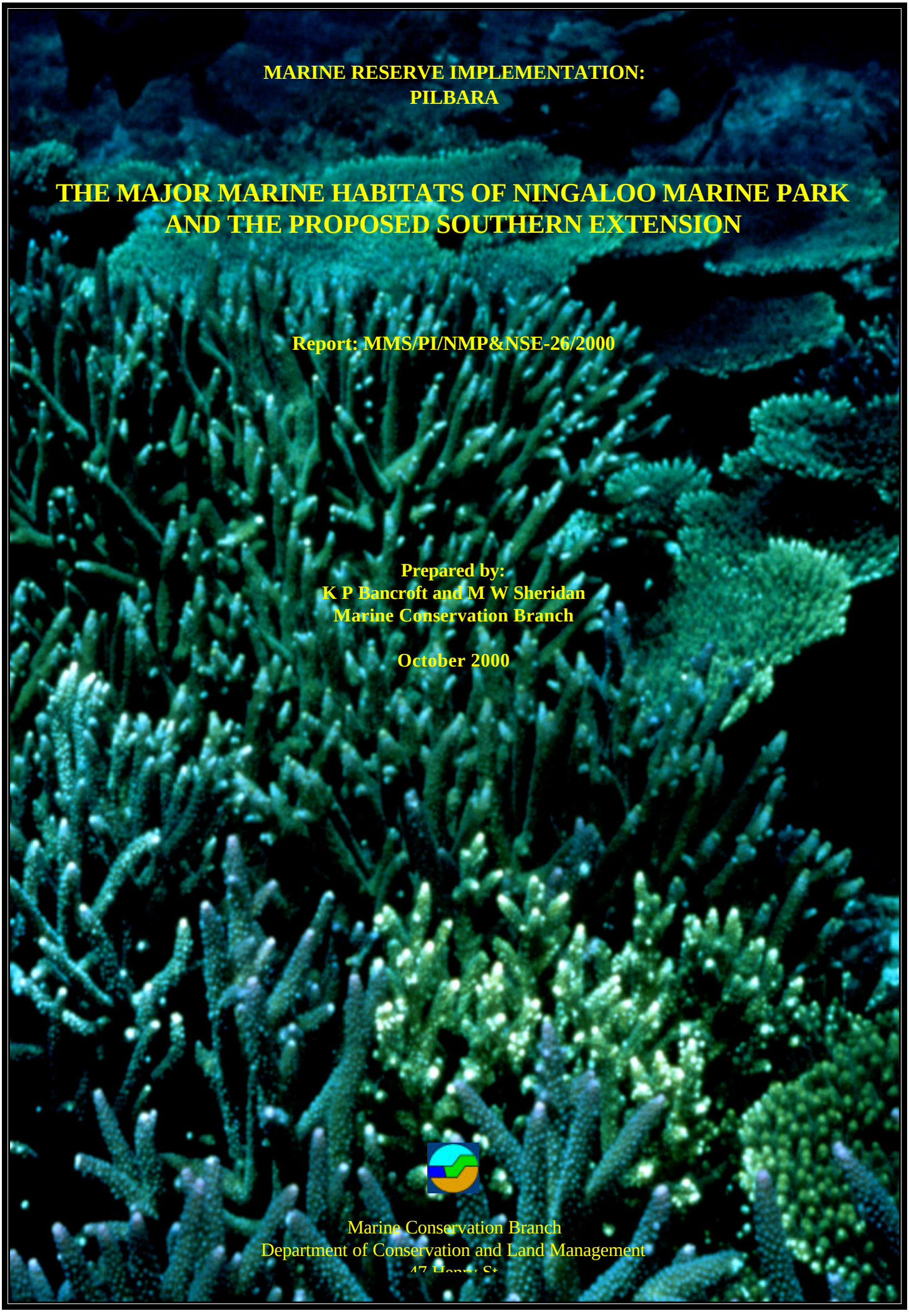

MARINE RESERVE IMPLEMENTATION:
PILBARA

THE MAJOR MARINE HABITATS OF NINGALOO MARINE PARK AND THE PROPOSED SOUTHERN EXTENSION

Report: MMS/PI/NMP&NSE-26/2000

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

October 2000

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EXECUTIVE SUMMARY

To present the biological resource information required for ongoing management of the Ningaloo Marine Park and the information requirements of the planning for the marine reserve implementation planning process for the proposed southern extension, a map highlighting the major marine benthic habitats of the 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 detailed small-scale species level biodiversity data (Ward *et al.*, 1999). The map of major marine benthic habitats of the study area will be used as a biodiversity surrogate and, as such will be used in the planning process and will also be essential for the future management of Ningaloo Marine Park and the proposed southern extension.

The purpose of this report is to:

(i) provide information, in the form of a broadscale map of the major marine benthic habitats for the Ningaloo Marine Park and the proposed southern extension;

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

(iii) document the metadata for the GIS information layers and;

(iv) provide a more comprehensive description of habitat types.

Cover: Coral reef community, Ningaloo Reef

This report may be cited as:

Bancroft, K. P. and Sheridan, M. W. (2000). The major marine habitats of Ningaloo Marine Park and the proposed southern extension. Report: MMS/PI/NMP&NSE-26/2000. October 2000. Marine Conservation Branch, Department of Conservation and Land Management, 47 Henry St., Fremantle, Western Australia, 6160. (unpublished report).

Copies of this report may be obtained from:

Marine Conservation Branch
Department of Conservation and Land Management
47 Henry St., Fremantle, Western Australia, 6160

Ph: 61-8-9432 5100; Fax: 61-8-9430 5408

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1 INTRODUCTION

Ningaloo reef is a fringing barrier coral reef system, which is situated on the western side of Cape Range Peninsula with the exception of the Bundegi area on the eastern side. In order to protect the conservation and recreation values of the coral reef system, the area was reserved as a Marine Park (CALM, 1989). Ningaloo Marine Park was gazetted in 1987.

To assist in managing the Ningaloo Marine Park, the Ningaloo Marine Park Management Plan was developed (CALM, 1989), in which there are many management strategies. It is necessary to have a comprehensive knowledge of the marine biological resources within the Ningaloo Marine Park to achieve many of these strategies.

In December 1997, the Western Australian Government, following advice provided by the Western Australian Marine Parks and Reserves Authority, announced the southern extension to Ningaloo Marine Park, a Marine Parks and Reserves Selection Working Group (MPRSWG) recommended area, as being a priority area for establishment as a marine conservation reserve. Subsequently, the Marine Conservation Branch (MCB) of the Department of CALM has initiated the planning process for implementing a marine conservation reserve.

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 present the biological resource information required for ongoing management of the Ningaloo Marine Park and the information requirements of the planning for the marine reserve implementation planning process for the proposed southern extension, a map highlighting the major marine benthic habitats of the 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 detailed small-scale species level biodiversity data (Ward *et al.*, 1999). The map of major marine benthic habitats of the study area will be used as a biodiversity surrogate and, as such will be used in the planning process and will also be essential for the future management of Ningaloo Marine Park and the proposed southern extension.

East, and covers an area of approximately 2600 km^2 (Figure 1).

The study area is broadly defined as the State Territorial Waters from Bundegi Reef 5 km north of Exmouth, to Red Bluff. This area includes Northwest Cape, Winderabandi Point, Point Cloates, Point Maud, Amherst Point and Cape Farquhar.

4 METHODS

4.1 HABITAT CLASSIFICATION

The major marine benthic habitats in the Ningaloo Marine Park and the proposed southern extension were based on the classification outlined in the draft statewide marine benthic habitat classification scheme presented in Appendix I. The classification system is being developed 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 and marine park management.

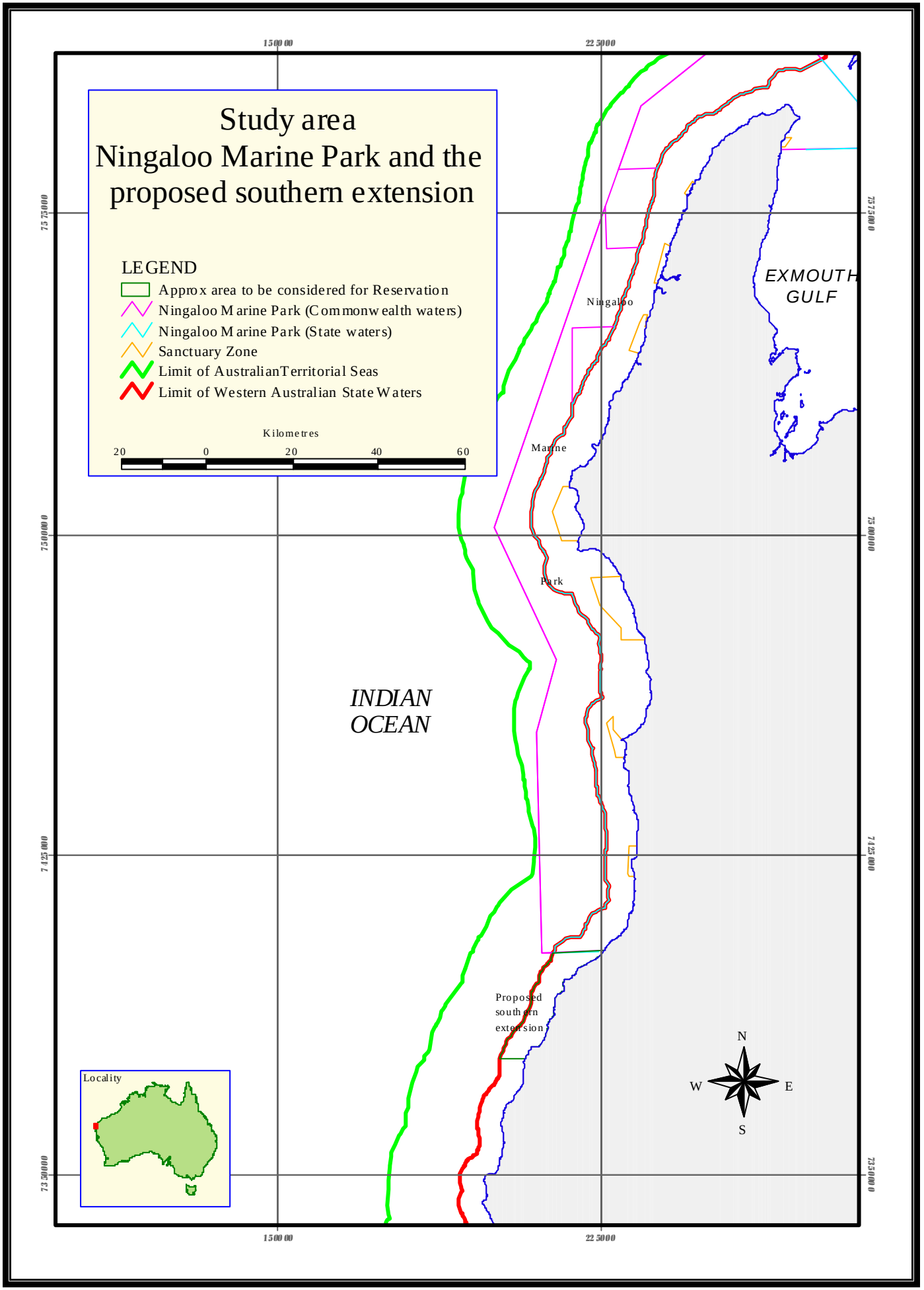

Figure 1. Study area for the Ningaloo Marine Park and propose southern extension

4.2 MAPPING METHODS

4.2.1. Major marine benthic habitats

The broadscale map of the major marine benthic habitats in the Ningaloo Marine Park and the proposed southern extension was developed using Geographical Information Systems (GIS) software, ArcView Version 3.2 (ESRI). Habitats were identified at a broadscale only and are suitable for regional analysis and representation at a scale of 1:100000. An outline of the method used in the mapping of the marine benthic habitats is as follows:

(a) Habitat polygons were delineated on a rectified Landsat 5TM base using hard copy aerial photographs as a guide, and identified using a combination of ortho-rectified and aerial photography, and expert knowledge.

(b) Habitat point data collected in the field (50 sites) by the MCB, was incorporated into the habitat map (Bancroft, 1999). This data assisted in further classification of habitat shapes.

(c) In areas where remotely sensed data was unavailable due to excessive depth (generally >10 m depth) and/or turbidity (e.g. nearshore habitats), 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).

Further detail on the methods and data sources may be found in the metadata, presented in Appendix II (major marine benthic habitats).

4.2.2. Major coastline habitats

Major coastline habitats were classified by referring to remote sensing imagery, such as Landsat TM and/or aerial photogrammetry at a scale of 1:20000.

In the major coastline habitat dataset for Ningaloo Marine Park and the proposed southern extension region, a *beach/rocky shore* classification was used. This classification describes intertidal areas where the 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 may be found in the metadata, presented in Appendix III (major coastline habitats).

4.3 MODELLING

The final phase in the development of habitat layers for the broadscale habitat map for the Ningaloo Marine Park and the proposed southern extension 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 October 1999 (Bancroft & Lapwood, 1999; Bancroft, 1999), and environmental and local knowledge to develop a simple linear interpolation model where these habitat types may occur.

Two modelling techniques were used:

1. Linear interpolation model, and;

2. Field verified bathymetric modelling.

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 using remote sensing and photogrammetry was difficult. The major areas that were modelled include the deeper (>10 m depth) offshore areas.

4.3.2. Field verified bathymetric model

The field verified bathymetric model uses a combination of field verified data, existing GIS layers, local knowledge and environmental parameters, such as depth, exposure to swell, waves and current speed. This model was developed using field data collected during the October 1999 survey of the proposed extension to the Ningaloo Marine Park (Bancroft & Lapwood, 1999; Bancroft, 1999) and information from the Ningaloo Marine Park Monitoring Program (Cary & Grubba, 1998; Cary *et al.*, 1998; Cary *et al.*, 1999; Daly & Cary, 1999). It was possible to use this model in the Ningaloo Marine Park as the habitat gradient was inshore - offshore (shoreline - lagoon - reef flat - reef crest - seaward reef slope - seabed) rather than a north - south gradient.

This model was mainly utilised to determine the classification and the spatial extent of habitats in:

(a) offshore turbid areas (breaker zone), and;

(b) offshore deeper (>10 m depth) reef platforms.

Offshore turbid areas (breaker zone)

The across reef model assumes that where the reef crest starts to drop off seaward (around the breaker line) is the transition between high coral cover (coral reef communities (subtidal)) and low coral cover (coral reef communities (intertidal or shallow/limestone)). Field verification data showed that the high live coral cover had a transition to subtidal reef (low relief/seaward) habitat at a depth of approximately 15 m. In some areas the photogrammetry discerned this transition and alternately in those areas where the transitions between habitats could not be discerned, the 20 m bathymetry was used to approximate this transition.

Subtidal reef (low relief/seaward) and subtidal reef (low relief/lagoonal)

Subtidal reef was split into two separate classifications: subtidal reef (low relief/seaward) and subtidal reef (low relief/lagoonal). These habitats are similar in substratum (low relief limestone pavement), however the exposure to different environmental conditions such as bathymetry, waves and currents influenced the spatial extent and biological assemblage structure.

Field data showed that the high live coral cover changed to subtidal reef (low relief/seaward) at a depth of approximately 15 m. In some areas, the photogrammetry discerned this transition and subsequently in those areas where it could not be discerned, the 20 m bathymetry was used to approximate this transition.

In the reef channels (ie. the breaks in the barrier reef) where the subtidal reef (low relief/seaward) meets the subtidal reef (low relief/lagoonal) habitats, the 10 m bathymetry was used to approximate this transition where no ground truth data was available.

4.4 HABITAT DESCRIPTIONS

Thirteen habitat types were identified in the broadscale map of the major marine benthic habitats of the Ningaloo Marine Park and the proposed southern extension (Figures 2 & 3):

1. Rocky shore;
2. Beach;
3. Saltmarsh;
4. Mangal;
5. Mudflat;
6. Shoreline reef;
7. Coral reef community (subtidal);
8. Coral reef community (intertidal or shallow);
9. Macroalgae (limestone reef/low relief);
10. Subtidal reef (low relief/lagoonal);
11. Subtidal reef (low relief/seaward);
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 Ningaloo Marine Park and the proposed southern extension marine.

4.4.1. 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 Ningaloo Marine Park and the proposed southern extension, rocky shores are typically wave-cut, unvegetated, low limestone reef which support a variety of mollusc species including oysters (*Saccostrea* spp.) and chitons (e.g. *Acanthopleura spinosa*) and other invertebrates such as crabs (Family Xanthidae).

4.4.2. 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 Ningaloo Marine Park and the proposed southern extension typically support a range of invertebrates including bivalve shells and seaurchins (*Diadema* sp.).

4.4.3. Salt marsh

The *salt marsh* habitat describes areas of low relief located in the upper intertidal and supratidal (immediately above HAT) zones of low energy coastlines. The substrata consist of muddy or silty terrigenous sediment. *Salt marsh* habitats often occur landward of mangals, tidal creeks and estuaries, and typically supports vegetation, but can also occur as unvegetated coastal saline flats. In the Ningaloo Marine Park and proposed extension burrowing crabs (*Uca* sp.) and ghost crabs (*Ocypode* sp.) are found in this habitat.

4.4.4. 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. There are two mangrove species, *Avicennia marina* and *Rhizophora stylosa*, which occur in the Ningaloo Marine Park and the proposed southern extension. Mangrove roots provide a substratum for many gastropods (e.g. *Natica*, *Cerithium*, *Strombus*) and other invertebrates, such as the mangrove crab (*Scylla serrata*) are often present.

4.4.5. 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*. In the Ningaloo Marine Park and the proposed southern extension, *mudflat* habitats are typically bare of vegetation, but support gastropods (e.g. *Cerinthium* sp.), crabs and invertebrate infauna.

4.4.6. 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 Ningaloo Marine Park and the proposed southern extension, *shoreline reef* habitat typically supports turf algae and invertebrates such as molluscs (*Tridacna* spp. clams, *Cypraea* sp. cowries), hermit crabs (*Dardanus* sp.) and isolated soft and hard coral communities.

4.4.7. Coral reef community (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 not 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

Ningaloo Marine Park and the proposed southern extension, areas of high coral cover are generally restricted to water depths of less than 15 m depth. Offshore, these habitats are dominated by the

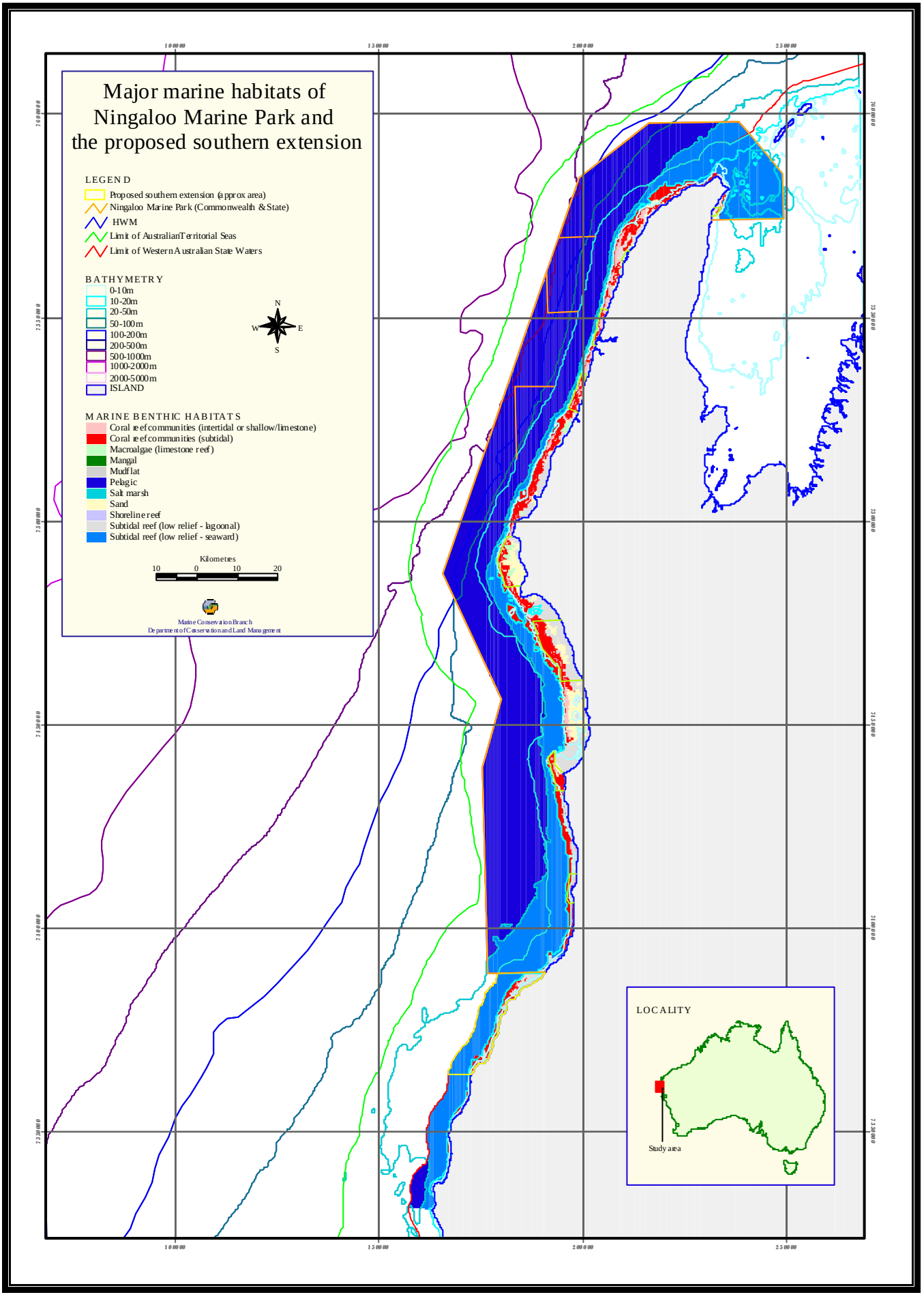

Figure 2. Broadscale map of the major marine habitats in the Ningaloo Marine Park and the proposed southern extension

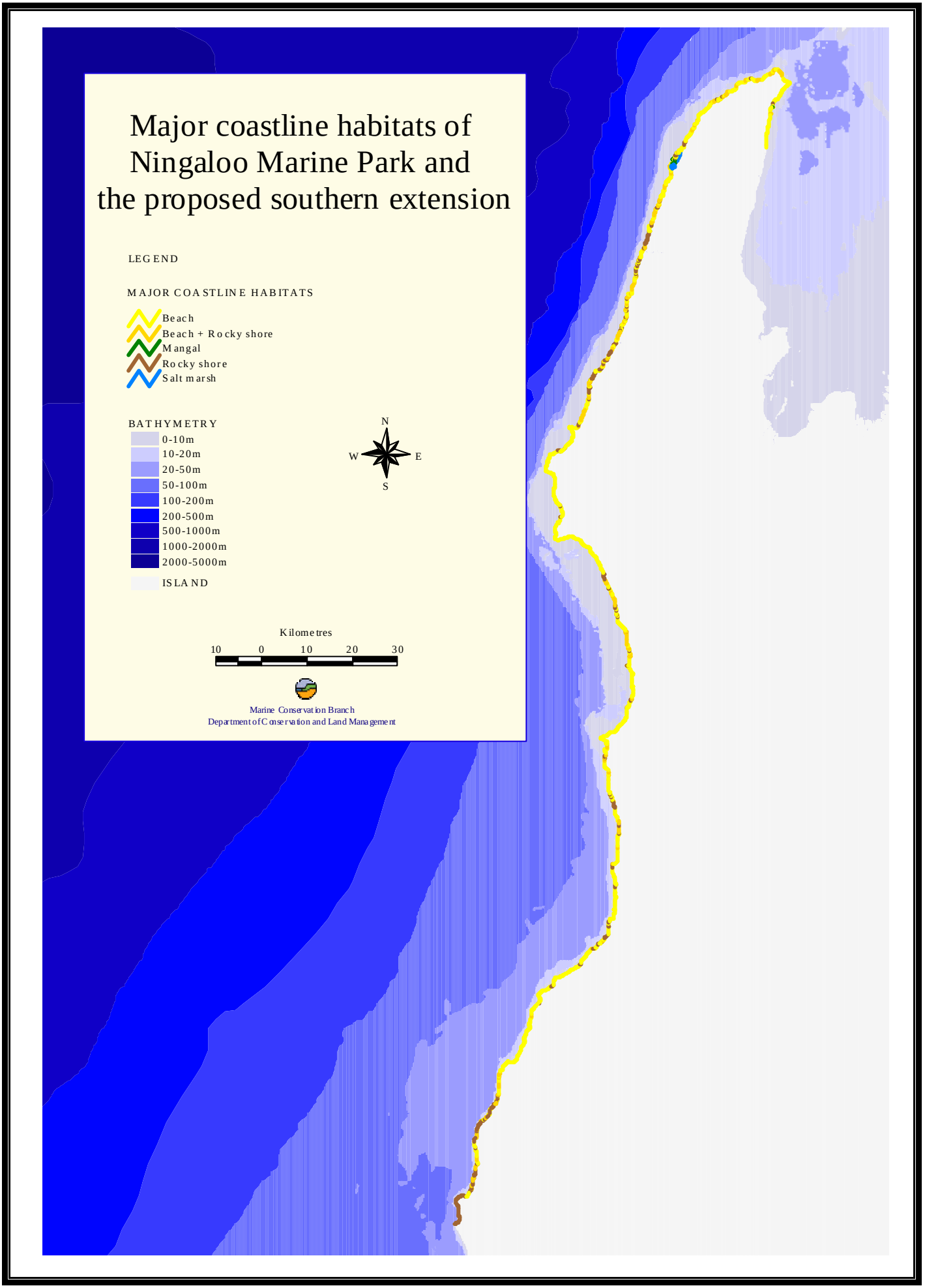

Figure 3. Broadscale map of the major coastline habitats in the Ningaloo Marine Park and the proposed southern extension

faster growing coral species such as *Acropora* (A. *hyacinthus*) and *Montipora* spp. However, in the lagoons of the Ningaloo Marine Park and the proposed southern extension, coral communities consist of a mixture *Acropora* species (e.g. *A. formosa*) and a diverse range of massive species, in particular from the family Faviidae. This habitat typically supports a high diversity and abundance of fish and other coral reef fauna.

4.4.8. Coral reef community (intertidal or shallow)

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.

4.4.9. Subtidal reef (low relief/lagoonal)

The subtidal reef (*low relief/lagoonal*) habitat describes subtidal areas of limestone substratum, that may incorporate sand patches, rubble and scattered isolated corals. This habitat typically is pavement, which may have low relief (<1 m high) and occurs within the sheltered shallow waters (<10 depth)of the lagoons of the Ningaloo Marine Park and the proposed southern extension. This habitat may support a diverse array of algae and sessile invertebrates including sponges, sea-whips and sea-pens, and may also support some macroalgae (e.g. *Turbinaria* sp., *Sargassum* sp., *Halimeda* sp.), or seagrass (e.g. *Halophila* sp.) in patchy mobile sands. Dugongs (*Dugong dugon*) are often seen feeding in this habitat within Ningaloo Marine Park, particularly north of Point Maud and off Bruboodjoo Point

4.4.10. Subtidal reef (low relief/seaward)

The subtidal reef (*low relief/seaward*) habitat describes subtidal areas of limestone substratum that may be predominantly covered by sand. This habitat typically is pavement, which may have low relief (<1 m high) and occurs in the more exposed deeper waters (>15 m depth) seaward of the barrier reef system of the Ningaloo Marine Park and the proposed southern extension. This habitat typically is bare or overlaid with large sand patches, however macroalgal turf and sessile invertebrates may also be present.

4.4.11. Macroalgae (limestone/low relief)

The *macroalgae (limestone reef)* habitats are areas of subtidal limestone substratum of low or high relief. In the Ningaloo Marine Park and the proposed southern extension, this habitat is found in shallower waters (<10 m depth) and may also incorporate mobile sand patches, and scattered isolated hard and soft corals. This habitat is generally 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.

4.4.12. 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 Ningaloo Marine Park and the proposed southern extension, *sand* habitats typically are bare, and may have seasonal vegetation or permanent patches of seagrass or macroalgae. Invertebrate infauna may also be present.

4.4.13. Pelagic

This category is specific to those areas that are greater that 50m in depth. The focus in this classification is not on substrates but rather on the macrobiology of the water column, hence pelagic environments may have various substrates. Pelagic fish and invertebrates, and larval stages of various phyla dominate the macrobiology of this habitat. In the Ningaloo Marine Park, whale sharks (*Rhincodon typus*) and manta rays (*Manta birostris*) are known to feed in the surface waters of this habitat.

4.5 HABITAT DISTRIBUTIONS

Marine benthic habitat percentages (Table 1) and coastal habitat percentages (Table 2) were calculated to highlight the dominant habitats in the Ningaloo Marine Park and the proposed southern extension.

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

Habitat type	Ningaloo Marine Park (%)	Proposed southern extension (%)	TOTAL Percentage (%)
Saltmarsh	<0.1	0	<0.1
Mangal	<0.1	0	<0.1
Mudflat	<0.1	0	<0.1
Shoreline reef	0.2	0.1	0.2
Coral reef community (subtidal)	7.1	2.5	6.1
Coral reef community (intertidal or shallow/limestone)	2.0	0.7	1.7
Subtidal reef (low relief/lagoonal)	5.5	2.1	4.7
Subtidal reef (low relief/seaward)	27.0	94.4	42.2
Macroalgae (limestone reef/low relief)	0.4	<0.1	0.3
Sand	5.5	2.1	4.7
Pelagic	55.2	0	43.0

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

Habitat classification	Ningaloo Marine Park (%)	Proposed southern extension (%)	TOTAL Percentage (%)
Beach	63.1	91.6	66.2
Beach/rocky shore	17.0	4.1	15.6
Rocky shore	12.3	4.3	11.4
Mangal	4.0	0	3.6
Saltmarsh	3.6	0	3.2

4.6 GROUND-TRUTHED DATA

There was a total of 50 habitat ground-truthing survey sites collected by the MCB during a survey conducted in October 1999 (Bancroft & Lapwood, 1999). This habitat data has been documented in a MCB Data Report (Bancroft, 1999). Habitat data collected for the Ningaloo Marine Park Monitoring Program were also referred to while developing the broadscale map of the marine benthic habitats for the Ningaloo Marine Park and the proposed southern extension (Cary *et al.*, 1998; 1999; 2000).

For further information on these habitat data, refer to the data reports: Bancroft, 1999; Cary *et al.*, 1998; 1999; 2000.

4.7 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 Ningaloo Marine Park and the proposed southern extension marine habitat data layers are presented in Appendix II (major marine benthic habitats) and Appendix III (major coastline habitats).

5 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 from a marine benthic habitat survey undertaken by the Marine Conservation Branch, Department of Conservation and Land Management.

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.

6 DATA MANAGEMENT

6.1 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 directory pathways:

1. The Marine Conservation Branch Server:
   mcb on 'StreetTalk\User Data@FREM.MCB@CALM'
   [T:\Current_MCB_reports\MMS\mms_2600]

2. MCB Server full backup DAT tape [T:\Current_MCB_reports\MMS\mms_2600]

3. CD-ROM [mms_2600]

4. MCB homepage on the Department of Conservation and Land Management Intranet CALMweb:
   http://calmweb.calm.wa.gov.au/drb/ncd/mcb/rep_pdf/mms_reps/mms_2000/mmsrep00.htm#mms_2600

6.2 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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8 APPENDICES

APPENDIX I. DRAFT BROADSCALE HABITAT CLASSIFICATION SCHEME (AS AT DEC 1999)

HABITAT CLASSIFICATION	TIDAL RANGE	SUBSTRATE TYPE	TROPICAL	TEMPERATE	RELIEF		MACROBIOLOGY	SUB-CATEGORIES	COMMENTS
1. Island	Supratidal	Sand igneous metamorphic sedimentary	✓	✓	high low	&	Can be vegetated or bare		• Permanent land above HWM • May have seasonal vegetation • Seabirds, terrestrial mammals & reptiles • Important for marine mammals as haul out or breeding areas
2. Rocky shore	Intertidal Supratidal	igneous metamorphic sedimentary	✓	✓	high low	&	bare		• continuous rocky shore • cliff, boulders, pavement • around HWM • "*uncomfortable to walk on*"
3. Beach	Intertidal Supratidal	sand	✓	✓	low		bare		• continuous intertidal sand • unvegetated • mobile sands • "*comfortable to walk on*"
4. Salt marsh	Intertidal Supratidal	mud silt	✓	✓	n/a		samphire saltmarsh blue-green algal mats can be 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	✓	✓	n/a		mangroves		• continuous mangrove cover (>1 ha) • mud/sand/intertidal reef/shoreline reef may be present

HABITAT CLASSIFICATION	TIDAL RANGE	SUBSTRATE TYPE	TROPICAL	TEMPERATE	RELIEF	MACROBIOLOGY	SUB-CATEGORIES	COMMENTS
								• intertidal gastropods and other invertebrates may be present
6. Mudflat	Intertidal	mud silts	✓	✓	low	bare blue-green algal mats		• continuous mudflat, intertidal or very shallow, <1m lowest astronomical tide (LAT) • includes mudflats behind mangals • intertidal gastropods and other invertebrates may be present
7. Sand shoal	Intertidal	sand	✓	✓	low	bare little macroalgae		• Often in offshore macrotidal areas • medium to coarse sand • highly mobile sand • Intertidal or very shallow, <1m lowest astronomical tide (LAT)
8. Shoreline reef	Intertidal	igneous metamorphic sedimentary	✓	✓	low	bare, algal turf		• continuous reef platform along the shoreline • may be bare or have macroalgal turf or sand patches • intertidal gastropods and other invertebrates may be present
9. Offshore intertidal reef	Intertidal	igneous metamorphic sedimentary	✓	✓	low	coralline algae, macroalgal turf, macroalgae		• Offshore reef • Intertidal or very shallow, <1m lowest astronomical tide (LAT) • intertidal gastropods and other invertebrates may be present

HABITAT CLASSIFICATION	TIDAL RANGE	SUBSTRATE TYPE	TROPICAL	TEMPERATE	RELIEF	MACROBIOLOGY	SUB-CATEGORIES	COMMENTS
10. Coral reef communities	Intertidal & subtidal	n/a	✓		high & low	hard & soft corals other sessile invertebrates	• **Coral reef communities (subtidal)** - subtidal, often high live coral cover , coral colonies with sand patches in lagoons ➢ *Seaward reef slope* ➢ *Deep lagoon* • **Coral reef communities (intertidal or shallow)** - intertidal or shallow, <1m lowest astronomical tide (LAT), often live coral cover is low, ➢ *Reef crest* ➢ *Back reef* ➢ *Reef flat* ➢ *Shallow lagoon*	• typical coral reef community-hard coral, soft coral, sponges, bryozoans, ascidians, etc. • seaward reef slope, reef crest, back reef, reef flat and individual bommies • some sand, pavement, macroalgae or seagrass interspersed
11. Subtidal reef platform	Subtidal	igneous metamorphic sedimentary	✓	✓	low	diverse algae sessile invertebrates (including sponges, sea-whips, sea-pens)	• **Subtidal reef platform (high relief)** - >1 m high • **Subtidal reef platform (low relief)** - <1 m high	• includes limestone pavement or low relief reef • may be covered with macroalgae or seagrass, patchy mobile sands • 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

HABITAT CLASSIFICATION	TIDAL RANGE	SUBSTRATE TYPE	TROPICAL	TEMPERATE	RELIEF	MACROBIOLOGY	SUB-CATEGORIES	COMMENTS
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
14. Seagrass meadows	Subtidal	sand pavement	✓	✓	low	seagrasses	• **Seagrass (perennial)** - ➢ Seagrass (perennial/dense) substrate cover < seagrass cover ➢ Seagrass (perennial/medium) substrate cover = seagrass cover ➢ Seagrass (perennial/sparse) substrate cover > seagrass cover • **Seagrass (ephemeral)** - ➢ Seagrass (ephemeral/dense) substrate cover < seagrass cover ➢ Seagrass (ephemeral/medium) substrate cover = seagrass cover ➢ Seagrass (ephemeral/sparse) substrate cover > 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

HABITAT CLASSIFICATION	TIDAL RANGE	SUBSTRATE TYPE	TROPICAL	TEMPERATE	RELIEF	MACROBIOLOGY	SUB-CATEGORIES	COMMENTS
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. METADATA FOR THE MAJOR MARINE HABITATS OF NINGALOO MARINE PARK AND THE PROPOSED SOUTHERN EXTENSION MARINE CONSERVATION RESERVE

DATASET	
Title	**Hab_ning15062000** - Major Marine Habitats of Ningaloo Reef 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 Ningaloo Reef area and covers the offshore waters of approximately 370 kilometres of coastline from Exmouth around to Red Bluff. Broad scale habitats extend from the shoreline to the boundary of the Ningaloo Marine Park in the northern part of the dataset, and from the shoreline to the Limit of Western Australian State Waters over the area under consideration for a proposed southern extension to the Ningaloo Marine Park. The dataset is complemented by a linework dataset detailing onshore coastline habitats of the Ningaloo reef area (**hab_ning_onshore11022000**). Habitats are identified at a broad scale only and are suitable for regional analysis and representation at 1:50 000. Habitats were delineated on a rectified Landsat 5 TM base using hard copy aerial photographs as a guide. Habitats were attributed using a combination of aerial photography, expert knowledge and ground-truthing from several field trips. The dataset was compiled by Mark Sheridan and Oliver Looker under direction from Ray Lawrie. The habitat classification system was developed by Dr Chris Simpson and Kevin Bancroft. Habitat attribution was undertaken by Kevin Bancroft, Dr Chris Simpson, and Jennie Cary. The project was undertaken in November 1999 - May 2000.
Search Word(s)	
Geographic Extent Name(s)	Ningaloo IMCRA region
DATA CURRENCY	
Begin Date	12/09/94
End Date	Current
DATASET STATUS	
Progress	In Progress
Maintenance & Update	As required

Frequency	
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 standard broad scale marine habitat classification system was developed by Dr Chris Simpson and Kevin Bancroft of CALM Marine Conservation Branch (see hab_classification.doc). NOTE: The classification system is being refined on an on-going basis. **2.** Hard copy base maps were compiled from a rectified Landsat 5 TM image covering the full extent of the habitat mapping project. These maps were produced at 1:20 000 scale and provided a spatially rectified base for the habitat mapping. **3.** Aerial photographs at equivalent scale to the base maps were then used as a reference to delineate habitat boundaries on the base maps. The aerial photographs were from Department of Land Administration job numbers 940592 (Point Quobba to North West Cape, 1:20 000, 12 - 27 September 1994) and 840048 (Ningaloo Marine Park, 1:20 000, 16 March 1985). Habitat boundaries were delineated according to CALM's standardised habitat classification system. Habitat identification was determined by expert knowledge of marine biologists (Kevin Bancroft, Dr Chris Simpson, Jennie Cary) who have many years experience in the area. Identification was aided by known ground-truth information collected on several CALM field trips to the area. **4.** Habitat boundaries were digitised on-screen using the Landsat image as a backdrop, and overlaid with ground-truth locations and their accompanying data. The current DOLA coastline was used to define the land water interface and hence the landward extent of the habitat mapping. This coastline was modified in only a few small areas where there was large conflict with the image data (e.g. Cape Farquhar). The Department of Transport 20 metre and 50 metre bathymetry contours were largely used as a surrogate to define the boundaries of the reef front coral habitat and the pelagic habitat. The Ningaloo Marine Park boundary/Limit of Australian Territorial Waters were used to define the seaward extent of the habitat mapping over the northern part of the area. The Limit of Western Australian State Waters boundary was used to define the seaward extent of the habitat mapping over the southern part of the area. **5.** The linework was reviewed, then cleaned and built in ArcInfo. The resultant polygons were then attributed. A dissolve in ArcView was run on the dataset based on interpreted habitat type. This was done to merge adjoining polygons of the same interpreted habitat type. Some of these dissolved polygons may need further ground-truthing.

Positional Accuracy	The rectified Landsat image used as a base to digitise the habitat boundaries is generally considered accurate to within 4 pixels or better. This equates to a positional accuracy of linework of +- 100 metres. Linework was digitised at scale 1:30 000 or better. While every effort was made to digitise the datasets accurately, the large pixel size (25 m) of the Landsat image, and the resultant spectral response, sometimes made it difficult to interpret corresponding locations on aerial photography and Landsat image. Some positional in-accuracies may have resulted, however these are estimated to be in-frequent.
Attribute Accuracy	The classification system used for this project is broad scale only, and designed for interpretation at regional scales of 1:100 000. The development of the standard broad scale habitat classification system on a statewide basis is a large and ongoing task. This system is close to a robust system, but will be refined and improved as anomalies arise that warrant modification to the system. Some polygons were difficult to attribute using the aerial photography, and the current knowledge and ground-truthing of the area. An interpretation of the marine habitat has been made on these polygons based on expert knowledge of marine biologists. This interpretation will remain until further field work verifies otherwise.
Logical Consistency	The digitised linework was cleaned and built in ArcInfo. It was then converted to an ArcView shapefile for attribution. The dataset has not been re-built after the dissolve based on habitat type was run in ArcView. The following points need to be considered when doing any further processing: - there is a small discrepancy in line locations (approx. 10 cm) between this dataset and its complementary coastline dataset. This is due to processing in ArcInfo in being done in single precision. As a result, any processing with this dataset and the DOLA coastline will result in sliver polygons being produced.
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	16 June 2000
ADDITIONAL METADATA	
Additional Metadata	- See accompanying habitat classification documentation further describing the classification system (see hab_classification.doc). NOTE: This system is still in development. Any feedback would be appreciated. See report: Bancroft, K.P. (1999). Broadscale habitat map and biological data of the major benthic habitats of the proposed southern extension to Ningaloo Marine Park (Amherst Point to Red Bluff). Data Report: MRI/MW/NSE-30/1999. December 1999. Marine Conservation Branch, Department of Conservation and Land Management, Fremantle, Western Australia. (Unpublished report).

APPENDIX III. METADATA FOR THE MAJOR COASTLINE HABITATS OF NINGALOO MARINE PARK AND THE PROPOSED SOUTHERN EXTENSION MARINE CONSERVATION RESERVE

DATASET	
Title	**HAB_NING_ONSHORE16062000** - Onshore Coastline Habitats of Ningaloo Reef 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 Ningaloo reef area and covers approximately 370 kilometers of coastline extending from Exmouth around to Red Bluff. The dataset was produced to complement the polygon dataset of marine benthic habitats of the Ningaloo reef area (hab_ning15062000). The coastline is delineated into areas of **Beach**, **Rocky shore**, or **Beach + Rocky shore** and attributed accordingly (there are also small areas of **Mangal** and **Salt marsh**). Lines are further attributed with direction the habitat is facing, habitat length (metres), beach width (maximum and average in metres). The base coastline linework was provided by DOLA. A source attribute has been added to each line based on DOLA's coastline source and/or method used to derive the coastline in any area. 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). Mark Sheridan compiled the dataset in December 1999 - January 2000.
Search Word(s)	
Geographic Extent Name(s)	Ningaloo IMCRA region
DATA CURRENCY	
Begin Date	12/09/94
End Date	Current
DATASET STATUS	
Progress	In Progress

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 standard broad scale marine habitat classification system was developed by Dr Chris Simpson and Kevin Bancroft of CALM Marine Conservation Branch (see **hab_classification.doc**). NOTE: The classification system is being refined on an on-going basis. **2.** A rectified Landsat 5 TM image covering the full extent of the habitat mapping project was used to provide a spatially rectified reference base for the habitat mapping, and facilitate accurate location of coastline features. **3.** The current DOLA coastline was used as the base linework for the coastline habitats to be 'split' and attributed as necessary. This coastline was modified in only a few small areas where there was large conflict with the image data (e.g. Cape Farquhar). A source attribute was been added to each line based on DOLA's coastline source and/or method used to derive the coastline in any area. **4.** Aerial photographs were then used as a reference to delineate habitat boundaries on the base coastline. The aerial photographs were from Department of Land Administration job numbers 940592 (Point Quobba to North West Cape, 1:20 000, 12 - 27 September 1994), 840048 (Ningaloo Marine Park, 1:20 000, 12 & 16 March 1985) and 820114 (Exmouth Peninsula, 1:25 000, 20 August, 1982). The 1994 photography was used wherever there was coverage. Coverage was not complete over the full length of the coastline, so the 1984 photography was used where this was the case, i.e. small areas on the western side of Cape Range, and on the eastern side from approximately Bundegi to Exmouth. The 1982 photography was only used for a small area of coastline (approx. 1.5km) located approximately 800 m north of Yardie Creek. Habitat identification was determined visually from the aerial photography, and also by using a scaled adjustable magnifying glass where necessary. Habitat boundaries were delineated (according to CALM's standardised habitat classification system) into areas of **Beach**, **Rocky shore**, or **Beach + Rocky shore** and attributed accordingly (there are also small areas of **Mangal** and **Salt marsh**). Delineation was done using the 'split line' functionality of ArcView 3.2 and was generally done to coincide with the offshore polygons contained in the complementary dataset of marine benthic habitats.

	Lines containing beach habitats were then attributed with beach width (average and maximum). This was estimated 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 is possible to determine from 1:20 000 scale aerial photography, and are estimated to be within 20 metres. Ground-truthing needs to be undertaken to determine them with greater accuracy. Accuracy of DOLA's coastline linework is not stated. DOLA has compiled this dataset from a number of sources of best available information including 1:2 000, 1:50 000 and 1:100 000 scale datasets. These source datasets were collected at various levels of positional accuracy, and as such each individual line is as accurate as its source data. The source attribute in the shapefile identifies these sources. The DOLA coastline was modified in only a few small areas where there was large conflict with the Landsat image data and the aerial photography (e.g. Cape Farquhar).
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 (12-27 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 determine habitats with greater accuracy. - Beach widths were estimated 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 5 metres. Ground-truthing needs to be undertaken to determine them with greater accuracy. - Habitat 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 marked conflicts in the digital coastline and the aerial photography, the aerial photography direction was used to override that of the digital coastline. This was very in-frequent. - Habitat lengths were determined based on the arc length of the DOLA coastline (after splitting) and calculated automatically using the CALM extension for Arcview3.2. Lengths were rounded to the nearest metre. - 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.
Logical Consistency	The digitised linework was converted to an ArcInfo coverage using double precision to remove inconsistencies in the data. The data was not cleaned as this was done on the coastline by DOLA. It was then converted back to a shapefile.
Completeness	The dataset will be upgraded as priorities, time and resources permit. Further work needs to be undertaken on ground-truthing.
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METADATA DATE	
Metadata Date	16 June 2000
ADDITIONAL METADATA	
Additional Metadata	- See accompanying habitat classification documentation further describing the classification system (see hab_classification.doc). NOTE: This system is still in development. Any feedback would be appreciated. - See report: Bancroft, K.P. (1999). Broadscale habitat map and biological data of the major benthic habitats of the proposed southern extension to Ningaloo Marine Park (Amherst Point to Red Bluff). Data Report: MRI/MW/NSE-30/1999. December 1999. Marine Conservation Branch, Department of Conservation and Land Management, Fremantle, Western Australia. (Unpublished report). - See DOLA coastline Metadata report for further details on the coastline.