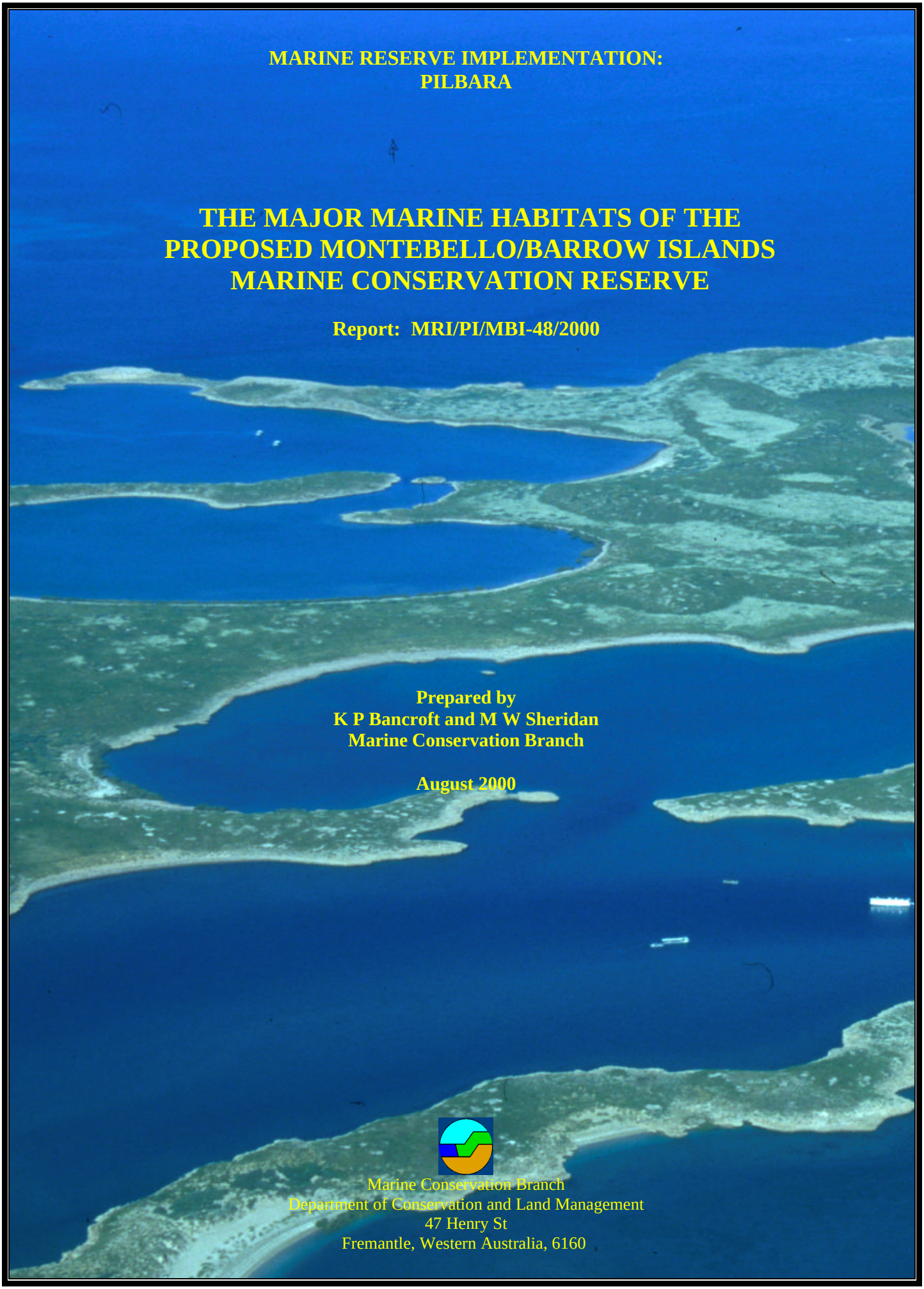

MARINE RESERVE IMPLEMENTATION:
PILBARA

THE MAJOR MARINE HABITATS OF THE PROPOSED MONTEBELLO/BARROW ISLANDS MARINE CONSERVATION RESERVE

Report: MRI/PI/MBI-48/2000

Prepared by
K P Bancroft and M W Sheridan
Marine Conservation Branch

August 2000

Marine Conservation Branch
Department of Conservation and Land Management
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Cover. Hermite Island, Montebello Islands

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1 INTRODUCTION

The Western Australian Government is committed to establishing a statewide representative system of multiple use marine conservation reserves under the Conservation and Land Management *(CALM)* Act 1984 to protect the diverse and valuable natural heritage values of our nearshore marine environment. The *CALM Act* provides the framework for sustainable commercial and recreational use of these resources. In 1986, a Marine Parks and Reserves Selection Working Group (MPRSWG) was established to identify marine areas that where thought to be worthy of consideration for marine reserve status. The MPRSWG identified 70 areas around the Western Australian coast (CALM 1994) which, if reserved, would provide a system of marine conservation reserves that would be representative of all the major ecosystems of the state.

In December 1997, the Western Australian Government, following advice provided by the Western Australian Marine Parks and Reserves Authority, announced the Montebello/Barrow islands region (areas recommended by the MPRSWG), as one of its priority areas for establishment as a marine conservation reserve. Subsequently, CALM through the Marine Conservation Branch (MCB), has initiated the planning process for implementing a marine conservation reserve in the region.

Under the State Government's marine conservation strategy detailed in *New Horizons - The way ahead in marine conservation and management* released by the Western Australian Government in 1998 (WA Government, undated), there is a requirement for:

> *"Extensive assessment, community consultation and management planning before a new marine conservation reserve is established."*

An essential component of this is that:

> *"A comprehensive assessment of the area's biological and economic resources, and social values is carried out."*

To achieve the biological resource component, a map highlighting the major marine benthic habitats of the Montebello/Barrow islands region was produced. Habitat diversity has been shown to be a high level surrogate of biological diversity (Ward *et al.* 1998), especially when supplemented with spatially detailed biodiversity data, to species level (Ward *et al.* 1999).

The map of major marine benthic habitats of the study area (Figure 1) will be used as a biodiversity surrogate and, as such will be used in the planning process. The habitat map will also be essential for the future management of the proposed marine conservation reserve once it is established.

2 PURPOSE

The purpose of this report is to:

(i) Detail the major marine benthic habitats of the Montebello/Barrow islands region in the form of a broadscale habitat map.

(ii) document the methods used to produce the broadscale habitat map;

(iii) provide a comprehensive description of habitat types presented in the broadscale habitat map;

(iv) document the metadata for the GIS information layers developed for the broadscale habitat map, and;

(v) document the storage location of the GIS information layers.

3 STUDY AREA

The study area for the proposed Montebello/Barrow islands marine conservation reserve (Figure 1) lies about 1600 km north of Perth, Western Australia, between 20.29º to 21.16º South and 115.25º to 115.64º East and covers an area of approximately 2099 km^2 of which 1831 km^2 is marine environment.

The area is broadly defined as the waters surrounding the Montebello/Barrow islands region stretching from the State Territorial Limit in the north and west, to the ten metre depth contour in the east and south.

4 METHODS

4.1 HABITAT CLASSIFICATION

The major marine benthic habitats in the Montebello/Barrow islands region were based on the classifications outlined in the draft statewide marine benthic habitat classification scheme presented in Appendix I. The classification system is being developed by the MCB to facilitate a more systematic and standardised approach to this issue and will continue to be refined on an on-going basis. At a regional level, specific sub-categories are being developed to provide the appropriate level of detail required for the marine reserve planning process.

4.2 MAPPING METHODS

The habitat map for the proposed Montebello/Barrow islands marine conservation reserve was developed using Geographical Information Systems (GIS) software, ArcView Version 3.2 (ESRI). An outline of the method used in the mapping of the marine benthic habitats is as follows:

(a) All available existing marine habitat maps were collated and an assessment was made of their accuracy and usefulness for the purpose of this project.

(b) A composite map was constructed using the existing habitat maps and any other related marine habitat data.

(c) The attributes to the datasets were cleaned for errors such as spelling and typing errors, and a restructure of habitat categories was performed.

(d) Habitat classifications used to describe habitat types in existing data were reconciled and standardised to conform with the CALM draft statewide marine benthic habitat classification scheme (Appendix I).

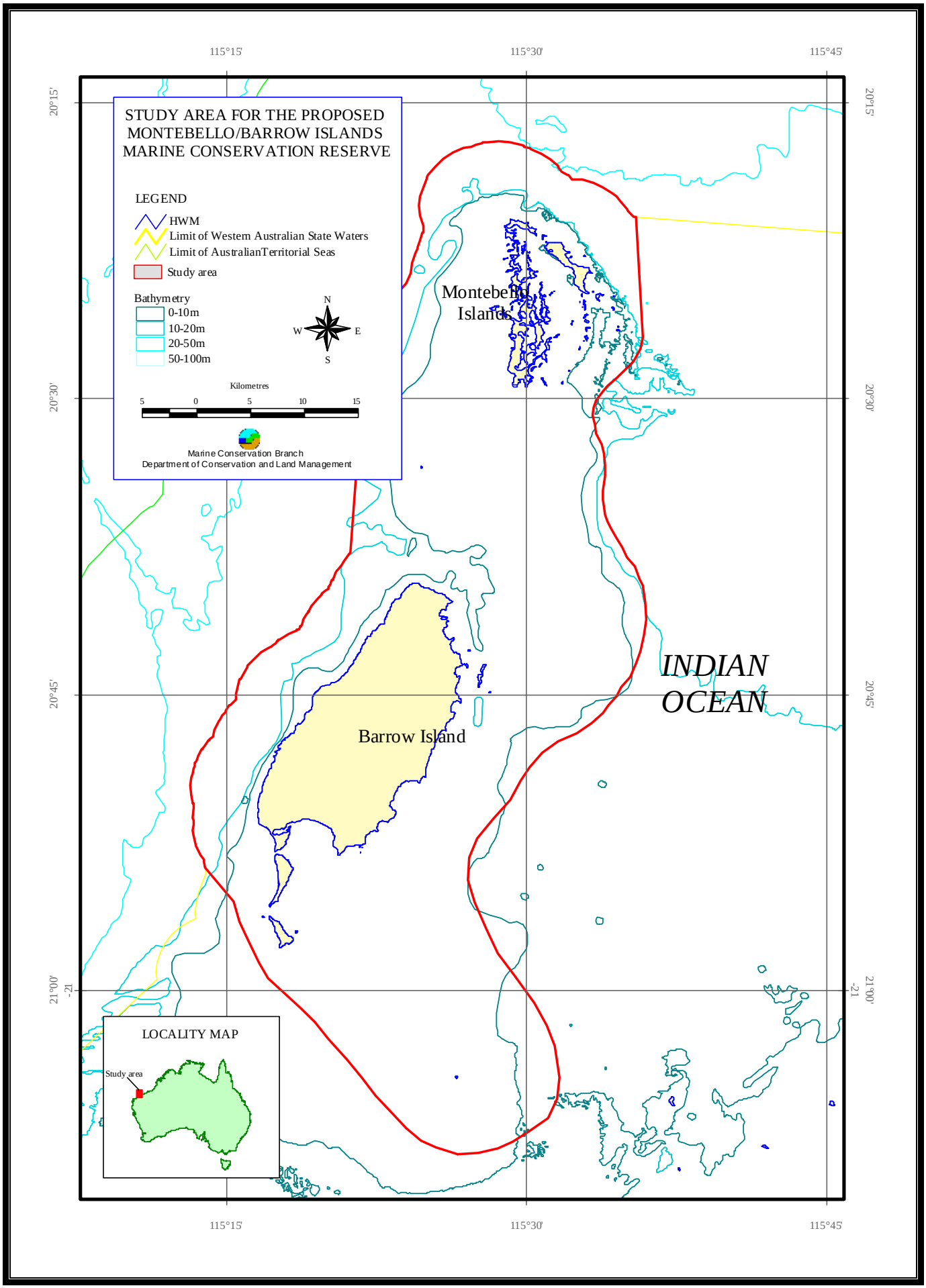

Figure 1. Study area for the proposed Montebello/Barrow islands marine conservation reserve

(e) Existing datasets were assessed for their spatial accuracy and extent, and habitat attribution. The lack of metadata associated with most of the GIS datasets made this task difficult. Where metadata were unavailable, it was assumed that the biological information was correct even if the spatial accuracy was not.

(f) The habitat data were draped onto Landsat TM and/or aerial and/or Digital Multi-Spectral Video (DMSV) imagery allowing an assessment to be made on the accuracy of habitat shapes (polygons). Adjustments were made where necessary.

(g) In areas where remotely sensed data was unavailable due to the limitations of depth (generally >10 m depth) and/or turbidity (typically occurs within channels between the islands), habitats were classified using a combination of bathymetry, ground-truthing and local knowledge about the likely distribution of habitats in these areas (*see* Section 4.3).

(h) Habitat point data collected in the field at 57 sites by the MCB, was used to ground-truth areas of major uncertainty.

Further detail on the methods and data sources associated with the major marine benthic habitats of the Montebello/Barrow islands region, may be found in the metadata presented in Appendix II.

4.2.1. Major coastline habitats

Major coastline habitats were classified by referring to remotely sensed imagery, such as Landsat TM and/or aerial photographs and/or Digital Multi-Spectral Video (DMSV), at a scale of 1:20000.

In the major coastline habitat dataset for the Montebello/Barrow islands region, a *beach/rocky shore* classification was used. This category describes intertidal areas where a shoreline reef was covered with a thin layer of sand or where there was sand above or below intertidal shoreline reef.

Further detail on the methods and data sources associated with the major coastline habitats of the Montebello/Barrow islands region, may be found in the metadata presented in Appendix III.

4.3 MODELLING

The final phase in the development of habitat GIS data layers for the broadscale habitat maps was to classify areas where remote sensing techniques could not be used. This was achieved using field verification data collected during a field survey undertaken in August 1999 (Bancroft, 1999), and local knowledge to develop simple linear interpolation models where these habitat types may occur.

4.3.1. Linear interpolation

The linear interpolation model is the simplest, where it is assumed that the boundary between two habitats lies midway between two sites of known habitat type.

This model was used mainly in areas where interpretation of benthic habitats from remote sensing and photogrammetry was difficult. Areas that were modelled include the more turbid shallow waters (silt and sand), channels, coral reef communities, lagoonal reef platforms and offshore areas.

Observations in the field indicated that lagoonal and seaward areas of subtidal reef varied in: (i) area of sand patches; (ii) macroalgae assemblages, and; (iii) macroalgae morphology. These differences may be contributed by the seaward areas being more exposed to wind, waves, and currents in comparison to the lagoonal areas, which are less exposed. Strong tidal currents typically scour the channels within the Montebello Islands, and these areas support turf algae and sessile invertebrate communities (e.g. soft corals), whereas the seaward areas tended to have more numerous and larger patches of sand. The field data and the bathymetry were used to model the *subtidal reef (low relief)* and *subtidal reef (low relief)/sand* habitats.

4.3.2. Subtidal reef (low relief)/sand

The limited number of ground-truthing sites in the offshore areas (>10 m), indicated a mixture of subtidal reef pavement and sand. These offshore areas were classified as *subtidal reef (low relief)/sand* and it was assumed that all offshore areas could be similarly classified.

5 RESULTS

5.1 HABITAT DESCRIPTIONS

Thirteen habitat types identified in the broadscale map of the major marine benthic habitats of the proposed Montebello/Barrow islands marine conservation reserve (Figure 2):

1. Island;
2. Rocky shore;
3. Beach;
4. Mangal;
5. Mudflat;
6. Sand shoal;
7. Shoreline reef;
8. Coral reef communities (subtidal);
9. Coral reef communities (intertidal or shallow/limestone);
10. Subtidal reef (low relief);
11. Macroalgae (limestone reef);
12. Sand, and;
13. Pelagic.

These 13 habitats are described in broad terms and these descriptions relate to the habitat types on the broadscale map (1:100000) for the marine benthic habitats of the Montebello/Barrow islands marine conservation reserve.

5.1.1. Island

The *island* habitat describes land over 0.05 ha that is surrounded by the sea and permanently above Highest Astronomical Tide (HAT). The substratum of *islands* in the Montebello/Barrow island region may consist of sand, igneous and sedimentary rock (limestone and sandstone). The land may be bare, vegetated or have seasonal vegetation. The larger islands in the Montebello/Barrow islands region, are typically vegetated by spinifex (*Triodea* spp.), however Barrow Island also supports figs, wattles and eucalypts (*Eucalyptus xerothemica*). The island habitats of the region are known to be important for

Figure 2

Figure 2. Revised broad-scale map of the major marine habitat types in the Montebello/Barrow Islands region.

breeding and nesting areas for sea turtles (e.g. green *Chelonia mydas*, hawksbill *Eretmochelys imbricata*) and seabirds (osprey *Pandion haliaetus*, caspian tern *Sterna bergii*, wedge-tailed shearwater *Puffinus pacificus*).

5.1.2. Rocky shore

The *rocky shore* habitat is located in the upper intertidal zone (between the Lowest Astronomical Tide (LAT) and HAT) and includes low cliffs (<5 m), boulder or pavement of igneous, metamorphic or sedimentary substratum located along the shoreline. For convenience shoreline high cliffs (>5 m) are included in this category. In the Montebello/Barrow islands region, rocky shores are typically wave-cut or undercut, unvegetated, low limestone cliffs which support a variety of mollusc species including oysters (*Saccostrea* spp.) and barnacles (e.g. *Tetraclita porosa*) and other invertebrates such as crabs (*Leptograspus* sp.).

5.1.3. Beach

The *beach* habitat is located in the upper intertidal and supratidal (immediately above HAT) zones and typically consists of unconsolidated carbonate sands. The *beach* habitat is mostly unvegetated however flora such as spinifex (*Spinifex longifolius*) may be present above HAT. Ghost crabs (*Ocypode* sp.) are conspicuous in this habitat at night. The intertidal sands of beach habitats in the Montebello/Barrow islands region typically support a range of invertebrates including lampshells (brachiopods), bivalve shells and seaurchins.

5.1.4. Mangal

The *mangal* habitat describes areas of mangrove forest greater than 0.05 ha and typically is located in the upper intertidal zone. The substratum of this habitat, typically comprises of mud and silt, however some mangrove species do occur on intertidal rocky shores. The most common mangrove species in the Montebello/Barrow islands region are *Rhizophora stylosa* and *Avicennia marina*. Mangrove roots provide a substratum for many gastropods (e.g. *Natica*, *Cerithium*, *Strombus*, *Telescopium*) and other invertebrates, such as the mangrove crab (*Scylla serrata*) are often present. In the Montebello/Barrow islands region, *mangals* are an important habitat for birds such as the mangrove whistler (*Pachycephala melanura*) and brahminy kite (*Haliastur indus*), and for juvenile fish.

5.1.5. Mudflat

The *mudflat* habitat is located in the lower intertidal zone and generally consists of terrigenous mud or silt sediments. *Mudflats* occur in areas of low energy and high deposition such as the areas seaward of *mangals*. *Mudflat* habitats are typically bare of vegetation, but support gastropods (e.g. *Cerinthium* sp.), crabs (e.g. *Uca* sp., *Macrophthalmus* sp.) and invertebrate infauna. In the Montebello/Barrow islands region, the major occurrence of *mudflat* habitat is in Stephenson Channel, Hermite Island.

5.1.6. Sand shoal

The *sand shoal* habitat is located in the lower intertidal zone, generally seaward of the shoreline habitats and are typically found in macrotidal (>2 m tidal range) areas where strong currents and wave action create offshore banks and shoals. These banks and shoals can also be connected to islands or the mainland. The *sand shoal* habitat consists of mobile, medium to coarse carbonate sands, is unvegetated and contains a low diversity of infauna. The small volute mollusc, *Amoria macandrewii*, which is endemic to the Montebello/Barrow islands region, is sometimes found in this habitat

5.1.7. Shoreline reef

The *shoreline reef* habitat is typically located in the lower intertidal or nearshore subtidal zones (<1 m below LAT) and occurs as low relief reef platforms of sedimentary (limestone or sandstone) substratum that are contiguous with the shoreline. In the Montebello/Barrow islands region, *shoreline reef* habitat typically supports turf algae and invertebrates such as gastropods (*Tridacna* spp. clams, *Barbantia* sp. bivalves) and isolated soft and hard coral communities.

5.1.8. Coral reef communities (intertidal or shallow/limestone)

The *coral reef communities (intertidal or shallow/limestone)* habitat is located in the intertidal or shallow regions (<1 m LAT) on a limestone substrate. This habitat includes the reef crest, reef flats and shallow back reef zones. Live coral cover varies greatly and some areas have a high proportion of coral rubble. Macroalgae, sand or pavement also may be present. Hard corals (e.g. *Acropora* spp.), soft corals (e.g. *Sinularia* spp.) are typical of the fauna present in these habitats. Parts of this habitat typically support a high diversity and abundance of fish and invertebrate fauna.

5.1.9. Coral reef communities (subtidal)

The *coral reef communities (subtidal)* habitat is located in the subtidal zone and often has high live coral cover with macroalgal turf and coralline algae covering areas of reef no occupied by living corals. Sand patches, bare pavement and rubble may also be present. This habitat is used to describe the upper seaward reef slope, sheltered back reef, deep lagoonal reef and bommie clusters. In the Montebello/Barrow islands region, areas of high coral cover are generally restricted to water depths of less than 10 m depth. Offshore, these habitats are dominated by the faster growing coral species such as *Acropora* (A. *hyacinthus*) and *Pocillopora* (*P. verrucosa*). This habitat typically supports a high diversity and abundance of fish and other coral reef fauna.

5.1.10. Subtidal reef (low relief)

The *coral subtidal reef (low relief)* habitat are areas of low relief subtidal limestone reef platform, which occurs in areas exposed to strong tidal currents but sheltered from high wave action, such as the channels between the islands. In the Montebello/Barrow islands region, this habitat typically supports little, however a high diversity of sessile filter feeders such as sponges, sea-pens, sea-whips, gorgonian corals, soft corals and isolated hard corals may be present. Macroalgal turf, sand patches or bare pavement may also be present.

5.1.11. Macroalgae (limestone reef)

The *macroalgae (limestone reef)* habitats are areas subtidal limestone substratum of low or high relief. In the Montebello/Barrow islands region, this habitat is found in shallower waters (<10 m depth) and also may incorporate mobile sand patches, and scattered isolated hard and soft corals. This habitat generally is covered in large fleshy macroalgae (e.g. *Sargassum* spp.) or macroalgal turf (red, green and brown algae). A wide range of invertebrate life such as sponges, ascidians and soft corals, are associated with this habitat.

5.1.12. Sand

The *sand* habitat is defined as subtidal habitats that have predominately white carbonate sands as a substrate, however the sand may overlay reef platform or have patches of other habitats present. In the Montebello/Barrow islands, *sand* habitats typically are bare, and may have seasonal vegetation or permanent patches of seagrass or macroalgae. Invertebrate infauna may also be present.

5.1.13. Silt

The *silt* habitat is located in subtidal areas with mud or silt substratum, with a significant terrigenous fraction. In the Montebello/Barrow islands, *silt* habitats occur in the sheltered areas (e.g. embayments) of the nearshore region of the archipelago and are usually unvegetated. *Silt* habitats support a rich variety of infauna such as polychaete worms, molluscs and crustaceans.

5.2 HABITAT DISTRIBUTIONS

Marine benthic habitat percentages (Table 1) and coastal habitat percentages (Table 2) were calculated to highlight the dominant habitats in the Montebello/Barrow islands region.

Table 1. Percentages of major benthic marine habitats in the study area

Habitat type	Percentage (%)
Beach	0.2
Mangal	<0.1
Mudflat	<0.1
Sand shoal	0.6
Shoreline reef	1.2
Coral reef communities (intertidal or shallow/limestone)	2.9
Coral reef communities (subtidal)	3.9
Subtidal reef (low relief)	3.9
Subtidal reef (low relief)/sand	39.7
Macroalgae (limestone reef)	45.2
Sand	2.3
Pelagic	<0.1

Table 2. Percentages of the major coastline habitats in the study area

Habitat classification	Montebello Islands	Lowendal Islands	Barrow Islands	Total study area
Beach	9.8	11.5	46.2	21.7
Beach/rocky shore	4.5	26.9	18.3	10.9
Rocky shore	81.3	61.5	30.0	62.0
Mangals	4.4	<0.1	5.5	4.4

5.3 GROUND-TRUTHED DATA

There was a total of 57 habitat ground-truthing survey sites collected by the MCB during a survey conducted in August 1999 (Bancroft, 1999). This habitat data has been documented in a MCB Data Report (Bancroft *et al.*, 2000). For further information on this habitat data, refer to the Data Report.

5.4 METADATA

The simplest definition of metadata is 'data about data'. It describes the content, quality, currency and availability of data. Metadata is required for a range of purposes and often includes detailed information such as, data collection methods, processing history and details of content, quality, accuracy, geographic extent and contact information of data sets. This information is important so potential users of existing data can assess its suitability for other purposes.

The metadata for the Montebello/Barrow island marine habitat data layers are presented in Appendix II (major marine benthic habitats) and Appendix III (major shoreline habitats).

6 CAVEAT

The marine benthic habitat map should not be used for navigational purposes.

This marine benthic habitat map has its origin in the dataset developed by Apache Energy Ltd. Numerous subsequent marine benthic habitat surveys undertaken by the public and private sectors have provided additional information.

The delineation between habitats on the map is shown by abrupt changes in habitat classification. In reality changes are more often a gradual transition from one habitat to another. As a result, the location of some habitat boundaries should be considered as approximate only.

In addition, relatively limited ground-truthing data has been used in determining these habitats due to their extensive area.

7 DATA MANAGEMENT

7.1 REPORT

Hard copies of this report will be held at three locations:

1. Marine Conservation Branch, Department of Conservation and Land Management, 47 Henry St., Fremantle Western Australia, 6160. Ph. (08) 9432 5100 Fax. (08) 9430 5408.

2. Woodvale Library, Science and Information Division, Ocean Reef Rd., Woodvale, Western Australia, 6026. Ph. (08) 9405 5100 Fax. (08) 9306 1641.

3. Archives, Woodvale Library, Science and Information Division, Ocean Reef Rd., Woodvale, Western Australia, 6026. Ph. (08) 9405 5100 Fax. (08) 9306 1641.

The Marine Conservation Branch will hold digital copies of this report at the following locations:

1. The Marine Conservation Branch on-site CD-ROM [mri_4800]

2. The Marine Conservation Branch off-site CD-ROM [mri_4800]

3. MCB homepage on the Department of Conservation and Land Management Intranet CALMweb:
http://calmweb.calm.wa.gov.au/drb/ncd/mcb/rep_pdf/mri_reps/mri_2000/mrirep00.htm#mri_4800

7.2 GIS DATA

Data presented in the form of GIS layers will be stored digitally at the following directory pathways:

1. The Marine Conservation Branch Server:
GIS Data@FREM.SHARED@CALM on 'StreetTalk'
[L:\Marine_Information\Data\Production\Marine_Biology\Benthic_habitats\CALM\]

2. MCB Server full backup DAT tape:
[L:\Marine_Information\Data\Production\Marine_Biology\Benthic_habitats\CALM\]

3. On GIS Information server:
[H:\Marine_Information\Data\Production\Marine_Biology\Benthic_habitats\CALM\]

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APPENDICES

APPENDIX I. DRAFT STATEWIDE MARINE BENTHIC HABITAT CLASSIFICATION

HABITAT CLASSIFICATION	TIDAL RANGE	SUBSTRATE TYPE	TROPICAL	TEMPERATE	RELIEF	MACROBIOLOGY	SUB -CATEGORIES	COMMENTS
1. Island		Sand igneous metamorphic sedimentary	✓	✓	high & low	Can be vegetated or bare		• Permanent land (>1 ha) above highest astronomical tide (HAT) • Surrounded by the sea • May have seasonal vegetation • Seabirds, terrestrial mammals & reptiles • Important as haul out or breeding/ nesting areas for marine mammals, marine reptiles and seabirds
2. Rocky shore	Intertidal Supratidal	igneous metamorphic sedimentary	✓	✓	high & low	bare		• continuous rocky shore • cliff, boulders, pavement • around HAT • typically unvegetated • "*uncomfortable to walk on*"
3. Beach	Intertidal Supratidal	Calcareous or siliceous sand	✓	✓	low	Bare Some molluscs		• continuous sand (calcareous or siliceous) • intertidal i.e. between HAT and lowest astronomical tide (LAT) • mostly unvegetated • mobile sands • "*comfortable to walk on*"
4. Salt marsh	Intertidal Supratidal	terrigenous mud or silt	✓	✓	n/a	samphire saltmarsh blue-green algal mats bare		• continuous salt marsh cover (>1 ha) • on protected or low energy coastline • often landward of mangals and estuaries • includes unvegetated coastal saline flats
5. Mangal	Intertidal	muds silts igneous or metamorphic or sedimentary rock	✓	✓	n/a	Mangroves intertidal gastropods and other invertebrates may be present		• continuous mangrove cover (>1 ha) • mud/sand/intertidal reef/shoreline reef may be present • upper intertidal
6. Mudflat	Intertidal	terrigenous mud or silt	✓	✓	low	bare blue-green algal mats intertidal gastropods and other invertebrates may be present		• continuous mudflat • terrigenous sediments • between HAT & LAT • typically seaward of mangals

HABITAT CLASSIFICATION	TIDAL RANGE	SUBSTRATE TYPE	TROPICAL	TEMPERATE	RELIEF	MACROBIOLOGY	SUB -CATEGORIES	COMMENTS
7. Sand shoal	Intertidal	sand	✓	✓	low	bare little macroalgae low diversity of infauna		• Often in offshore macrotidal areas • medium to coarse sand • highly mobile sand • between HAT & LAT
8. Shoreline reef	Intertidal	igneous metamorphic sedimentary	✓	✓	low	bare, algal turf intertidal gastropods and other invertebrates may be present		• continuous reef platform along the shoreline • may be bare or have macroalgal turf or sand patches • between HAT & LAT
9. Offshore intertidal reef	Intertidal or shallow	igneous metamorphic sedimentary	✓	✓	high/low	coralline algae, macroalgal turf, macroalgae intertidal gastropods and other invertebrates may be present		• Offshore reef • between HAT & LAT • contiguous with shoreline
10. Coral reef communities	Intertidal & subtidal	igneous metamorphic sedimentary	✓		high & low	typical coral reef communities hard coral, soft coral, sponges, bryozoans, ascidians, octocorals etc. other invertebrates supports diverse fish community	• **Coral reef communities** (i**ntertidal or shallow)** - intertidal or shallow, <1m lowest astronomical tide (LAT), often live coral cover is low, Covers reef crest, back reef, reef flat, shallow lagoon • **Coral reef communities (subtidal)** - subtidal, often high live coral cover , coral colonies with sand patches in lagoons Covers the upper seaward reef slope, deep lagoon, sheltered deep back reef, deep reef platform	• seaward reef slope, reef crest, reef flat, back reef and individual bommies • some sand, pavement, macroalgae or seagrass interspersed

HABITAT CLASSIFICATION	TIDAL RANGE	SUBSTRATE TYPE	TROPICAL	TEMPERATE	RELIEF	MACROBIOLOGY	SUB -CATEGORIES	COMMENTS
11. Subtidal reef	Subtidal	igneous metamorphic sedimentary	✓	✓	low	diverse algae sessile invertebrates (including sponges, soft corals, isolated hard corals, sea-whips, sea-pens)	• **Subtidal reef (high relief)** - >1 m high • **Subtidal reef (low relief)** - <1 m high ➢ *Lagoonal reef platform* - usually tropical, inshore sheltered lagoon, low levels of exposure to swell. ➢ *Seaward reef platform* – deeper water platform, similar to lagoonal reef platform however more exposed, biology may be different to lagoonal reef platform	• includes limestone pavement or low relief reef • may be covered with macroalgae or seagrass • may incorporate sand patches, rubble and scattered isolated corals
12. Macroalgae (limestone reef)	Subtidal	sedimentary	✓	✓	high & low	large fleshy macroalgae invertebrates	• **Macroalgae (limestone reef/high relief)** - >1 m high • **Macroalgae (limestone reef/low relief)** - <1 m high	• typically covered in macroalgae with diverse invertebrate life in overhangs & caves • may incorporate sand patches, rubble and scattered isolated corals
13. Macroalgae (granite reef)	Subtidal	igneous metamorphic	✓	✓	high & low	Large fleshy macroalgae invertebrates	• **Macroalgae (granite reef/high relief)** - >1 m high • **Macroalgae (granite reef/low relief)** - <1 m high	• typically covered in macroalgae with diverse invertebrate life in overhangs & caves • may incorporate sand patches, rubble and scattered isolated corals

HABITAT CLASSIFICATION	TIDAL RANGE	SUBSTRATE TYPE	TROPICAL	TEMPERATE	RELIEF	MACROBIOLOGY	SUB -CATEGORIES	COMMENTS
14. Seagrass meadows	Subtidal	sand pavement	✓	✓	low	seagrasses	• **Perennial seagrass** - Perennial seagrass (dense) exposed substrate < seagrass cover Perennial seagrass (medium) exposed substrate = seagrass cover Perennial seagrass (sparse) exposed substrate > seagrass cover • **Ephemeral seagrass** - Ephemeral seagrass (dense) exposed substrate < seagrass cover Ephemeral seagrass (medium) exposed substrate = seagrass cover Ephemeral seagrass (sparse) s exposed substrate > seagrass cover	• continuous seagrass coverage (>1 ha) • ephemeral seagrass species *Halophila,* *Halodule* • perennial seagrass species *Amphibolis,* *Cymodocea,* *Enhalus,* *Heterozostera,* *Posidonia,* *Syringodium,* *Thalassia* *Thalassodendron,* *Zostera*
15. Sand	Subtidal	Sand (generally white)	✓	✓	low	Bare may have seagrass or macroalgal patches		• little or no vegetation • may have patches of other habitat • may overlay reef platform • may have patches of seagrass or macroalgae • may have seasonal vegetation
16. Silt	Subtidal	muds silts	✓	✓	low	bare		• marine and/or terrigenous muds & silts • little or no vegetation • may have seasonal vegetation
17. Pelagic	In waters >50m	various	✓	✓	N/a	Mainly pelagic fish and invertebrates		• This category is specific to those areas that are greater than 50 metres in depth. • May have various substrates however the water column is dominant

APPENDIX II. GIS METADATA FOR THE MAJOR MARINE BENTHIC HABITATS FOR THE PROPOSED MONTEBELLO/BARROW ISLANDS MARINE CONSERVATION RESERVE

DATASET	
Title	**Hab_montes08092000_amg50_agd84 -** Major Marine Habitats of the Montebello/Lowendal/Barrow Island's Area
Custodian	Department of Conservation and Land Management (CALM)
Jurisdiction	Western Australia
DESCRIPTION	
Abstract	This dataset consists of polygons detailing the major marine habitats of WA's Montebello/Lowendal/Barrow Island's area. The dataset is complemented by a linework dataset detailing onshore coastline habitats of the same area (hab_montes_onshoreddmmyyyy_amg50_agd84). These datasets were developed to assist in the planning process for the implementation of a proposed Montebello/Barrow Island marine reserve. Habitats are identified at a broad scale only and are suitable for regional analysis and representation. Habitats were compiled by i) gathering and assessing all available marine habitat data over the area, ii) standardising the datasets, iii) unioning the datasets, iv) comparing and prioritising the datasets based on attribute and spatial accuracy, v) assigning a habitat classification based on the draft CALM standardised broadscale marine benthic habitat classification system, vi) review of the compiled dataset primarily for attribute accuracy and secondarily for spatial accuracy. This was undertaken using CALM ground-truth information, reference datasets, and expert knowledge to review the attribution and model additional habitat polygons. The dataset was compiled by Mark Sheridan under direction from Ray Lawrie. Habitat attribution was undertaken by Kevin Bancroft. The habitat classification system was developed by Dr Chris Simpson and Kevin Bancroft. The project was undertaken in phases over the period September 1999 - August 2000.
Search Word(s)	
Geographic Extent Name(s)	Pilbara (offshore) IMCRA region
DATA CURRENCY	
Begin Date	Not known
End Date	08/09/2000

DATASET STATUS	
Progress	Complete
Maintenance & Update Frequency	As required
ACCESS	
Stored Data Format	DIGITAL ArcView shapefile, projected to Australian Map Grid Zone 50 from Australian Geodetic Datum 1984 (AGD84).
Available Format Type	DIGITAL ArcView 3.2 shapefile
Access Constraint	Data available for external use subject to transfer fee and license conditions. Data is not to be distributed without authorisation from CALM. Contact CALM's database administrator for further details.
DATA QUALITY	
Lineage	**1.** All available marine habitat datasets existing over the North West Shelf region were gathered from a variety of sources in the public and private sectors. These included Apache Energy, Department of Environmental Protection, Department of Conservation and Land Management, WA Museum, CSIRO, Australian Petroleum Production and Exploration Association (APPEA), AUSLIG, Woodside Petroleum, BHP, Bowman Bishaw Gorham, and LeProvost Dames and Moore. A total of 21 existing datasets were gathered that covered various parts of the region, with many of these datasets overlapping in spatial extent. **2.** Data was assessed for use in developing a regional dataset. There was little documentation available with individual datasets, so an initial assessment of these datasets was made on screen. It was found that; i) there were varying degrees of overlap in the spatial extent of these datasets, ii) a wide range of habitat classifications were used in the various datasets with minimal standardisation and conflicts in habitat description, iii) a wide range of methodologies were used to collect and develop this data and ground-truth the results. Detailed documentation of these methodologies was not available to assess the reliability and accuracy of these datasets and therefore prioritise their use. It was concluded that the spatial and attribute accuracy potentially varied widely both within and between datasets, but there was a lack of information detailing the level of accuracy in any particular area. To develop a single regional dataset it was decided to union the various datasets, prioritise them based on an assessment of their individual habitats and/or the individual dataset as a whole, and align their habitat classifications to the draft CALM standardised broadscale marine benthic habitat classification system. **3.** Datasets were prepared for unioning of data by undertaking the following steps; i) Datasets were standardised for projection and datum (geographical co-ordinates based on a WGS84 datum). ii) Standard attributes were assigned to each dataset. These were habitat description, source of dataset ground-truth information (if any available), and source of data (i.e. filename or reference data source). Attributes were populated across all datasets with some of this information being extracted from information supplied with the data.

iii) Attribute fields in the source datasets that were superfluous in relation to this project were removed.

4. Datasets were unioned in order to bring all datasets into one layer. This was done using the union functionality of the Geoprocessing wizard in Arcview3.2. A total of 15 unions were made. There were areas of spatial overlap in the individual datasets, sometimes with similar habitat descriptions, sometimes different. To accommodate these extra descriptions in the unioned dataset, three extra sets of the standard attributes were added. As such the final unioned dataset consisted of a single layer containing all polygons from all source datasets with 4 sets of attributes of habitat description, source dataset ground-truth information, and source of data.

5. The four sets of habitat attribute values were looked at for similarity. Those that were definitely the same were resolved into one description, and their source information was also resolved into one attribute value with a '+' delimiting them. To assist this process, existing habitat attribute values were standardised as much as possible to resolve the problem of multiple occurrences of the same habitat type being coded in different ways.

6. A new attribute (D*_CALM where * = attribute set number) was added to each of the four sets of attributes. This was to accommodate the CALM interpreted habitat type from the CALM standard broad scale marine habitat classification system (see 'Additional Metadata' below for further details of this system). This field would be populated through several steps over the final processing of the data with D1_CALM becoming CALM's final interpreted/interpolated habitat type.

The first stage of the population of this attribute was done in the following steps;

i) the attribute was populated if a direct interpretation could be made from the existing source dataset habitat classification without making subjective assumptions.

ii) superfluous attribute values were removed if there was no other description e.g. blanks , 'water', 'unknown - lack of data', etc.

7. The dataset was reduced in size to cover the Montebello/Barrow/Lowendal Islands marine conservation reserve study area and slightly beyond.

8. The dataset datum was converted to AGD84 and data was projected to AMG Zone50 for later calculation of habitat areas, and in order to facilitate dataset overlay and comparison with digital satellite imagery and Digital Multi-Spectral Video (DMSV) data.

9.A spatial data clean-up process was undertaken concurrently with further attribute clean-up using specialist knowledge of marine ecologist, GIS specialists, and field officers familiar with the region. This was done through the following steps;

i) In order to resolve multiple habitat descriptions, all habitat datasets were compared on screen and prioritised based primarily on their attribute accuracy, and secondarily on their spatial accuracy. The priority habitat description was moved into the primary set of habitat attributes, i.e. D1_CALM and its associated source information. This comparison was done at the habitat attribute level, as well as the dataset level in order to get the best available spatial and attribute representation for each habitat type. Where datasets overlapped, this prioritisation was an exhaustive process that was undertaken using expert knowledge to assess attribute accuracy, and referring to hard copy aerial photography, high resolution DMSV data, and digital satellite imagery to assess spatial accuracy. Further documentation of the details of this prioritisation is available in the PROCESSING directory.

The priority sources of attribute information were the ground truth point data from a CALM field trip undertaken in June 1999, a habitat map supplied by the Australian Petroleum Production and Exploration Association Ltd (APPEA), aerial photography from DOLA job number 940591 (West Pilbara Coast & Islands, 1:20 000, 25 August - 17 September 1994), and digital multi-spectral video (DMSV) data supplied by Apache Energy.

The priority sources of spatial information were bathymetric data provided by Department of Transport and Apache Energy, the DMSV data and aerial photography mentioned above, and digital geo-referenced Landsat5 satellite image scenes.

	ii) Draft habitat maps at equivalent scale to aerial photography (1:20000) were produced for review. These maps contained habitats, bathymetry and ground-truth information. Adjustments to the draft maps were made using CALM ground-truth information as a guide, visual interpretation based on the aerial photography and DMSV where habitats were visible, and using a modelling process where they were not visible, e.g. for the coral community around bommie fields (see Bancroft et al (2000) for further details). iii) Adjustments made to the draft maps were incorporated digitally into the unioned dataset. The source datasets used as a reference for the adjustments were added to the SOURCE_D* attribute to enable tracking of these contextual datasets. Further documentation of the details of this process are available in the PROCESSING directory. Any necessary additional digitising was generally done at 1:30 000 scale or better. Several data sources were used directly, or as references to supplement or improve the dataset. **10.** Two rounds of drafts were produced and reviewed, and changes incorporated into the data. **11.** GIS processes were run on the dataset to identify areas of overlapping polygons. These areas were prioritised based on habitat classification, and duplicate areas removed. **12**. Attribute values were checked for standardisation, and anomalies resolved.
Positional Accuracy	Habitats are identified at a broad scale only and are suitable for regional analysis and representation. The spatial accuracy varies across the dataset depending on the accuracy of the source dataset used in a particular area. Ideally ortho-rectified digital aerial photography would be used as a base on which to assess positional accuracy, however this was not available over the full extent of the study area. Further metadata was requested with supplied datasets, but was not readily available. Data suppliers informed us that information existed in several reports which would have to be located and interrogated for relevant metadata. Even then it would be difficult attaching each dataset to the detail in a particular report. Thus to acquire metadata as per the ANZLIC standard would require substantial work and resources. Due to the absence of detailed metadata, source data could not be assessed for spatial accuracy based on the methodology used to collect the data. Source dataset ground-truthing point data and a description of how this was collected was not available. Details of the backdrop used to delineate the boundaries of the source data habitat was also not available. As such, data processing had to proceed in the absence of this information. Additional linework was added to the unioned dataset from a variety of reference sources, particularly for CALM interpolated habitats. Reference datasets were used based on the most accurate, or only available relevant data, and include bathymetry data from Dept of Transport and Apache Energy, coastline data from Dept of Land Administration (DOLA) and Apache Energy, habitat data from Australian Petroleum Production and Exploration Association Ltd (APPEA), digital satellite imagery from DOLA, hard copy aerial photography from DOLA, and digital multi-spectral video(DMSV) data from Apache Energy. Reference datasets were used by either incorporating original linework into the unioned dataset, or digitising linework using the source dataset as a guide (see the field SOURCE_D* in the dataset for details). Linework was digitised at scale 1:30 000 or better. The spatial accuracy of these reference datasets varies both between and within these datasets. Detailed accuracy information is not readily available with most datasets. Available information on spatial accuracies is detailed below; - the Landsat imagery is generally considered accurate to within 4 pixels or better, i.e. +- 100 metres.

Attribute Accuracy	The classification system used for this project is broad scale only, and designed for interpretation at regional scales. The development of the standard broad scale habitat classification system on a statewide basis is a large and ongoing task. This system is being developed to facilitate a more systematic and standardised approach to marine habitat classification and will be refined and improved as anomalies arise that warrant modification to the system. Specific sub-categories are being developed to provide the appropriate level of detail required for the marine reserve planning process. Due to the absence of detailed metadata, source data could not be assessed for attribute accuracy based on the methodology used to collect the data. The ground-truthing point data and a description of how this was collected was not available. As such, data processing had to proceed in its absence. It was thus assumed that attribute classification was correct. For every polygon in the unioned dataset, there were up to four habitat attributes. As part of the prioritising process, source data layers were assessed for their habitat attribute accuracy, and the priority layer moved into the group of primary attributes. The source dataset from which every individual polygon was derived is detailed in the field SOURCE_D* in the dataset. When a new line was added to the data, the details of how it was derived are also detailed in the field SOURCE_D*. Attribute accuracy of habitat polygons could potentially be affected by a shift in positional location in the source dataset. This was taken into account (where possible) by visual inspection and identification of corresponding habitat shapes on aerial photography/Landsat imagery. While every effort was made to accurately attribute habitat polygons, a balance had to be maintained between achieving accuracy on a regional scale (versus a local scale) and the time available to produce this dataset. Some polygons were difficult to attribute accurately using the available data, aerial photography, and the current knowledge and ground-truthing of the area. In these cases, habitat boundary delineation was modelled based on either linear interpolation between points of known habitat type, or field verified bathymetric modelling. See Bancroft et al., (2000) for further details. This interpretation will remain until further field work verifies otherwise. The delineation between habitats is shown by abrupt changes in habitat classification. In reality some changes are more often a gradual transition from one habitat to another. As a result the location of some habitat boundaries should be considered as approximate only. These habitats include many of the extensive deeper subtidal (10m depth) and nearshore subtidal habitats which were difficult to distinguish with remotely sensed information. In addition, relatively limited ground-truthing data has been used in determining these habitats due to their extensive area. See Bancroft et al., (2000) for further details.
Logical Consistency	Topological problems were discovered in the data, many of these originating in the source datasets as a result of their method of derivation. Some are also due to the data processing software. Many of these problems were resolved during the processing of the data, however some anomalies with regard to overlapping polygons, duplicate areas, and unattributed sliver polygons of small area still exist in the data. These need to be resolved using ArcInfo.
Completeness	The dataset will be upgraded as priorities, time and resources permit. Further work needs to be undertaken on delineation and ground-truthing of many habitat features, particularly those that have been modelled and are of extensive area, and those that are less substantial in size, e.g. shoreline reefs. See Bancroft et al., (2000) for further details. Also many major sand patches are still incorporated in the 'Macroalgae(limestone reef)' classification and need to be delineated.
CONTACT INFORMATION	
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METADATA DATE	
Metadata Date	08 September 2000
ADDITIONAL METADATA	
Additional Metadata	

APPENDIX III. GIS METADATA FOR THE MAJOR COASTLINE HABITATS FOR THE PROPOSED MONTEBELLO/BARROW ISLANDS MARINE CONSERVATION RESERVE

DATASET	
Title	**Hab_montes_onshore27072000_amg50_agd84** - Onshore Coastline Habitats of the Montebello/Lowendal/Barrow Island's Area
Custodian	Department of Conservation and Land Management (CALM)
Jurisdiction	Western Australia
DESCRIPTION	
Abstract	This dataset consists of linework detailing the onshore coastline habitats of WA's Montebello Islands, Barrow Island and Lowendal Islands and covers approximately 384 kilometers of coastline. The dataset is complemented by a polygon dataset detailing the major marine benthic habitats of the same area (hab_montesddmmyyyy_amg50_agd84). These datasets were developed to assist in the planning process for the implementation of a proposed Montebello/Barrow Island marine reserve. The coastline is delineated into areas of '**Beach**', '**Rocky shore**', '**Beach + Rocky shore',** or '**Mangal**' and attributed accordingly. Lines are further attributed with direction the habitat is facing, habitat length (metres), and beach width (maximum and average in metres). The base coastline linework was provided by Apache Energy coastline datasets. The DOLA coastline was not used due to the much lower resolution in this area. A source attribute has been added to each line based on Apache Energy's source dataset. NOTE: Since the compilation of this dataset, DOLA have reviewed the coastline in this area and have now incorporated the Apache coastline linework data into the statewide DOLA coastline dataset. Habitats were identified from aerial photography. Beach widths were measured from the aerial photography using a scale rule, and a scaled adjustable magnifying glass where necessary. Habitat facing directions were determined using a transparency of a compass rose (360 degree circle). The dataset was compiled by Kristin Milton and Oliver Looker in July 2000.
Search Word(s)	
Geographic Extent Name(s)	Pilbara (offshore) IMCRA region
DATA CURRENCY	
Begin Date	30/08/1994
End Date	17/09/1994
DATASET STATUS	
Progress	Complete
Maintenance & Update Frequency	As required

ACCESS	
Stored Data Format	DIGITAL ArcView shapefile, projected to Australian Map Grid Zone 50 from Australian Geodetic Datum 1984 (AGD84).
Available Format Type	DIGITAL ArcView 3.2 shapefile
Access Constraint	Data available for external use subject to transfer fee and license conditions. Data is not to be distributed without authorisation from CALM. Contact CALM's database administrator for further details.
DATA QUALITY	
Lineage	**1.** A draft standardised broadscale marine habitat classification system was developed by Kevin Bancroft and Dr Chris Simpson of CALM Marine Conservation Branch (see 'Additional Metadata' below for further details of this system). NOTE: The classification system is being refined on an on-going basis. **2.** Over the Montebello' s and Lowendal's, a rectified digital multi-spectral video (DMSV) image of 2metre resolution (supplied by Apache Energy) was used as a reference base for the habitat mapping to facilitate accurate location of coastline features. Over Barrow Island, a rectified Landsat 5 TM image was used as a reference base. **3.** The Apache Energy coastline datasets were used as the base linework for the coastline habitats to be 'split' and attributed as necessary. A source attribute was been added to each line based on the filename of Apache Energy's coastline source. The field DISCREPANCY was added to note any large discrepancy between aerial photographs and the coastline dataset. This occurred infrequently. **4.** Aerial photographs were then used as a reference to delineate onshore coastal habitat boundaries on the base coastline. The aerial photographs were from Department of Land Administration job number 940591.00 (West Pilbara Coast & Islands, 1:20 000, 30 August - 17 September 1994). Aerial photography coverage was not complete over the full length of the coastline. In such instances the Landsat data was used to determine coastline habitat. These areas are identified in the field SOURCE_A and were in-frequent. Habitat identification was determined visually from the hard copy aerial photography, and also by using a scaled adjustable magnifying glass where necessary. Habitat boundaries were delineated (according to CALM's draft standardised habitat classification system) into areas of '**Beach**', '**Rocky shore**', '**Beach + Rocky shore**' or '**Mangal**' and attributed accordingly. Delineation was done using the 'split line' functionality of ArcView 3.2. Lines containing beach habitats were then attributed with beach width (average and maximum). This was measured in metres from the aerial photography using a scale rule, and a scaled adjustable magnifying glass where necessary. Habitats were further attributed with direction the habitat is facing. This was determined using a transparency of a compass rose (360 degree circle). See 'Attribute Accuracy' below for further details. Habitat length was calculated using the CALM added functionality extension (Calc length).

Positional Accuracy	Habitats extents were delineated as accurately as was possible in the time frame for the project. Lengths are estimated to be within 100 metres over areas covered by aerial photography, however the accuracy is probably better in many areas. Ground-truthing needs to be undertaken to verify this accuracy. Positional accuracy of the coastline is as accurate as the source dataset, i.e. the Apache Energy coastline. Positional accuracy information and details of collection methodology were not supplied with the Apache Energy data. Visual inspection of the Apache coastline indicated close correlation with the DMSV data and this may have been used as a base upon which the coastline was digitised. The accuracy of the coastline in relation to its geo-referencing was not assessed. The DISCREPANCY field was used to note any large discrepancy between aerial photographs and the coastline dataset. This occurred infrequently.
Attribute Accuracy	Habitat classifications were determined visually from aerial photography, and while every effort has been made to assign these correctly, there may be some errors. The habitats are accurate as best determined at the time of aerial photography (August - September 1994). Coastlines by their very nature are dynamic and subject to change due to natural and man-made forces. This is particularly the case with the movement of sand up and down the coast, and as such beaches may form and disappear with the passing of time. Ground-truthing needs to be undertaken to verify attribute accuracy. Beach widths were measured from the aerial photography using a scale rule, and a scaled adjustable magnifying glass where necessary. These widths are estimated to be accurate to within 10 metres at the time of photography. Ground-truthing needs to be undertaken to verify this accuracy. Beach directions were determined using a transparency of a compass rose (360 degree circle) and the digital linework. Directions were assigned based on the seaward direction the habitat was facing. The following domain was used based on the seaward perpendicular of the bearing of the habitat. east = 337.5^o- 22.5^o south-east = 22.5^o - 67.5^o south = 67.5^o - 112.5^o south-west = 112.5^o - 157.5^o west = 157.5^o - 202.5^o north-west = 202.5^o - 247.5^o north = 247.5^o- 292.5^o north-east = 292.5^o - 337.5^o Where there were obvious conflicts in the digital coastline and the aerial photography, the digital coastline direction was used to override that of the aerial photography. This was very in-frequent. Where small islands (perimeter < 50m) were found with only one type of coastline habitat, the line was not split, and the DIRECTION attribute was labelled 'NEW' (i.e. the coastline facing 360 degrees). The classification **Beach + Rocky shore** included both the following areas: 1) where there was a beach that had a rocky shore abutting it from the landward side, and may also have had the rocky shore extending into the beach, 2) where a beach was divided along its extent by the emergence of a rock platform through the beach. These classifications have not been discerned in the dataset. To determine which category a particular **Beach + Rocky shore** classification falls into, the relevant aerial photograph would need

	to be viewed. Areas where Landsat data was used to attribute habitat (i.e. where there was no aerial photography coverage) include part of the west coast of Barrow Island, the southern half of Bode Island, and Pasco Island. Habitat delineation and attribution is less reliable in these areas due to the reference data resolution. These areas were not attributed with a direction. The small area of mangrove in the Lowendal Islands(Varanus Island) has not been identified in the dataset.
Logical Consistency	DOLA ran the original coastline through a cleansing program to ensure there were no gaps, undershoots or overshoots, resulting in a complete coastline.
Completeness	The dataset will be upgraded as priorities, time and resources permit. Further work needs to be undertaken on ground-truthing.
CONTACT INFORMATION	
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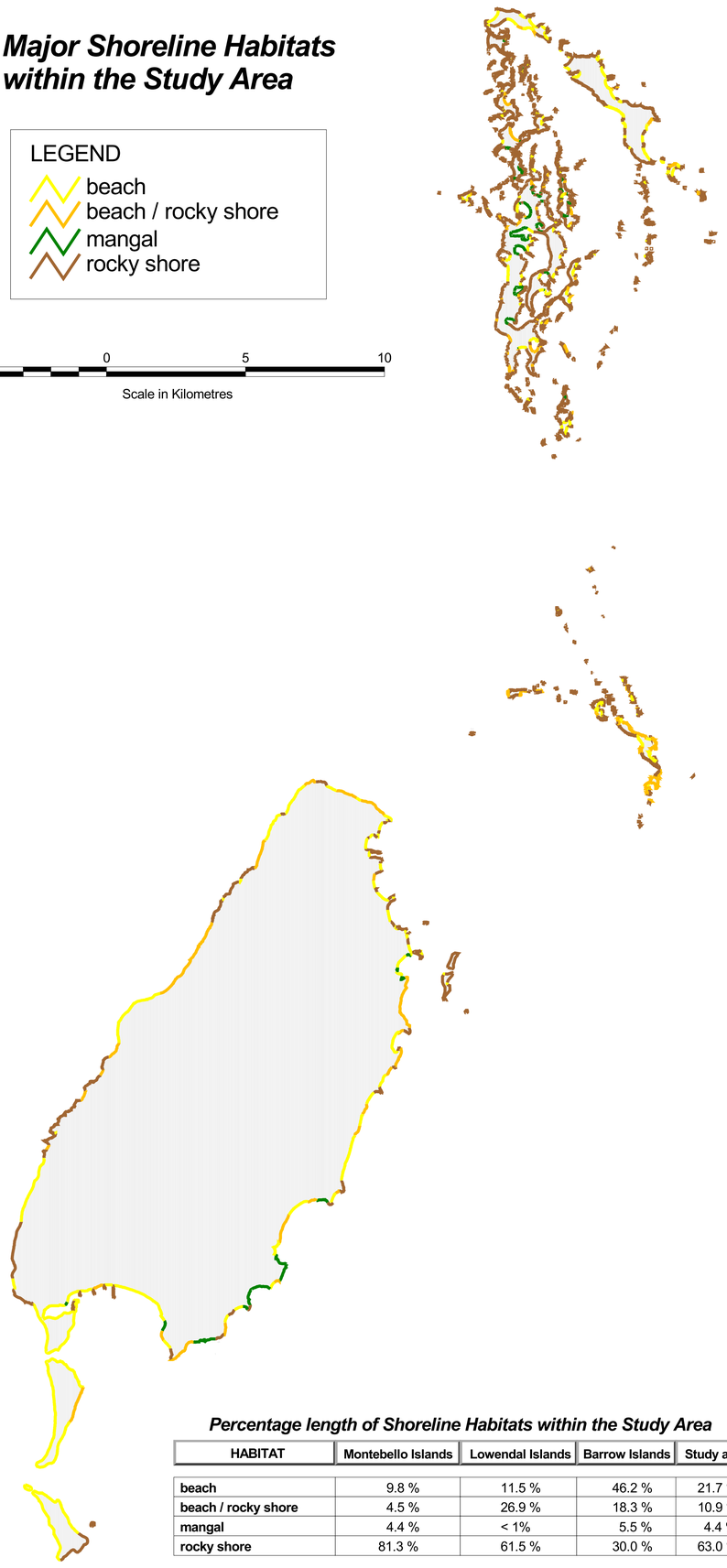
METADATA DATE	
Metadata Date	14 September 2000
ADDITIONAL METADATA	
Additional Metadata	

Major Shoreline Habitats within the Study Area

LEGEND
- beach
- beach / rocky shore
- mangal
- rocky shore

5 0 5 10
Scale in Kilometres



Percentage length of Shoreline Habitats within the Study Area

HABITAT	Montebello Islands	Lowendal Islands	Barrow Islands	Study area
beach	9.8 %	11.5 %	46.2 %	21.7 %
beach / rocky shore	4.5 %	26.9 %	18.3 %	10.9 %
mangal	4.4 %	< 1%	5.5 %	4.4 %
rocky shore	81.3 %	61.5 %	30.0 %	63.0 %

Major Marine Habitats of the Montebello/Barrow Islands Region

Compiled by CALM Marine Conservation Branch, August 2000

CALM
CONSERVATION & LAND MANAGEMENT

Legend and Percentage Area of Habitats within the Study Area

		% Area
	Study area for a proposed Montebello/Barrow Island's marine conservation reserve	
	Land	NA
	Beach	0.2
	Mangal	< 0.1
	Mudflat	< 0.1
	Sand shoal	0.6
	Shoreline reef	1.2
	Coral reef communities (intertidal or shallow/limestone)	2.9
	Coral reef communities (subtidal)	3.9
	Subtidal reef (low relief)	3.9
	Subtidal reef (low relief) / Sand	39.7
	Macroalgae (limestone reef)	45.2
	Sand	2.3
	Pelagic	< 0.1

Scale in Kilometres
5 0 5 10

This marine habitat map has its origins in the datasets developed by Apache Energy. Numerous subsequent marine benthic habitat surveys undertaken by the public and private sectors have provided additional information.

This map should not be used for navigational purposes.

The delineation between habitats on the map is shown by abrupt changes in habitat classification. In reality changes are more often a gradual transition from one habitat to another. As a result, the location of some habitat boundaries should be considered as approximate only.

In addition relatively limited ground-truthing data has been used in determining these habitats due to their extensive area.

For further information on data sources and methods, refer to:

Bancroft K.P. and Sheridan M.W. (2000). The major marine habitats of the proposed Montebello /Barrow Island's marine conservation reserve. Report MRI/PI/MBI-48/2000. August 2000. Marine Conservation Branch, Department of Conservation and Land Management, Fremantle, Western Australia. (Unpublished report).

D:\Projects\Pilbara\Montes_Dampier\Habmaps' habmaps_finals.apr (Montes A0)

North West Island
Alpha Island
Trimouille Island
MONTEBELLO ISLANDS
Hermite Island
Ah Chong Island
Parakeelya Island
LOWENDAL ISLANDS
Varanus Island
Abutilon Island
Cape Dupuy
Surf Point
Cape Malouet
Whitlock Cove
Double Island
Flacourt Bay
Dove Point
Latitude Point
BARROW ISLAND
Cape Poivre
Town Point
Eagles Nest
Bandicoot Bay
Shark Point
South End
Stokes Point
Middle Island
Boodie Island
Pasco Island
Barrow Island
Shoals

N W E S