very accurately, but would predict the presence of Seagrass very poorly. This issue, coupled with the highly variable distribution of Seagrass through time (Section
1.4.4), prevented the use of modelling to reliably predict and map Seagrass distribution across the study area.

Subsequently, the distribution of Seagrass was mapped using only the observed locations from the towed video transects undertaken in 2008 and 2009. The nature and variability of Seagrass distribution in the study area is discussed in detail in a separate report (SKM, 2010c), but an overview is provide in Section 3.2.2.3.

2.7. **Modelling and mapping Hard Coral cover**

As stated above, the predicted distribution of Hard Coral presence and absence was modelled using the combined 2008 and 2009 data sets. The predicted distribution of Hard Coral cover (density) was then modelled using 2009 data only as no cover information was recorded for the 2008 data. The final mapping output for Hard Coral cover was derived by applying the 2009 Hard Coral cover predictions to those areas where Hard Coral was predicted to be present, based on 2008 and 2009 distribution. The predictive accuracy of Hard Coral distribution (2008 and 2009 presence/absence) was assessed and is included in Section 3.2.3.
3. Results

3.1. Video Classification for 2008 and 2009 data

The general trends observed while classifying the towed video footage are provided below. As Seagrass distribution could not be modelled, a more detailed description of Seagrass distribution as observed from towed video surveys is also included.

3.1.1. Substrate

The substrate classes were defined as Hard Substrate, Sediment, or as combined Sediment Obscured Hard Substrate (Appendix A). Sediment was observed on 99% and 100% of the video transects in 2008 and 2009 respectively. Soft sediments consisted of large areas of sand which were commonly flat with some areas containing sand ripples (25-75 cm high) (Figure 10).

Hard substrate was found throughout the study area and was most distinguishable in areas of high profile reef; elsewhere it was obscured by a thin layer of sand. This sand obscured low profile reef dominated the study area, with varying degrees of sand inundation present (Figure 11).

As it was not always possible to quantify what substrate type was present as it was covered by biota, it was assumed that all biota which are known to attach to a hard substrate (i.e. macroalgae, coral and filter feeder biota) were attached to a rock substrate. In some instances it appeared that filter feeders were growing in sand, although the substrate was classified as sand obscured hard substrate based on the view that filter feeders will require some form of hard substrate to attach to.

![Figure 10 Soft sediment examples, including sand with sea urchins (left) and sand ripples (right)](image-url)
3.1.2. Biota

The majority of the biotic communities in the James Price Point study area consisted of complex mixed communities of sessile invertebrates, hard and soft coral communities and macroalgae growing on hard substrates obscured by a thin layer of sand. General biota cover in the study area was sparse to medium density (5-50%) and was generally restricted to certain near shore areas with favourable or complex topography (Figure 12).
The mixed communities were generally dominated by filter feeding, sessile invertebrates, including sea whips, gorgonian fans and sponges, with individual hard coral specimens present (Figure 13). In some areas the sand obscured reef provided a suitable habitat for patches of seagrass, resulting in a mosaic of all biota types.

- Figure 13 Examples of the different biota types that made up the mixed communities

3.1.3. Algae

Algal communities were classified as either ‘Small Algae’ (between 20 mm and 20 cm tall) or ‘Canopy Algae’ (greater than 20 cm tall). Both algal classes were well represented throughout the study area.

3.1.3.1. Small Algae

A high diversity of small macroalgae was observed consisting of red, green and brown varieties. Filamentous red algae were the most abundant small algae but some habitats supported the green foliaceous algae Calerpa spp. and Halimeda spp. (Figure 14). Encrusting algae (such as calcareous red algae) were observed on high profile reef structures mixed in with hard coral and other turfing algae species.
3.1.3.2. Canopy Algae

Canopy Algae consisted of large brown algal species, such as Sargassum spp. often observed in large areas of varying densities ranging from 5 to > 75% (Figure 15). Canopy Algae were often mixed with an understory of small algae. Algae were often mixed with other biota types, particularly Hard Coral and Sessile Invertebrates.
3.1.3.3. Microphytobenthos

Microphytobenthos comprises the microscopic algae living in soft-sediments, however, it is not possible to distinguish unequivocally between living benthic microalgae and recently settled phytoplankton. Patches of MPB were observed as a thin green-brown covering over the sediment and seen throughout the study area in varying densities. Patches were usually present within extensive areas of sand substrate. Microphytobenthos was observed across all depths but more commonly in deeper habitats.

3.1.4. Hard Coral

The majority of Hard Coral was observed in video collected north of James Price Point off the coast of Coulomb Point in areas of high profile reef. Hard Coral was scattered throughout the study area but was only observed to be in trace (1-5% cover) or sparse 5-10% cover) density in mixed habitats with other biota types, such as macroalgae and filter feeders. Areas near Coulomb Point had the greatest density and diversity of Hard Coral, although only a few isolated patches were found where the cover was greater than 10%.

Coral morphologies included foliose, encrusting and sub massive specimens (Figure 16). Turbinaria and Favid species were most commonly observed, or a mix of these types with others, such as Porites.
3.1.5. Soft Coral (BPP only)

The Soft Coral biota group (BPP only) includes photosynthetic octocorals (Sub-Class Octocorallia) classed as benthic primary producers (BPP). All non-BPP soft corals have been included under the Sessile Invertebrate biota group.

It was often difficult to distinguish between photosynthesising and non-photosynthesising soft corals and the majority of species use a combination of heterotrophic feeding and photosynthesis to produce energy. However, the photosynthetic Soft Corals from the family Nephtheidae were observed in mixed reef communities mixed with Sessile Invertebrates, Hard Coral and Algae (Figure 17).

There were no distinct subtidal BPP Soft Coral communities composed of photosynthetic soft corals from the genera *Sarcophyton*, *Lobophyton* or *Simularia*, as has been found in similar habitats recorded in other areas of the north west of Australia (e.g. within the Dampier

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**Figure 16** Variety of Hard Coral biota observed including *Turbinaria* (top left), *Turbinaria* and *Porites* (top right), encrusting morphologies (bottom left) and mixed foliose, submassive and encrusting corals (bottom right)
Nearshore Benthic Habitat Modelling and Mapping, James Price Point Archipelago, SKM, 2008). However, intertidal occurrences of *Sarcophytum* and *Lobophytum* soft corals were observed in a mosaic of hard coral and algae near James Price Point itself (SKM, 2009c). These occurrences were relatively rare, very sparse and made up less than an average of 0.15% of benthic cover at each survey area.

![Image](image1.png)

**Figure 17 Soft Coral examples containing branching and bushy morphologies**

### 3.1.6. Sessile Invertebrates

The Sessile Invertebrate group consisted of ahermatypic sessile invertebrates not classed as benthic primary producers (BPPs) in this report. Non-BPPs were predominantly sponges, gorgonian fans, sea whips, sea pens and ascidians and some non-photosynthetic soft corals (Order: Alcyonacea) (Figure 18).

Soft corals included in the sessile invertebrate biota group comprised those varieties considered as non-BPPs. The majority of the soft corals (non-BPPs) found in this study were branched, bushy and fan-shaped morphologies which appeared to be non-photosynthetic species from the Alcyonace order (e.g. *Dendronephtya*) and Scleraxonia group that included sea whips and gorgonian fans). Sessile Invertebrates were considered as all invertebrates that were attached to the substrate. Sessile

Sinclair Knight Merz
Invertebrates in this classification process included all organisms meeting this definition (i.e. sponges, ascidians, etc) with the exception of hard and soft corals.

Soft corals (non-BPP) and Sessile Invertebrates were wide spread throughout the study area yet habitats containing exclusively soft coral were more common in transects collected in deeper, offshore areas. These classes were present in varying densities, in mixed and exclusive habitats on hard substrate often covered in a layer of sediment.

3.1.7. Seagrass

Seagrass was observed growing in soft sediments in mixed communities between patches of reef hard substrate. Homogenous meadows of seagrass (*Halophila* spp.) (Figure 19) were also observed in various densities and patch sizes. It was difficult to consistently identify Seagrass from the towed video footage due to the small size of some species, the smothering by epiphytes and microphytobenthos (MPB) and the shading of larger biota. However, *Halophila* was the dominant genus recorded and was the clearest to identify from the video footage. It was not possible to determine the species present, although *Halophila decipens*, *H. ovalis*, *H. ovate* and *H. minor* are
common in tropical north-west waters and were assumed to be present in the study areas. Other seagrasses (possibly *Halodule univervis*, *Cymodocea* spp. and *Syringodium* spp.) were observed among *Halophila* at some sites.

![Figure 19 Seagrass including Halophila meadows (top left), Halophila univervis (top right), Halophila spinulosa (bottom left) and Halophila growing on sand obscured reef (bottom right)](image)

Based on towed video observations, patches of seagrass were observed throughout the study area (*Figure 20*). Contiguous areas of seagrass habitat were found to occur close to Quondong Point, in nearshore waters, and also to the south along the coastline near Cape Boileau. Small patches were evident nearshore, adjacent to James Price Point and Coulomb Point. Offshore Seagrass was observed along what appeared to be a ridgeline system, running in a north south line the length of the study area. Little seagrass was observed between this ridgeline and James Price Point.

Generally, Seagrass patches were very sparse (1-5%) in extent. Very sparse Seagrass was scattered throughout the inner part of the study area, from north to south. Nearshore areas near Coulomb Point and Cape Boileau had sparse coverage areas (5-25%), whilst medium density Seagrass areas
(25-50%) was predicted to occur in smaller patches near James Price Point, Quondong Point and offshore, approximately 7 km west of Coulomb Point.

The same general trends in Seagrass distribution and density were observed between the 2008 and 2009 survey. However, Seagrass was observed more frequently north of JPP in the 2009 survey and new, medium density areas were sampled in the north of the study area in 2009 that were not present in 2008. More Seagrass in the 1-5% and greater than 50% category were observed in 2009 compared to 2008. In contrast, some repeated transects had Seagrass in 2008 but bare substrate in 2009. At certain transects in 2009 the condition of the Seagrass appeared less healthy than that observed in 2008. For example, certain patches of seagrass had a high degree of epiphytic growth in 2009 compared to 2008. This trend was not consistent for all repeated transects and in some circumstances the reverse pattern was observed.

The ecology, extent and temporal variability of Seagrass distribution are discussed further in SKM (2010c).
Figure 20 Observed distribution of Seagrass across the study area based on towed video surveys during June 2008 and November 2009
3.2. Habitat Modelling and Mapping

This section presents maps showing the model predicted distribution of the different substrate and biota classes that were modelled (listed in Table 3-1). Two overall habitat maps of the modelled classes (excluding Seagrass) are also presented, representing the combinations of biota predicted to occur across the study area. The accuracy of each of the models developed is provided, based on the area under the curve (AUC) and correct classification rate (CCR) accuracy measures.

- **Table 3-1 List of figures of mapped substrate and biota classes based on predicted distributions. Predicted presence.**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Habitat Class Description</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 21</td>
<td>Hard Substrate</td>
<td>Predicted distribution of presence (&gt;5%) within the study area using combined 2008 and 2009 data</td>
</tr>
<tr>
<td>Figure 22</td>
<td>Algae (Canopy and Small Algae combined)</td>
<td>Predicted distribution of presence (&gt;5%) within the study area using combined 2008 and 2009 data</td>
</tr>
<tr>
<td>Figure 23</td>
<td>Canopy Algae</td>
<td>Predicted distribution of presence (&gt;5%) within the study area using combined 2008 and 2009 data</td>
</tr>
<tr>
<td>Figure 24</td>
<td>Small Algae</td>
<td>Predicted distribution of presence (&gt;5%) within the study area using combined 2008 and 2009 data</td>
</tr>
<tr>
<td>Figure 25</td>
<td>Hard Coral</td>
<td>Predicted distribution of cover at 5-10% and 10-25% within the study area using 2009 data</td>
</tr>
<tr>
<td>Figure 26</td>
<td>Soft Coral (BPP)</td>
<td>Predicted distribution of presence (&gt;5%) within the study area using combined 2008 and 2009 data</td>
</tr>
<tr>
<td>Figure 27</td>
<td>Sessile Invertebrates</td>
<td>Predicted distribution of presence (&gt;5%) within the study area using combined 2008 and 2009 data</td>
</tr>
<tr>
<td>Figure 28</td>
<td>Combined BPPs</td>
<td>Predicted distribution of presence (&gt;5%) within the study area using combined 2008 and 2009 data</td>
</tr>
<tr>
<td>Figure 29</td>
<td>Combined biota (all BPP and Sessile Invertebrates except Seagrass)</td>
<td>Predicted distribution of presence (&gt;5%) within the study area using combined 2008 and 2009 data</td>
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</tbody>
</table>

3.2.1. Substrate Characteristics

Sediment was present at 99% of the ground truthed sites and consequently, it was predicted to occur across the entire survey area. Therefore, the predicted distribution of Sediment occurrence is not presented. The predicted distribution of Hard Substrate, either partially or fully obscured by sediment (Figure 21) correlates well with the observed seabed characteristics and topographic complexity visible in the bathymetry data (Figure 1). Large inshore areas of hard substrate are found principally in the north of the study area. This band of Hard Substrate narrows to the south...
near James Price Point. An offshore band of Hard Substrate 5-7 km from the coast also extends from the north to James Price Point, where a break in Hard Substrate occurs, which resumes to the south opposite Quondong Point.

3.2.2. Biota Characteristics

Within the predictive mapping process, the distributions of the following biota types were modelled individually:

- Algae (including Canopy and Small Algae);
- Hard Coral;
- Soft Coral; and
- Sessile Invertebrates.

The combination of individual biota types with substrate resulting in a combined habitat map of benthic primary producer occurrence (excluding Seagrass) is presented in Section 3.3.

3.2.2.1. Algae

Overall, Algae was well represented across the entire study area, being the most ubiquitous biota of all the types modelled (Figure 22). The distribution of Algae was consistent with the occurrence of Hard Substrate, with extensive coverage in the north and offshore of Coloumb Point. There were some Algae within two kilometres of James Price Point, however Algae coverage decreased sharply further to the west.

Within the Algae classification, sufficient observations of Canopy Algae and Small Algae were recorded to allow these groups to be modelled individually (Figure 23 and Figure 24). Both biotic groups were predicted to occur broadly throughout the survey area and were consistent with the overall Algae distribution. Density of Algae cover was not classified from the video footage and thus was not modelled. As presence observations were based on a minimum of 5% cover, any predicted presence indicates a minimum of 5% cover.

While it is recognised that microphytobenthos (MPB) contributes to the benthic primary producer productivity, given its extensive coverage on the Sediment substrates found across the entire study area and the fact that it is common and widespread across the Kimberley coastline, its distribution was not modelled.

3.2.2.2. Hard Coral distribution and cover

The predicted distribution of Hard Coral (Figure 25) was consistent with the occurrence of Hard Substrate with some degree of topographic complexity (as opposed to flat terrain), as seen in the
LADS data (Figure 1). In particular, the majority of Hard Coral was found close to the coastline (generally within 4 km).

Modelling Hard Coral cover identified that the majority of the coral present was in sparse-trace coverage (1-5% cover) (Figure 25). The distribution of coral communities with 5-10% coverage was confined to a nearshore band from north of Coulomb Point to James Price Point, with another area around Quondong Point. Coverage of denser corals (10-25%) was only predicted to occur in small isolated patches nearshore in the immediate vicinity of Quondong Point and James Price Point. Hard Coral was only observed as single colonies, appose to large continuous coverage. Most colonies observed were *Turbinaria* spp. and ranged in size from large, established colonies to small recruits with no dominant size fraction observed. Those colonies that were observed appeared to be healthy and occupied available space within other habitat types (Algae and Sessile Invertebrates). However, there were differences in the size and condition of Hard Coral communities throughout the study area and there was no evidence of coral reef structures. Smaller colonies, with some degree of algal growth, were more common in deeper areas offshore and scattered amongst sessile invertebrates. Larger, apparently healthier and denser aggregations of colonies were observed in small pockets closer to shore.

While Hard Corals were classified to morphology (e.g. foliose, encrusting, digitate, massive and sub-massive) there was insufficient data to model the distribution of the different morphological types separately.
Figure 21 Predicted distribution of Hard Substrate presence within the study area

As access to Pearl Lease Areas was restricted, no sampling was undertaken in these areas. Consequently no information was available to train models and therefore these areas have been excluded from the mapping.
Figure 22 Predicted distribution of Algae presence (Canopy and Small Algae combined) within the study area
Figure 23 Predicted distribution of Canopy Algae presence within the study area
Figure 24 Predicted distribution of Small Algae presence within the study area

- As access to Pearl Lease Areas was restricted, no sampling was undertaken in these areas. Consequently no information was available to train models and therefore these areas have been excluded from the mapping.
3.2.2.3. Soft Coral distribution

The Soft Coral grouping was comprised of organisms considered as BPP (e.g. photosynthesising Alyconians such as *Sarcophyton* or *Simularia* spp.). The distribution of non-BPP soft corals (e.g. non-photosynthesising *Dendronephthya* spp.) were modelled as part of the Sessile Invertebrates group. The distribution map for Soft Corals represents presence only. Cover data was not extracted from the video and thus, was not predicted.

Soft Corals were predicted to occur across both inshore and offshore systems within the survey area (Figure 26). A narrow inshore band was predicted from James Price Point to approximately 3 km south of Quondong Point and Soft Coral was also scattered through the nearshore parts of the study area to the north of Coulomb Point. Patches with greater extent were observed offshore from Quondong Point, but the largest areas can be found in the northern region in deeper water, particularly on the outer ridge line, approximately 10 km from the coast.

The predicted distribution of Soft Coral presence generally occupied areas distinct from the predicted occurrence of Algae (Figure 26), with Soft Corals predicted to be present on the leading edge of Hard Substrate, reef systems typically colonised with Algae. In particular, Algae were predicted to occur adjacent to leading edges of Hard Substrate systems while Soft Coral were predicted to be present on the leading edges of these systems (Figure 26).

3.2.2.4. Sessile Invertebrate distribution

Sessile Invertebrates are invertebrates that are attached to the substrate. Sessile Invertebrates in this classification process included all organisms meeting this definition (i.e. sponges, ascidians, non-BPP soft corals, etc.) with the exception of Hard Corals and BPP Soft Corals which were modelled separately. The predicted presence of Sessile Invertebrates was broadly represented throughout the entire survey area (Figure 27), and was largely coincident with hard substrate (Figure 21), although deeper instances not associated with hard substrates were observed, principally in the south of the study area. Sessile Invertebrates were predicted to co-occur with other biota classes including Algae (Figure 28) and Hard Coral (Figure 29). Again, it should be noted that predicted occurrence represents presence only and not density of cover.
Figure 25 Predicted distribution of Hard Coral cover within the study area based on 2009 data only
Figure 26 Predicted distribution of Soft Coral presence (BPP) within the study area
Figure 27 Predicted distribution of Sessile Invertebrate presence within the study area
3.2.2.5. Combined Biota Characteristics

The predicted benthic primary producer habitat within the survey area around James Price Point can be described as a mixed mosaic of benthic primary producers (Figure 28). Algae was the only biota type found alone extensively across the study area, although mixed BPP habitat types were also dominant, particularly the combination of macroalgae and hard coral.

Discrete coverage of Algae was extensive, with Canopy Algae notably dominant on the outer fringes of offshore Hard Substrates mixed with Sediment. Hard Coral presence was predicted to co-occur with Algae, particularly on nearshore Hard Substrates mixed with Sediment. Discrete assemblages of Hard Coral only were also predicted to occur within the survey area, but were extremely limited in occurrence. Hard Coral only groupings were found on both Hard Substrates and Sediment Obscured Hard Substrates.

Sessile Invertebrates are not included in the combined benthic primary producer habitat map (Figure 28). However, they have been included in the overall biota map to illustrate the broad extent of Sessile Invertebrates across the study area (Figure 29).

Two map series are provided which divides the region into northern, central and southern sections. Appendix D shows the combined predicted distribution of BPP presence excluding Seagrass and Appendix E shows the combined predicted distribution of all biota (BPP and Sessile Invertebrates excluding Seagrass).

The distribution of Seagrass was less extensive than that of the Algae and Hard Coral components. Seagrass was found predominantly within Sediment areas only, although occurrences were observed in areas of Sediment Obscured Hard Substrate. Seagrass was often observed in areas where Algae occurred, principally in nearshore environments and in isolated offshore areas of Sediment Obscured Hard Substrate to the south west of James Price Point.
Figure 28 Combined predicted distribution of benthic primary producer (BPP) presence excluding Seagrass within the study area.

Legend
- Combined Benthic Primary Producer
- Habitat based on combining the predicted presences of the different BPP classes.
- Predicted presence indicates a minimum coverage of 5% at that location.
- Algae presence
- Hard Coral Presence
- Soft Coral presence
- Mixed mosaic of Soft Coral and Algae
- Mixed mosaic of Hard Coral and Soft Coral
- Mixed mosaic of Hard Coral with Algae and Soft Coral
- No BPP predicted to occur
- Pearl Lease Areas (approximate)
- LADS extent
- Approximate 10m Bathymetric Contour Line

As access to Pearl Lease areas was restricted, no sampling was undertaken in these areas. Consequently, no information was available to train models and therefore these areas have been excluded from the mapping.
Figure 29 Combined predicted distribution of all biota presence (BPP and Sessile Invertebrates excluding Seagrass) within the study area.
3.2.3. Predictive accuracy

Overall, the models developed (with the exception of Seagrass models) have been evaluated to have very good predictive accuracy. The ability of the models to discriminate between presence and absence states was considered very good, with all but the Sessile Invertebrates model having a high discriminatory ability (AUC values > 0.8) (Table 3-2). The Sessile Invertebrate model had acceptable discriminatory ability (AUC = 0.75).

The overall predictive accuracy of all models was also considered to be very good, with each having a correct classification rate of 75% or higher (Table 3-2). As all classes except the Sediment substrate class had less than 50% occurrence (number of presence observations for a class/total number of observations), it is likely that the high predictive accuracy may be primarily due to the correct prediction of absences.

Table 3-2 The predictive accuracy of the substrate and biota models as evaluated using correct classification rate and AUC. Observed number of presences and occurrence is provided to give insight into the prevalence of each class from towed video footage.

<table>
<thead>
<tr>
<th>Substrate or Biota type</th>
<th>Sub Class</th>
<th>Observed No. of Presences</th>
<th>Occurrence* (%)</th>
<th>Correct Classification Rate (%)</th>
<th>Area Under Curve (AUC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Substrate</td>
<td>All</td>
<td>20639</td>
<td>39.5</td>
<td>76.7</td>
<td>0.80</td>
</tr>
<tr>
<td>Algae</td>
<td>All</td>
<td>15224</td>
<td>29.1</td>
<td>83.7</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>Canopy</td>
<td>9485</td>
<td>18.1</td>
<td>88.4</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>Small</td>
<td>13143</td>
<td>25.1</td>
<td>84.4</td>
<td>0.83</td>
</tr>
<tr>
<td>Hard Coral</td>
<td>All</td>
<td>8832</td>
<td>16.9</td>
<td>86.7</td>
<td>0.81</td>
</tr>
<tr>
<td>Soft Coral</td>
<td>All</td>
<td>2675</td>
<td>5.1</td>
<td>96.8</td>
<td>0.87</td>
</tr>
<tr>
<td>Sessile Invertebrates</td>
<td>All</td>
<td>19644</td>
<td>37.6</td>
<td>75.3</td>
<td>0.75</td>
</tr>
</tbody>
</table>

*Occurrence is calculated by dividing the number of presence observations for a class by the total number of observations. It is a measure of how prevalent the class was across the area (from the towed video), it does not reflect percent cover.

3.3. Limitations to the modelling

Like any modelling exercise, the models are used to develop a realisation of the benthic habitat characteristics based on the collected data, as no model can ever replicate the complexities of the natural system. The robustness and accuracy of the models is directly dependent on the quality and quantity of the data used to develop them. For this study, there was considerable observed habitat data collected from towed video surveys across the full spatial extent and environmental gradients present in the area. There will be a small inaccuracy in the geo-referencing of the habitat data derived from the towed video collected from different studies, which could influence the...
relationships derived. However, it is considered that this would only have a minor influence on the overall model accuracy due to the quantity of data available.

The predicted and mapped distributions may also contain some irregularities as a result of artefact that was present in the LADS bathymetry data along overlapping flight lines that ran in a north-south direction. This artefact caused artificial ‘high and low’ points in the bathymetry data that would influence the values of some of the derived datasets which may result in BPP being predicted to occur in areas where it may otherwise not have been predicted. The artefact is portrayed in the predicted distributions of the different habitat classes as evident from Figure 30 which shows part of the combined benthic primary producer habitat distribution at a larger scale. The predicted distributions of the combined habitats have an artificial north-south direction and ‘banding’ is clearly visible between Quandong Point and Cape Boileau (within the area circled in Figure 30). While this artefact and banding should have limited influence on the overall patterns of distribution for the different habitat classes, it does influence the actual shape and size of the predicted habitat patches. Overall, the models are considered to be a robust and reliable representation of the actual habitats present in the area.
Figure 30 Combined predicted distribution of benthic primary producers (BPP) within the southern section of the study area demonstrating the influence the artefact in the bathymetry data had on the predicted distributions.
4. Discussion

The LADS data collected for the James Price Point coastal area has provided insight into the topography of the region and when combined with the towed video footage, an opportunity to model and map the extent of different substrate and biota types at finer scales than has previously been possible. The maps provide a quantitative assessment of the fine scale distribution of the different habitat classes in the area and build upon the existing maps of the substratum and biohabitat provided by Fry et al. (2008), which provided a broad scale indication of the dominant substratum characteristics and benthic biohabitat communities that were most likely to occur across the area.

The validation process determined that all habitat classes (with the exception of seagrass) could be modelled accurately, and identified that the models were able to discriminate well between presences and absences, with AUC values being high (> 0.8) or acceptable (0.7–0.8). The correct classification rates for all models ranged between 75-96% and the models for the BPP classes had correct classification rates above 83%. This result provides confidence that the predicted distributions provide an accurate reflection of the actual distribution and extent of all of the different habitat classes modelled. As there is a high level of confidence in the mapped distributions, there can be greater confidence in future risk and impact assessment processes.

Sediment was present throughout the study area, overlaying Hard Substrate and as Sediment areas only. This constituted a large proportion of the study area as previously documented by Fry et al. (2008). In general, biota coverage across the study area was considered to be relatively sparse and restricted to certain nearshore areas with favourable or complex topography. Areas of increased topographic complexity typically contain a mixed mosaic of biota. Mixed habitats were found with Hard and Soft Coral co-occurring on hard coralline structures, interspersed among Algae and Sessile Invertebrates such as ascidians and sponges. This was consistent with the findings of Fry et al. (2008).

Algae and Sessile Invertebrates had the most extensive range of the biota classes modelled, typically in areas of low topographic complexity (flat terrain). Sessile invertebrates, including non-BPP soft corals were widespread throughout the study area, but had low coverage. Seagrass had the most restricted distribution, limited to a north western patch north of James Price Point, a western ridge running from Coulomb Point to James Price Point and some small areas south of Quondong Point.

Restricted areas of mixed habitat containing hard and soft corals occurred along the Hard Substrate ridge system between Coulomb and James Price Points, in a north-south direction. Shallower (< 10 m), Hard Coral habitats, excluding Sessile Invertebrates, were found closer to shore near James Price and Quondong Points, although little Hard Coral was found to the south of James Price
Point in between these two areas. Nearshore, mixed biota habitats typically consisted of *Turbinaria* and favids, or a mix of both, which have been found to commonly occur in shallow reef areas of the north west shelf and display high sediment tolerance (e.g. Blakeway and Radford, 2005; MScience, 2010).

The coral communities in this region were typically sparse (5-10%) in coverage and are not coral reefs. There were very few areas with more than 10% coral cover identified by this study, unlike other regions to the north, such as at Packer Island and Perpendicular Head, which had higher coral coverage (35-50%) (Fry *et al*., 2008). Masini *et al.* (2009) and Fry *et al.* (2008) recorded less than 1% mean coverage of coral communities from Quondong to Coulomb Points, with individual species or a few small patches of hard coral observed within mixed habitats. Hard Corals were typically found within a mosaic of other biota types, including Algae, Soft Coral, Seagrass and Sessile Invertebrates. This study has improved the mapping of coral habitats, identifying areas of both trace (<5%) and sparse (5-10%) coral cover across the region, though very little coral cover is found within the vicinity of James Price Point itself, aside from areas immediately adjacent to the shore.

Coral communities are not well developed in the James Price Point coastal area and colonies that were present were typically small, suggesting periodic natural disturbances occur in the area. It is also likely that the almost complete coverage of hard substrate in the area by sediment has acts to inhibit the formation of coral reef structures. No unique Hard Coral dominated habitats were mapped. Coral communities found within the study area were unlike typical reef building coral communities found offshore in areas such as Scott or Ningaloo Reefs, or those found fringing islands and within the Kimberley, such as at the nearby Buccaneer Archipelago and Maret Islands, which support a high abundance and diversity of corals (Wells *et al*., 2005; INPEX, 2008; Irvine & Keesing, 2009; Masini *et al*., 2009). Whilst the broader Kimberley Bioregion may be considered one of the most coral diverse regions in WA (INPEX, 2008), the study area is relatively similar in coral diversity to other nearshore areas located further south, such as Port Hedland, Cape Lambert and Mermaid Sound (Rio Tinto, 2008; MScience, 2010; SKM, 2010a). Foliose (e.g. *Turbinaria*), encrusting and massive species are more commonly found in these turbid nearshore areas, instead of branching *Acropora* species observed in the northern Kimberley. However, these areas to the south typically support coral cover up to 20-30%, whereas the James Price Point study area is dominated by Algae and Sessile Invertebrates with a lower cover of Hard Coral (~10%).

This study predicted extensive algal occurrence throughout the study area, as has been found previously (Walker, 1996; Fry *et al*., 2008). Algal communities were well represented, including Canopy and Small algae, and distributed throughout the study area and across the broader Kimberley region, thus they were not considered to be unique to the James Price Point region. Coverage was extensive in the north of the study area, adjacent to Coloumb Point, with patches of *Sargassum* sp. observed both in the shallows (5–10 m depth) and extending into deeper waters.
Algal cover represented more than 50% of the biota identified within 2008 transects off Coulomb Point (Fry et al., 2008). Coverage decreased near James Price Point and to the south of Quondong Point, with most algal cover observed in less than 10 m of water. Macroalgal communities are strongly seasonal in their occurrence, growth and reproduction (Nizamuddin, 1970; Price, 1989; Ateweberhan et al., 2006). Dominant canopy algae such as *Sargassum* show pronounced peaks in biomass during the summer and retain low biomass during the winter (Martin-Smith, 1992; Schaffelke and Klumpp, 1997). *Sargassum* beds are thus characterised by large and dense canopies of healthy and relatively clean macroalgae in summer, but persist largely as basal parts only, after a severe seasonal dieback in winter (senescence) during which time they become heavily covered in epiphytic growth (Martin-Smith, 1992). Since the 2009 survey (summer) conducted by SKM was largely aimed at targeting areas of seagrass, the majority of ground truth data collected within the study area which classified macroalgae was from June 2008 (winter). Thus, it could be assumed that predicted macroalgae within the study area is more representative of a winter distribution.

This study also identified the presence of algae with other biota types, such as Hard Coral and Sessile Invertebrates. Non BPP Sessile Invertebrates were extensive through the entire study area, overlapping with all other biota types. These mixed mosaics of habitat were not clearly identified in previous studies, although represent a substantial portion of the study area mapped. Modelling and mapping of biota types individually, as has been undertaken in this study, allows clear areas of possible habitat co-occurrence to be identified.

Modelling has identified restricted occurrences of BPP Soft Corals based on presence of areas greater than 5% in coverage. Fry et al. (2008) mainly identified sparse to medium density soft corals on low relief reef features between Quondong Point and Coulomb Point. In this study, soft corals were mapped in similar deeper areas (> 10 m), with one large, shallow, nearshore band of soft corals adjoining the coast from James Price Point to Quondong Point. As there were very few inshore video transects from both studies (due to depth restrictions during survey), further ground validation is required to determine if this feature is extensive as mapped or is possibly be an artefact of the modelling.

Seagrass distribution alone was mainly sparse and patchy across the study area and Fry et al. (2008) found seagrass interspersed with filter feeding communities and on sand areas between reef patches. The mean percent coverage of this assemblage was less than 6% for the entire study area (Fry et al., 2008) and Seagrass does not feature widely in the vicinity of James Price Point. However, patches of *Halophila* were found by Fry et al. (2008) who observed patches of sparse and dense Seagrass just south of Coulomb Point, within 5–10 m water depth. Some small patches were also recorded further south between Quondong and James Price Points and similar patches were observed in this area during 2009. Similar patterns in Seagrass distribution were observed during the 2009 survey, with the largest areas observed just south of Coulomb Point and smaller patches south of James Price Point.
Comparisons of observed Seagrass distribution between June 2008 and November 2009 highlight the variability in Seagrass distribution, areas that had Seagrass present in 2008 not having any Seagrass in 2009 and vice versa. There was no clear pattern of increase or decrease in distribution or coverage between the 2008 and 2009 survey.
5. Conclusion

High resolution bathymetry and towed video survey data were combined to develop models that accurately defined the relationships that exist between the different habitat classes and the environmental conditions present in the James Price Point coastal area. The models were able to accurately predict the distribution of the benthic habitats, resulting in full coverage, fine spatial scale maps (6 x 6 m resolution).

The predicted distribution has demonstrated that the inshore portion of the study area consists of largely overlapping hard and sediment substrate, while offshore, Sediment substrate dominates. Typical habitat within the study area contained a mixed mosaic of biota types and was commonly present on areas of topographic complexity and/or Hard Substrate ridgelines. Algae and Sessile Invertebrates had the most extensive range of the biota classes modelled, typically in flat areas. Based on the towed video surveys, Seagrass had the most restricted distribution.

The habitats observed and mapped within the study area were indicative of the benthic habitats found across the wider region and they do not show any unique or local examples of difference. It is concluded that the mapping products provide the necessary information and detail required to make future assessments of any potentials impact that a proposed development in the area could have on the nearshore benthic primary producer habitats.
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### Appendix A  Substrate definitions

<table>
<thead>
<tr>
<th>Substrate Type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consolidated (Reef) substrate</td>
<td>Any substrate predominantly made up of particles of cobble size (&gt;64mm diameter) or larger.</td>
</tr>
<tr>
<td>Unconsolidated (Sand) substrate</td>
<td>Any substrate predominantly made up of particles of pebble size (&lt;64mm diameter) or smaller.</td>
</tr>
<tr>
<td>Reef</td>
<td></td>
</tr>
<tr>
<td>Biotic reef</td>
<td>Biota covers &gt;5% of reef</td>
</tr>
<tr>
<td>Abiotic reef</td>
<td>Biota covers &lt;5% of reef</td>
</tr>
<tr>
<td>Reef Particle Size</td>
<td></td>
</tr>
<tr>
<td>Rock (unbroken)</td>
<td>Unbroken rock substrate</td>
</tr>
<tr>
<td>Boulder</td>
<td>Particles &gt;256mm</td>
</tr>
<tr>
<td>Cobble</td>
<td>Particles 64-256mm</td>
</tr>
<tr>
<td>Reef Profile</td>
<td></td>
</tr>
<tr>
<td>High Profile</td>
<td>&gt;4m rise over 2m; a hard or solid substrate with slopes greater than 70 degrees</td>
</tr>
<tr>
<td>Medium Profile</td>
<td>1-4m rise over 2m; a hard or solid substrate with slopes between 30 and 70 degrees</td>
</tr>
<tr>
<td>Low Profile</td>
<td>A hard or solid substrate with slopes between 2 and 30 degrees.</td>
</tr>
<tr>
<td>Flat</td>
<td>&lt;1m over 2m; a hard or solid substrate with slopes of less than 5 degrees</td>
</tr>
<tr>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>Biotic sediment</td>
<td>Biota covers &gt;5% of sediment</td>
</tr>
<tr>
<td>Abiotic sediment</td>
<td>Biota covers &lt;5% of sediment</td>
</tr>
<tr>
<td>Sand Particle Size</td>
<td></td>
</tr>
<tr>
<td>Pebble</td>
<td>Particles 4-64mm</td>
</tr>
<tr>
<td>Gravel</td>
<td>Particles 2-4mm; used to describe large grains of sediment; biogenic particles such as shells and coral rubble</td>
</tr>
<tr>
<td>Sand</td>
<td>Particles 63um-2mm</td>
</tr>
<tr>
<td>Mud</td>
<td>Particles &lt;63um</td>
</tr>
<tr>
<td>Sand Profile</td>
<td></td>
</tr>
<tr>
<td>Flat</td>
<td>Sediment with undulations &lt; 25cm high</td>
</tr>
<tr>
<td>Ripples</td>
<td>Sediment with undulations 25 - 75cm high</td>
</tr>
<tr>
<td>Waves</td>
<td>Sediment with undulations &gt; 75cm high</td>
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## Appendix B  Biota definitions

<table>
<thead>
<tr>
<th>Biota Classes</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustose coralline algae (CCA)</td>
<td>Encrusting algae</td>
</tr>
<tr>
<td>Turfing algae</td>
<td>Hair-like algae &lt;20mm</td>
</tr>
<tr>
<td>Filamentous algae</td>
<td>Hair-like algae &gt;20mm</td>
</tr>
<tr>
<td>Small Algae</td>
<td>Macro algae 20mm-20cm</td>
</tr>
<tr>
<td>Lobed</td>
<td>Membrane-like (e.g. Lobophora spp., Padina spp.)</td>
</tr>
<tr>
<td>Folaceous</td>
<td>Folaceous; branching (e.g. Gfoll = Cauverpa spp.)</td>
</tr>
<tr>
<td>Fleshy</td>
<td>e.g. Codium spp.</td>
</tr>
<tr>
<td>Canopy Algae</td>
<td>Macro algae &gt;20cm</td>
</tr>
<tr>
<td>Canopy species</td>
<td>e.g. Sargassum spp.</td>
</tr>
<tr>
<td>Flat</td>
<td>e.g. Ecklonia</td>
</tr>
<tr>
<td>Seagrass</td>
<td>Can be separated into genus e.g. Halophila, Posidonia, Zostera, Amphibolis</td>
</tr>
<tr>
<td>Hard Coral</td>
<td>Morphological group defined in English et al. 1997</td>
</tr>
<tr>
<td>Branching</td>
<td>At least 20 branching (e.g. Seriatopora hystrix)</td>
</tr>
<tr>
<td>Digitate</td>
<td>No 20 branching (e.g. Acropora digitifera)</td>
</tr>
<tr>
<td>Tabular</td>
<td>Horizontal flattened plates (e.g. Acropora hyacinthus)</td>
</tr>
<tr>
<td>Encrusting</td>
<td>Major portion attached to substrate as a laminar plate (e.g. Porites vaughani)</td>
</tr>
<tr>
<td>Foliose</td>
<td>Coral attached at one or more points, leaf-like appearance e.g. Turbinaria spp.</td>
</tr>
<tr>
<td>Massive</td>
<td>Solid boulder or mound (e.g. Favites spp.)</td>
</tr>
<tr>
<td>Submassive</td>
<td>Tends to small columns, knobs or edges</td>
</tr>
<tr>
<td>Soft Coral (BPP)</td>
<td>Photosynthetic soft corals (e.g. Alcyoniidae spp. (BPP))</td>
</tr>
<tr>
<td>Soft Coral (non-BPP)</td>
<td>Non-photosynthetic soft corals (e.g. Gorgonian fans, Alcyoniidae (non-BPP) Dendronephthia spp.)</td>
</tr>
<tr>
<td>Filter Feeders (non-BPP)</td>
<td>Ahermatypic animals (not defined as BPP)</td>
</tr>
<tr>
<td>Sponges</td>
<td>Can note morphological groups</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Density of biota (Qualitative assessment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Dense</td>
</tr>
<tr>
<td>Dense</td>
</tr>
<tr>
<td>Medium</td>
</tr>
<tr>
<td>Sparse - Medium</td>
</tr>
<tr>
<td>Sparse</td>
</tr>
<tr>
<td>Trace</td>
</tr>
<tr>
<td>No biota</td>
</tr>
</tbody>
</table>
Appendix C  Quantifying the qualitative video analysis

To improve the confidence in the qualitative analysis of the video footage, subsamples of the 2009 video transects were quantitatively analysed to calibrate the analysts hard coral cover classifications. The aim of the calibration was to detect if predetermined percent cover classes could be accurately (consistently) identified from the video footage by two video analysts; referred to in this report as MS1 and MS2.

Video transects with the highest hard coral cover of all the video transects collected during the 2009 towed video study were selected for this study; 6 video transects were selected and qualitatively analysed by MS1 and MS2 using the SKM video analysis software. This data was used to select 30 second subsamples of video which had consistent hard coral cover classifications (i.e. the analyst had classified a constant cover without change for 30 seconds). Four sections from the hard coral cover classes 0-5%, 5-10% and 10-25% (coverage) for each analyst were subsampled for quantitative analysis. To reduce the number of subsections for quantitative analysis, all video sections that had 30 seconds of consistent qualitative classifications from both MS1 and MS2 were selected as subsections for the quantitative analysis; the statistics from one subsection could be used to calibrate both MS1 and MS2.

The SKM Video Transect Analysis (VTAS) software was used to quantify the hard coral cover. The VTAS software is a Microsoft Access (2007) application which uses Windows Media Player as the viewer and randomly captures still images from the video footage and overlays a user defined number of random points onto the still image. The software allows the user to assign biota and substrate attributes to the corresponding points that are recorded to the database. The VTAS software was programmed to assign 5 random points overlayed onto 30 random frames, which equals a total of 150 points per transect. The mean hard coral cover and the range of values between the 4 subsections were interpreted to determine suitable cover classes for the qualitative analysis.

Results
The cover class 0-5% cover was accurately classified by both MS1 and MS2 with a quantitative percent cover average of 1.17%. Coral cover was not recorded in the quantitative analysis on one transect, but was classified as 0-5% cover in the qualitative video survey. The video shows that hard coral is present but was too sparse (approximately one small coral colony every 5 meters) to be detected from the 150 random video points in the quantitative analysis. The cover class 5-10% cover was also accurately classified by both MS1 and MS2.

The hard coral cover class of 10-25% was classified in small patches by MS1 but was not used to classify any habitats by MS2. The quantitative analysis for the subsections identified as 10-25%
showed that the average percent cover was 8.5% cover with a large range between 6-13.33% cover. Although one subsection had hard coral cover greater than 10% (13.33% cover) the other three subsections were less than 10%. This indicates that the 10-25% cover class was an overestimate of biota cover and could not be identified as a separate class to the 5-10% cover class.

### Table C 1 Results of the quantitative analysis for the hard coral cover classes

<table>
<thead>
<tr>
<th>Analyst</th>
<th>0-5%</th>
<th>5-10%</th>
<th>10-25%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Average</td>
<td>Range</td>
</tr>
<tr>
<td>MS1</td>
<td>0-2.01%</td>
<td>1.17%</td>
<td>4-10%</td>
</tr>
<tr>
<td>MS2</td>
<td>0-2.01%</td>
<td>1.17%</td>
<td>6-9.33%</td>
</tr>
</tbody>
</table>

The quantitative analysis of the video transects indicates that 0-5% and 5-10% cover classes could be consistently identified from the video footage. The 10-25% cover classification was an overestimation of the hard coral cover and was not used for the qualitative analysis of hard coral cover. The 6 video transects used to calibrate the qualitative video cover classes were identified as the transects with the highest coral cover. Thus the hard coral cover in the remaining video transects is not expected to be greater than 10% cover. The hard coral classes used for the qualitative analysis was 0-5% and 5-10% cover.
Appendix D  Habitat map series showing predicted distribution of BPP excluding Seagrass
As access to Pearl Lease Areas was restricted, no validation was undertaken in these areas. Consequently, no information was available to train models and therefore these areas have been excluded from the mapping.
17.1...
As access to Pearl Lease Areas was restricted, no sampling was undertaken in these areas. Consequently no information was available to train models and therefore these areas have been excluded from the mapping.
Appendix E  Habitat map series showing predicted distribution of all biota (BPP and Sessile Invertebrates excluding Seagrass )
As access to Pearl Lease Areas was restricted, no sampling was undertaken in these areas. Consequently, no information was available to train models, and therefore these areas have been excluded from the mapping.
Nearshore Benthic Habitat Modelling and Mapping, James Price Point

Legend - Southern Section of LADS Extent

- Combined BPP and Sessile invertebrates
- Habitats based on combining the previous presence of ten different BPP classes. Predicted presence indicates a minimum coverage of 5% at that location.

- Littoral algae
- Sessile invertebrates, only
- Mixed mosaics of hard coral and algae
- Mixed mosaics of soft coral and algae
- No BPP predicted to occur

As access to Pearl Lease Areas was restricted, no sampling was undertaken in these areas. Consequently, no information was available to train models, and therefore these areas have been excluded from the mapping.