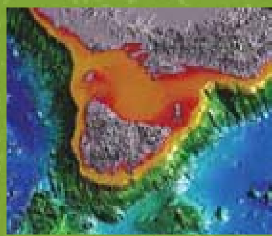
2005

National Marine Bioregionalisation *of* Australia






NATIONAL BENTHIC MARINE BIOREGIONALISATION

Australian Government
Department of the Environment and Heritage
Geoscience Australia

CSIRO

Benthic Marine Bioregionalisation of Australia's Exclusive Economic Zone

Report to the National Oceans Office on the Development of a National Benthic Marine Bioregionalisation in support of Regional Marine Planning

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Acknowledgements

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EXECUTIVE SUMMARY

This report details the development of a draft National Benthic Marine Bioregionalisation (NBMB) for the Economic Exclusive Zone (EEZ) of Australia, including the offshore island territories of Norfolk, Cocos (Keeling), Christmas and Macquarie Islands. The draft NBMB covers areas of the EEZ beyond the shelf break or approximately 80% of Australia's EEZ and complements the existing Interim Marine and Coastal Regionalisation of Australia (IMCRA) framework which covers the shelf. The distribution and abundance of the bioregions in the draft NBMB describes some of the complexity of benthic marine habitats and associated biodiversity in the EEZ beyond the shelf break. Interpreting the draft NBMB is based on the assumption that the greater the number of bioregions the greater the potential benthic marine biodiversity.

The draft NBMB is a hierarchy of bioregions at progressively smaller spatial scales, consisting of:

- Three *Ocean Basins* (i.e., Indian Ocean, Southern Ocean, Tasman Sea) that provide the bio-geographic and evolutionary context for benthic marine biota;
- Five *Ocean Climate Zones* (i.e., tropical, sub-tropical, warm-temperate, cold-temperate, sub-polar) that represent contemporary modifiers to the bio-geographic distributions and evolutionary traits of benthic marine biota;
- Three *Primary Bathymetric Units* (i.e., slope, rise, abyssal plain/deep ocean floor) that represent regional-scale bathymetric features and distributions of benthic biota;
- 24 *Provincial Bioregions* that are large bio-geographic regions defined by the provincial structure of demersal fishes and large-scale geomorphic features below 2,000 m; and
- 300 *Biomes* that define three strong depth intervals in the demersal fishes on the upper to mid slope (i.e., <1,000 m).

The Provincial Bioregions are of two major types: 1) Provinces which represent areas of endemism, and 2) Transitions, which represent areas of faunal mixing (Table Ex.1). In addition to the 24 newly created Provincial Bioregions covering the slope, rise and abyssal plain/deep ocean floor, the existing 17 Provincial Bioregions on the shelf contained in the IMCRA are also provided.

Table Ex.1. Nature of Provincial Bioregions contained in the draft NBMB and IMCRA.

Provincial Bioregions	NBMB	IMCRA
Provinces	15	9
Transitions	9	8

Within each of the provincial bioregions are Biomes which capture more detail of benthic marine habitats and biodiversity on the upper to mid slope (Table Ex.2). Due to available data, Biomes could only defined for the 15 Provincial Bioregions adjacent to the mainland. Of these, 14 contained all three Biome types and one contained two Biome types. Biomes were not defined for the offshore island Provincial Bioregions due to the absence of demersal fish data.

Table Ex.2. Number of Provincial Bioregions containing each Biome type.

Biome Type	Upper Slope	Mid-Upper Slope	Mid Slope
No. of NBMB Provincial Bioregions	15	14	15

Also provided are two possible applications of the physical data: 1) clustering of the geomorphic features into Geomorphic Units representing areas of similar geomorphology (Table Ex.3); and 2) derivation of Seabed Facies representing the results of integrating geological and oceanographic data on the shelf. These two applications are provided as additional information. They show two potential examples of subdividing the NBMB bioregions into smaller regions for the development of marine plans.

Table Ex.3. Distribution of Geomorphic Units.

Geomorphic Units Classes	1	2	3	4	5	6	7	8	9	10	11	12	13	14
No. of NBMB Provincial Bioregions	15	21	8	13	11	15	21	15	12	4	1	15	6	6
No. of IMCRA Provincial Bioregions	17	0	0	4	0	2	13	1	2	2	9	13	0	3

The Geomorphic Units and Seabed Facies both highlight some of the finer-scale spatial complexity of the EEZ within the Provincial Bioregions. Overall, the NBMB Provincial Bioregions contained more Geomorphic Units than the IMCRA shelf Provincial Bioregions. IMCRA shelf Provincial Bioregions on the tropical north, northeast and northwest margins contain relatively more Geomorphic Units than those on the southern margins. These regions represent relatively complex parts of the margin.

The present draft NBMB is based on considerably more geological, oceanographic and biological data than previous regionalisations. It is the only consistent management framework beyond the shelf break. The bioregions in the draft NBMB have been defined based on patterns in the data and conform to natural boundaries so that they are defined by valid representations of natural benthic marine boundaries based on relatively high-quality biological and physical data. The Provincial Bioregions specifically capture endemism in the benthic marine fauna. This structure is crucial for management because the definitive species in each of the Provinces occur nowhere else in Australia.

The absence of biological data and relative lack of high-resolution bathymetry data in water depths of >2,000 m means that bioregions with the greatest uncertainty in their boundaries occur:

- on the eastern margin, in the Tasman Sea and Norfolk Island region (PB12-14, PB16-17); and
- next to the offshore island territories (PB21-24), with the exception of the *Macquarie Island Province* (PB24), which contains large areas mapped by high-resolution swath sonar.

Some uncertainty also occurs about the nature and boundaries of bioregions in the deep ocean regions around the entire Australian EEZ. Exceptions are the Diamantina Fracture Zone on the southwest margin, Murray Canyon complex on the south margin, and South Tasman Rise on the southeast margin, which are "iconic" features of complex geomorphology.

A significant limitation of the draft NBMB is that is only a static "snap-shot" of the spatial distribution of the broad-scale physical and biological components the seabed. Temporal processes (e.g., competition) and longer-term changes due to climate and sea level changes are not considered. The draft NBMB has been developed on the premise that there are valid relationships between geomorphology, oceanography, sediment type and benthic marine biota, yet these relationships are not well-understood. Further research is needed to explore and establish the complex interactions between the nature of the seabed and biota over a range of spatial scales. Expanding and enhancing national databases in support of Regional Marine Planning must also be a high priority.

The hierarchical framework of the draft NBMB allows environmental managers to select the appropriate spatial scale with which to analyse information so that they relate logically to habitat and biodiversity characteristics. The Provincial Bioregions defined in this framework also provide the physical and biological context for the derivation of a National Representative System of Marine Protected Areas.

1. INTRODUCTION

This report details the development of a draft National Benthic Marine Bioregionalisation (NBMB) for the Exclusive Economic Zone (EEZ)[1] of Australia (Fig. 1.1). The draft NBMB is designed as a management tool that has most application for the development and implementation of regional marine plans. The NBMB has been constructed for areas of the EEZ beyond the shelf break (i.e., slope, rise and abyssal plain/deep ocean floor) to complement the existing Interim Marine and Coastal Regionalisation of Australia (IMCRA) (IMCRA Technical Group, 1998). IMCRA is the existing national ecologically-based planning framework which covers the shelf areas of the EEZ.

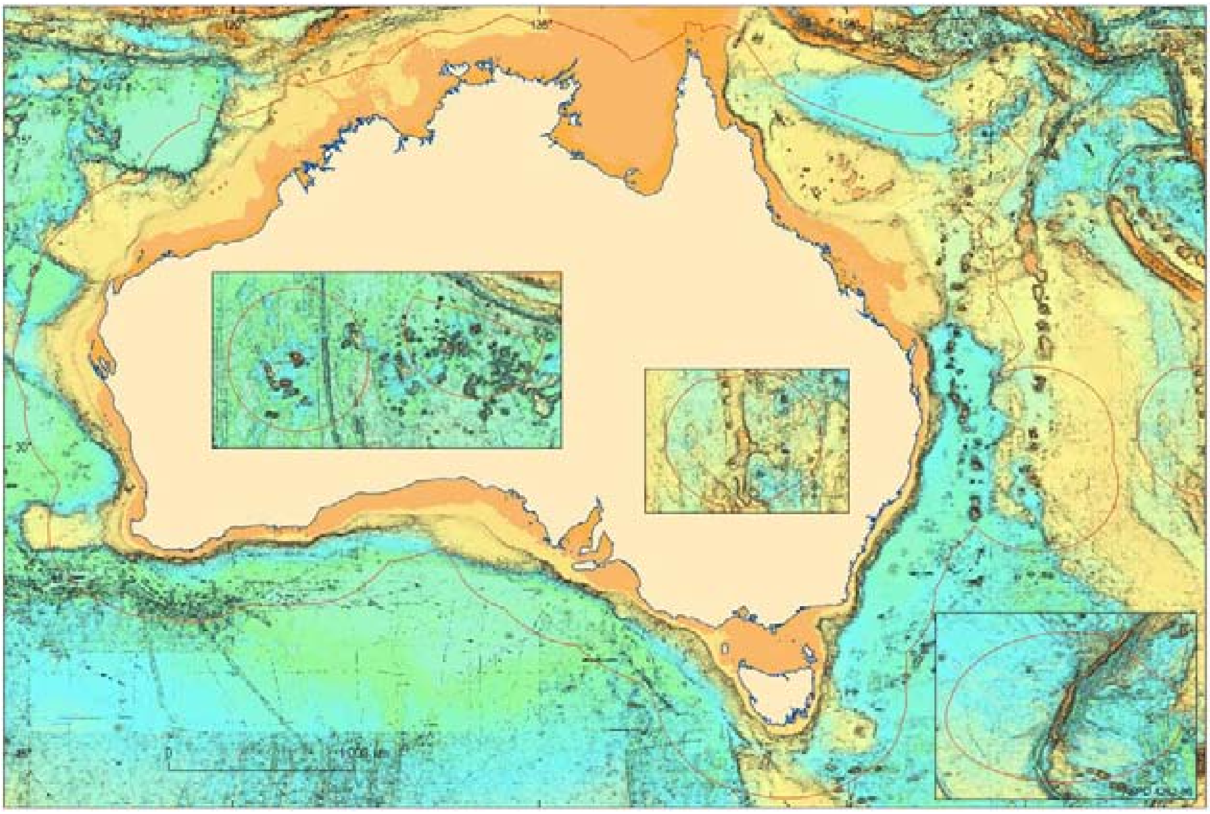

Figure 1.1. Map of EEZ boundary of Australia including offshore island territories (red line). General bathymetry from 250 m spatial resolution bathymetry model is also shown.

The draft NBMB is the culmination of collaborative work by Geoscience Australia, CSIRO – Marine Research and the Department of the Environment and Heritage (National Oceans Office), supported by the Bioregionalisation Working Group (BWG), which is comprised of scientists and environmental managers from federal, state and territory agencies[2]. The basis of the draft NBMB is a hierarchical framework of benthic marine bioregions at smaller spatial scales that together capture habitat distributions in the form of benthic marine biodiversity. The draft NBMB is a 'mixed' classification in that the benthic

[1] Generally in this report, where the term "EEZ" has been used it includes all waters and seabed lying landward of Australia's exclusive economic zone. Under the Seas and Submerged Lands Act 1973 (Cth), the outer limit of the EEZ extends 200 nautical miles off Australia's territorial sea baseline except in the northwest, north, northeast and southeast, where it coincides with treaty boundaries with Papua New Guinea, Solomon Islands and France and lines of equidistance between Australian territory on one hand and that of countries with which boundary treaties have yet to come into force (Indonesia, New Zealand) or be negotiated (East Timor).

[2] A list of the Bioregionalisation Working Group members and their affiliations is provided in Appendix A.

marine bioregions have been defined by biological data (i.e., demersal fishes), where available, and where biological data are not available, by geological properties (e.g., geomorphology) within the context of the Ocean Basins and regional-scale Ocean Climate Zones. This approach ensures that the bioregions are defined by the most widespread and robust data available across Australia's EEZ. Interpreting the draft NBMB is based on the assumption that the greater the number of bioregions the greater the potential benthic marine biodiversity. Products arising from this work will be incorporated into regional marine plans in support of regional marine planning.

The draft NBMB and supporting data layers are contained in a Geographical Information System (GIS) developed by Geoscience Australia. Other products developed as part of this project, include an interactive DVD that contains the draft NBMB and draft pelagic regionalisation GIS, the final reports, and audio-visual products.

1.1. Background

Under Australia's *Oceans Policy* (1998), the Federal Government is committed to taking an integrated, ecosystem-based approach to oceans management. This approach requires that planning and management is based on habitat and biodiversity distributions rather than solely on sectoral or jurisdictional boundaries. Bioregionalisations are one useful approach for defining benthic marine habitats and biodiversity because they delimit areas of the seabed based on similarities in physical (i.e., geomorphology, sedimentary, oceanography) and biological properties (e.g., Butler *et al.*, 2001).

The development of the draft NBMB is part of a National Science Work Program by the National Oceans Office to provide strategic scientific support for the development and implementation of regional marine plans. The National Oceans Office, through the National Marine Bioregionalisation project, is collating and analysing marine geological, biological and oceanographic data within the EEZ, with particular emphasis on waters greater than 40 metres and three nautical miles offshore.

The National Marine Bioregionalisation project is divided into constructing: 1) a National Benthic Marine Bioregionalisation (NBMB) focused on the habitat distribution and associated biodiversity of the seabed and subsoil; and 2) a national pelagic marine regionalisation focused on structures and processes of the water column. The principal outcome of the work will be an agreed set of benthic marine bioregions and pelagic regions in a hierarchical structure which will underpin a spatial framework to support planning and management of Australia's oceans. Geoscience Australia is leading the development of the draft NBMB, which is the subject of this report. The national pelagic marine regionalisation is the subject of a separate report written by CSIRO – Marine Research. Further information about the development of the National Marine Bioregionalisation project is available from the National Oceans Office (http://www.oceans.gov.au).

1.2. Rationale

The existing marine planning framework for the seabed, IMCRA, only covers the shelf. Thus approximately 80% of Australia's EEZ seabed is not covered by an agreed spatial management framework. Also, analysing physical and biological data at a national scale reveals broad-scale trends and patterns, which are missed or distorted by simply focusing on specific regions. In fact, this was recognised as one of the major deficiencies of the draft interim benthic marine bioregionalisation for the SE region (Butler *et al.*, 2001).

At a regional scale, Australia's EEZ has been divided into 10 Large Marine Domains (e.g., Lyne *et al.*, 1998). Large Marine Domains provide a broad-scale classification, based principally on demersal fish data from the shelf combined with oceanographic and geologic features. Notwithstanding the fact that the Large Marine Domains are based on no data beyond the shelf and the boundaries have simply been extrapolated out to the EEZ boundary, it was noted in the draft interim benthic marine bioregionalisation for the SE region (Butler *et al.*, 2001) that the implementation of regional marine plans requires finer spatial scale management units based on ecological characteristics (geological, chemical, physical, biological). These factors prompted the development of a national approach to ecosystem-based management of Australia's EEZ which has culminated in the development of the draft NBMB.

1.2.1. Project Aims

The aim of the draft NBMB is to capture broad habitat distributions and associated biodiversity on the seabed of the EEZ beyond the shelf break by collating and integrating available biophysical information in a systematic manner into a suite of benthic marine bioregions. The bioregions reflect seabed habitat diversity and biodiversity and incorporate finer-scale information where it is available (e.g., the Great Barrier Reef). The draft NBMB serves a number of fundamental applications in support of regional marine planning, including:

- defining ecologically-based planning and management units in Australia's EEZ beyond the shelf break, mapping their location and describing as best as possible their spatial distributions;
- defining the basis for a National Representative System of Marine Protected Areas by identifying (to the extent possible at any particular scale) the spatial patterns of benthic marine habitats and biodiversity;
- providing a spatial framework for "state of the environment" reporting and performance assessment for regional marine planning; and
- providing a vehicle for communicating information about the spatial complexity of benthic marine habitats and biodiversity.

Bioregionalisations provide a means of simplifying complex models about spatial patterns in biological characteristics (e.g., habitats), which can be represented visually to assist public understanding (e.g., Roff *et al.*, 2003; Diaz *et al.*, 2004). In addition, the results of the present analysis can be used to extend the existing IMCRA management framework.

1.2.2. Project Objectives

The principal objectives of the project are to:

1. produce a draft NBMB based on both physical and biological data that contains a national set of benthic marine bioregions for the EEZ beyond the shelf that underpin a spatial framework in support of the management of Australia's seabed;
2. collate a suite of publicly accessible datasets for key geological, biological and oceanographic data used in the development of the draft NBMB; and
3. produce an interactive GIS product for communication of the draft NBMB to the general public.

More specifically, the draft NBMB provides a management framework at a range of appropriate spatial scales so that data can be analysed in such as way that it relates logically to the hierarchy of benthic marine habitats. Additional analyses of some of the national physical datasets are also provided as one possible approach that environmental managers might use in developing finer scale management frameworks within the draft NBMB structure.

1.3. National Benthic Marine Bioregionalisation Framework

Mapping of benthic marine habitats has been the subject of many studies over the last 10 years (e.g., Perry & Smith, 1994; Magorrian *et al.*, 1995; Greene *et al.*, 1999; Kostylev *et al.*, 2001; Brown *et al.*, 2002; Kenny *et al.*, 2003). These studies have been developed by individual researchers on specific study sites. Classification schemes based on these studies capture the complexity and variation of benthic marine habitats in relatively small (<100 km^2) regions of the seabed where intensive sampling is used to ground-truth mapping (e.g., Magorrian *et al.*, 1995; Kloser *et al.*, 2001; Kostylev *et al.*, 2001; Brown *et al.*, 2002). Relationships between biota and physical properties recognised at these small scales may not always extend over large scales and existing classification schemes based on these relationships are not necessarily applicable for all benthic marine habitats and biota. Published seabed classification schemes are difficult or inappropriate to apply strictly beyond the region of study, and may require significant adaptation to capture the multi-scale nature of benthic marine habitats and biodiversity and be useful for ecosystem-based management (e.g., Holling, 1992; Langton *et al.*, 1995; Garcia-Charton & Perez-Ruzafa, 1999; Greene *et al.*, 1999; Poiani *et al.*, 2000; Roff & Evans, 2002). A classification scheme should identify habitats at a range of scales for regional marine planning purposes (e.g., Roff & Taylor, 2000).

1.3.1. Hierarchical Framework

A nested framework originally developed by CSIRO – Marine Research for the Northwest Shelf Environmental Study (CSIRO, 2002) with input from other published schemes and adapted specifically for Australia has already been successfully implemented in the construction of a draft interim benthic marine bioregionalisation of the SE region (Butler *et al.*, 2001). Due to the success of this framework and to maintain congruence with the existing management structures and to incorporate the findings of current international literature, it was adapted into a hierarchical framework to form the basis of the present draft NBMB.

The hierarchical framework used in the draft NBMB is composed of a series of benthic marine bioregions at progressively smaller spatial scales located within the ocean basins. For the purposes of the draft NBMB, a benthic marine bioregion is defined as a complex area of the seabed composed of a cluster of interacting habitats and associated biota that are repeated in similar form throughout. Regional descriptions contained in the draft NBMB describe the dominant 'seascape' in terms of a hierarchy of interacting physical and biological attributes. Due to the broad-scale requirements of regional marine planning and availability of national data only broad-scale bioregion units are appropriate for the draft NBMB (Table 1.1). To maintain the integrity of the IMCRA framework, the shelf was separated out from the draft NBMB.

1.3.2. National Benthic Marine Bioregionalisation Process

The draft NBMB is based largely on data generated from projects commissioned by the National Oceans Office in the lead up to the present project. These are:

1. *Australian Bathymetry Database:*– this project collated bathymetry data for the Australian margin which were loaded into Geoscience Australia's existing bathymetry database (Harris *et al.*, 2005). The aim of this project was to produce a robust and comprehensive 250 m spatial scale bathymetry model for Australia's EEZ by collating all available data. This model was then used to derive the geomorphic features of the Australian margin (Heap *et al.*, 2004) and incorporated into the draft NBMB GIS;

2. *National Marine Sediments Database (MARS):*– this project collated numerical sediment data from the Australian margin (Passlow *et al.*, 2004). These data were then loaded into Geoscience Australia's marine sediment database, MARS. The aim of this project was to develop a centralised national marine sediments database by collating all accessible sediment data. The data were used to generate maps of sediment properties for a large part of the Australian shelf and incorporated into the GIS for the present project;
3. *Demersal Fish Project:*– data on the distributions and abundances of demersal fish were collated on the margin from the outer shelf to mid slope (i.e., 40 to 2,000 m) around Australia (Last *et al.*, 2005). The data were then transformed into a series of 'strings' that delineated a series of bio-geographic provinces around the continent to provide a robust appraisal of Australia's deep-water demersal fishes; and
4. *Sponges Project:*– this project collated the distribution and species of sponges for northern Australian tropical marine waters (Hooper & Ekins, 2004). The aims of this project were to validate identifications of sponges in the Queensland Museum collection and create datasets of sample distributions and interpreted species distributions. The data were used to generate broad-scale bioregions that highlighted endemic species.

Data from these complementary projects were analysed by scientists at Geoscience Australia and CSIRO – Marine Research and then integrated into the draft NBMB at a series of workshops, with expert advice from the BWG. Counsel from the BWG members significantly influenced the structure of the draft NBMB.

Table 1.1. Units contained in the hierarchical framework for the draft National Benthic Marine Bioregionalisation.

Name	Description	Indicative Area
Ocean Basins	Provide bio-geographic and evolutionary context with origins dating back to the separation of Gondwana.	>100,000 km^2
Ocean Climate Zones	Contemporary modifiers of bio-geographic distributions and evolutionary traits of benthic marine faunal assemblages.	>100,000 km^2
Primary Bathymetric Units	Regional-scale bathymetric features and benthic marine faunal distributions of slope, rise and abyssal plain.	>100,000 km^2
Provincial Bioregions	Large bio-geographic regions principally based on the broad-scale distribution of benthic marine fauna.	10,000 – 100,000 km^2
Biomes (slope only)	Bio-geographic regions based on benthic marine faunal communities, some with narrow spatial distributions and depth ranges. These units have only been defined on the slope due to available data.	<1,000 – 10,000 km^2

1.3.3. Timelines

The National Marine Bioregionalisation project commenced on June 1, 2004 and is due for completion by 30 June, 2005. Data from the bathymetry, sediments and demersal fish projects, and other existing data sets were initially loaded into the GIS. From these data, the boundaries of the Provincial Bioregions were defined at a workshop at CSIRO – Maine Research in Hobart on 3-5 August, 2004 in conjunction with input from the BWG and also a panel of scientific experts. The biome boundaries were then constructed. A second workshop was held at Geoscience Australia on the 6-7 October, 2004 with the BWG to discuss these boundaries. A draft report was submitted in December containing the completed draft NBMB (including the revisions from the October workshop), which was reviewed by the BWG members on 14-15 December, 2004. Revisions of the report and GIS required a contract variation between the partners that extended the timelines for the draft report, GIS and DVD products. The report was externally reviewed by two reviewers and revisions incorporated and the final report delivered in April 2005. Development of the DVD commenced after the second workshop and it was submitted at the end of May 2005.

1.4. Access to Data

Products generated for and by this project will be accessible from Geoscience Australia's website (http://www.ga.gov.au) and through a web-based Oceans Portal located on the National Oceans Office website (http://neptune.oceans.gov.au/index.html). The purpose of the Oceans Portal is to make all bioregionalisation data products accessible from one website without the necessity to "house" them in one geographic location. Products available from the websites include the entire draft NBMB and pelagic regionalisation GIS, each of the GIS layers, the reports, and associated figures and large-format maps. Alternatively, the GIS for the benthic and pelagic regionalisations, and associated products including fly-throughs of the final bioregionalisation, reports and large-format maps are contained on a DVD that can be obtained directly from Geoscience Australia's Sales Centre and the National Oceans Office (see inside cover for address details). The draft NBMB and GIS represent a "snap-shot" of the data. Some data types are continually up-dated (e.g., bathymetry) but these data will not necessarily be continually updated in the bioregionalisation GIS. Revisions and up-dates of the draft NBMB will be undertaken periodically.

2. DATA TYPES

There are a wide variety of possible physical and biological data useful for developing bioregionalisations. The draft NBMB focuses on a subset of these that are deemed to be broad surrogates for benthic marine habitat distributions and biodiversity. Data used to develop the draft NBMB were of three broad types: biological, geological and oceanographic. The data were mostly supplied from existing national datasets for the EEZ held at Geoscience Australia and CSIRO – Marine Research, supplemented with additional data on sponges in Australian waters from the Queensland Museum. In the lead up to this project, significant resources were committed by all agencies to update and acquire new data for these national datasets. A list of the final data layers contained in the draft NBMB GIS are provided in Appendix B.

Data obtained from Geoscience Australia were:

- Bathymetry (water depth);
- Geomorphic features;
- Ocean crust age;
- Sedimentary basins;
- Gravel content of the sediments (%gravel);
- Mud content of the sediments (%mud);
- Calcium carbonate content of sediments (%$CaCO_3$);
- Mean grain size of the sediments;
- Movement of sediments due to tides;
- Movement of sediments due to waves;
- Maximum tidal energy at the bed;
- Mean wave energy at the bed.

Data obtained from CSIRO – Marine Research were:

- Demersal fish provinces;
- Demersal fish biomes;
- Phytoplankton map;
- Oceanographic features based on SST;
- Bottom temperature, salinity, nutrients, dissolved oxygen.

Data obtained from the Queensland Museum (via the National Oceans Office) were:

- Distribution and species of sponges for northern Australian tropical waters.

Not all of these datasets were used to derive the bioregions in the draft NBMB. Some of the datasets, such as sponge species, mean tidal and wave energy, and sedimentary parameters (i.e., %gravel, %mud, %$CaCO_3$, mean grain size) are only available for the shelf, and they exhibit finer-scale patterns of variability than is required for the draft NBMB. These data are provided in the draft NBMB GIS as additional information that may be used to guide or assist with potential subdivision of the draft NBMB bioregions when developing management plans or frameworks.

In the Great Barrier Reef (GBR) marine park, the existing GBR benthic marine bioregions have also been included in the GIS for the draft NBMB. These bioregions were derived by the Great Barrier Reef Marine Park Authority from a variety of physical and biological data that were different to the draft NBMB datasets. These data were analysed at a more detailed spatial resolution than required for this project. We have noted the existence of this bioregionalisation and have included the bioregions and associated metadata as provincial layers in the accompanying GIS as additional supporting data.

2.1. Data from Geoscience Australia

Data from Geoscience Australia were derived from existing national geoscience datasets. A brief description of each of the datasets is provided with a reference for further details.

2.1.1. Bathymetry (Water Depth)

Water depth affects temperature, light, nutrients, energy regimes, and seabed sediment conditions—key drivers of benthic marine biota. A detailed bathymetry model of Australia's EEZ provides crucial information for the draft NBMB. Bathymetry data from >900 marine surveys were contained in Geoscience Australia's database representing >280 million data points. The database contains water depths determined from swath sonar surveys, laser airborne depth sounder surveys, Royal Australian Navy fairsheets, seismic surveys, as well as from ships' echo-sounders. The data thus are of variable quality and spatial resolution. The dataset represents a bathymetric model gridded at 250 m spatial resolution for Australia's EEZ (Fig. 2.1). A detailed explanation of the bathymetry data and the modelling procedure are provided in Harris *et al.* (2005).

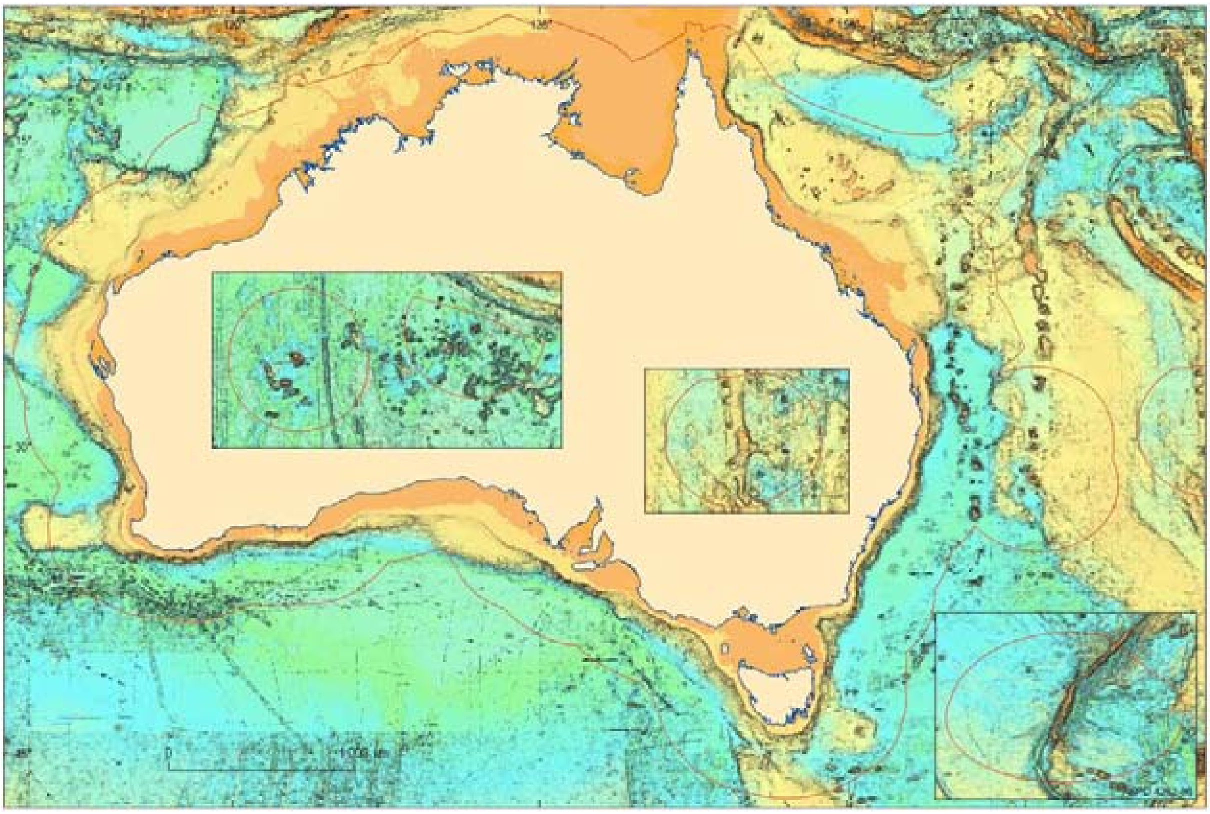

Figure 2.1. Map of the 250 m spatial resolution bathymetry model of Australia.

2.1.2. Geomorphic Features

A total of 21 geomorphic feature types were defined using the 250 m bathymetric model of Australia's EEZ (Fig. 2.2). Geomorphic features provide an important predictor of species assemblages at a large scale. For example, on the slope different species live on low-gradient terraces compared to those on the steep-walled submarine canyons. Each geomorphic feature type identified was an officially defined feature from the 53 contained in the International Hydrographic Organisation scheme (http://www.iho.shom.fr/publicat/free/files/B6efEd3.pdf). A further feature "Sand-wave/Sand bank" was also added to capture the common features on the Australian shelf. The features were mapped at a scale of 1:5,000,000, so the smallest feature that could be resolved was 5 x 5 mm on the map (or approximately

10 km in size). The shelf break and foot-of-slope were also resolved, which delineate the shelf, slope, rise and abyssal plain/deep ocean floor (Fig. 2.3). Further details regarding the identification and mapping of the geomorphic features are provided by Harris *et al.* (2005).

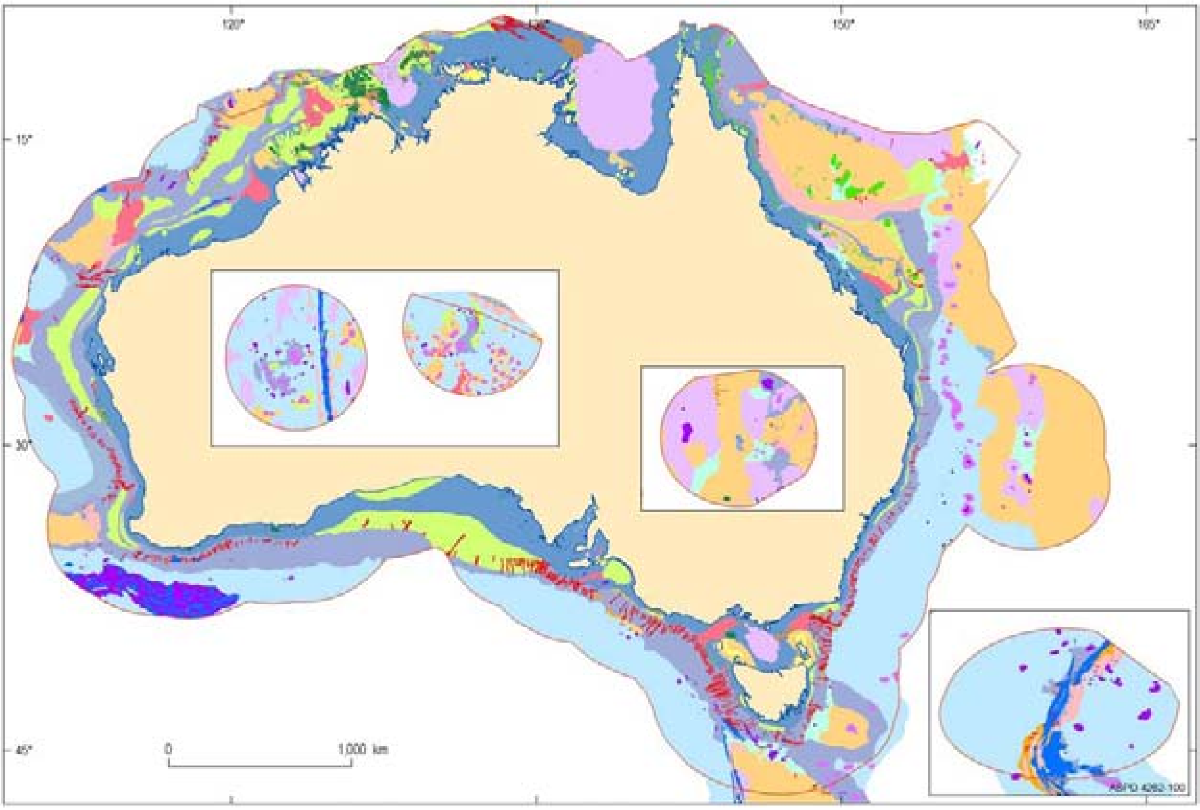

Figure 2.2. Map of the geomorphic features of the continental margin of Australia. See page 72 for legend.

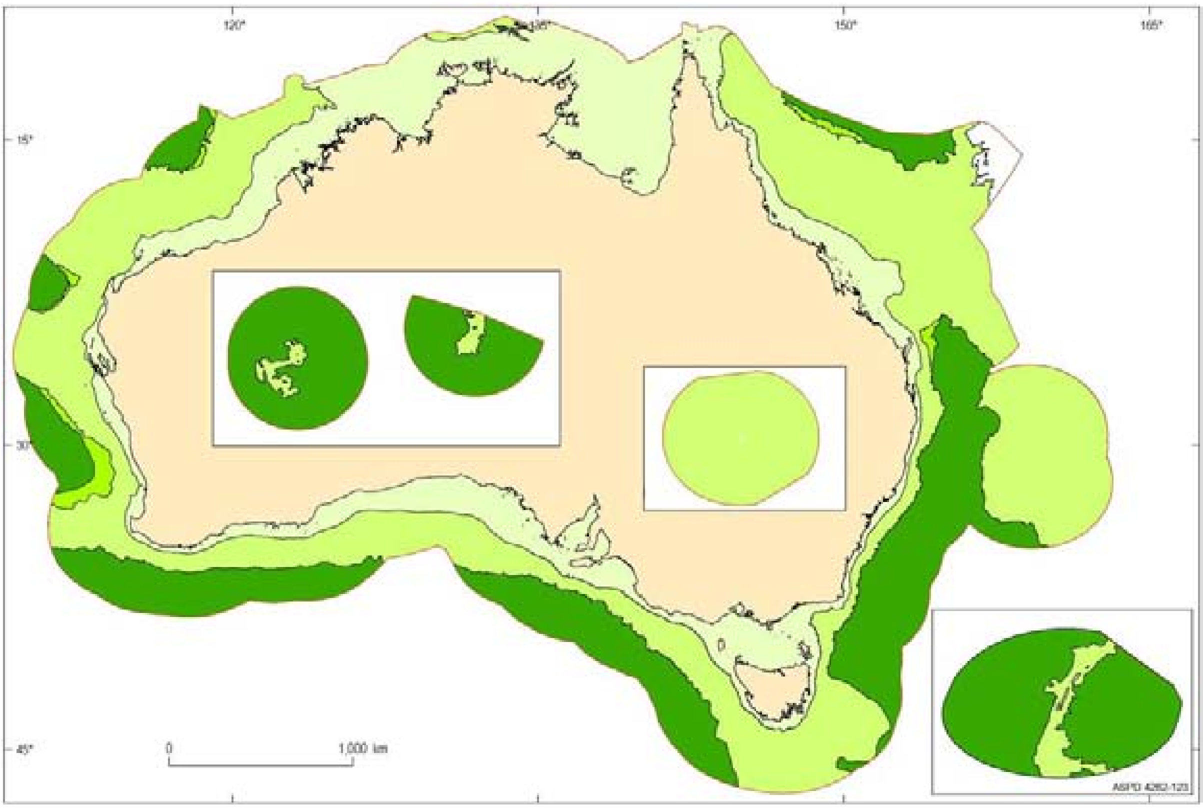

Figure 2.3. Map of the major geomorphic provinces of Australia. See page 72 for legend.

2.1.3. Ocean Crust Age

The age of the ocean crust is related to the opening of the ocean basins, which have their origins in the separation of Gondwana more than 80 million years ago. The age of the ocean crust is a proxy for the evolutionary history of the ocean basin, which can influence the distribution, connectivity and evolutionary traits of populations of benthic marine biota. In the case of the draft interim benthic marine bioregionalisation for the SE region (Butler *et al.*, 2001) crustal ages of the Southern Ocean and Tasman Sea were correlated with the evolutionary traits of demersal fishes from each of those ocean basins. Three ocean basins occur in Australia's EEZ: the Indian Ocean, the Southern Ocean, and the Tasman Sea. Ocean crust age of 6-arc minutes has been derived from a self-consistent set of global isochrons and associated plate reconstructions for these ocean basins around Australia (Fig. 2.4). The ages of the oceanic crust at each grid location was determined by linear interpolation between adjacent isochrons in the direction of spreading. The ages are thus parallel to the axis of the ocean basin and associated spreading centre so that the age increases from the spreading centre, and is oldest near the continents. Further details regarding the determination of the ocean crust age in Australia's EEZ can be found on Geoscience Australia's website (www.ga.gov.au).

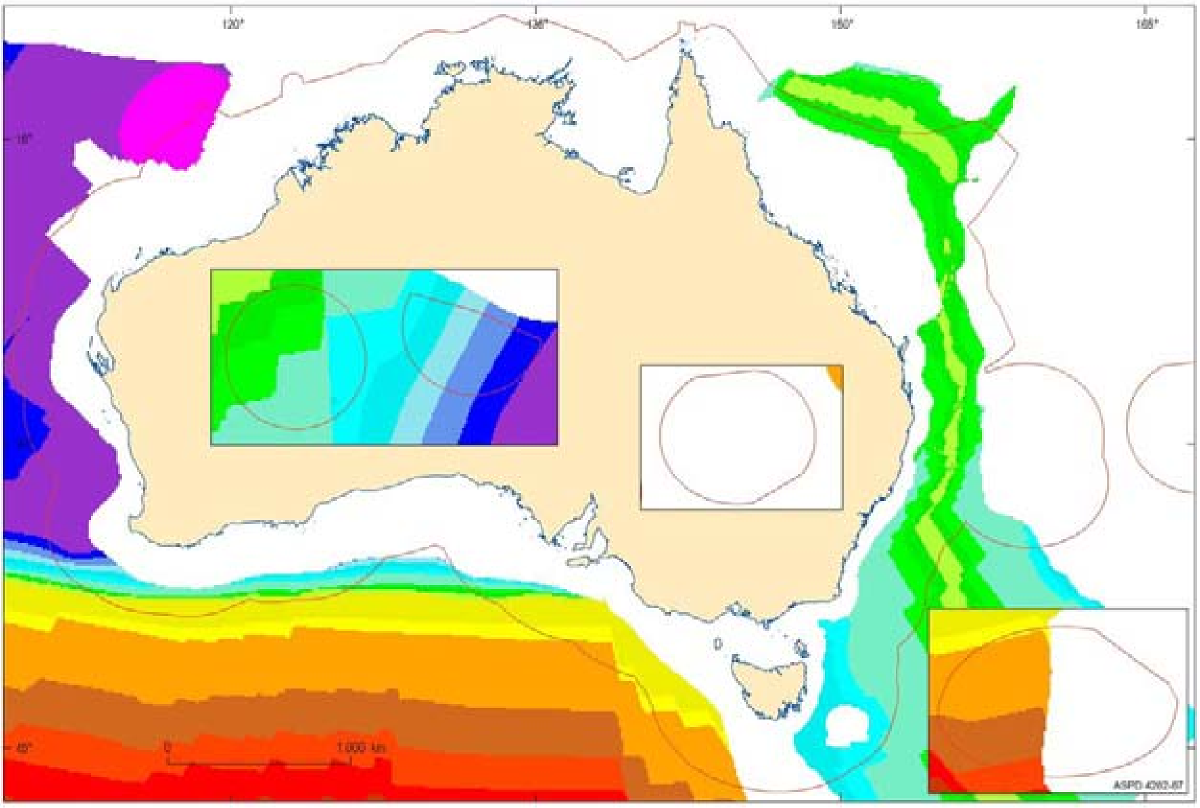

Figure 2.4. Map of the age of ocean crustal age for ocean basins around Australia. See page 72 for legend.

2.1.4. Sedimentary Basins

Geological province data provide information on the maximum extent of offshore sedimentary basins (Fig. 2.5). Sedimentary basins often can have surface expressions on the seabed because they contain different sediment types that have undergone different tectonic histories. In some cases, the rocks of the sedimentary basin also crop out on the seabed and result in a variety of benthic marine habitats. The offshore sedimentary basins have been interpreted directly from seismic reflection data that ranged from grid surveys (10-50 km line spacing) to more widely-spaced regional lines. The boundaries were interpolated between the seismic lines with the aid of gravity, magnetic and bathymetry data, with reference to previously published reports and maps. Further details regarding definition of the offshore sedimentary basins can be found in Geoscience Australia's interactive Oracle database: Provinces (http://www.ga.gov.au/oracle/provinces).

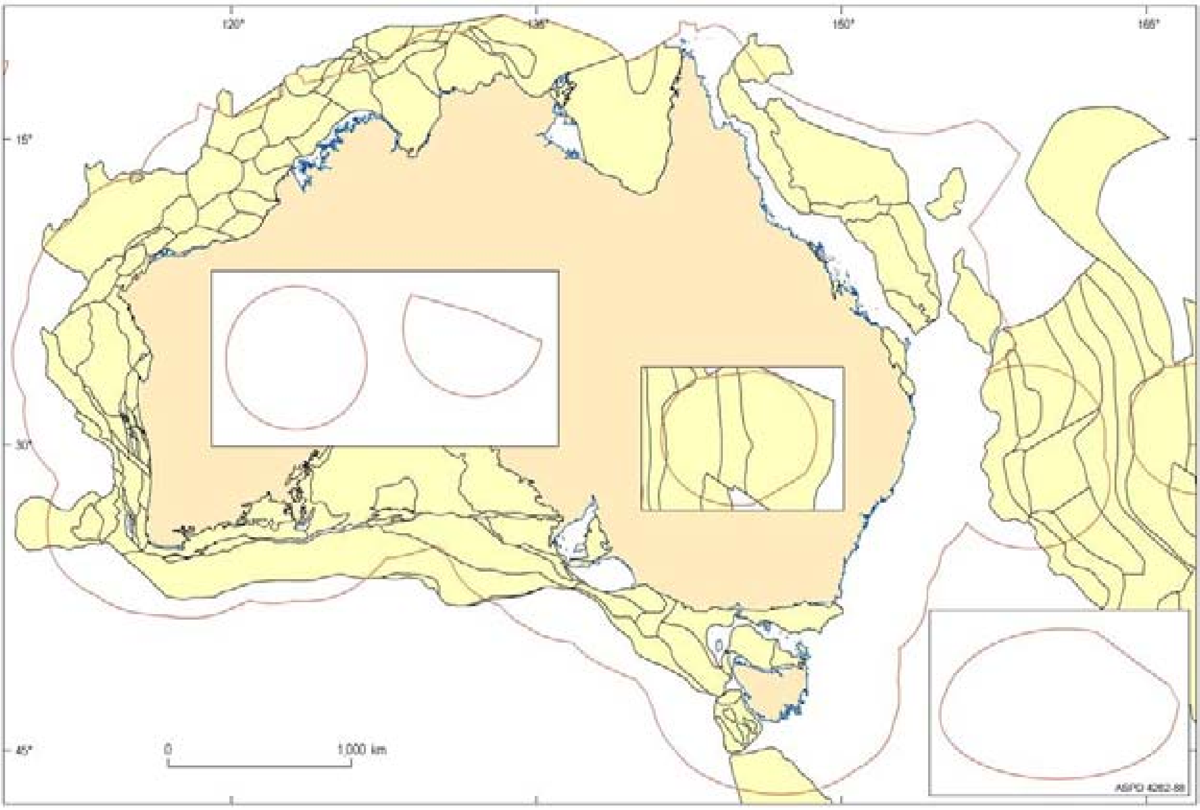

Figure 2.5. Map of the boundaries of offshore sedimentary basins of Australia.

2.1.5. Sediment Parameters

Basic sediment parameters (%gravel, %mud, %$CaCO_3$ and mean grain size) were derived from seabed samples that contained relevant numerical data in the MARS marine sediment database (Figs. 2.6-2.10). The sediment parameters combine to define the nature of the seabed available for benthic marine organisms to feed and live on/in. Crucially, the composition and grain size influence the concentrations of organic matter and nutrients (e.g., oxygen) in the sediment, as well as affecting water circulation between the grains (Gray, 1981). Approximately 7,800 samples were available for analysis, except for $CaCO_3$ which was derived from approximately 4,500 samples. Data coverage was largely restricted to the shelf and upper slope of the EEZ (i.e., <300 m) and extended from Northwest Cape, across northern Australia and down the east coast to Cape Banks, including Tasmania. Deeper water samples (i.e., >300 m) are restricted to south of Tasmania and Great Australian Bight. The data were generated from a linear interpolation between the data points and the results gridded at 0.01° (~1 km) spatial resolution, giving a maximum extrapolation distance of 0.45° between samples. Further details regarding the sediment data are provided by Passlow *et al.* (2004).

2.1.6. Wave Exceedance

Wave-induced exceedance was calculated using Geoscience Australia's sediment mobility model GEOMAT (Harris *et al.*, 2000). It is a measure of the ability of surface gravity waves to mobilise sediment on the seabed and has been expressed as a time percentage, based on

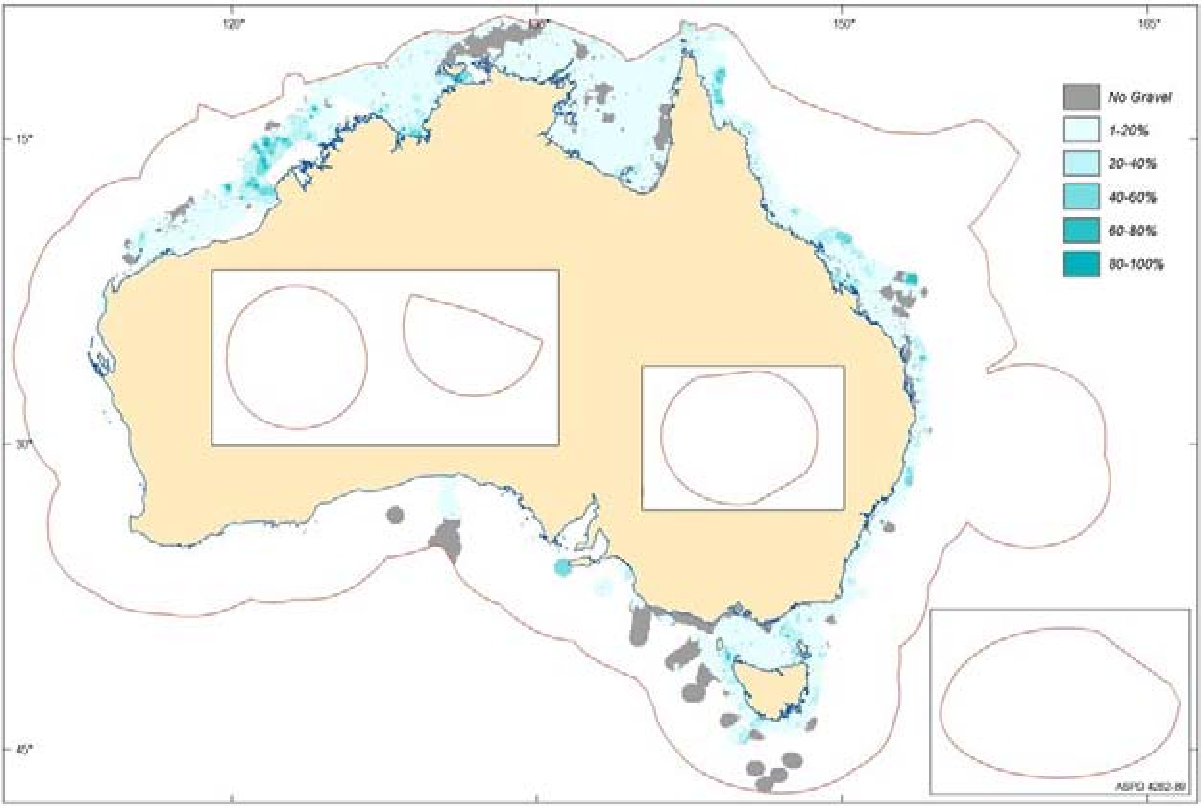

Figure 2.6. Map of gravel concentrations for water depths of <300 m.

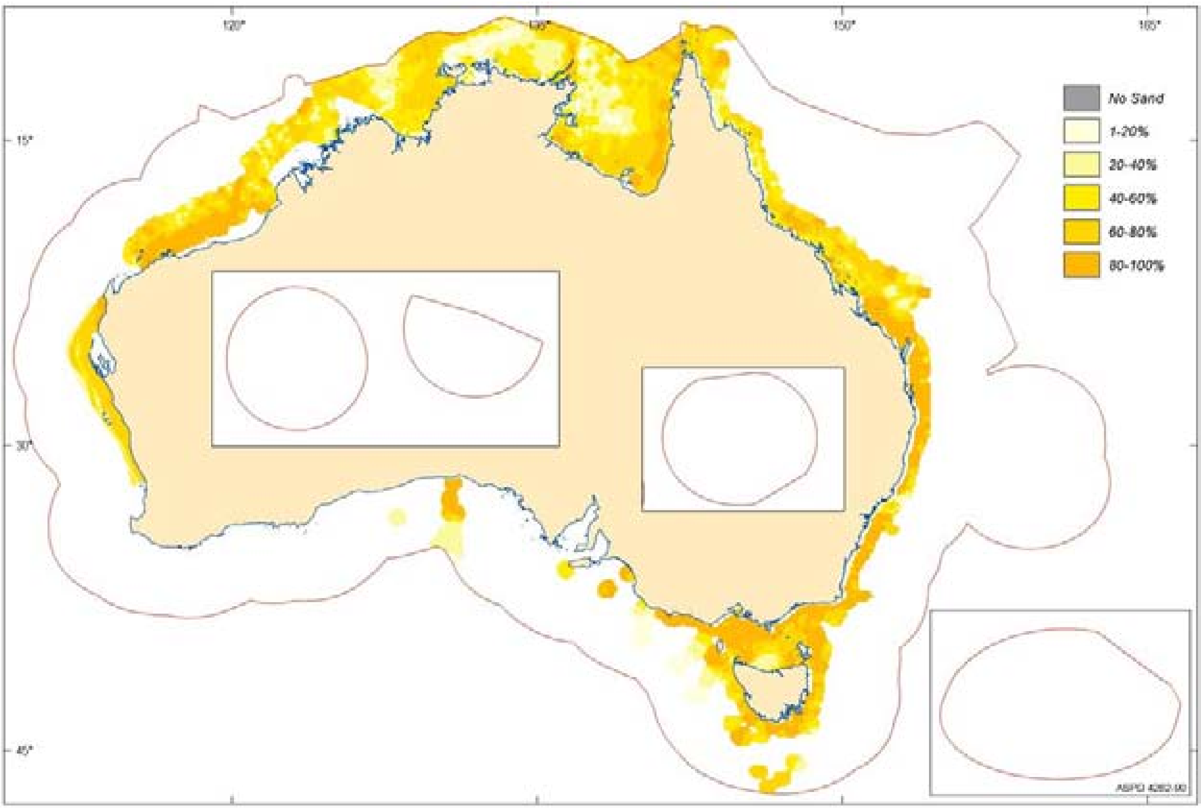

Figure 2.7. Map of sand concentrations for water depths of <300 m.

wave model predictions for March 1998 to February 2004 (Fig. 2.11). Movement of bed sediment by waves is an important determinant of benthic marine community structure because they have a significant influence on seabed and habitat stability. The initial 10-km

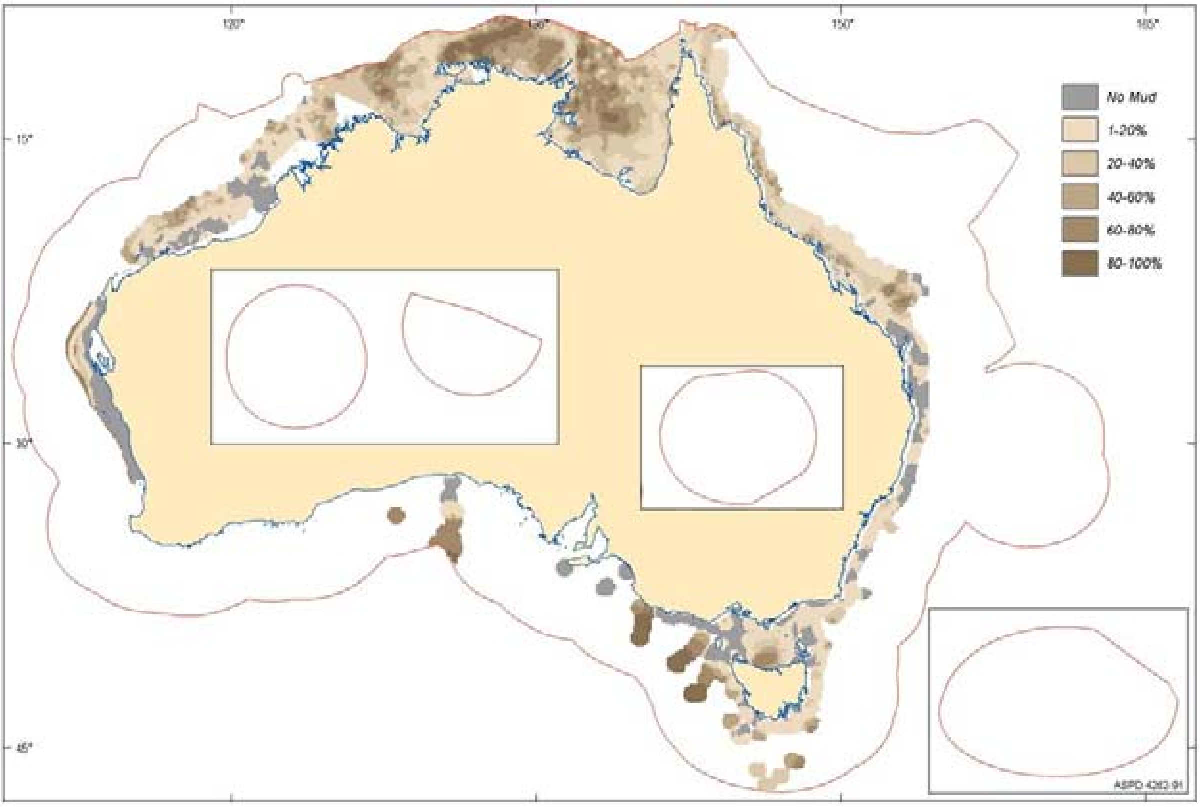

Figure 2.8. Map of mud concentrations for water depths of <300 m.

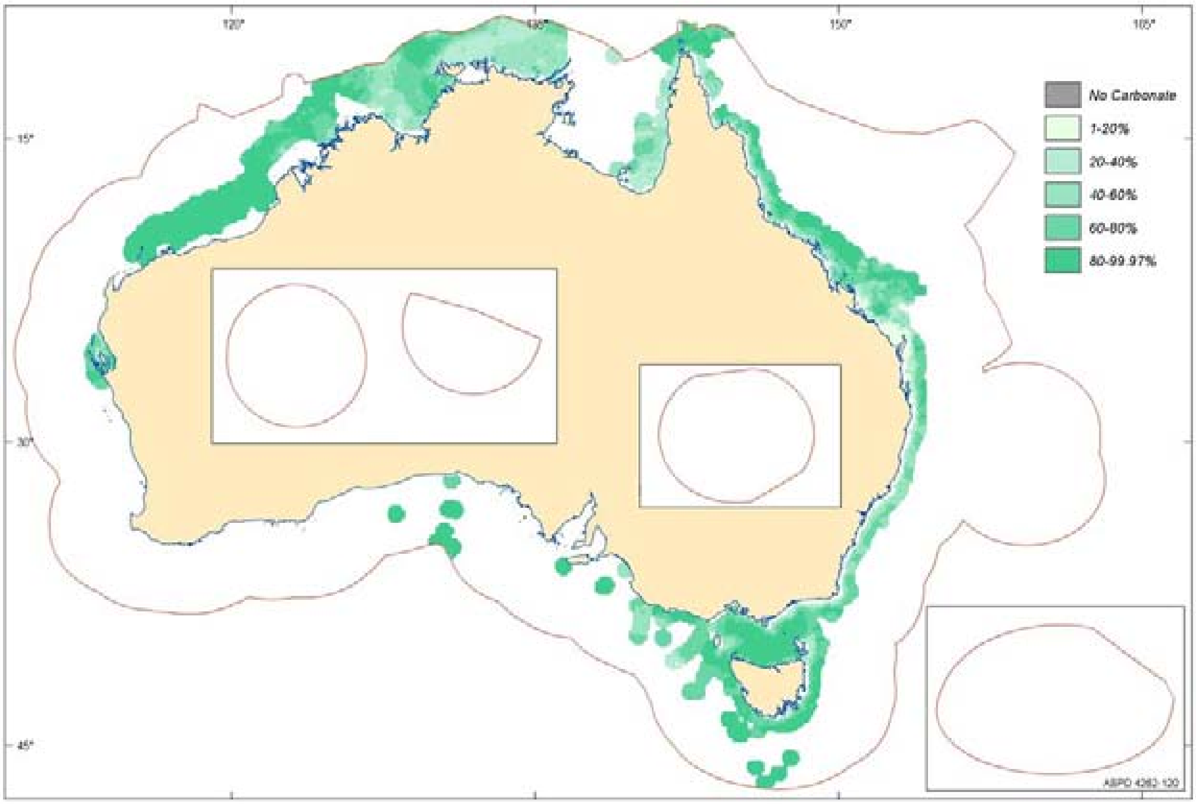

Figure 2.9. Map of calcium carbonate concentrations for water depths of <300 m.

grid of wave model predictions was gridded to 0.01° (~1 km) resolution using a linear interpolation for water depths of <300 m to produce 6-hourly estimates of maximum near-bed orbital velocities. Wave-induced exceedance was then calculated by first determining the

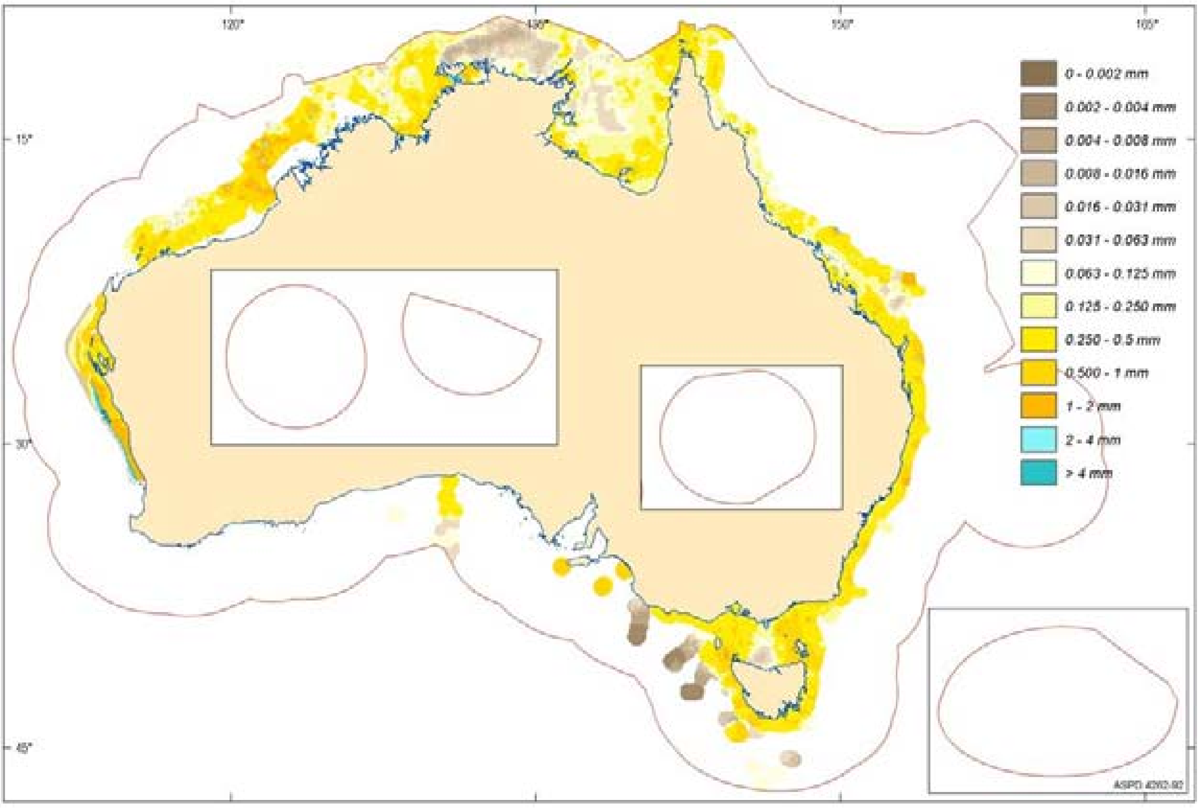

Figure 2.10. Map of mean grain size for water depths of <300 m.

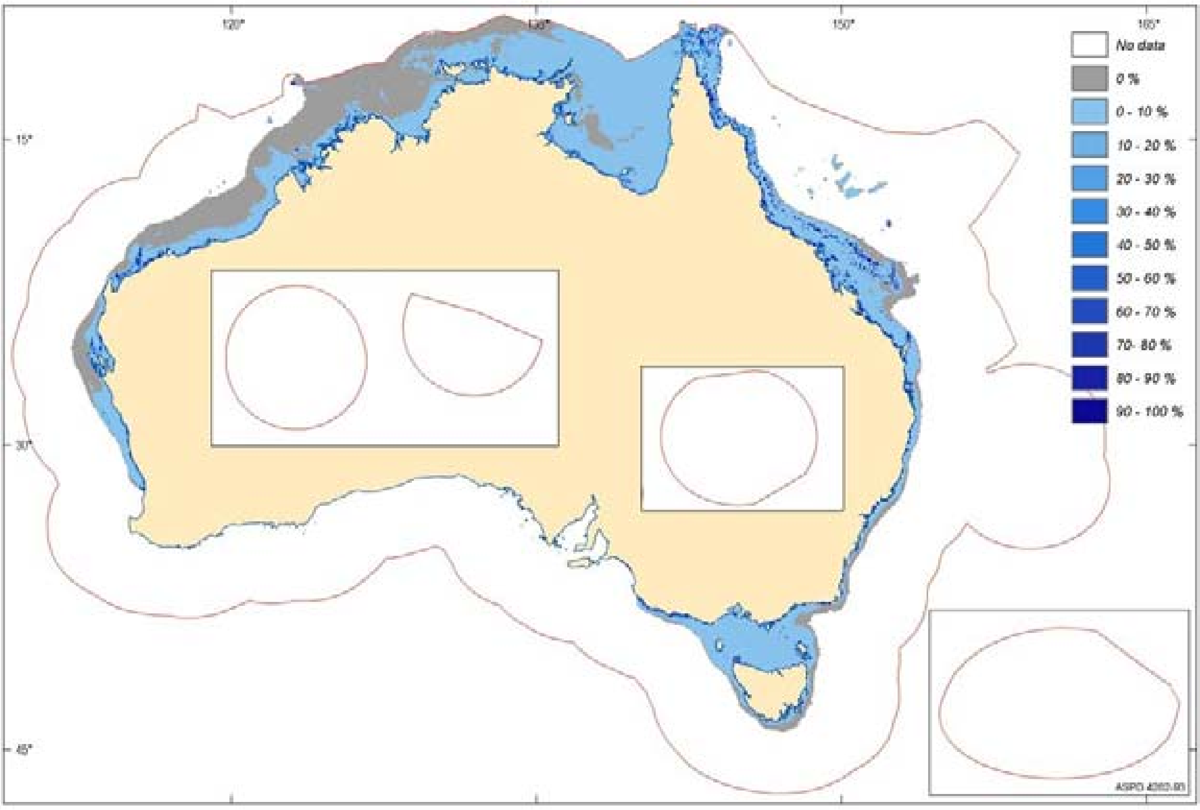

Figure 2.11. Map of wave-induced exceedance for water depths of <300 m.

critical speed for initiating sediment motion, as a function of the measured mean grain size. Bottom wave orbital velocities were then calculated for the 5 years of predicted significant wave height and wave period data based on the water depth. Finally, the percentage of time that bottom wave orbital velocity exceeded the critical speed for initiating sediment motion was calculated. This calculation was performed for every grid location of the 0.01° grid. Further details about the gridding procedure and estimation of wave-induced exceedance are provided by Harris *et al.* (2000).

2.1.7. Tide Exceedance

Tide-induced exceedance was calculated using Geoscience Australia's sediment mobility model GEOMAT (Harris *et al.*, 2000). It is a measure of the ability of tidal currents to mobilise sediment on the sea bed and has been expressed as a time percentage based on a spring-neap tidal cycle (~14 days) (Fig. 2.12). Movement of bed sediment by tides is an important determinant of benthic marine community structure because they have a significant influence on seabed and habitat stability. Tide exceedance is calculated by first determining the critical speed for initiating sediment motion, as a function of the measured mean grain size and then calculating the percentage of time that tidal current speeds exceed the critical speed for initiating sediment motion over the 14 day period. This calculation is undertaken for every grid location. Hourly-averaged, depth-averaged tidal currents were estimated using a hydrodynamic tidal model for the Australian shelf with a spatial resolution of 0.067° (Harris *et al.*, 2000). Tide-induced exceedance values were then gridded at 0.01° (~1 km) spatial resolution using a linear interpolation for water depths of <300 m. Further details about the gridding procedure and estimation of tide-induced exceedance are provided by Harris *et al.* (2000).

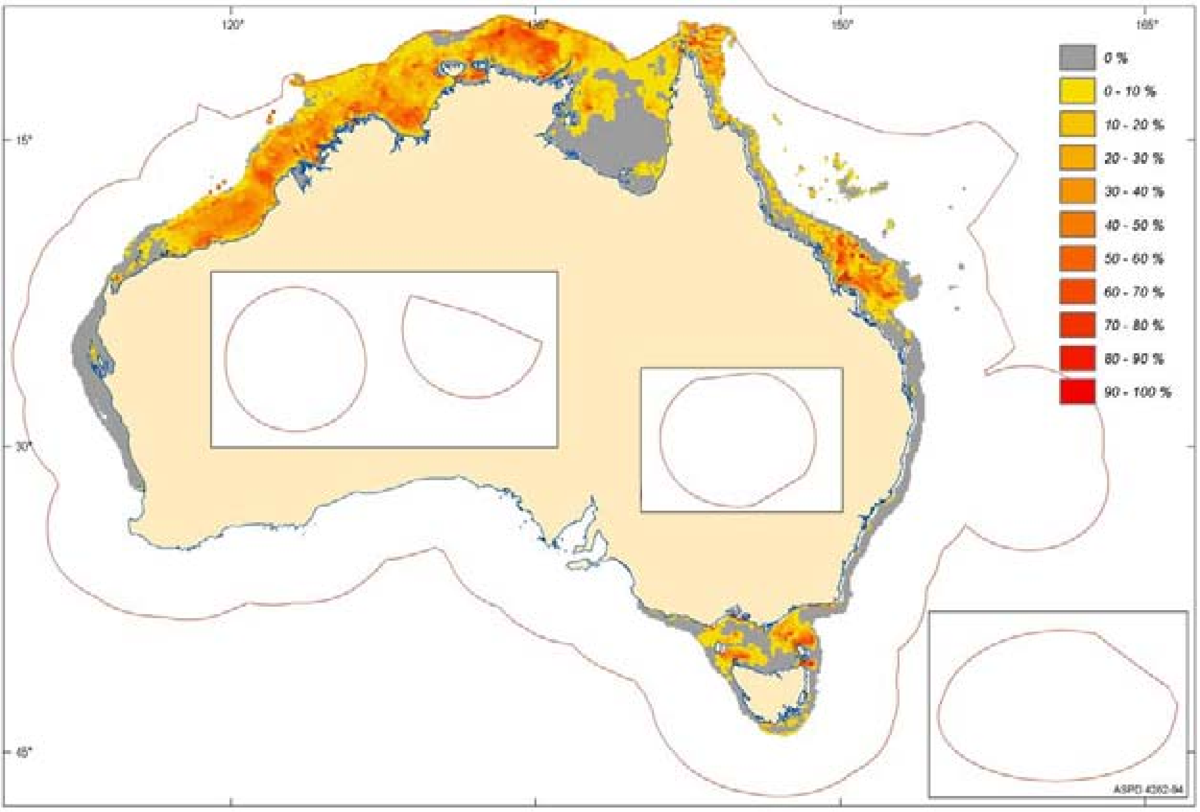

Figure 2.12. Map of tide-induced exceedance for water depths of <300 m.

2.1.8. Mean Wave Energy

Mean wave energy was calculated from Geoscience Australia's sediment mobility model GEOMAT (Harris *et al.*, 2000). Energy exerted on the seabed by waves can influence benthic marine biota through repeated and frequent agitation of the seabed. Agitation of the bed also enhances the transfer of nutrients (e.g., oxygen) between the sediments and water. The initial

10-km grid of wave model predictions was gridded to 0.01° (~1 km) resolution using a linear interpolation for water depths of <300 m to produce 6-hourly estimates of maximum near-bed orbital velocity. The mean total energy of surface gravity waves was then calculated per unit area of the seabed (J m^{-2}) (Fig. 2.13). This quantity is a measure of the wave energy available to mobilise sediments on the seabed, and is a direct function of significant wave height. The mean wave energy is calculated from significant wave height data for March 1998 to February 2004.

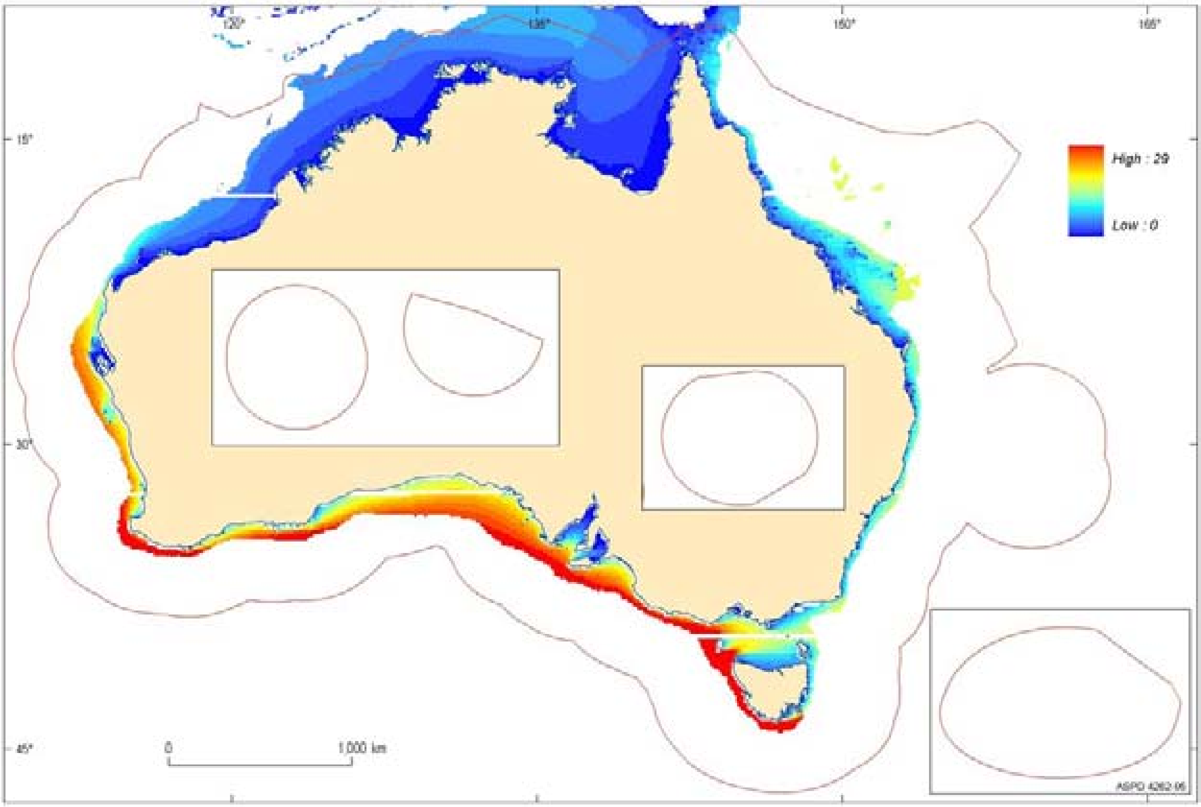

Figure 2.13. Map of mean wave energy (J m^{-2}) for water depths of <300 m. Mean wave energy is generated by the GEOMAT model.

2.1.9. Maximum Tide Energy

Maximum tide energy was calculated from Geoscience Australia's sediment mobility model GEOMAT (Harris *et al*., 2000). Energy exerted on the seabed by tides can influence benthic marine biota through repeated and frequent agitation of the seabed. Agitation of the bed also enhances the transfer of nutrients (e.g., oxygen) between the sediments and water. Maximum tide energy is a measure of the maximum speed (cm s^{-1}) that tidal currents reach at each location over a spring-neap tidal cycle (~14 days). The maximum tidal current speed is calculated as the maximum speed obtained at each grid location from the 2 weeks of tidal current predictions (Fig. 2.14). Hourly-averaged, depth-averaged tidal currents were estimated using a hydrodynamic tidal model for the Australian continental shelf with a spatial resolution of 0.067°. Maximum wave energy values were then gridded at 0.01° (~1 km) spatial resolution using a linear interpolation for water depths of <300 m.

2.2. Data from CSIRO – Marine Research

Data from CSIRO – Marine Research used in the draft NBMB were derived from existing national datasets and were also collated specifically for this project. A brief description of each of the datasets is provided with a reference for further details.

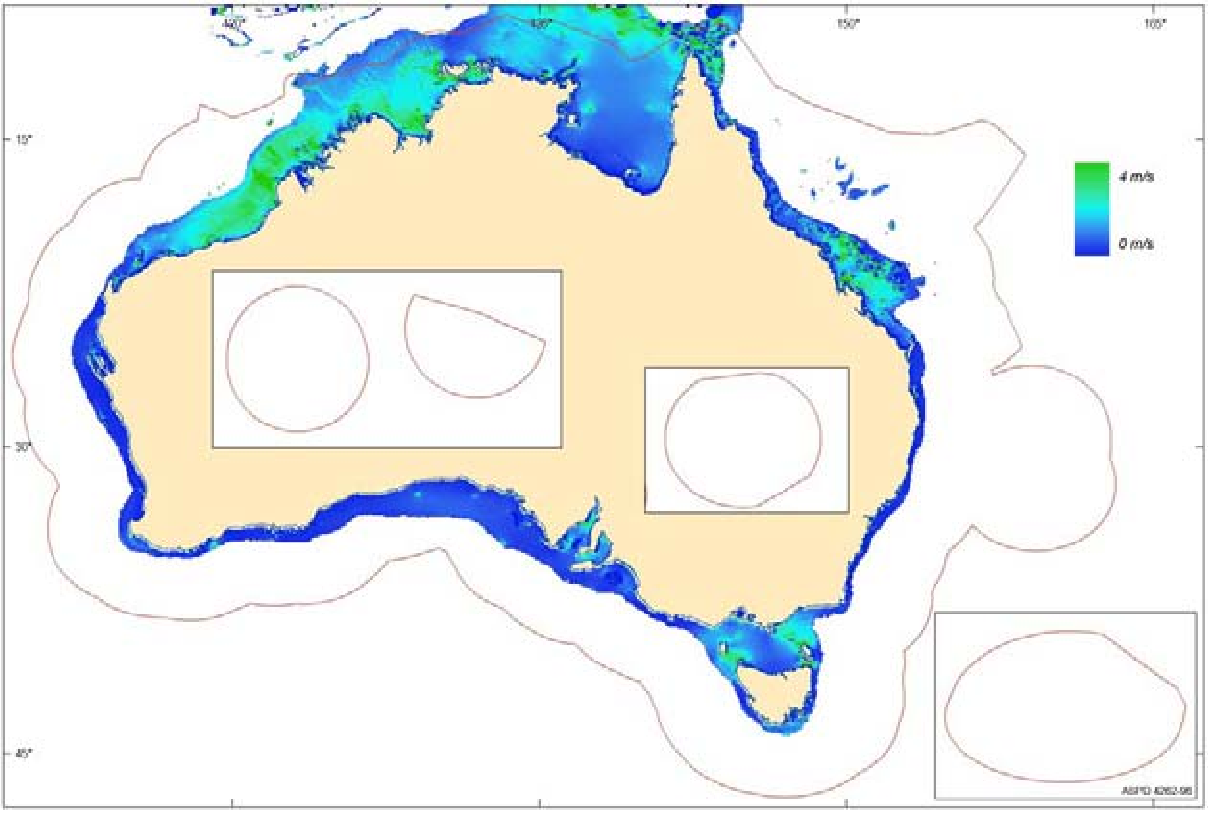

Figure 2.14. Map of maximum tidal current speed (m s^{-1}) for water depths of <300 m. Maximum tidal current speed is generated by the GEOMAT model.

2.2.1. Demersal Fish

The demersal fish dataset is one of the principal datasets for bio-geographic analysis because it is the only available biological dataset with adequate national spatial coverage and taxonomic resolution to provide robust analysis of broad-scale bio-geographic patterns. A national analysis of deep-water demersal fish data for Australia was thus undertaken specifically as a result of the lessons learnt from developing the draft interim bioregionalisation for the SE region (Butler *et al*., 2001). This exercise provided a more robust assessment of the demersal fish bio-geography in the EEZ that could be used as the basis for developing the draft NBMB. Deep-water demersal fish species data were collated from 240 CSIRO research surveys across the EEZ supplemented with data from external fisheries agencies in Australia. The dataset consisted of specimen and point data and catch composition data which revealed the distributional patterns of Australia's deep-water demersal fish for 1,489 species from 494 genera (representing 121 families). The data included details of the spatial distributions (i.e., latitude and longitude) and depth distributions for each species, where known. This basic information was then transferred to a one-dimensional string that circumnavigated the Australian continent corresponding to the 500 m bathymetric contour. This database presents the most recent biogeographical assessment of deep-sea demersal fishes in Australia. Further details regarding the collation and analysis of the demersal fish data are provided in Last *et al.* (2005).

2.2.2. Temperature, Salinity, Nutrients, Dissolved Oxygen

Bottom temperature, salinity, nutrients and dissolved oxygen were estimated from the CSIRO Atlas of Regional Seas (CARS) database. These variables are important drivers of ecological structure and processes on the seabed largely through the effects of large-scale variation in water temperature, light and nutrients on primary productivity. The outputs from CARS represent a least-squares map of the oceanographic data interpolated to a 0.02° (~2 km) spatial resolution grid (Ridgway *et al.*, 2002). The mapping methodology also explicitly accounts for separation of water masses by land and complex bathymetry (Dunn & Ridgway, 2002). These data were used to guide the derivation of Provincial Bioregion boundaries and have been included as supporting information to help characterise the benthic marine bioregions. Further information regarding the mapping of oceanographic data using the CARS database is presented in Ridgeway *et al.* (2002). The oceanographic data are contained in the National Marine Bioregionalisation GIS for reference.

2.3. Data from Queensland Museum

2.3.1. Sponges

The sponge dataset consists of specimen point data collated from collections residing at the Queensland Museum (c. 31,000 records) along with recent collections (of a subset of 721 'surrogate' species) of tropical fauna by the Australian Institute of Marine Science (c. 4,000 records), Museum and Art Gallery of the Northern Territory and Western Australian Museum (c. 4,100 records) (Hooper & Ekins, 2004). The resulting database contains approximately 3,800 'species' (or operational taxonomic units) from >4,000 localities that represents a total of 425 genera, 120 families, 26 orders and 3 classes of Porifera, of which approximately 2,250 species occur in marine waters of tropical Australia. The sponge dataset consisted of point data, including genus and species names, latitude and longitude and water depth, which were collated and interpreted within a community structure. The edited datasets were then sorted spatially into an agreed set of bioregions, after which the data were again sorted for endemic species (i.e., those species with a distribution range of only one bioregion) to yield a distribution of endemic species in northern Australia. The sponge data are contained in the GIS compatible relational specimen database 'Biolink' developed by CSIRO. Further information regarding the collation and interpretation of the sponge data is presented in Hooper and Ekins (2004). The sponge data have been used to guide the derivation of some of the Provincial Bioregion boundaries in northern Australia, and will also be valuable in defining smaller scale bioregions. The data are contained as a layer in the draft national bioregionalisation GIS for reference.

2.4. Data Robustness

A detailed treatment regarding the robustness of the data generated in the lead-up to the present project are provided in the individual reports associated with those projects (Hooper & Ekins, 2004; Passlow *et al.*, 2004; Harris *et al.*, 2005; Last *et al.*, 2005). These data have formed the basis for the draft NBMB. Below are brief comments regarding the general nature of these data in the present project.

2.4.1. Bathymetry

The 250 m spatial resolution bathymetry model is made up from a range of data, including swath sonar, Hydrographric Charts, ship echo-sounders, the General Bathymetric Chart of the Oceans (GEBCO), and seismic data. Swath sonar data is by far the most accurate and represents the highest quality data attainable. In the present project it provides an extensive and essential dataset, especially on the slope (i.e., 80 – 4,500 m). The southwest, south, southeast and Macquarie Island margins contain the largest contiguous regions of swath sonar data. Hydrographic Charts represent the next most comprehensive and accurate dataset, but are most detailed for shallow shelf regions, particularly major shipping channels. Ship echo-sounders and seismic data provide reasonably accurate data depending on the type of positioning system but are restricted to a single line of data denoting the ship's track. The GEBCO bathymetric model provides data at 1 minute spatial resolution and these data have principally been used in the very deep regions of the margin (i.e., abyssal plain/deep ocean floor) where no other data exist. While the 250 m bathymetry model covers 100% of the Australian EEZ, data coverage and quality is not consistent across the entire region. A reliability diagram of the bathymetry data showing the coverage of each of the data types for this area is currently unavailable.

2.4.2. Sedimentology

Geological data such as sedimentary basins and ocean crustal age cover the entire EEZ and provide a regional perspective of the gross structure of the seabed that other less spatially extensive datasets can not provide. Interestingly, these datasets also provide background and contextual information for more detailed biological data. For example, the different evolutionary histories contained in the demersal fish data from the southern and eastern margins are evident in the timing of the formation and development of the Southern Ocean and Tasman Sea ocean basins, as was evident from the draft interim benthic marine bioregionalisation of the SE region (Butler *et al.*, 2001). Sediment texture and composition data provide more detailed information on the nature of the seabed and the sedimentary and oceanographic processes that affect it. In the present bioregionalisation, these data are mostly in areas of <300 m water depth but are relatively scarce on the southern and western margins. As well as directly affecting marine biota, these data are valuable in elucidating regional and local trends in the make up of the seabed including inferring the location of sediment sources and sinks, and transport pathways.

2.4.3. Benthic Marine Biota

Data regarding the benthic marine biota on the margin are relatively scarce compared with the geological information. There is no comprehensive information base on the abundance and distribution of benthic marine biota in Australia's EEZ. This is a reflection of the relative unexplored state of Australia's marine environment and the cost and operational difficulty of survey work offshore. The demersal fish data are most reliable data for benthic marine fauna for the upper to mid slope regions and represent a robust dataset for the present project. The dataset is the best and most extensive ever collated and analysed for demersal fishes in Australia's EEZ. However, the data are mainly restricted to water depths of <1,000 m (or 36% of the total area of Australia's EEZ) and there are no samples for water depths of >2,000 m (or 54% of the total area of Australia's EEZ). The demersal fish data have been used based on the assumption that they are a surrogate for marine faunal distributions. However, given the patchy nature of the data and general paucity of biological datasets with good spatial coverage of waters of >2000 m depth, there is no robust way of testing this assumption for the draft NBMB. Nearly all of the sponge data are for northern Australian waters, and there are no data for regions of the margin for water depths of >2,000 m.

3. BENTHIC BIOREGIONALISATION FRAMEWORK

The draft NBMB framework consists of five levels that together capture the broad scale spatial patterns in distribution of biodiversity of Australia's EEZ beyond the shelf break and contain information that is valuable in guiding the regional marine planning process. The process of constructing a draft NBMB in this way requires partitioning the seabed into a hierarchical set of coherent and ecologically meaningful benthic marine bioregions within the context of the ocean basins. The bioregions have been defined by biological data (i.e., demersal fishes) and where no biological data are available, geological properties are used. As such, the bioregions are defined by the most widespread and robust data available across Australia's EEZ. Different datasets have been used at different levels to reflect the increasing detail and complexity of benthic marine habitats and biodiversity at the finer levels of the hierarchy. This section describes the construction of the draft NBMB bioregions. Descriptions and details of the draft NBMB Provincial Bioregions are provided in Appendix C.

3.1. Ocean Basins

All of the benthic marine bioregions in the draft NBMB reside within the physical "containers" of the Ocean Basins located between the continents. Ocean Basins provide the bio-geographic and evolutionary context for the benthic marine bioregions. For the purposes of this project the Ocean Basins are defined as the regions of seabed between the continental landmasses including their associated physical features and biota. The opening of the Ocean Basins dates back to the separation of Gondwana more than 80 million years ago and has influenced the distribution, evolution and connectivity of populations of benthic marine species. There are three Ocean Basins in Australia's EEZ, namely: the Indian Ocean in the west, the Southern Ocean to the south, and the Tasman Sea in the east.

3.2. Climate Zones

Within the Ocean Basins are Ocean Climate Zones. The Ocean Climate Zones capture the broad differences in water masses as defined by physical properties (e.g., temperature, salinity, nutrients) which are contemporary modifiers of the bio-geographic distributions and evolutionary traits of benthic marine faunal assemblages captured by the Ocean Basins. These broad Ocean Climate Zones have been defined principally on the spatial distribution of the deep-water demersal fishes around the Australian continent and water temperature (Last *et al*., 2005). Tropical waters are restricted to north of the Tropic of Capricorn; sub-tropical waters occur on the western margin and extend from Shark Bay in the north to Rottenest Island in the south; warm temperate waters extend along the southern margin from Cape Leeuwin to Kangaroo Island and on the eastern margin from Moreton Bay to Sydney Harbour including Norfolk and Lord Howe Islands; cold temperate waters are restricted to the seabed around Tasmania, extending from the vicinity of Cape Grim to the Tasman Peninsula; and sub-polar waters occur around Macquarie Island.

3.3. Primary Bathymetric Units

Primary Bathymetric Units define the major divisions of the benthic marine faunal communities and are represented by the major morphological features of the seabed (Table 1.1). These are the shelf, slope, rise (where applicable), and abyssal plain/deep ocean floor (Fig. 3.1). Processes affecting the evolutionary bio-geography of benthic marine biota are different for the shallow-water shelf regions compared with the deep-water slope and rise,

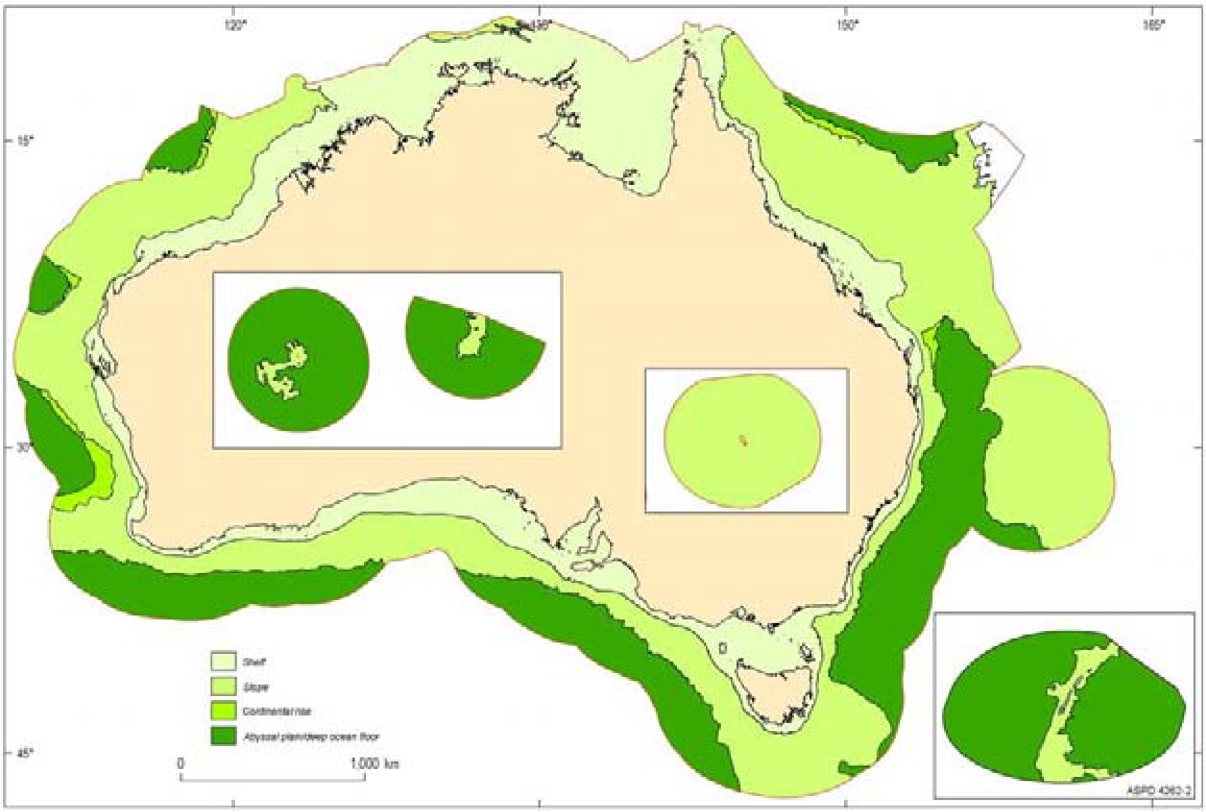

Figure 3.1. Map of the Primary Bathymetric Units consisting of: shelf, slope, rise and abyssal plain/deep ocean floor. See page 72 for legend.

and abyssal depths of the abyssal plain/deep ocean floor environments which result in distinct communities. The Primary Bathymetric Units thus specifically capture regional-scale differences in the bio-geography of benthic marine biota as a consequence of water depth and seabed gradient and may fall into different Ocean Climate Zones. The boundary between the shelf and slope is defined by the shelf break. The boundary between the slope and abyssal plain/deep ocean floor and, where applicable, the rise and abyssal plain/deep ocean floor is defined by the foot-of-slope.

3.3.1. Shelf Break

The shelf break was picked as an abrupt increase in seabed gradient denoted by closely spaced contours at the seaward edge of the outer shelf (Harris *et al*., 2005). In most places this location was easily recognised. Where possible, previous studies were used to help establish the location, particularly in regions where no clear shelf break could be identified from the contours, such as the northwest margin and western Arafura Sea. In the few cases where no information was available, a logical location, based on change in gradient was used that was consistent with adjacent regions where the shelf break could be determined.

Around Australia the shelf break occurs in water depths of approximately 80 m to 250 m and is a sharp change in gradient in all places except for the northwest margin where the gradient is much shallower and it forms a broad slope (Collins, 2002). The shelf break is shallowest on the northeast margin where it occurs at approximately 80-100 m water depth seaward of the GBR, and gradually deepens to 200-220 m on the east and southeast margins, and 220-250 m on the southern margin. On the southwest margin the shelf break is between 150-200 and shallows again towards the north to 100-150 m on the west margin and 150-180 m on the northwest margin.

3.3.2. Foot-of-Slope

The outer boundary of the slope is defined by the "foot-of-slope" which represents the boundary between continental and oceanic rocks. The foot-of-slope commonly defines the boundary between the slope and abyssal plain/deep ocean floor and less commonly the rise and abyssal plain/deep ocean floor. Identifying the foot-of-slope is not straightforward. In this study, the foot-of-slope was picked from bathymetric and seismic profiles in regions where Geoscience Australia has undertaken an analysis of the margin using provisions set out in Article 76 of the UN Convention on the Law of the Sea (UNCLOS; e.g., Symonds & Willcox, 1988). Only those profiles normal to the margin and with high-quality navigation information were used. In these cases the foot-of-slope was defined as the point of maximum change of gradient at the base of the continental slope.

Determination of the point of maximum change of gradient was made with the assistance of a special extension written for ArcView®, which identifies the changes in gradient down the profile between adjacent sample points. Several potential foot-of-slope positions (inner, intermediate, outer) were selected within the lower slope zone and then one was subsequently chosen as the 'preferred' pick, taking into account adjacent profiles. At all other locations, the foot-of-slope was determined from changes in the gradient of the bathymetry. As a guide, the boundary was considered to be in water depths of >4,000 m and where the surface gradient of the adjacent plain was <1:1,000 denoted by widely spaced contours (Symonds & Willcox, 1988). In places where a rise was present (defined in the scientific and technical guidelines to UNCLOS as "a wedge of sediment at the base of the continental slope"), the foot-of-slope was picked as the seaward edge of the rise, at the rise-abyssal plain/deep ocean floor boundary.

Beyond the slope and rise (where applicable) the abyssal plain/deep ocean floor comprises the remaining primary bathymetric unit over the EEZ. The abyssal plain/deep ocean floor unit extends out to the limit of the EEZ. Around the Australian margin the foot-of-slope occurs at comparable water depths. The foot-of-slope is shallowest on the northeast margin where it occurs at approximately 3,500 m. Over the rest of the EEZ the foot-of-slope occurs in water depths of 4,500-5,000 m.

3.3.3. Primary Bathymetric Units

Across the Australian EEZ, the shelf covers an area of more than 1.9 million km^2, the slope nearly 4.1 million km^2, the rise more than 97,000 km^2, and the abyssal plain/deep ocean floor almost 2.9 million km^2 (Table 3.1.). Nearly half of the EEZ is characterised by benthic marine habitats and biota on the slope with the abyssal plain/deep ocean floor habitats and biota covering nearly a third of the remaining area.

Table 3.1. Area of Primary Bathymetric Units for the Australian EEZ.

Primary Bathymetric Unit	Area (km^2)	Area (%)
Shelf	1,976,110	21.91
Slope	4,059,760	45.02
Rise	97,070	1.08
Abyssal plain/deep ocean floor	2,884,590	31.99
Total	**9,017,530**	**100**

In the north, the shelf comprises >90% of the area. By contrast, in the east the continental shelf comprises a relatively small area and >90% of the area of the margin is slope and abyssal plain/deep ocean floor. Similarly, >85% of the area of the margins surrounding the island territories of Christmas, Cocos (Keeling) and Macquarie Islands is abyssal plain/deep ocean floor. These trends are reflected in the composition of the Provincial Bioregions (Appendix C).

The slope is broadest and most well developed on the northwest, northeast, southeast, south and southwest margins, where it contains large marginal terraces and plateaus. The presence of the plateaus and terraces indicates that the geological structure of the slope around Australia is highly diverse and complex. The slope is steepest along the east margin, where the shelf is narrow and slope is incised by numerous submarine canyons.

The rise is most well developed on the west margin, poorly developed on the northeast margin, and absent on the east, southeast and south margins. On the west margin, the rise covers an area of 71,290 km^2 and is discontinuous, occurring in basins separated by margin plateaus and spurs.

The abyssal plain/deep ocean floor occurs in water depths of >4,000 m on all margins except for the north and Norfolk Island margins. The abyssal plain/deep ocean floor is broadest in the east and south, particularly where the slope is steep and narrow. In the east, the abyssal plain/deep ocean floor region covers 624,950 km^2 and is punctuated by seamounts of the Tasmantid Seamount chain (McDougall & Duncan, 1988). In the southwest, the abyssal plain/deep ocean floor surrounds the rugged seabed of the Diamantina Zone.

3.4. Provincial Bioregions

The Provincial Bioregions are large bio-geographic regions that capture the broad-scale distribution of benthic marine fauna and broad patterns in benthic marine biodiversity for areas of the EEZ seaward of the shelf break. The Provincial Bioregions were defined from the regional structure of demersal fishes for water depths of <2,000 m (not including the shelf). The demersal fish structure was generated by CSIRO – Marine Research as part of the national assessment of deep-water demersal fish species in Australia (Last *et al.*, 2005). This approach is based on the assumption that the demersal fish distributions are a surrogate of marine faunal distributions across Australia's EEZ. The boundaries of the Provincial Bioregions have been drawn across the lower slope, rise and abyssal plain/deep ocean floor to the EEZ boundary because of the absence of biological data for these deep-water regions. The absence of biological data for these deep-water regions is a significant limitation of the present project.

To construct the Provincial Bioregions, the demersal fish data were converted to a one dimensional 'string' made up of 281 nodes that corresponds to the 500 m isobath around the Australian mainland. None of the offshore island territories were included in the assessment and analysis. The string analysis produced a series of 17 demersal fish provinces and transitions that each covers a number of string nodes that defines their location around the Australian continent (Table 3.2). The demersal fish provinces represent areas of endemism and the demersal fish transitions represent areas of species overlap and faunal mixing. The boundaries of the demersal fish provinces were defined by a Jaccard Analysis of the fish distributions (Last *et al.*, 2005). The demersal fish provinces are the evolutionary products of palaeo-historical events modified by the contemporary environment. Strong provinces would be expected to have high numbers of endemics and/or a broad geographic coverage within the Australian region. Weak provinces have few endemics, which are often narrowly distributed. A data confidence level exceeding three was considered to indicate a well-defined or strong demersal fish province. In the present draft NBMB the Provincial Bioregions around the mainland correspond to each of these 17 demersal fish Provinces and Transitions (Fig. 3.2).

Table 3.2. Provincial structure of demersal fishes around Australia.

String Position	Demersal Fish Provinces (from Last *et al*., 2005)	Total number of species	Number of endemic species	Number of species of depth >200 m	Number of species of depth >200 m & string <130	Number of species of depth >200 m & string <60	Number of species of depth >200 m & string <25	Strength*
0–2	North-East "edge"	257		84	31	6	2	
2–12	CP: Cape Province	302	24	106	46	18	6	0.9
12–20	NET:- North Eastern Transition	421		219	125	95	38	
20–39	NEP: North Eastern Province	441	70	243	134	102	32	**4.7**
39–53	CET: Central Eastern Transition	518		305	159	119	37	
53–70	CEP: Central Eastern Province	639	56	445	266	146	51	**3.4**
70–80	SET: South Eastern Transition	536		398	234	105	37	
80–103	TasP: Tasmanian Province	486	52	377	219	83	31	**4.3**
103–118	WtasT: Western Tasmanian Transition	456		348	191	50	11	
118–170	SP: Southern Province	463	26	336	175	34	12	**4.8**
170–175	SWT: South Western Transition	398		283	121	26	8	
175–190	CWP: Central Western Province	480	31	319	145	62	22	1.7
190–200	CWT: Central Western Transition	462		272	109	72	34	
200–208	NWP: North Western Province	508	76	289	143	106	53	2.2
208–218	NWT: North Western Transition	505		283	166	137	68	
218–252	TP: Timor Province	418	64	198	120	88	26	**7.7**
252–	TT: Timor Transition	284		109	65	33	2	

* Strength = string length x number of endemics / total number of string points. Numbers in bold text are considered "strong" or well-defined demersal fish Provinces (see section 3.4 for explanation).

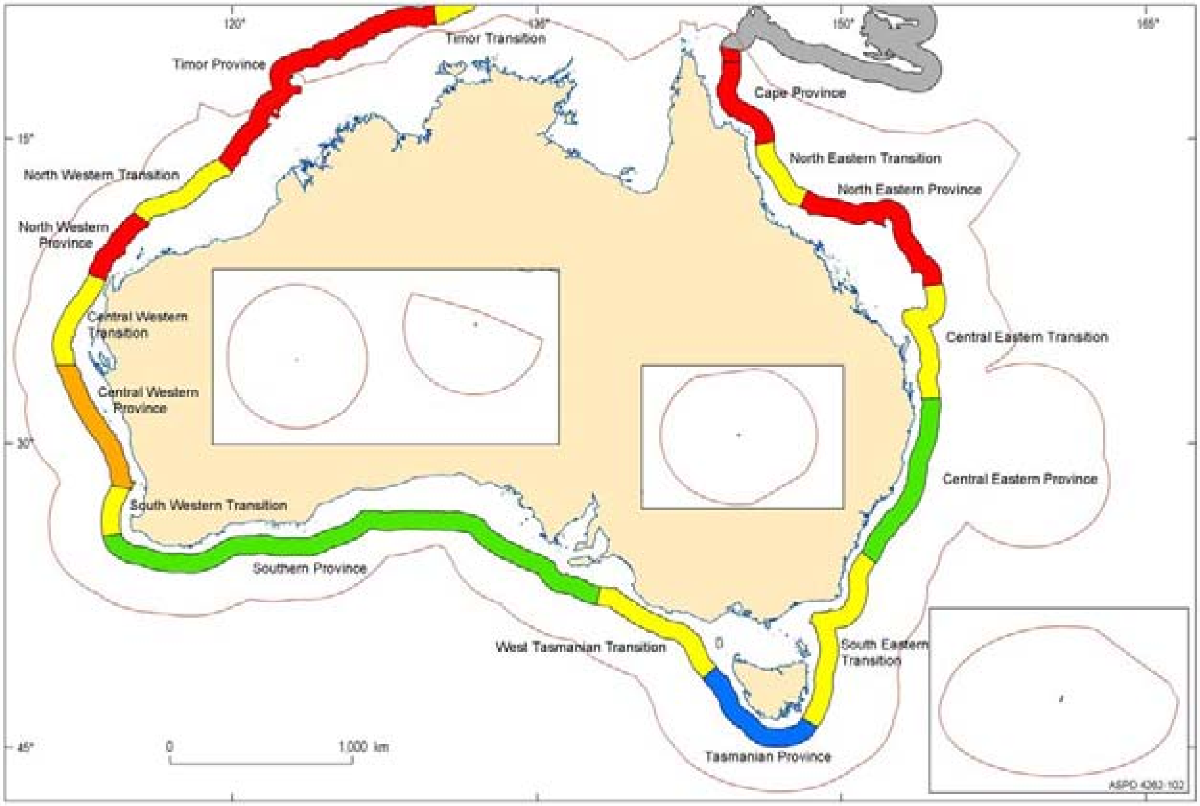

Figure 3.2. Map of the provincial structure in the demersal fish data (from Last *et al.*, 2005). The demersal fish provinces have been defined from a 1-dimensional string consisting of 281 nodes corresponding to the 500 m depth contour that encircles the continent. Note that none of the offshore island territories were included in the analysis.

Where no demersal fish data were available (i.e., water depths >2,000 m) the boundaries of the Provincial Bioregions were defined using the geomorphic features (Fig. 2.2; Table 3.3). The advantage of using the geomorphic features is that they cover 100% of the seabed of Australia's EEZ. Apart from representing the only reliable physical data available for deep water regions, using the boundaries of the geomorphic features is reasonable based on the assumption that they mark broad-scale biotic changes. For example, in the deep ocean, there are likely to be significant differences in benthic marine biota between the steeper slopes of seamounts compared with the gentle gradients and often sedimented slopes of the adjacent abyssal plain/deep ocean floor.

The boundaries of the Provincial Bioregions contained in the draft NBMB are labelled uniquely from B1 – B24 and define a total of 24 separate Provincial Bioregions in the EEZ seaward of the shelf break (PB1 – PB24; Fig. 3.3). Two types of Provincial Bioregions are delimited by the boundaries: 1) Provinces, which are regions of endemism; and 2) Transitions, which are less well-defined mixing areas that capture the overlap of demersal fish species ranges. Full boundary definitions are provided in Table 3.3.

Provincial Bioregions on the shelf have not been defined in the present project. On the shelf, the Provincial Bioregions are the existing demersal Provinces and Transitions (referred to biotones) contained in the IMCRA framework (IMCRA Technical Group, 1998). Full details of how the IMCRA Provinces and Transitions were constructed and defined are presented in the final IMCRA report (IMCRA Technical Group, 1998). For the purposes of this report these bioregions have been termed IMCRA Provincial Bioregions (PB25 – PB41). The newly created Provincial Bioregions for the draft NBMB thus extend from the shelf break (as defined from the geomorphology; Fig. 2.3) to the outer limit of the EEZ. In this report these bioregions have been termed NBMB Provincial Bioregions (PB1 – PB24).

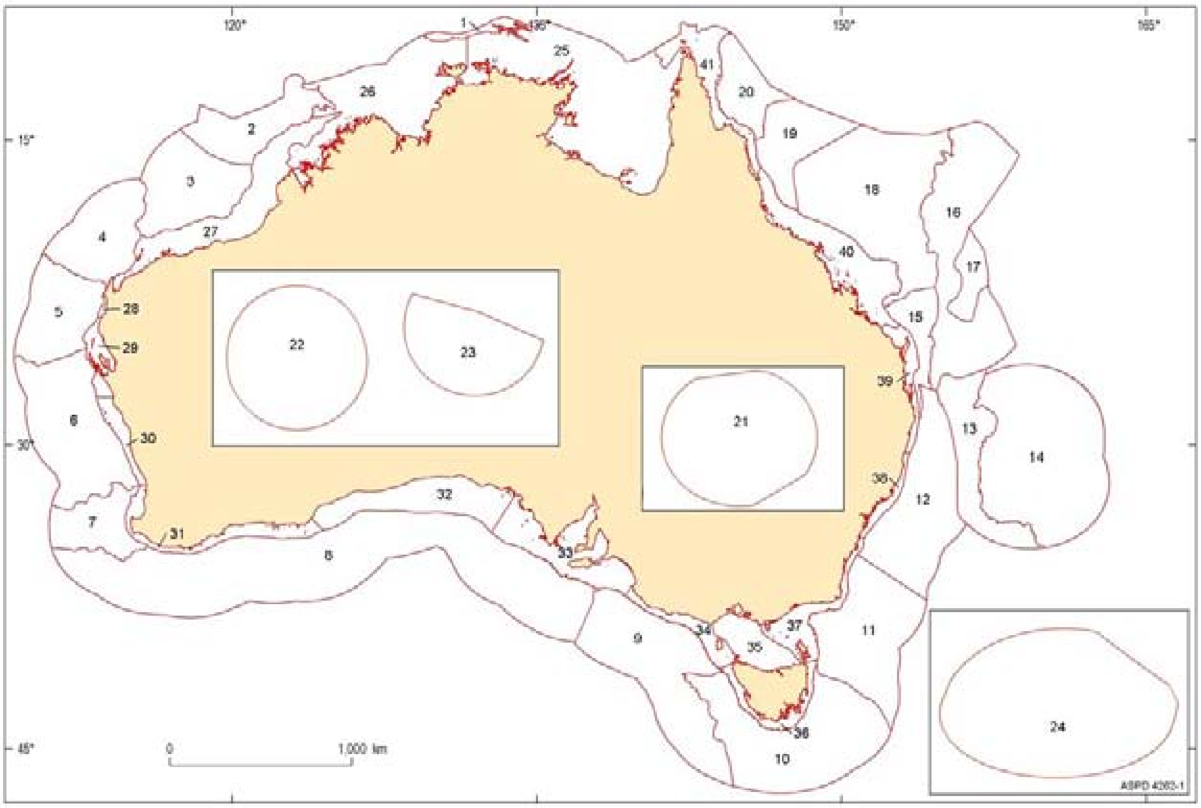

Figure 3.3. Map of the Provincial Bioregions. The boundaries of the draft NBMB Provincial Bioregions (1-24) are defined by the provincial structure in the demersal fish data, where available, and then by geomorphology with reference to supporting data. The IMCRA shelf Provincial Bioregions (25-41) are those contained in the IMCRA shelf regionalisation framework (IMCRA Technical Group, 1998).

Table 3.3. Definition of Provincial Bioregion boundaries.

Unique ID	Definition
B1	Defined by the shelf break as drawn on the geomorphic features map (Fig. 2.2).
B2	Defined on the upper slope by the boundary between demersal fish provinces TP and NWT, then down the slope across the Rowley Terrace following the northern limit of a series of submarine canyons, and then bisects the Argo Abyssal Plain to intersect with the 200 nautical mile boundary.
B3	Defined on the upper slope by the boundary between demersal fish provinces NWT and NWP, then extends down the slope following the eastern and northern edges of the Exmouth Trough to the 200 nautical mile boundary.
B4	Defined on the upper slope by the boundary between demersal fish provinces NWP and CWT, then follows the northern edge of the Carnarvon Terrace down the slope following the southern flank of a submarine canyon to the base of the slope, then follows the base of the slope on the southern margin of the Exmouth Plateau to the 200 nautical mile boundary.
B5	Defined on the upper slope by the boundary between demersal fish provinces CWT and CWP, then traverses the slope bisecting the Carnarvon Terrace to run along the southern boundary of the Carnarvon Saddle to the 200 nautical mile boundary.
B6	Defined on the upper slope by the boundary between demersal fish provinces CWP and SWT, and then follows the axis of the Perth Canyon down the slope, then runs along the base of the slope on the northern flank of the Naturaliste Plateau to the 200 nautical mile boundary.
B7	Defined on the upper slope by the boundary between demersal fish provinces SWT and SP, then runs down the slope following the southern edge of two terraces and upslope of a series of submarine canyons, then follows the base of the slope the southern flank of the Naturaliste Plateau to the 200 nautical mile boundary.*
B8	Defined on the upper slope by the boundary between demersal fish provinces SP and WTasT east of the Murray Canyons to the base of the slope, and then bisects the abyssal plain to extend to the 200 nautical mile boundary.†

B9	Defined on the upper slope by the boundary between demersal fish provinces WTasT and TasP between two areas of closely-spaced submarine canyons (recognising there is a lack of data), and then follows the northern boundary of a series of knolls located at the base of the slope, then bisects the abyssal plain out to the 200 nautical mile boundary.
B10	Defined on upper slope by the boundary between demersal fish provinces TasP and SET and along the southern edge of a submarine canyon system, then along the base of the slope on the northern flank of the East Tasman Plateau, and then bisects the abyssal plain out to the 200 nautical mile boundary.
B11	Defined on the upper slope by the boundary between demersal fish provinces SET and CEP, then extends directly down the slope between two submarine canyons and bisects the abyssal plain out to the 200 nautical mile boundary.
B12	Defined on the upper slope by the boundary between demersal fish provinces CEP and CET, and sponge distribution, then follows the 200 m contour, and then extends down the slope to the intersection with B13, B16 and B18.
B13	Extends along the western margin of the base of the Tasmantid Seamounts and along the base of the slope to the intersection of B12, B16 and B18.
B14	Extends along the base of the slope on the western flank of the Dampier Ridge and Lord Howe Ridge and along the 200 nautical mile boundary.
B15	Defined by the 200 nautical mile boundary and treaty boundaries with France and New Zealand.
B16	Extends from the intersection of B12, B13, and B18 around the northern perimeter of the Brisbane Guyot and then bisects the abyssal plain to the 200 nautical mile boundary.
B17	Defined on the upper slope by a demersal fish boundary that is delimited by the 2,000 m bathymetric contour and the treaty boundary with France.
B18	Extends north along the western margin of the Cato Basin, and the western margins of the Cato Saddle, Mellish Plateau and Louisiade Plateau, and then extends along the eastern margin of the Coral Sea Basin to the treaty boundary with Papua New Guinea.
B19	Defined on the slope by the boundary between demersal fish provinces CET and NEP, and extends down the slope to the western margin of the Cato Basin where it intersects B18.
B20	Defined on the upper slope by the boundary between demersal fish provinces NEP and NET, and extends across the Queensland Plateau encompassing the southern coral reef province on the plateau, then bisects the rise and Coral Sea Basin to the treaty boundary with Papua New Guinea.
B21	Defined on the upper slope by the boundary between demersal fish provinces NET and CP, and extends across the Queensland Plateau encompassing the northern coral reef province on the plateau, then bisects the rise and Coral Sea Basin to the treaty boundary with Papua New Guinea.
B22	Defined by the AEEZ.
B23	Defined by the AEEZ.
B24	Defined by the 200 nautical mile boundary and treaty boundary with New Zealand.

Notes:

* Demersal fish data indicate that the actual boundary is further to the east. However, the boundary was shifted slightly to the west to maintain the integrity of the submarine canyon systems to the east.

† This boundary was defined so as to maintain the integrity of the Murray Canyons complex and any associated palaeo-channels.

3.5. Biomes

Biomes are bio-geographic regions that capture the narrow spatial distributions in the benthic marine fauna contained within the Provincial Bioregions. In the draft NBMB the biomic structure was defined by the demersal fish data in the Provinces (Last *et al.,* 2005) based on the assumption that the demersal fishes are a surrogate for distributions of benthic marine fauna. The narrow spatial distributions defined in the distributions of demersal fishes around Australia were revealed as strong patterns of bathymetric zoning for key indicator species on the upper to mid slope (Table 3.4). The demersal fish data showed strong biomic structure on the slope which is reflected in the NBMB Provincial Bioregions (Last *et al.,* 2005). No Biomes were defined for the offshore island territories nor for the shelf.

Table 3.4. Details of demersal fish biomic depth intervals in the Provinces.

Provincial Bioregion	Biome			
	Outer Shelf (m)	Upper Slope (m)	Mid-upper Slope (m)	Mid Slope (m)
Timor Province (PB2)	140 – 220	225 – 500	N/A	750 – 1000
Northwest Province (PB4)	150 – 225	300 – 530	650 – 780	900 – 1100
Central Western Province (PB6)	145 – 230	300 – 510	650 – 800	890 – 1075
Southern Province (PB8)	80 – 220	310 – 520	650 – 750	860 – 1140
Tasmania Province (PB10)	90 – 220	310 – 520	650 – 775	880 – 1100
Central Eastern Province (PB12)	80 – 220	280 – 490	610 – 830	910 – 1080
Northeast Province (PB18)	125 – 225	250 – 475	600 – 760	890 – 1130
Cape Province(PB20)	125 – 220	200 – 470	590 – 780	890 – 1130
No. of Species*	106	187	30	100

* Total number of species in each Biome.

In the Provinces, three distinct Biomes were defined from the demersal fishes, separated by zones representing overlap in the demersal fish depth distributions (Table 3.4). Here, we present the aggregated demersal fish data used by Last *et al*. (2005) to define the individual slope Biomes. Full details of the demersal fish species making up each of the Biomes on the slope is provided in Last *et al*. (2005).

The Mid-upper Slope Biome is defined by the lowest number of key indicator demersal fish species (n = 30) while the Upper Slope Biome is defined by the greatest number of key indicator fish species (n = 187). The Upper Slope Biome is defined based on almost twice as many species as the Mid Slope Biome and six times more species than for the Mid-upper Slope Biome. The numbers of species in each Biome reveal the evolutionary history of each of the Biomes. Biomes with larger number of species represent distinct, well-established Biomes with a relatively long evolutionary history (Last *et al.*, 2005). This is reflected also in the degree to which the boundaries change in location on the slope around the margin between the well-defined Upper Slope and Mid Slope Biomes and the less well-established Mid-upper Slope Biome.

The Biome boundaries vary in depth around the continent and are generally deeper in the Provincial Bioregions on the southern margins. This depth variation is most evident for the upper boundary of the Upper Slope Biome and occurs to variable degrees for the other Biome boundaries. The Mid Slope Biome is defined by the greatest range of depths around the mainland margin. The upper boundary varies in location on the slope by up to 160 m and the lower boundary by 140 m across the Provinces. Conversely, the Mid-upper Slope Biome is defined by the smallest range of depths on the slope, at 60 m and 80 m for the upper and lower boundaries, respectively. This is not surprising given that the Mid-upper Slope Biome covers the narrowest depth ranges (average = 147 m) and the Upper and Mid Slope Biomes cover wider and comparable depth ranges (average 260 m and 258 m, respectively).

A poorly-defined Outer Shelf Biome was also evident from the analysis of the demersal fish data. The upper boundary of this Biome was not well defined because the present study lacks a full analysis of the demersal fish data for the shelf and coastal zone (Last *et al.*, 2005), which must be completed to fully reveal the demersal depth structure. For this reason, the Outer Shelf Biome has not been considered in the draft NBMB.

For the Transitions, the upper and lower depths of each Biome down the slope were arbitrarily set to the mid-point between the upper and lower depths of the corresponding Biomes in the adjacent Provinces. This approach was undertaken to represent the variation in biomic structure between the Provinces, as captured by the Transitions. This approach seems reasonable as the demersal fish data for the entire continental margin indicate that the biomic structure is very strong down the slope (Table 3.4; Last *et al.*, 2005). Biomes in the Transitions would thus be at comparable depths to those of the adjacent Provinces. The boundaries were then projected onto the 250 m bathymetry model according to the depth structure presented in Table 3.4 to create the spatial extent of the Biomes over the EEZ (Fig. 3.4).

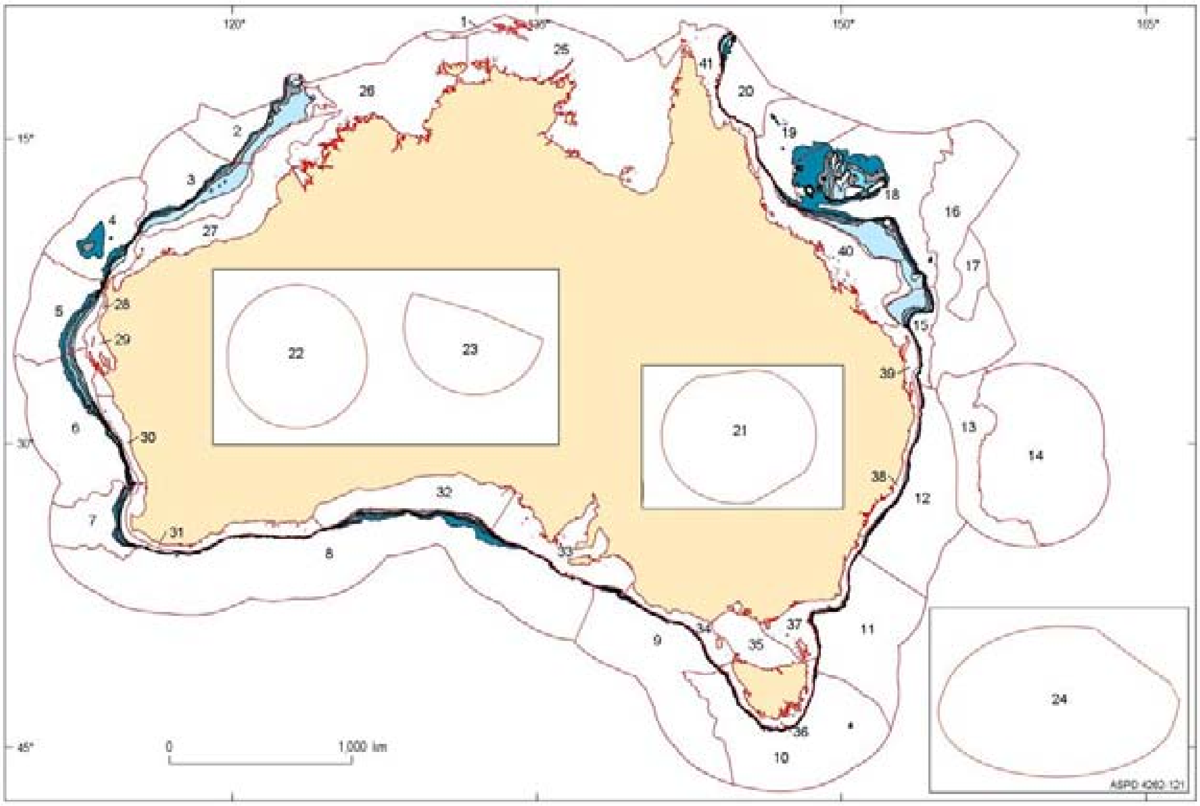

Figure 3.4. Map of Biomes on the slope. The Biomes are defined by the depth structure in the demersal fish data and have been overlain onto the 250 m bathymetry model. See page 72 for legend.

4. APPLICATIONS OF PHYSICAL DATA

Provincial Bioregions and Biomes together define benthic marine bioregions of >1,000-100,000 km^2. These need to be subdivided further for application to management issues that are relevant at smaller spatial scales. We have attempted two approaches and the results of these analyses are provided here as additional information. First, a cluster analysis of the geomorphic features has been undertaken to produce Geomorphic Units that represent broad-scale regions of similar geomorphology. Second, a cluster analysis of different geological and oceanographic datasets collected for this project has been undertaken to produce Seabed Facies, which define regions of the shelf that contain a suite of geological and oceanographic attributes that distinguish it from adjacent regions (e.g., Walker 1994).

Both of these analyses represent examples of potential ways the physical data might be used to subdivide the draft NBMB bioregions. Geomorphic Units and Seabed Facies provide valuable information for targeting specific habitats or particular environments for management and protection. These analyses also produce bioregions that reflect the biological complexity in benthic marine habitats at scales required for defining a National Representative System of Marine Protected Areas. Similar analyses of the physical data were undertaken in construction of the draft interim benthic marine bioregionalisation for the SE region (Butler *et al.*, 2001).

4.1. Geomorphic Units

Individual geomorphic features add information about the spatial distribution of benthic marine biota. This is based on the assumption that the features are broad surrogates for biota. While individual features are probably biologically very significant, many are too small in size and too numerous to be applied effectively for ecosystem-based management. Therefore the individual features were clustered into Geomorphic Units which represent regions of similar geomorphology over the EEZ and capture some of the smaller-scale benthic marine habitat distributions. Thus the objective of the analysis was to define Geomorphic Units or areas of like geomorphology to highlight regions of similar benthic marine biodiversity at a spatial scale relevant for regional marine planning. In constructing the Geomorphic Units a quantitative analysis of the individual geomorphic features (Fig. 2.2) was first undertaken to objectively describe the spatial distribution of the geomorphology. The results of this analysis were used to guide a subjective clustering based on the presence and absence and relative spacing of smaller and more numerous geomorphic features on the shelf and slope.

4.1.1. Analysis of Spatial Data

Spatial clustering of geographic elements in the seascape by computer is difficult because the mathematical equations describing spatial patterns are not obvious or simple. One useful method is to quantify the spatial characteristics by calculating a range of metrics that describe patterns in the landscape (He *et al.*, 2000; Read & Lam, 2002; Ekstrom, 2003). There is a plethora of metrics available and the first problem is the choice of the metrics to apply (e.g., He *et al.*, 2000). This is compounded by the difficulty in deciding how many metrics to use because of the high degree of correlation amongst them. Using too many metrics results in redundancy and too few may comprise the sensitivity of the spatial classification. A further decision must then be made as to where to stop the clustering process so that meaningful and appropriate classes are generated.

4.1.2. Spatial Metrics

In order to quantitatively describe the spatial distribution of the individual geomorphic features, several spatial metrics were calculated using the spatial pattern analysis program, Fragstats® (http://www.umass.edu/landeco/research/fragstats/fragstats.html). Using this approach, the seascape (i.e., Australian EEZ) contains a suite of classes representing geomorphic feature types (e.g., plateau) that consists of a number of patches each representing individual geomorphic features (e.g., Queensland Plateau). The metrics can be calculated at the landscape, class, and patch level.

The appropriate level for our analysis is the class level, where a class is defined as one of the geomorphic feature types. A number of class metrics, provided by the Fragstats® software package, were considered as a means of quantifying the perceived spatial patterns in the geomorphic data, including: perimeters, areas and spatial densities of the patches, as well as more sophisticated spatial metrics such as the dominance, isolation, connectivity and cohesion of individual patches. We initially undertook an assessment of these metrics and considered that patch cohesion and patch connectivity (see Appendix D for full definitions) provided the best measures of the spatial characteristics of the geomorphic features. The two metrics are not significantly correlated (Table 4.1) and so complement each other and provide for a more robust analysis.

Table 4.1. Correlation matrix of descriptive metrics for geomorphic feature types.

Fragstats Metric	Percent Cover*	Patch Density	Edge Density	Cohesion	Connect (10 km)	Connect (100 km)	Connect (1,000 km)
Percent Cover*	1.00						
Patch Density	-0.13	1.00					
Edge Density	**0.68**†	-0.03	1.00				
Cohesion	0.32	-0.28	0.30	1.00			
Connect (10 km)	0.05	-0.14	-0.03	0.20	1.00		
Connect (100 km)	-0.09	0.14	-0.21	-0.11	**0.60**†	1.00	
Connect (1,000 km)	-0.23	**0.60**†	-0.17	-0.18	0.10	**0.44**†	1.00

* Percent Cover is the percentage of the total area covered by each geomorphic feature type.
† Numbers in bold text are significant at 95% confidence.

The patch cohesion index measures the physical connectedness of the individual patches over the EEZ and is calculated, as follows:

$$COHESION = \left[1 - \frac{\sum_{j=1}^{n} p_{ij}}{\sum_{j=1}^{n} p_{ij}\sqrt{a_{ij}}}\right]\left[1 - \frac{1}{\sqrt{A}}\right]^{-1}(100) \quad (1)$$

where p_{ij} is the perimeter of patch ij in terms of number of cell surfaces, a_{ij} is the area of patch ij in terms of number of cells, and A is the total number of cells in the seascape. Patch cohesion is a measure of the degree to which the patches differ from a single perfect circle, either by being disjoint into several smaller shapes or as a single irregular shape. The more irregular or disjoint the shape(s) the closer the cohesion value is to zero. A perfect circle has a patch cohesion value of 100.

The patch connectance index is a measure of the total number of joinings between individual patches for the whole of the EEZ, subject to a threshold distance specified by the user, as follows:

$$CONNECT = \left[\frac{\sum_{j \neq k}^{n} c_{ijk}}{\frac{n_i(n_i - 1)}{2}} \right](100) \qquad (2)$$

where c_{ijk} is the joining between patch *j* and *k* of the corresponding patch type (*i*), based on the threshold distance and n_i is the number of patches over the EEZ of the corresponding patch type. Connectivity increases as the number of connections increases. A class consisting of a single patch and a class with a number of patches that are not connected at the threshold distance will have a connectivity of 0 regardless of shape. A class with every patch connected will have a connectivity of 100. At smaller threshold distances fewer patches are connected.

Given that the data have been gridded at approximately 1 km, a 1 km threshold distance would mean that virtually no patches would be connected. Threshold distances of 10, 100, and 1,000 km were used in the connectance analysis to test which scale gave the widest range of connectivity. A threshold value of 1,000 km showed the most variation between the patches and was considered most useful for the analysis (Table 4.2).

Table 4.2. Patch cohesion and connectance indices for different geomorphic feature types (i.e., classes).

Type	Geomorphic Feature	Cohesion	Connectivity (10 km)	Connectivity (100 km)	Connectivity (1,000 km)
1	Shelf	99.8597	0.8691	3.7929	25.6925
2	Slope	99.7884	2.1227	7.0094	35.7656
3	Rise	99.2085	6.6667	11.1111	31.1111
4	Abyssal Plain/Deep Ocean Floor	99.8454	1.3072	6.5359	27.451
5	Bank	96.0362	0.5696	6.3254	43.3382
6	Deep	97.9530	0.6560	5.8930	40.2723
7	Trench	99.2224	0.5263	7.3684	14.7368
8	Basin	99.4482	0.2899	3.6715	19.4203
9	Reef	90.0101	0.2855	8.0610	62.0950
10	Canyon	95.8093	0.3479	2.3180	20.3728
11	Knoll	99.2421	0.2256	2.2099	18.1664
12	Ridge	98.6103	1.4278	8.7188	32.3815
13	Seamount	96.7371	0.3386	3.8458	30.0976
14	Pinnacle	74.879	0.4086	6.3146	23.0285
15	Plateau	99.5995	1.4873	4.7785	20.7595
16	Saddle	99.0085	0.9524	3.9683	16.3492
17	Apron	95.0236	1.0000	6.3333	46.6667
18	Escarpment	97.7435	1.9608	7.6649	39.3939
19	Sill	98.4891	0	0	33.3333
20	Terrace	99.2086	0.7248	2.7293	20.0716
21	Sandwave	96.5847	2.3762	16.2178	41.6832

Other spatial metrics are available in Fragstats® for describing the spatial distribution of the landscape including the popular Shannon’s Diversity Index (Shannon & Weaver, 1949) and Modified Simpson’s Diversity Index (Simpson, 1949; Pielou, 1975). Shannon’s Diversity index is a measure of patch diversity and Modified Simpson’s Diversity Index is a measure of patch distribution and abundance and both have been used extensively in ecological studies to quantify landscape composition. These indices combine patch richness and evenness into a single measure. In constructing the Geomorphic Units it is more informative to evaluate patch richness and evenness independently through the use of patch cohesion and patch connectivity metrics.

4.1.3. Cluster Analysis

The two metrics themselves do not provide a spatial classification and an appropriate cluster algorithm is required to group the geomorphic features into meaningful classes (i.e., Geomorphic Units). A cluster analysis was carried out using the patch cohesion and patch connectance values (Table 4.2) in order to associate classes of similar spatial characteristics and reduce the number of geomorphic features to create the Geomorphic Units. Since the final number of Geomorphic Units was unspecified, the 'Joining Tree' algorithm of the statistical software package Statistica™ was used. The 'Complete Linkage' rule and the 'Euclidean Distance (non-standardised) measure was applied as standard options and it was not considered necessary to consider more advanced options. Because of the need to take into account geomorphic expertise to ensure the final Geomorphic Units were meaningful, the degree of clustering (i.e., the linkage distance) was decided by a visual inspection of the joining tree rather than relying on an arbitrary cut-off value.

The results of the cluster analysis provided 14 Geomorphic Unit classes at a linkage distance of two (Fig. 4.1). This linkage distance was chosen as it clustered those Geomorphic Units considered to be very similar. The red horizontal lines show the partitioning of the geomorphic features to produce the new Geomorphic Units which are labelled 1 to 14. A visual inspection of the results concurred with our expectations of the spatial nature of the Geomorphic Units.

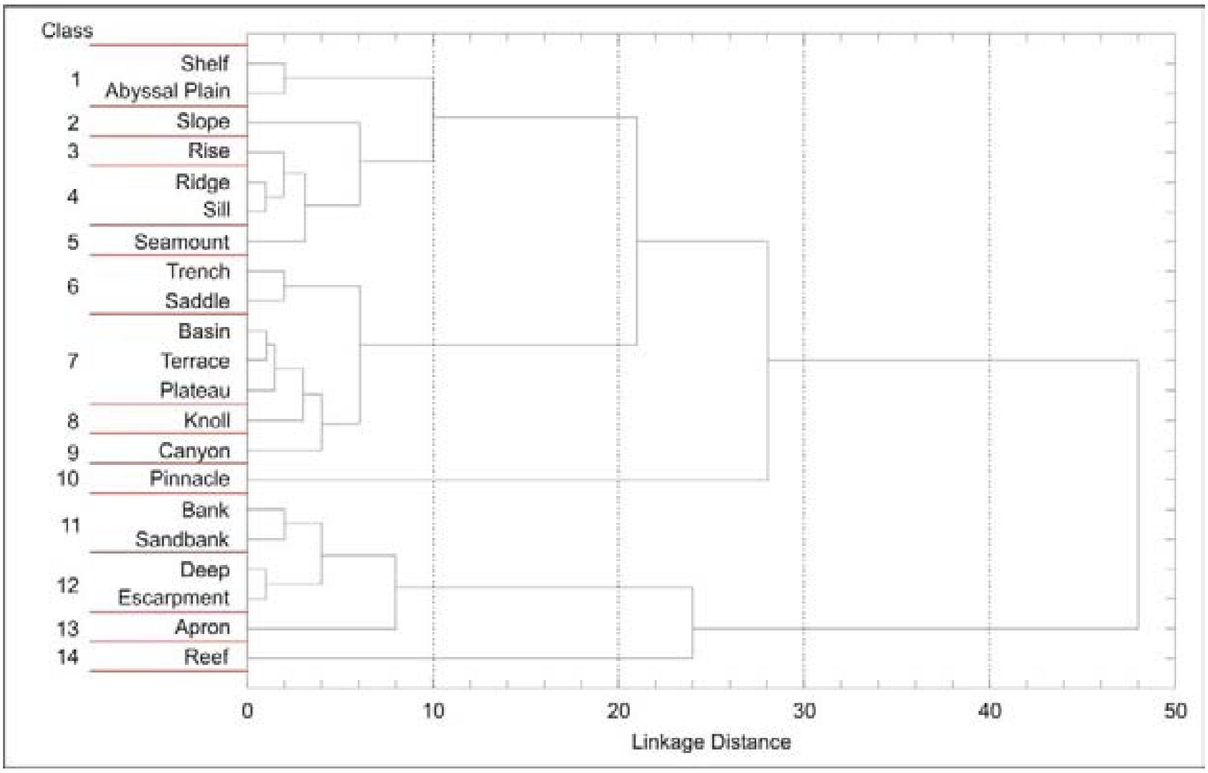

Figure 4.1. Cluster diagram of results of the cluster analysis of geomorphic features based on the patch cohesion and patch connectance indices. A total of 14 geomorphic units were defined by the cluster analysis. The red horizontal lines show the partitioning of the classes, which represents a linkage distance of two.

One outcome of the cluster analysis was that some of the smaller patches remained isolated. This result was restricted to reefs, pinnacles, banks and sandwaves/sand banks. A visual inspection of the 14 Geomorphic Unit classes was then undertaken to identify regions of the slope and shelf that were distinctly different from each other based on the distribution of these smaller and more numerous features. Two rules were implemented: 1) the slope was subdivided into regions based on the presence and absence and relative spacing of submarine canyons along the margin (Table 4.3), and 2) the shelf was subdivided into regions based on the presence or absence of reefs, banks and sandwaves/sand banks (Table 4.4). The product was the final Geomorphic Units for the Australian EEZ (Fig. 4.2).

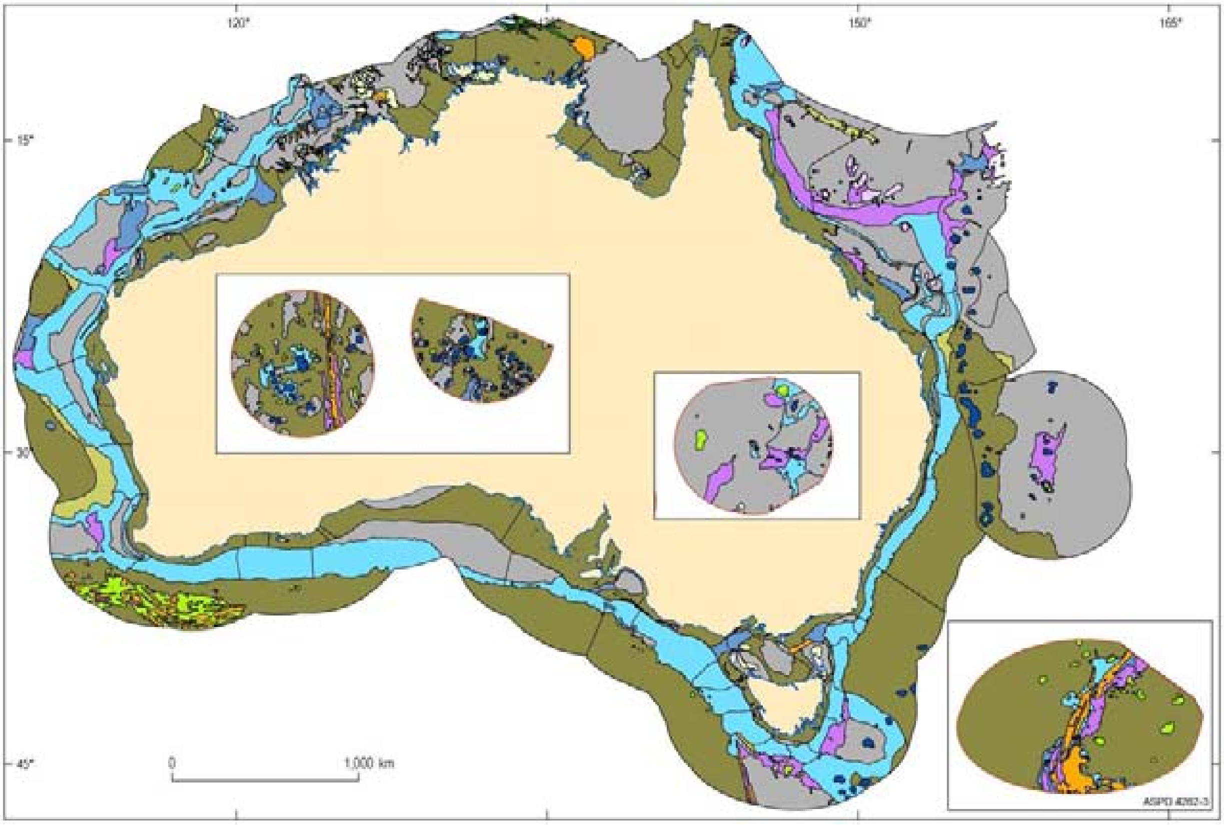

Figure 4.2. Map of Geomorphic Units. A total of 14 meaningful Geomorphic Units were identified. In addition, the slope was subdivided into regions based on the presence and absence and relative spacing of submarine canyons along the margin, and the shelf was subdivided into regions based on the presence or absence of reefs, banks and sandwaves/sand banks. See page 72 for legend.

This approach produced meaningful Geomorphic Units, with regions of similar geomorphology contained in the same class. For example, basins, terraces and plateaus, which are characterised on the Australian margin by relatively expansive low-gradient surfaces, all clustered together. Other features with similar geomorphology that clustered together included banks and sandbanks and trenches and saddles. Notably, reefs and pinnacles separate out early in the analysis because they have the greatest connectivity over the margin due to their relatively large numbers and small patch areas. Comparisons of the Geomorphic Units with the spatial distributions of benthic marine biota will ascertain the degree to which the 14 Geomorphic Unit classes reflect the spatial complexity of benthic marine habitats and biota.

Table 4.3. Description of slope regions separated out based on visual inspection of Geomorphic Units.

Provincial Bioregion	Region	Reason
Northwest Province (PB4)	i	Defines a region of bifurcating submarine canyons that extend across the slope.
Central Western Transition (PB5)	i	Defines a region of bifurcating submarine canyons that extend across the slope.
Central Western Province (PB6)	i	Defines a region containing numerous submarine canyons.
	ii	Defines a region containing numerous closely-spaced submarine canyons.
Southwest Transition (PB7)	i	Defines a region containing sparse submarine canyons.
Southern Province (PB8)	i	Defines a region containing numerous deeply-incised and bifurcating submarine canyons.
	ii	Defines a region containing sparse submarine canyons.
	iii	Defines a region containing sparse and widely-spaced submarine canyons.
	iv	Defines a region containing numerous closely-spaced, deeply-incised and bifurcating submarine canyons (including the vast Murray Canyon complex) that extend on to the shelf and across the entire slope.
West Tasmania Transition (PB9)	i	Defines a region containing sparse submarine canyons.*
	ii	Defines a region containing numerous closely-spaced mostly bifurcating submarine canyons.*
	iii	Defines a region containing numerous closely-spaced single channel submarine canyons.*
Tasmania Province (PB10)	i	Defines a region containing numerous closely-spaced, well-developed and bifurcating submarine canyons that extend on to the shelf.*
	ii	Defines a region containing numerous closely-spaced, well-developed and bifurcating submarine canyons that extend across the entire slope.*
	iii	Defines a region containing no submarine canyons but numerous knolls and ridges.*
	iv	Defines a region containing sparse submarine canyons and numerous pinnacles.*
	v	Defines a region containing numerous bifurcating submarine canyons.*
	vi	Defines a region containing sparse submarine canyons.*
Southeast Transition (PB11)	i	Defines a region containing numerous closely-spaced bifurcating submarine canyons that extend on to the continental shelf and across the entire slope.*
	ii	Defines a region containing the major submarine canyon complex of Bass Canyon.*
	iii	Defines a region containing sparse submarine canyons.*
	iv	Defines a region containing closely-spaced, well-developed and bifurcating submarine canyons.*
Central Eastern Province (PB12)	i	Defines a region containing widely-spaced and bifurcating submarine canyons.
	ii	Defines a region containing closely-spaced bifurcating submarine canyons.
	iii	Defines a region containing sparse submarine canyons.
Central Eastern Transition (PB15)	i	Defines a region containing sparse submarine canyons.
Northeast Province (PB18)	i	Defines a region containing sparse and widely-spaced submarine canyons.

Northeast Transition (PB19)	i	Defines a region containing numerous closely-spaced submarine canyons.
Cape Province (PB20)	i	Defines a region containing sparse and widely-spaced submarine canyons.
Norfolk Island Province (PB21)	i	Defines a region containing numerous pinnacles.

* Existing Level 3 Units for the draft interim benthic marine bioregionalisation for the SE region (Butler *et al.*, 2001).

Table 4.4. Description of shelf regions separated out based on visual inspection of Geomorphic Units.

IMCRA Shelf Bioregion	Region	Reason
Northern IMCRA Province (PB25)	i) Cape York to Jackson River	Defines a region of numerous sandwaves / sand banks in western Torres Strait.
	ii) Nassau River to Bing Bong Creek	Defines a region of numerous submerged reefs and pinnacles in the southern Gulf of Carpentaria.
Northwest IMCRA Transition (PB26)	i) Cape Dombey to Cape Londonderry	Defines a region of numerous banks and sandwaves / sand banks in Joseph Bonaparte Gulf.
	ii) Cape Londonderry to Cape Baskerville	Defines a region of numerous rocky and coral reefs of the Kimberly shelf and Bonaparte Archipelago.
Northwest IMCRA Province (PB27)	i) Yule River to northern tip of Northwest Cape	Defines a region of reefs, banks and pinnacles of the Dampier Archipelago and Exmouth Gulf.
Southwest IMCRA Transition (PB30)	i) Port Denison to Moore River	Defines the Houtman-Abrolhos reef province.
Southwest IMCRA Province (PB31)	i) Hopetoun to PB32 boundary.	Defines a region of numerous rocky reefs and pinnacles.
Great Australian Bight IMCRA Transition (PB32)	i) PB32 boundary to Pt Dempster	Defines a region of numerous rocky reefs and pinnacles of the Recherche Archipelago.
Spencer Gulf IMCRA Province (PB33)	All regions	Defines a region of numerous banks and sandbanks in Spencer Gulf and Gulf of St Vincent.
Central Eastern IMCRA Transition (PB39)	All regions	Defines a region of numerous coral reefs and banks of the Great Barrier Reef.
Northeast IMCRA Province (PB40)	All regions	Defines a region of numerous coral reefs and banks of the Great Barrier Reef.
Northeast IMCRA Transition (PB41)	i) PB41 boundary to Cape York	Defines a region of numerous coral reefs and banks of the Great Barrier Reef.
	ii) Torres Strait	Defines a region of numerous sandwaves / sand banks in cental and eastern Torres Strait

4.2. Seabed Facies

Although not used to derive the present draft NBMB Provincial Bioregions, the geomorphic, sedimentary (i.e., %gravel, %mud, %CaCO3, mean grain size) and oceanographic data (i.e., mean tidal and wave energy, wave- and tide-exceedance) capture vital information regarding the finer-scale distributions of benthic marine habitats. As such, Geoscience Australia has undertaken an analysis of available sediment, oceanographic and bathymetry (geomorphic) data to define Seabed Facies on the shelf around Australia (i.e., <300 m) that represent smaller-scale bioregions. The objective of the analysis was to define regions of physical complexity (as defined by the sediment, oceanographic and bathymetry data) on the shelf and by inference highlight areas of biological complexity. This was based on the premise that the interactions of the physical variables influence the patterns and distributions of benthic marine biota. The analysis was restricted to the shelf because it is a relatively homogenous geomorphic region and most of the physical data was restricted to water depths of <300 m. The distribution and relationship of the Seabed Facies to each other can indicate changes in seabed processes and/or environments (e.g., habitats).

4.2.1. Data Types and Data Analysis

Due to the variable data coverage, it was necessary to divide the Australian shelf into four regions in order to maximise the use of available data. Each region was distinguished based on the combination of datasets available for that region (Table 4.5). The spatial extent of each region was defined by the coverage of the datasets available. The four regions are:

- *East* –extending from eastern Gulf of Carpentaria around to Cape Banks and including Tasmania;
- *Southwest* –extending from Cape Banks around to Perth;
- *Northwest* –extending from Northwest Cape to the Wessel Islands; and
- *Gulf of Carpentaria* – the epicontinental seaway forming the Gulf of Carpentaria.

Data used for deriving the Seabed Facies for each of the regions (Table 4.5) were obtained from existing Geoscience Australia sources, including: the 250 m bathymetry model of Australia, the geomorphic features map, MARS sediment database, and outputs from the GEOMAT model. The input data to the classification are all continuous variables except for the geomorphic features. Although geomorphic features is a categorical variable, it was included with the continuous variables because geomorphology has a strong influence on benthic marine fauna and thus crucial to the analysis. Like the continuous variables, the geomorphic features category was scaled to the range 0 to 100 to give it an equal weighting so that the effects of the sediment and oceanographic data were not excluded.

Table 4.5. Data types used for each region.

	Region			
Data Type	East	Southwest	Northwest	Gulf of Carpentaria
Bathymetry	X	X	X	X
Geomorphology	X	X	X	X
%gravel	X		X	X
%mud	X		X	X
%$CaCO_3$	X		X	
Mean Grain Size	X		X	X
Wave-exceedance	X		X	X
Tide-exceedance	X		X	X
Mean Wave Energy		X		
Max. Tide Current		X		

All datasets were gridded at 0.01 degree (~1 km) spatial resolution from the original sample sites using a linear interpolation. The interpolation caused some artefacts such as bulls-eyes. Each dataset was then scaled from 0 to 100 to give each variable equal weighting in the classification analysis. Distributions for the wave and tide data were highly skewed so that, except for those classes containing a few large values, these data would have had a small effect on determining the other classes. Several erroneous values in the bathymetric data for the Gulf of Carpentaria were removed by setting these pixel values to the adjacent value.

4.2.2. Classification of Seabed Facies

The classification was undertaken using the spatial analysis software program ERMapper™ and consisted of an unsupervised ISOCLASS algorithm. This algorithm starts with a nominal class (facies) and categorises all pixels with similar spectral signatures into classes (facies) according to user-defined parameters. In the simple two class example shown in Figure 4.3, the data fall into three clusters. Once the number of starting classes (facies) has been specified the algorithm picks the initial centres for the clusters, spaced evenly along the diagonal. If an image is specified, the cluster means from the specified image are used. In the example shown in Figure 4.3 the number of starting classes (facies) is specified as 6. Then the distance of every data point from each centre is calculated. Each point is allocated to the cluster with the closest centre. The centre of each cluster is then recalculated (the average coordinate in each dimension) and any merging or splitting is carried out. The process repeats until one of the processing limits has been reached (e.g., % variation explained). The parameters for merging and splitting classes (facies) and ending the classification process are set in the Unsupervised Classification dialog box (Fig. 4.4).

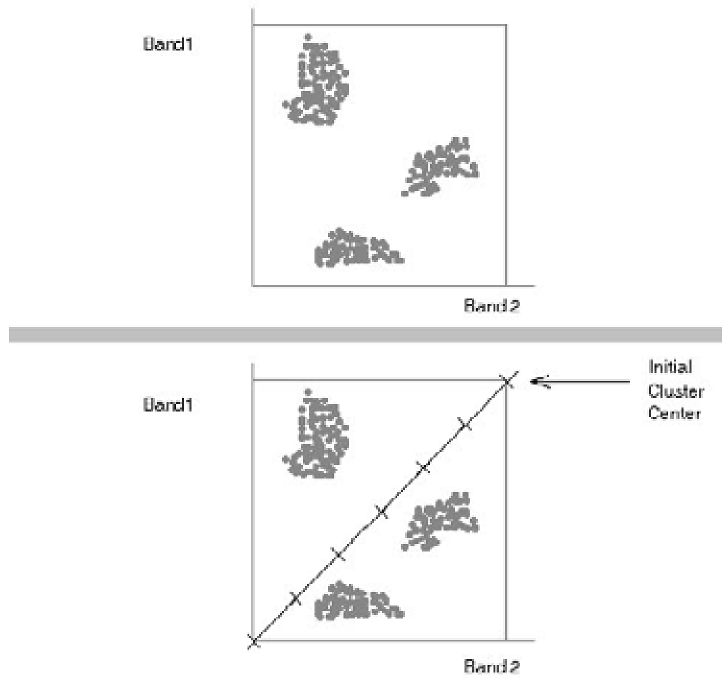

Figure 4.3. Diagram of data clusters treated by cluster algorithm.

For the classification of the Seabed Facies the procedure was run until the algorithm reached a point where 100% of the facies were unchanged with successive iterations. The number of initial facies used equalled one. All other parameters were left as their default settings. In some cases the algorithm did not reach the 100% unchanged point and had to be terminated manually.

The number of facies used for each classification was initially determined by running several classifications for different numbers of facies and plotting the mean of the average distances to the facies centres versus the number of facies. In cases where there was one or more facies with relatively few facies members the average distances were weighted by the

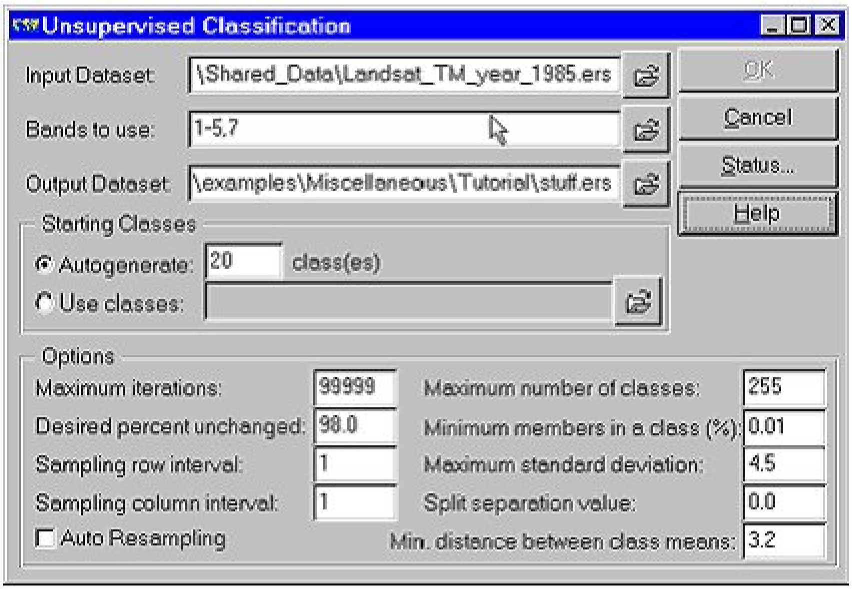

Figure 4.4. Figure of dialog box of classification parameters showing classification parameters for clustering of Seabed Facies.

proportion of members in the facies and these distances used instead (i.e., Southwest, Gulf of Carpentaria). The choice of the number of facies was a compromise between minimising the mean average distance and minimising the number of facies. A larger number of facies increases the distance ratio and a lower number of facies increases the weighted distance ratio. Where no minimum average distance to the centres occurred or was not obvious, the number of facies was selected at a point where the curve began to flatten out, indicating that changes in the mean average distance with increasing facies started to decrease. Because geomorphic feature classes are arbitrarily arranged, the final classifications may be slightly dependent on this arrangement as adjacent geomorphic classes may be arbitrarily grouped together in the classifications.

4.2.2.1. East

Nine facies were chosen, as this is where the curve showing mean average distances first starts to flatten out (Fig. 4.5). Differences between the facies means are highly significant (Fig. 4.6), with only a few cases containing insignificant differences for a single variable. The final classification (Fig. 4.7) is principally based on textural features of the sediment with %gravel, %mud and %$CaCO_3$ explaining most of the variation, and to a lesser degree bathymetry and geomorphology. Mean grain size, wave- and tide-induced exceedance contributed least to the derivation of the facies. The facies names reflect these patterns. Wave-induced exceedance featured strongly in Facies 3 (Shallow Wave-Carb.). This facies is largely restricted in its extent to small pockets adjacent to the coast and next to island and the coral reefs in Torres Strait (Fig. 4.7). Tide-induced exceedance featured prominently in Facies 7 and Facies 9 (Tide-Carb. and Tide-Plateau-Carb.). These two facies are principally located at the southern end of the GBR where tidal ranges are relatively large and between the islands and reefs of Torres Strait. In these two regions, tidal currents are locally accelerated between the dense reef frameworks (Hemer *et al*., 2004).

4.2.2.2. Southwest

For the southwest region, two classifications were undertaken to determine the weighted distance ratio plot. The weighted distance ratio was used as a few of the facies did not have many data points. In the first classification, the ISOCLASS algorithm was allowed to proceed

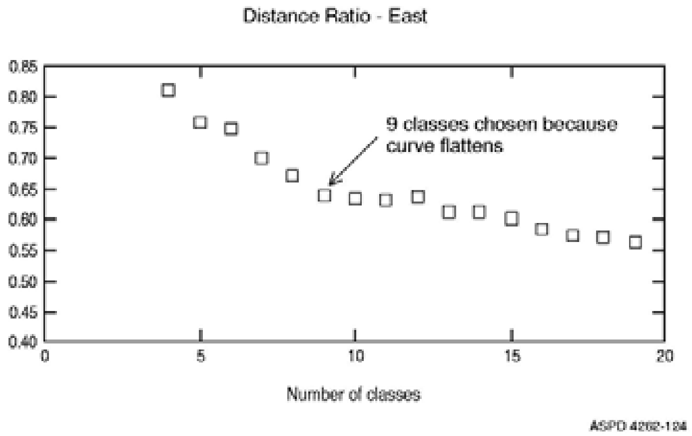

Figure 4.5. Graph of mean average distances for data in the East region.

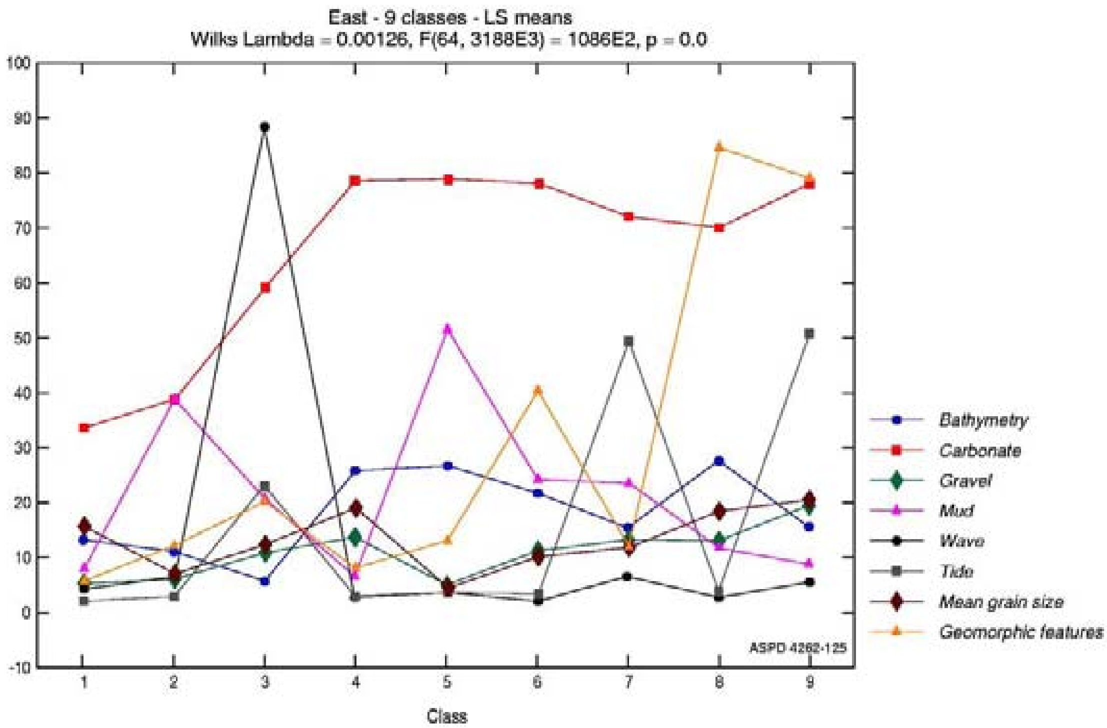

Figure 4.6. Graph of facies means for the East region.

until either 100% of the facies were unchanged between iterations or the percent unchanged became stable after many iterations. The second classification was stopped manually at the percent unchanged value reached a maximum; this was generally achieved in the first few iterations. A total of eight facies were selected corresponding to the local minimum in weighted distance ratio (Fig. 4.8). A visual inspection of the facies distributions for each of the variables indicated that the eight original facies could be reduced to five. The facies grouped together were considered too similar to justify them remaining as separate facies. Differences between the facies means are highly significant although means for maximum tidal current speed are similar (Fig. 4.9). The final classifications (Fig. 4.10) are dominated by mean wave energy, bathymetry and geomorphology and to a lesser degree by maximum tidal current speed. The facies names reflect these patterns. The distribution of facies broadly

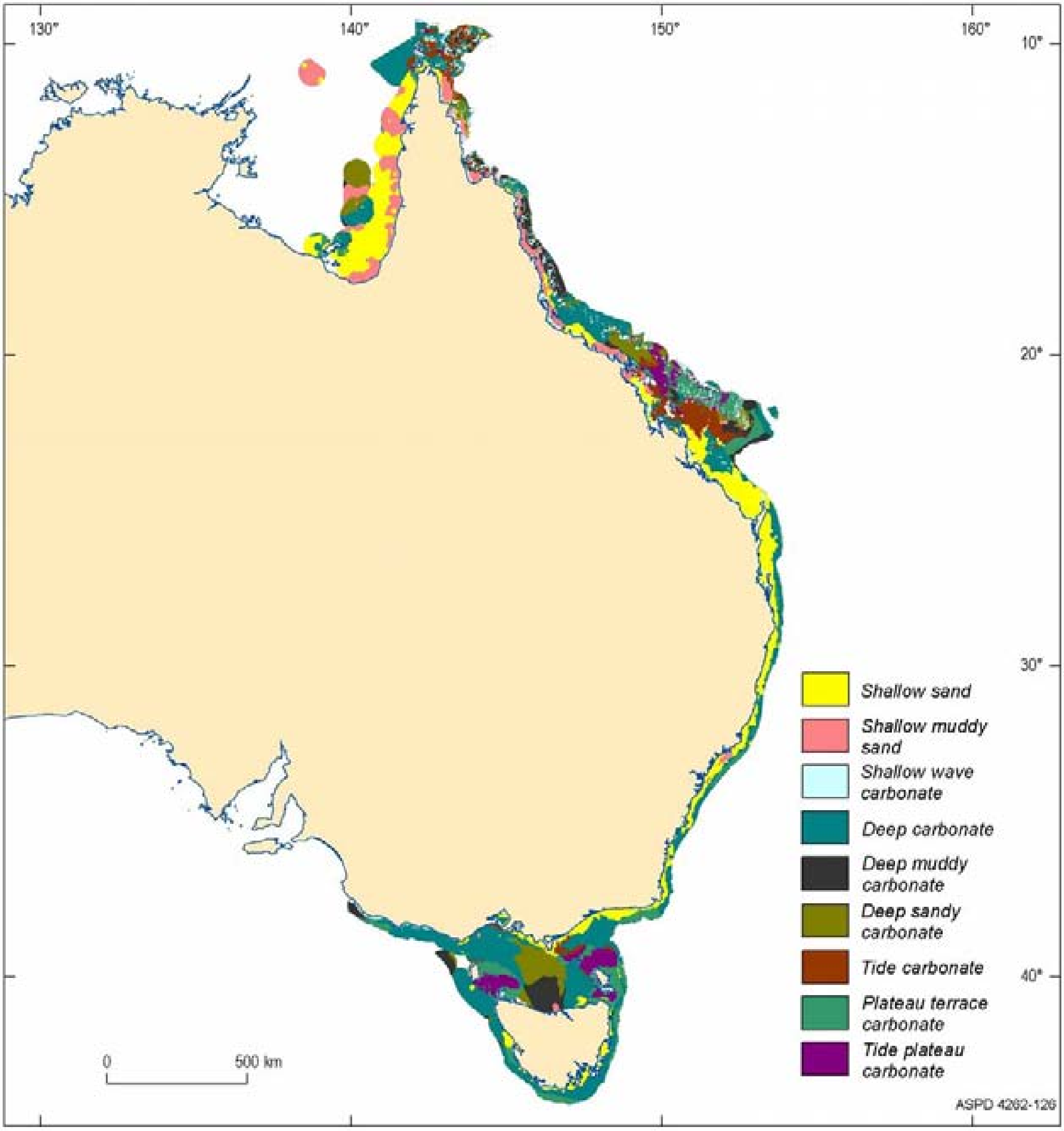

Figure 4.7. Map of Seabed Facies for the East region.

reflects mean wave energy from the Southern Ocean. This pattern is produced by water depth with the amount of energy ocean swell waves impart on the seabed decreasing with increasing water depth. Facies 1 (Tide-shelf), where maximum tidal current speed is prominent in defining the facies, is largely restricted to Spencer Gulf and the Gulf of St Vincent, where the shelf is relatively sheltered from ocean swell waves.

4.2.2.3. Northwest

A total of seven facies were selected corresponding to the local minimum in the distance ratio (Fig. 4.11). A visual inspection of the distributions for each of the variables indicated that Facies 7 had a bi-modal distribution for bathymetry (Fig. 4.12). This could occur, for example, if the facies consisted of geomorphology dominated by two different depths such as around the base of and on top of a plateau. On this basis, this facies was spit into two classes, one corresponding to the statistical population with lower values of bathymetry, and

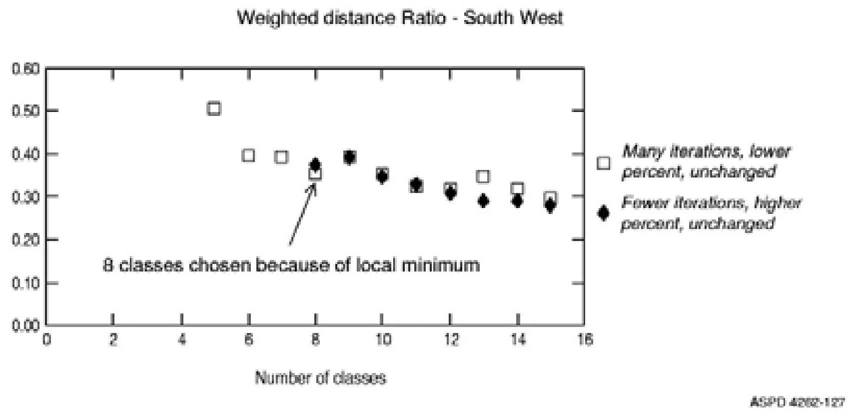

Figure 4.8. Graph of mean average distances for data in the Southwest region.

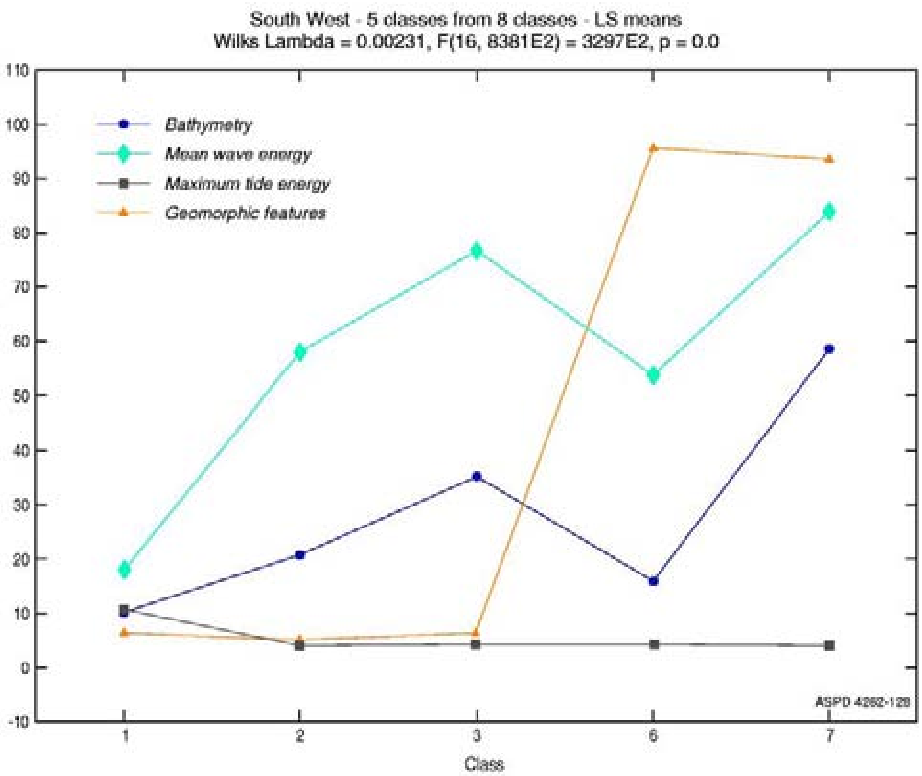

Figure 4.9. Graph of facies means for the Southwest region.

one to higher values of bathymetry, to give eight facies in total. Differences between the facies means are highly significant (Fig. 4.13), except for wave-induced exceedance. The final classifications (Fig. 4.14) are dominated by bathymetry, geomorphology, %$CaCO_3$ and %mud, followed by wave- and tide-induced exceedance, mean grain size and %gravel, with tide-induced exceedance a feature of only Facies 4 (Fig. 4.13). The facies names reflect these patterns. The distribution of facies shows a relatively complex distribution that is strongly influenced by the underlying geomorphic features, with facies boundaries aligned with geomorphic feature boundaries (Fig. 4.14). The region is broadly characterised by a muddy province in the north and a sandy carbonate province in the south. Facies characterised by relatively high concentrations of carbonate occur at all water depths while facies characterised by relatively high concentrations of sand are restricted to shallow shelf regions, except for Facies 8, which occurs in the vicinity of large coral reefs on the mid-shelf, and may signify areas of local carbonate accumulation.

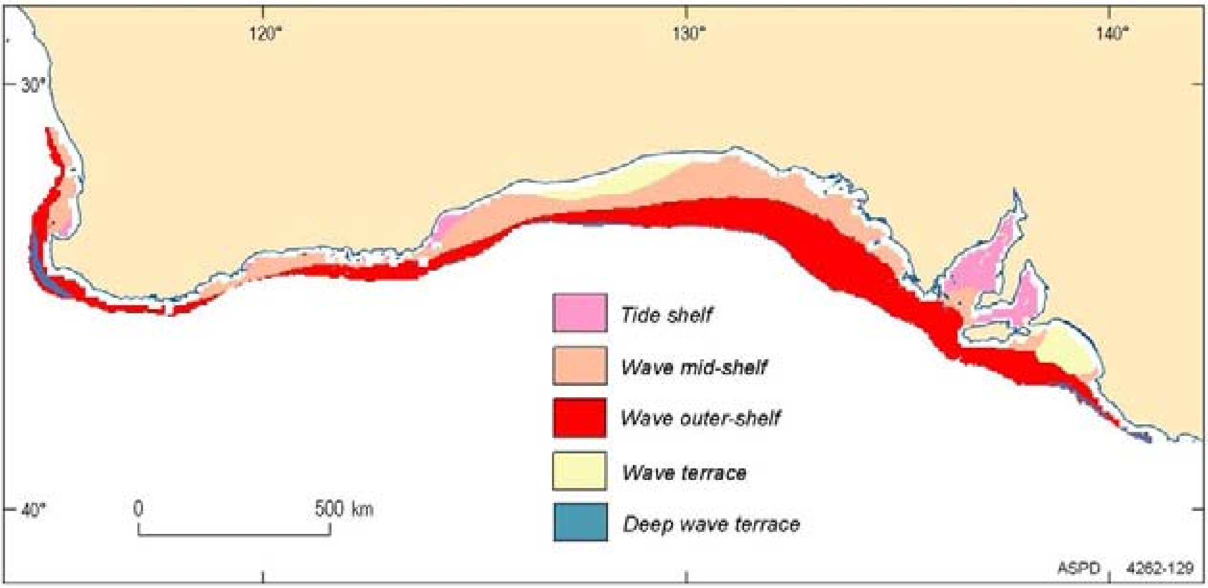

Figure 4.10. Map of Seabed Facies for the Southwest region.

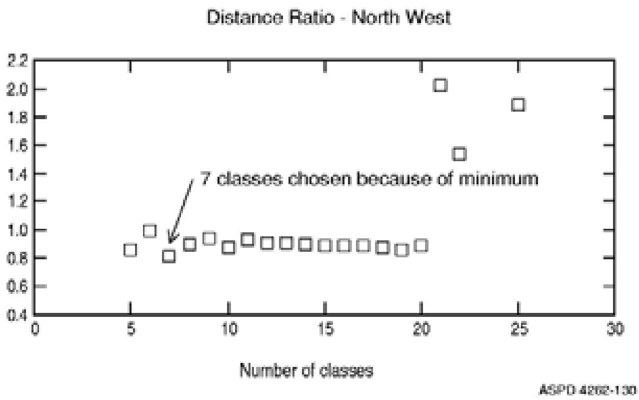

Figure 4.11. Graph of mean average distances for data in the Northwest region.

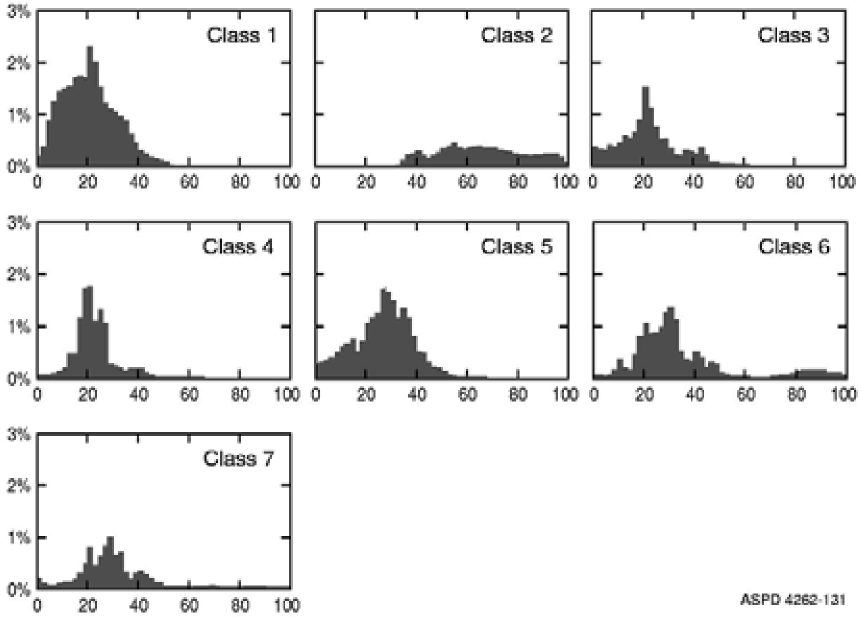

Figure 4.12. Histograms for the Seabed Facies classes in the Northwest region.

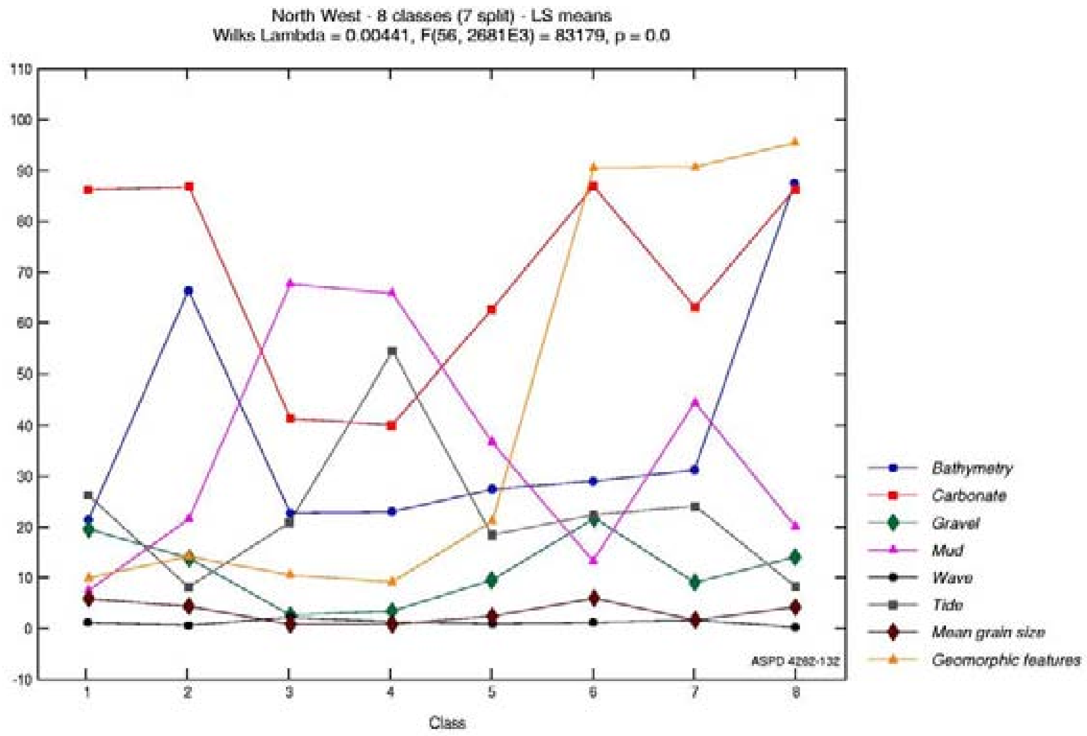

Figure 4.13. Graph of facies means for the Northwest region.

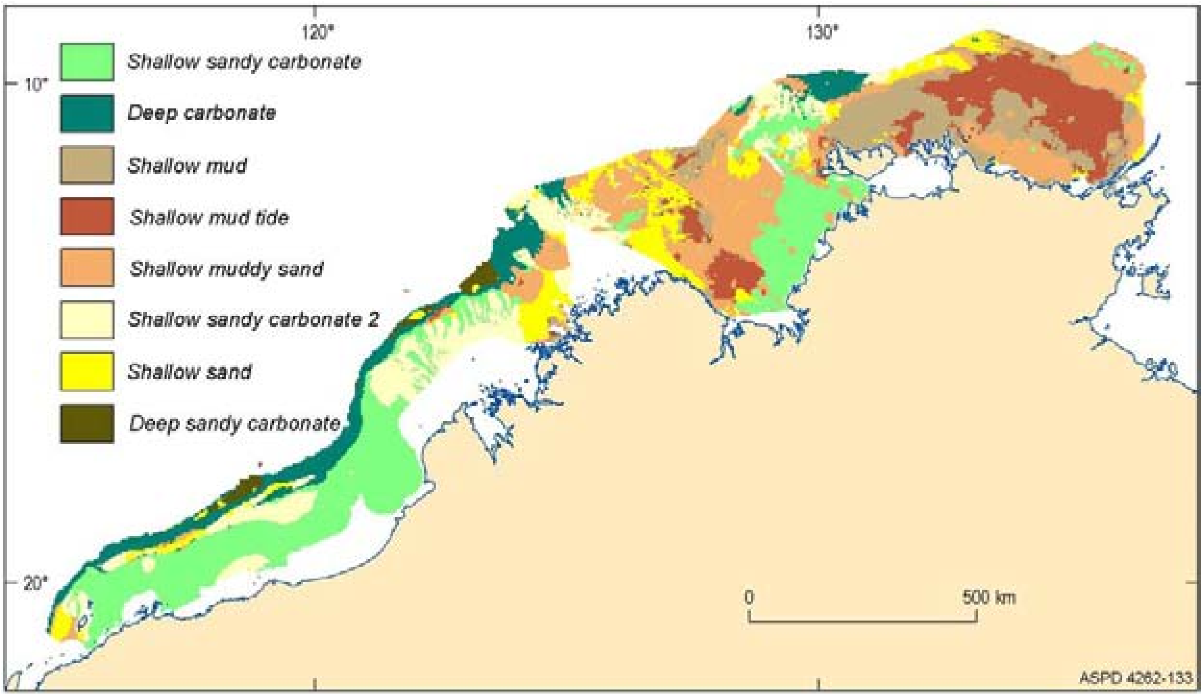

Figure 4.14. Map of Seabed Facies for the Northwest region.

4.2.2.4. Gulf of Carpentaria

A total of six facies were selected corresponding to the local minimum in the distance ratio and weighted distance ratio (Fig. 4.15). Differences between the facies means are highly significant (Fig. 4.16), with only a few cases containing insignificant differences for a single variable. Note that because the Gulf of Carpentaria is a shallow epicontinental seaway on the shelf, 'deep' is used in a relative sense, compared with the other regions. The final classifications (Fig. 4.17) are dominated by bathymetry, geomorphology and %mud,

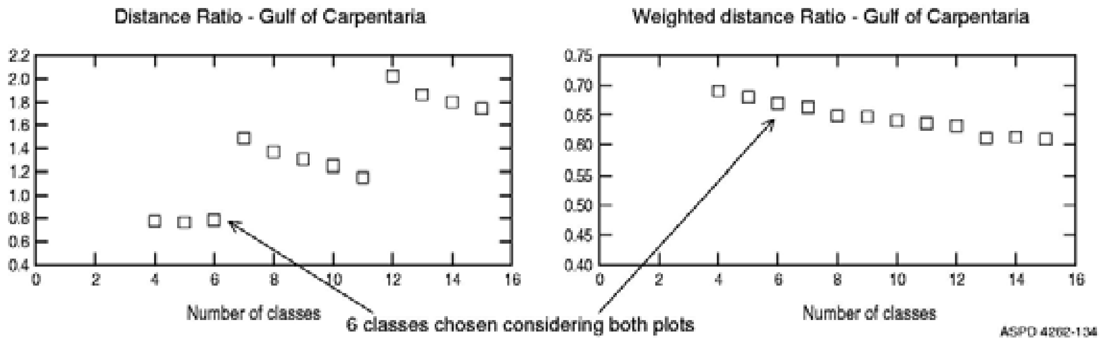

Figure 4.15. Graph of mean average distances for data in the Gulf of Carpentaria region.

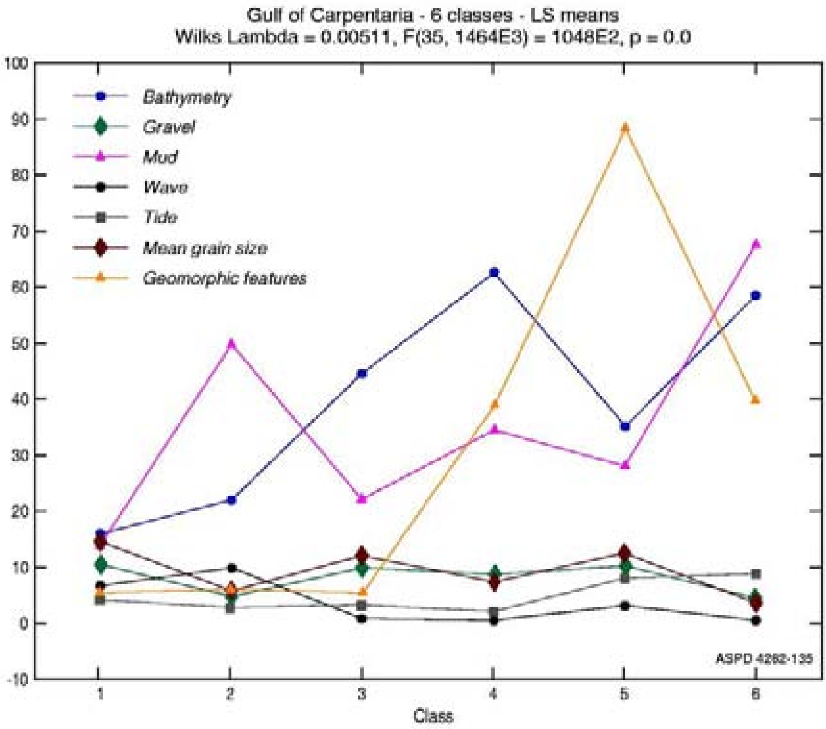

Figure 4.16. Graph of facies means for the Gulf of Carpentaria region.

followed by wave- and tide-exceedance, %gravel and mean grain size. The facies names reflect these patterns. The facies broadly reflect an increase in mud concentrations with water depth, and exhibit an offshore transition from facies dominated by sand to facies dominated by mud. This offshore pattern is also reflected in a transition from facies characterised by wave-induced exceedance to tide-induced exceedance.

4.2.3. Regional Patterns in Seabed Facies

Overall, the Seabed Facies are most strongly delineated by bathymetry and geomorphology for all regions except the East region. Percent mud is also a major determinant of the classifications for all regions that contain sediment data (i.e., East, Northwest, Gulf of Carpentaria). Wave and tide statistics contributed the least to the classifications in all regions that contained morphological and sediment data.

The spatial distributions of the classifications for each region reflect these compositional trends, with many of the facies mirroring the outlines of individual geomorphic features. In

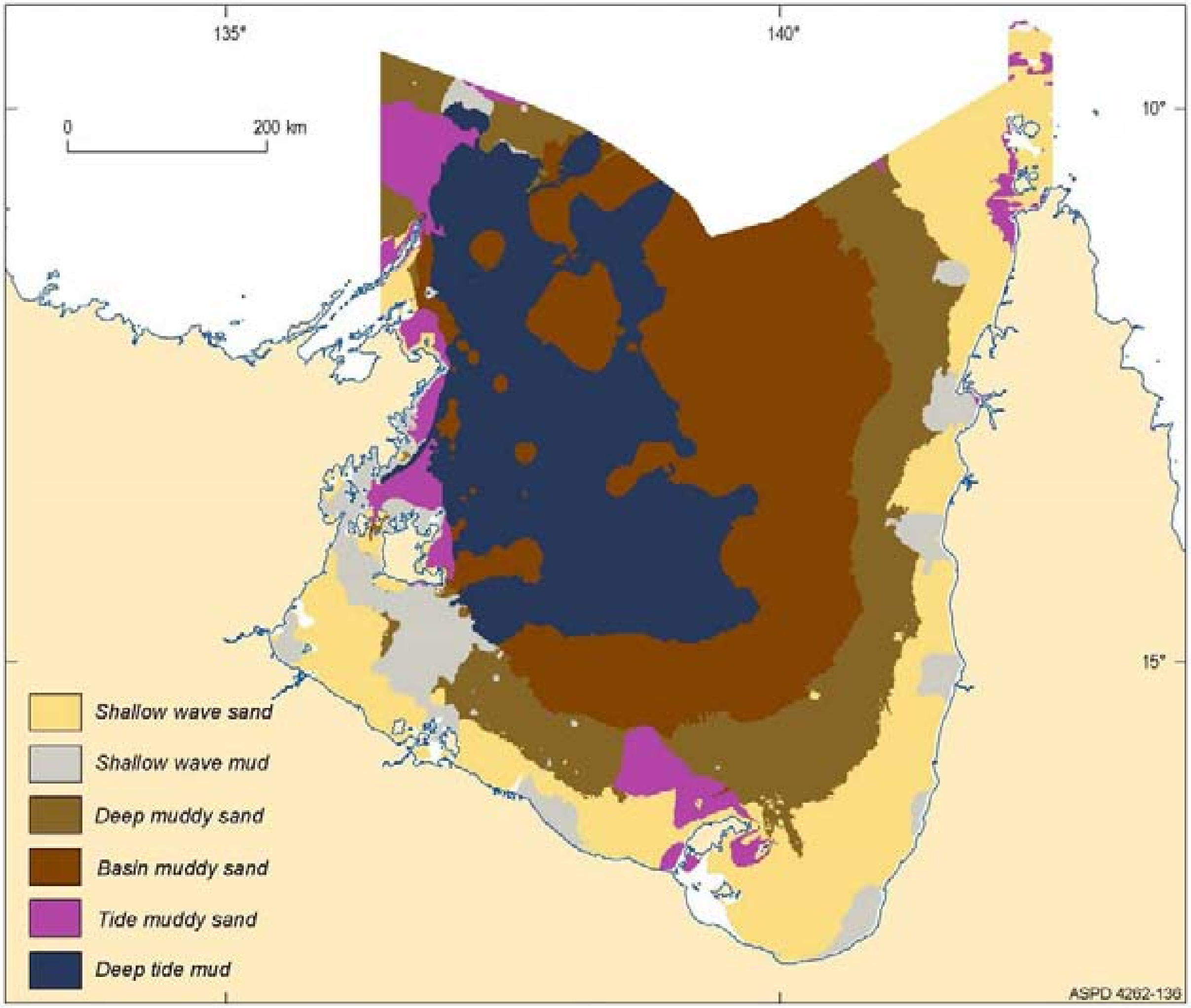

Figure 4.17. Map of Seabed Facies for the Gulf of Carpentaria region.

the Northwest region, Facies 3 (Shallow muddy-sand) is strongly correlated with shallow carbonate banks (e.g., Sahul Banks), shallow shelf valleys and basins (e.g., Bonaparte Basin; Fig. 4.14). In areas of the margin where fewer Geomorphic Units occur the classes are broadly defined by water depth (i.e., bathymetry) and their boundaries lie roughly parallel with the bathymetric contours (e.g., Southwest; Fig. 4.10).

In all regions where sediment data are available, the shallow, inner shelf is dominated by a facies characterised by sand, although regional trends are evident. In the northwest, the inner-shelf facies is characterised by sandy material with high carbonate concentrations (Figs. 4.12) and in the East region patches of muddy sand are present (Fig. 4.7). In the Gulf of Carpentaria region, the inner-shelf sand facies is interspersed by a facies characterised by relatively high mud concentrations that occurs at the mouths of the major rivers, where relatively high inputs of terrigenous sediment occur (Jones, 1986), and in a relatively low-energy zone south of Groote Eylandt. In the East and Northwest regions, facies on the deeper mid to outer-shelf are increasingly defined by carbonate concentrations. This trend probably reflects the relatively small quantities of terrigenous sediment exported from the Australian continent.

When mixing categorical and continuous data, there is a tendency for the categorical data to dominate the analysis and much of the spatial pattern in the categorical data will be preserved in the final classification. However, while geomorphology was a strong descriptor for most Seabed Facies, individual geomorphic features did not exclusively dominate the facies classifications. In fact, there was a spread of several geomorphic features in each facies.

There may be some bias in the resulting classifications because of the highly-skewed nature of the continuous data, with the tail of the distributions being identified as distinctive. These effects could be reduced by applying an appropriate transformation to the distributions which more closely corresponds to the distributions of the benthic marine biota. However, due to the lack of available biological data, the appropriate transformations are unknown. Further work is required to obtain the relevant biological information to determine the appropriate distribution. Also, due to time constraints, no analysis has been undertaken of the relationships (if any) between the distribution and nature of the Seabed Facies and benthic marine biota. These relationships need to be investigated in future.

5. DISCUSSION

The draft NBMB has been developed in support of Australia's *Oceans Policy* (1998). It has been designed principally as a management tool that has most application for the development and implementation of regional marine plans. Ecosystem-based planning of the seabed requires information on the geology, oceanography and benthic marine biota and the draft NBMB represents a national synthesis of key data. Below, we briefly evaluate the draft NBMB by highlighting the significant advancements and limitations of the present framework, areas of greatest uncertainty, and science gaps associated with its development.

5.1. Significant Advances of the draft NBMB

The present draft NBMB is based on considerably more geological, oceanographic and biological data than previous regionalisations. It is the only consistent management framework beyond the shelf break and thus applies to approximately 80% of the total area of Australia's EEZ. The data used represent the most extensive and up-to-date datasets of key deep-water demersal fish species and geological elements presently available for the seabed of Australia's EEZ. There are improved data on all of the variables used in construction of the draft NBMB. Data for supporting information including sediment properties, sponge bioregions, and oceanographic processes at the seabed (i.e., GEOMAT outputs) are now available at a national scale, and the GEOMAT outputs present a more realistic view of seabed dynamics and processes for the entire shelf and upper slope than was previously available from existing regional models.

Interpreting the draft NBMB is based on the assumption that the greater the number of units in each Provincial Bioregion the greater the potential biodiversity of that bioregion. On this basis it can be inferred that the more Biomes and Geomorphic Units in each bioregion the greater the habitat heterogeneity and associated biodiversity. Provincial Bioregions with fewer Biomes and Geomorphic Units may be characterised by relatively lower biodiversity. The draft NBMB can thus be used as a broad measure of the resilience of benthic marine habitats to external influences. For example, habitats in Provincial Bioregions with numerous Biomes may be more vulnerable to changes because of their increased fragmentation than those that are relatively contiguous.

The bioregions in the draft NBMB have been defined based on patterns in the data and conform to natural boundaries. The shelf-slope boundary, which has been preserved to maintain the existing IMCRA scheme, is a natural faunal, oceanographic and geomorphic boundary. The bioregions of the draft NBMB are defined by valid representations of natural seabed boundaries based on relatively high-quality biological and physical data. The draft NBMB contains Provinces that are defined as centres of endemicity. This structure is crucial for management because the definitive species that occur in each of the Provinces occur nowhere else in Australia. Areas of faunal mixing are also specifically captured in the draft NBMB by the Transitions, which separate the Provinces and capture the overlap in species distributions from the adjacent Provinces.

The broad-scale bioregions in this framework also provide the background and context of the physical environment for the identification and derivation of a National Representative System of Marine Protected Areas. The actual boundaries of the candidate marine protected areas are likely to be defined using data collected and analysed at a much smaller spatial scale (see section 4). However, the draft NBMB bioregions can be used to make regional comparisons when trying to identify areas of high biodiversity.

5.2. Areas of Greatest Uncertainty

The draft NBMB has been constructed with imperfect data and information which means that the all of the bioregions contained in the draft NBMB contain a degree of uncertainty with regard to the location of their boundaries and the habitats and biota they represent. Data coverage for all of the data layers in the draft NBMB was not 100%. All of the datasets, while reasonably robust, lacked spatial coverage, particularly for the deeper regions of the margin (i.e., >2,000 m). Even the bathymetry dataset which had the most coverage was of variable quality in many places. All Provincial Bioregion boundaries below 2,000 m water depth have a relative degree of uncertainty in their location due to the relatively poor definition of geomorphic features at these depths. As such, Provincial Bioregions on the east, south and west margins, and offshore island territories contain most uncertainty regarding the fauna that each represents.

Greatest uncertainty in the representativeness of the Provincial Bioregions stems from the absence of any biological data for water depths of >2,000 m. Regions of >2,000 m water depth cover a total area of >4,899,800 km^2 or >54% of the total EEZ area. Moreover, as mentioned in Section 2, most of the biological data in the draft NBMB are for water depths of <1,000 m and restricted to the Provincial Bioregions around the Australian mainland. As such, there is significant uncertainty as to the provincial structure of demersal fishes (and thus other faunal assemblages) in water depths of >1,000 m, and no demersal fish data for any of the offshore island territories. This means that >5,835,840 km^2 or >64% of the total EEZ area lacks comprehensive and detailed biological data. In these deep regions, we have relied very heavily on surrogates with geomorphology being the only data set with 100% coverage of the EEZ.

Relatively few demersal fish data for water depths between 1,000-2,000 m also means that the biomic structure in the fauna could only be reconciled as far as the mid-slope, and no Biomes could be defined beyond about 1,100 m. Depth structuring in the fauna probably occurs below these depths (Last *et al.*, 2005) but this remains unresolved with available data. In addition, there are no demersal fish data for any of the offshore island territories (PB21-PB24). It was assumed that each of the offshore islands contained a distinct Provincial Bioregion. This assumption may be valid, but supporting data are lacking. It also likely that there is biomic structure in each of these bioregions, but this too remains unresolved due to the lack of demersal fish data from these offshore regions.

Generally, regions below 2,000 m water depth also lack high-resolution bathymetry data (i.e., swath sonar). The east, south and west margins are thus relatively data poor, as are the offshore island territories. These deep regions and the offshore island territories also contain very little geologic information due to the relative difficulty of obtaining samples from the seabed at these water depths. In the deep water regions where the bathymetry is mostly derived from single-beam ship echo sounders and the GEBCO and high-resolution bathymetry data are lacking, the interpretation of geomorphic features is not as precise compared to areas on the upper to mid-slope around the mainland where swath sonar data are abundant and the features are revealed in unprecedented detail.

On the east margin the *Tasman Basin Province* (PB13), *Lord Howe Province* (PB14), *Kenn Transition* (PB16) and *Kenn Province* (PB17) divide up an area of the seabed that is entirely >1,000 m water depth and mostly >2,000 m (except for several isolated submerged seamounts and islands). The boundaries between these Provincial Bioregions are based entirely on bathymetry and geomorphology, with no biological data available, and are relatively poorly defined. On the south and southeast margins the *Southern Province* (PB8), *West Tasmania Transition* (PB9), *Southeast Transition* (PB11) and *Central Eastern Province* (PB12) contain vast areas of abyssal plain/deep ocean floor in water depths of over 4,000 m. The interpretation of geomorphic features in these regions is relatively ambiguous and their extent and boundaries are poorly-defined, particularly relatively subtle features such as submarine fans at the base of the slope or hills on the abyssal plain/deep ocean floor. Notable exceptions are the Diamantina Fracture Zone and Murray Canyon complex in the western and eastern regions of the *Southern Province* (PB8), respectively, the South Tasman Rise and Tasman Fracture Zone south of Tasmania in the *Tasmania Province* (PB10), and the trench system in the *Macquarie Island Province* (PB24) which are all well defined by high-resolution swath sonar data (e.g., Hill *et al*., 1995; Royer & Beslier, 1998; Bernardel *et al*., 2000; Hill & DeDeckker, 2004).

5.3. Limitations of the draft NBMB.

The draft NBMB is a static "snap-shot" of the spatial distribution of the broad-scale key physical and biological components of Australia's EEZ. Benthic marine habitats have spatial and temporal components. The temporal components, which can be characterised by inter- and intra-annual variations and El Nino oscillations and longer global climate trends, have not been captured in the present framework.

Notwithstanding these variations, other major influences not captured by the draft NBMB such as sea-level change from global climate change will also affect benthic marine habitats and biota. The effects of sea-level change will be most evident and numerous in the shallow waters of the shelf and upper-slope while the effects on deeper-water habitats and biota will be more subtle. Changes may be very difficult to identify or predict, particularly if there is significant lag time between the effect and response. Present-day marine habitats and biota must now respond to very rapid changes in global climate, at rates far greater than in the past (Yokoyama *et al*., 2001). The ability of fauna to adapt or move to new areas in the face of rapid global climate change is not well-established (e.g., response of coral reefs to rising sea surface temperatures). Biota at the edge of their bio-geographic range are probably at most at risk; where does biota endemic to the rocky shoreline and shallow water of the south coast of Tasmania migrate to if sea temperatures rise beyond their temperature range?

The draft NBMB is designed to describe the benthic marine bioregions based on the premise that the evolutionary and ecological characteristics of the biota are more similar within a bioregion than between neighbouring bioregions. It provides a hierarchical spatial framework for planning and management and for more specific investigations. However, caution should be used in applying the draft NBMB to infer exact information at the finer scale, such as specific locations within individual bioregions. Also, there are no physical surrogates for biological processes (e.g., speciation, competition and predation). Such processes have not been captured by the present draft NBMB.

5.4. Future Work

In the present project, it would have been desirable to undertake a thorough quantitative analysis of the datasets, including a detailed spatial investigation of the statistical relationships between the biological and geological data in the GIS. Such an analysis would permit a quantitative examination of any correlations and contrasts within the data. Part of this analysis could involve assessing the significance of patterns identified through a Monte-Carlo-type analysis. An alternative approach would be to undertake a more objective assessment of the distribution and complexity of the spatial data through a procedure of pattern recognition. These types of analyses would be useful to confirm our interpretations of the data, although we believe that they would not significantly alter the present distribution.

Relationships between geomorphology, oceanography, sediment type and benthic marine biota are not well understood. However, the existence of these relationships remains the key assumption in the application of ecosystem-based management. Further analysis of the relationships between the physical and biotic data should be undertaken as they will improve our understanding of the biological patterns exhibited in the draft NBMB.

Because the geomorphic or sedimentary units are present does not imply that the biota exist or that the biological assemblages are necessarily the same everywhere. Further research into the nature of these surrogacy relationships, to advance our understanding of the complex interactions between the nature of the seabed and biota over a range of spatial scales, could lead to the establishment of more well-defined and representative bioregions. The data may inform us that bioregions need to be coalesced or subdivided. For example, it is possible that the biota associated with the interfluves, slopes and floors of submarine canyons are distinct meaning that these environments need to be recognised separately. Further, research into the degree to which demersal fish can be used as a surrogate for broader marine faunal distributions could result in the identification of indicator species that can be used to assess the biodiversity of the seabed. In addition, a faunal inventory in the bioregions must be undertaken to determine whether what is observed in the bioregions is what is predicted to be there.

The demersal fish data for the shelf and slope have not been analysed concurrently for depth structures. Biomes based on demersal fishes exist on the shelf, with the available data indicating a distinct Biome on the outer shelf (Last *et al*., 2005). As such, the Upper Slope Biome is not well defined by demersal fish data on the shelf. An integrated provincial analysis of the demersal fishes on the shelf and slope is required to fully constrain the Upper Slope and Outer Shelf Biomes for the present draft NBMB. The definition of the Biomes on the shelf would also complement the existing IMCRA framework.

Reports written for the projects that provided fundamental data for the present project contain sections recommending a future strategy of continued data collection and sample analysis, particularly in data poor regions, to support regional marine planning (e.g., Harris *et al*., 2005; Passlow *et al*., 2004; Last *et al*., 2005). A targeted strategy to obtain and collate data from these data poor regions is required. This strategy must also include appropriate protocols for collating these additional data through governmental committees such as the Ocean Policy Science Advisory Group and the tools for enforcing these protocols.

As part of the on-going commitment to Australia's *Oceans Policy* (1998), and in light of the above, the draft NBMB will need to be revisited in the future to up-date the existing data layers and add new data. Fundamental national marine datasets, such as the bathymetry and sediment datasets are continually updated as new marine surveys are completed. For example, at the time of writing this report, newly acquired high-resolution bathymetry for the southwest, south, east and northeast margins covering deep water regions lacking high-quality bathymetry had been incorporated into the bathymetry model. All of these data have been acquired using the high-resolution swath sonar equipment on Australia's marine research vessel RV *Southern Surveyor*. These new data will need to be added to future versions and the draft NBMB redrafted. Expanding and enhancing national databases in support of Regional Marine Planning must also be a high priority.

6. CONCLUSIONS

An analysis of key biological and geological data has culminated in a draft NBMB for Australia's EEZ, including the offshore island territories of Norfolk, Cocos (Keeling), Christmas and Macquarie Islands, that complements the existing IMCRA management framework. The draft NBMB is a hierarchy of benthic marine bioregions at smaller spatial scales for the seabed beyond the shelf break and covers approximately 80% of the total area of Australia's EEZ. It represents a national synthesis of key geological, oceanographic and benthic biological data and has been designed as a management tool for the development and implementation of regional marine plans in the implementation of Australia's *Oceans Policy* (1998). The draft NBMB bioregions describe the spatial distribution of benthic marine habitats and associated biota using biological and physical proxies and consist of:

- Three *Ocean Basins* (i.e., Indian Ocean, Southern Ocean, Tasman Sea) that provide the bio-geographic and evolutionary context for benthic marine biota;
- Five *Ocean Climate Zones* (i.e., tropical, sub-tropical, warm-temperate, cold-temperate, sub-polar) that represent contemporary modifiers to the bio-geographic distributions and evolutionary traits of benthic marine biota;
- Three *Primary Bathymetric Units* (i.e., slope, rise and abyssal plain/deep ocean floor) that represent regional-scale bathymetric features and distributions of benthic marine biota in the context of ocean basins;
- 24 *Provincial Bioregions* that are large bio-geographic regions defined by the provincial structure of demersal fishes and large-scale geomorphic features that may fall into different ocean climate zones. Two types of Provincial Bioregions are defined: 1) Provinces, which represent areas of endemism, and 2) Transitions, which represent areas of faunal mixing; and
- 300 *biomes* that define three strong depth intervals in the demersal fish data on the upper to mid slope (i.e., <1,000 m) for 15 Provincial Bioregions around the mainland.

The draft NBMB is a 'mixed' classification in that the bioregions have been defined over the EEZ by patterns in biological data (i.e., demersal fishes), where available, and where biological data are not available, by geological properties (e.g., geomorphology). Interpreting the draft NBMB is based on the assumption that the greater the number of bioregions the greater the potential benthic marine biodiversity. The most diverse bioregions are located on the tropical northeast and northwest margins (e.g., *Northeast Province* – PB18, *Northwest Province* – PB4), and the cool-temperate southeast margin (e.g., *Tasmania Province* – PB10). Bioregions in these regions also contain significant smaller-scale complexity as defined by Geomorphic Units (which represent areas of similar geomorphology). Integration of geologic and oceanographic data to produce Seabed Facies on the shelf indicates that the seabed of north and northwest shelf regions contain the greatest smaller-scale complexity.

The boundaries and nature of bioregions in the deep ocean are relatively poorly defined because of a lack of biological and high-resolution bathymetry data below >2,000 m; this represents an area of 4,899,800 km^2 or approximately 54% of the total area of Australia's EEZ. The greatest uncertainty occurs on the east margin in the Tasman Sea where the seabed is divided up by a number of bioregions located in water depths of >1,000 m. Bioregions on the southern margin and around the offshore island territories have been defined with limited data.

The static nature of the available data means that the draft NBMB is a "snap-shot" of the spatial distribution of broad-scale benthic marine habitats. Temporal processes such as competition and longer term fluctuations due to climate and sea level changes are not captured in the present framework. Moreover, further research investigating and validating the surrogacy relationships between physical seabed properties and biota–the key premise upon which the bioregions have been defined–must be conducted. The development and continued population of national datasets must continue to support this research.

The draft NBMB represents an improved understanding of the spatial distribution for approximately 80% of the benthic marine habitats and associated biota of Australia's EEZ. Because the bioregions in this framework form the background and context for derivation of a National Representative System of Marine Protected Areas, they can be used to quantitatively assess candidate marine protected areas. Environmental managers can now confidently select the appropriate spatial scale on which to analyse information so that they relate logically to seabed habitat characteristics in the development of management plans.

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8. APPENDIX A

Table A.1. Bioregionalisation Working Group members and their affiliations.

Name	Affiliation		State / Territory
Mr Colin Creighton (Chair)	Water Manager	Land and Water Australia	ACT
Ms Patricia von Baumgarten*	Marine Advisor	Dept of Environment and Heritage	SA
Dr Rob Coles	Senior Research Scientist	Queensland Fisheries Service	QLD
Dr Bob Creese	Principal Conservation Scientist	New South Wales Fisheries	NSW
Mr Ian Cresswell†	Assistant Secretary	Marine Branch, Marine and Water Division, Environment Australia	ACT
Dr Jon Day	Director of Biodiversity Conservation and World Heritage	Great Barrier Reef Marine Park Authority	QLD
Dr Peter Doherty	Senior Research Scientist	Australian Institute of Marine Science	QLD
Mr Don Hough	Manager	Marine Strategy Section, Dept of Natural Resources and Environment	VIC
Mr Chris Simpson	Manager	Marine Research, Dept of Conservation and Land Management	WA
Dr Rob Taylor‡	Senior Conservation Management Officer	Parks and Wildlife Service Department of Infrastructure, Planning and Environment	NT
Dr Sally Troy	Chief Scientist	Dept of Environment and Heritage, National Oceans Office.	TAS
Mr Bruce Wallner§	Research Manager	Australian Fisheries Management Authority	ACT

* Replaced by Mr Bryan McDonald.
† Now Assistant Secretary, National Oceans Office, Marine Division, Dept of Environment and Heritage.
‡ Replaced by Dr Marnie Campbell.
§ Previously Dr Sam Nelson and Mr Paul Ryan.

APPENDIX B

Table B.1. Data contained in the draft National Benthic Marine Bioregionalisation GIS.

GIS Layer	Description
Primary Bathymetric Units	Outlines of the major geomorphic features (i.e., shelf, slope, rise, abyssal plain/deep ocean floor).
Provincial Bioregions	Draft National Benthic Marine Bioregionalisation Provincial Bioregions and their boundaries as defined from demersal fish provincial structure and geomorphology. For the shelf, the Provincial Bioregions are the existing IMCRA Provinces and Biotones.
Biomes	Draft National Benthic Marine Bioregionalisation Biomes and their boundaries as defined from demersal fish depth structure.
Geomorphic Units	Geomorphic units and their boundaries as defined from a cluster analysis of the geomorphic features.
Seabed Facies	Seabed facies and their boundaries for water depths of <300 m as defined from a cluster analysis of sediment, geomorphic and oceanographic data.
Coastline (250k)	Australian coastline (including islands) shown at a scale of 1:250,000.
Australian EEZ	Australian Exclusive Economic Zone boundary.
Bathymetry (contours)	Bathymetric contours derived from the 250 m spatial resolution bathymetry model.
Bathymetry (image)	Tagged Image File format (TIFF) colour-ramped image of the 250 m spatial resolution bathymetry model.
Sedimentary Basins	Outlines of offshore sedimentary basins.
Geomorphic Features	Outlines of 21 types of geomorphic features.
Ocean Crust Age	Outlines of regions showing oceanic crustal rocks of equal age.
Percent Carbonate	Calcium carbonate ($CaCO_3$) concentrations over the seabed for water depths of <300 m interpolated to a 0.01° (~1 km) grid.
Percent Gravel	Gravel concentrations over the seabed for water depths of <300 m interpolated to a 0.01° (~1 km) grid.
Percent Sand	Sand concentrations over the seabed for water depths of <300 m interpolated to a 0.01° (~1 km) grid.
Percent Mud	Mud concentrations over the seabed for water depths of <300 m interpolated to a 0.01° (~1 km) grid.
Mean Grain Size	Mean grain size in mm of seabed sediment for water depths of <300 m interpolated to a 0.01° (~1 km) grid.
Sediment Mobility Regime	Outlines showing the relative influence of waves and tides in mobilising sediment on an annual basis for water depths of <300 m.
Australian Sponge Distribution	Points showing the distribution of sponges.
Demersal Fish Provinces (slope)	Outlines of the major provincial structure of deep-water demersal fishes for water depths of 40-2,000 m.
Demersal Fish Provinces (shelf)	Outlines of the provincial structure of demersal fishes on the shelf (<200 m).
IMCRA (shelf)	Outlines showing the boundaries of the shelf Provinces and Biotones contained in the Interim Marine and Coastal Regionalisation of Australia.
GBRMP Reef Bioregions	Outlines showing the boundaries of the reef bioregions in the Great Barrier Reef Marine Park.
GBRMP Non-reef Bioregions	Outlines showing the boundaries of the non-reef bioregions in the Great Barrier Reef Marine Park
Seabed Temperature	Average annual seabed temperature in °C generated from the CSIRO Atlas of Regional Seas (CARS) database interpolated to a 0.01° (~1 km) grid.

Seabed Salinity	Average annual seabed salinity in practical salinity units (psu) generated from the CSIRO Atlas of Regional Seas (CARS) database interpolated to a 0.01° (~1 km) grid.
Seabed Nitrate	Average seabed nitrate concentrations in micro-molar (μM) units generated from the CSIRO Atlas of Regional Seas (CARS) database interpolated to a 0.01° (~1 km) grid.
Seabed Silicate	Average seabed silicate concentrations in micro-molar (μM) units generated from the CSIRO Atlas of Regional Seas (CARS) database interpolated to a 0.01° (~1 km) grid.
Seabed Oxygen	Average seabed oxygen concentrations in micro-molar (μM) units generated from the CSIRO Atlas of Regional Seas (CARS) database interpolated to a 0.01° (~1 km) grid.
Seabed Phosphate	Average seabed phosphate concentrations in micro-molar (μM) units generated from the CSIRO Atlas of Regional Seas (CARS) database interpolated to a 0.01° (~1 km) grid.

APPENDIX C

C.1. Provincial Bioregion Descriptions

The draft NBMB is described on the basis of the individual Provincial Bioregions. For convenience, the draft NBMB Provincial Bioregions have been separated from the IMCRA Provincial Bioregions. The principal features of each Provincial Bioregion are provided in the descriptions, including the key candidate indicator demersal fish species that were used to define each of the draft NBMB Provinces. These fish species are taken from Last *et al.* (2005). Other previously published information for each bioregion is also presented, where applicable. All areas quoted are "map areas" and are calculated for regions as projected on to a flat surface. In regions with considerable topographic relief the areas will not be equal to the actual "surface area" of the seabed.

PB1 – Timor Transition

This bioregion is located on the northern margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
24,040	-15	-357	-161	53

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 0		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
24,040	-	-	-	-	-

No. of Demersal Fish Species:	284 (>2 string nodes)
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 13													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	3	5,720	-	-	2	680	-	-	-	-	2	7,490

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	4	7,330	-	-	-	-	1	130	1	2,590	1	100

Notes:

- This bioregion is the shallowest on average of all the NBMB bioregions due to its location on the upper slope of the north margin.
- This bioregion is one of six NBMB bioregions to cover only one Primary Bathymetric Unit, and one of five to occur only on the slope.
- This bioregion contains the 2nd smallest area of slope of all the NBMB bioregions.
- The demersal fish data indicate that this bioregion has a strong boundary with Indonesian and Papua New Guinea fauna, although the similarity of the demersal fishes in this bioregion to Timor and Indonesian fauna has not been fully established (Last *et al.*, 2005).
- This bioregion is the only NBMB bioregion adjacent to the mainland not to contain any Biomes.
- This bioregion is one of four NBMB bioregions to contain seven classes of geomorphic units.

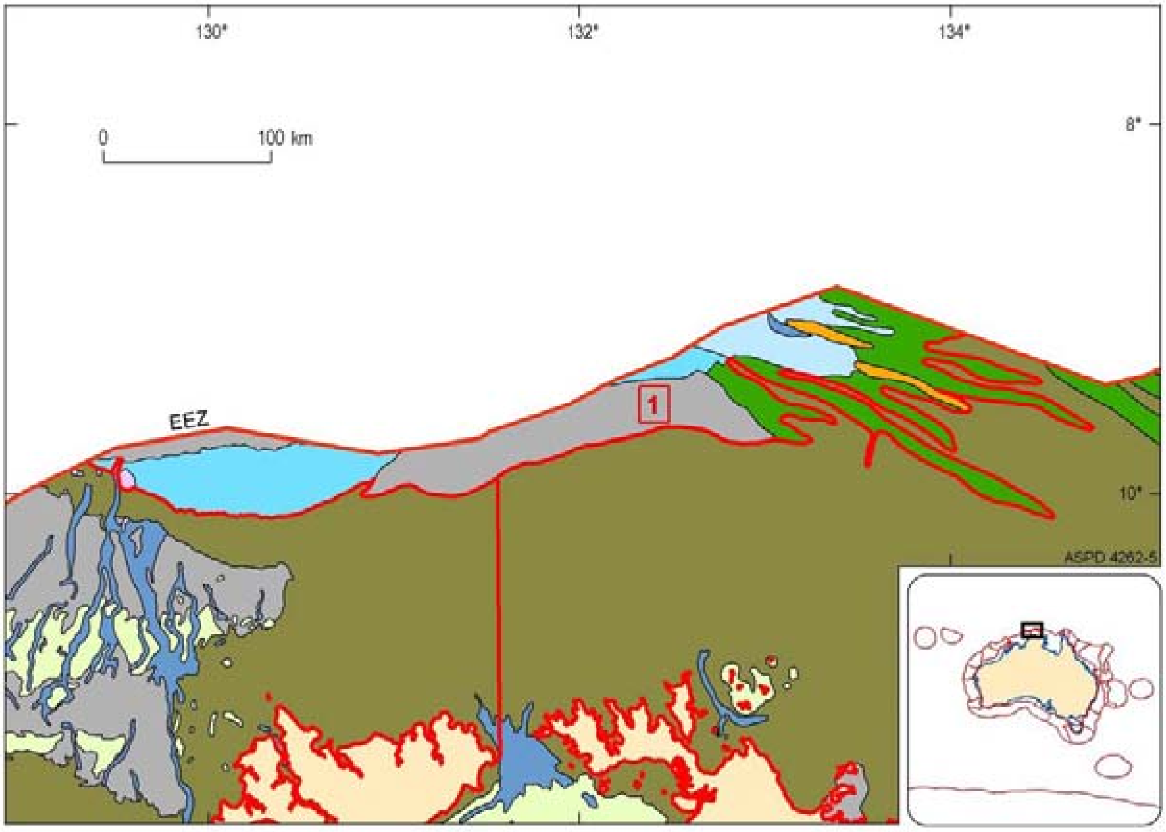

Figure C.1. Map of Geomorphic Units in Provincial Bioregion 1 (PB1 – *Timor Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB2 – Timor Province

This bioregion is located on the northwest margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
160,690	0	-5,819	-2,022	1,864

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 4		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
138,150	4,530	18,020	40,940	-	5,290

No. of Demersal Fish Species:	418 (34 string nodes)
Key Indicator Demersal Fish Species:	
Bembrops nelsoni, *Bythaelurus* sp., *Halicmetus* sp., *Malthopsis* spp, *Neobythites australiensis*, *Nobythites bimaculatus*, *Neobythites macrops*, *Neobythites soelae*, *Parapterygotrigla* sp., *Physiculus roseus*	
No. of Endemics:	64
Strength:	7.7 (strongly defined)

Geomorphic Units (km^2) *N* = 30													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	18,020	4	54,030	2	4,850	-	-	-	-	-	-	8	66,400

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	350	8	2,180	-	-	-	-	1	13,200	3	380	4	1,830

Notes:

- This bioregion is one of seven NBMB bioregions to cover all three Primary Bathymetric Units.
- This bioregion contains the 5th largest area of rise of all the NBMB bioregions.
- This bioregion is the only NBMB bioregion to contain two biome types.
- The ratio of endemics to total species is the second highest for all the NBMB bioregions.
- The demersal fish fauna in this bioregion are linked to the Indonesian slope demersal fish fauna.
- Biomes defined by the demersal fish depth structure in this bioregion are the second largest in terms of area and cover the third largest area as a percentage of the area of the bioregion.
- This bioregion is the only NBMB bioregion to contain nine classes of geomorphic units.

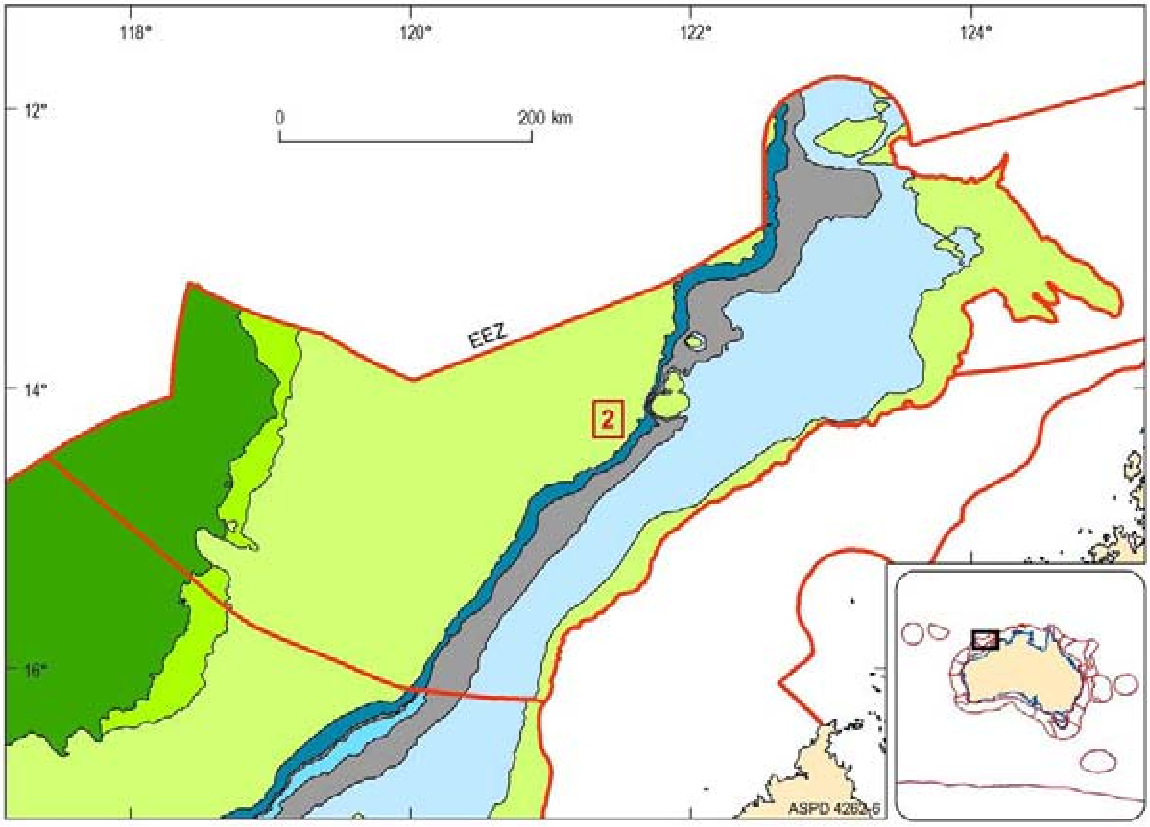

Figure C.2a. Map of Biomes in Provincial Bioregion 2 (PB2 – *Timor Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

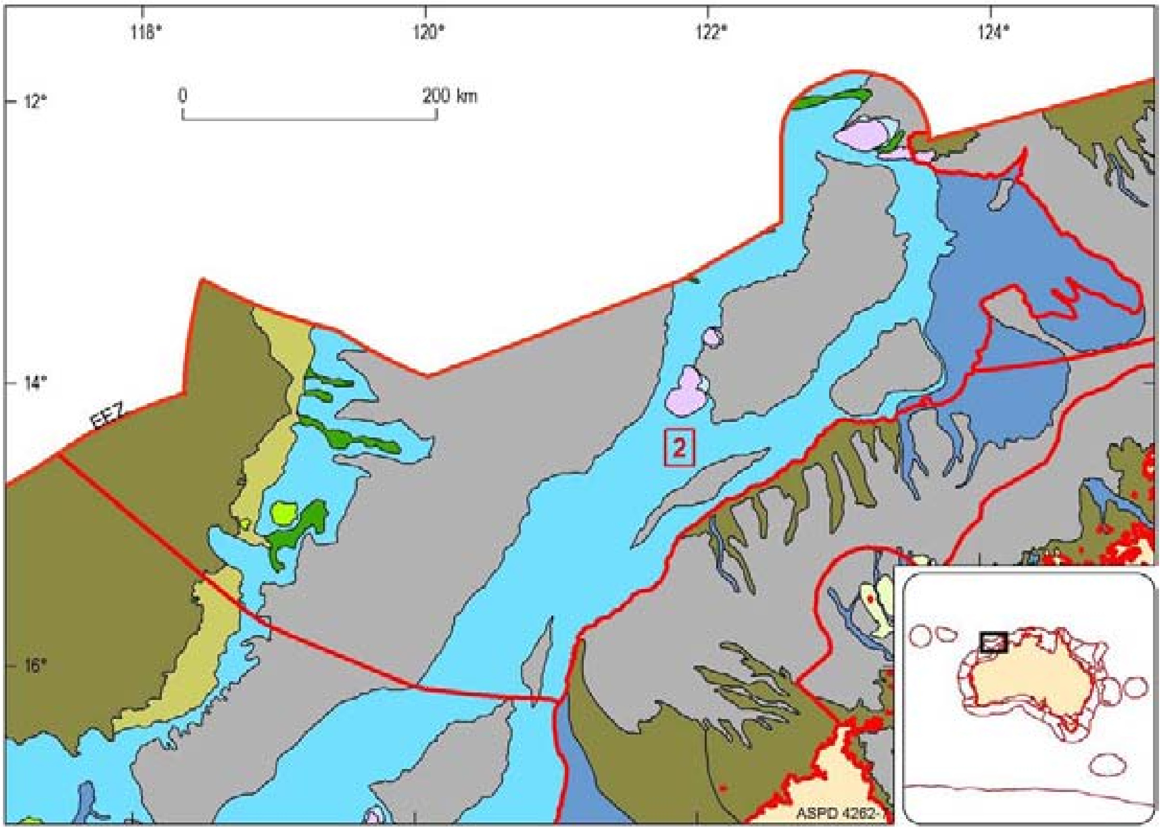

Figure C.2b. Map of Geomorphic Units in Provincial Bioregion 2 (PB2 – *Timor Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB3 – Northwest Transition

This bioregion is located on the northwest margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
217,230	0	-5,895	-2,144	2,086

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 3		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
172,810	3,800	40,630	34,110	4,530	5,880

No. of Demersal Fish Species:	505 (10 string nodes)
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 25													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	40,630	2	114,050	1	3,800	1	2,570	-	-	1	110	7	50,700

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	1,370	1	880	-	-	-	-	3	1,910	3	690	3	520

Notes:

- Class 2 in this bioregion is the 3rd largest in area for all of the NBMB bioregions.
- This bioregion is one of seven NBMB bioregions to cover all three Primary Bathymetric Units.
- The demersal fish fauna in this bioregion are mixed and could be related to the bight in the Exmouth Plateau.
- This is one of 14 NBMB bioregions to contain three biome types.
- Biomes defined by the demersal fish depth structure in this bioregion are the fourth largest in terms of their total area and cover the fourth largest area as a percentage of the bioregion area.
- This bioregion is one of two NBMB bioregions to contain 11 classes of geomorphic units. This bioregion along with PB18 contains the most classes of geomorphic units of all the NBMB bioregions.

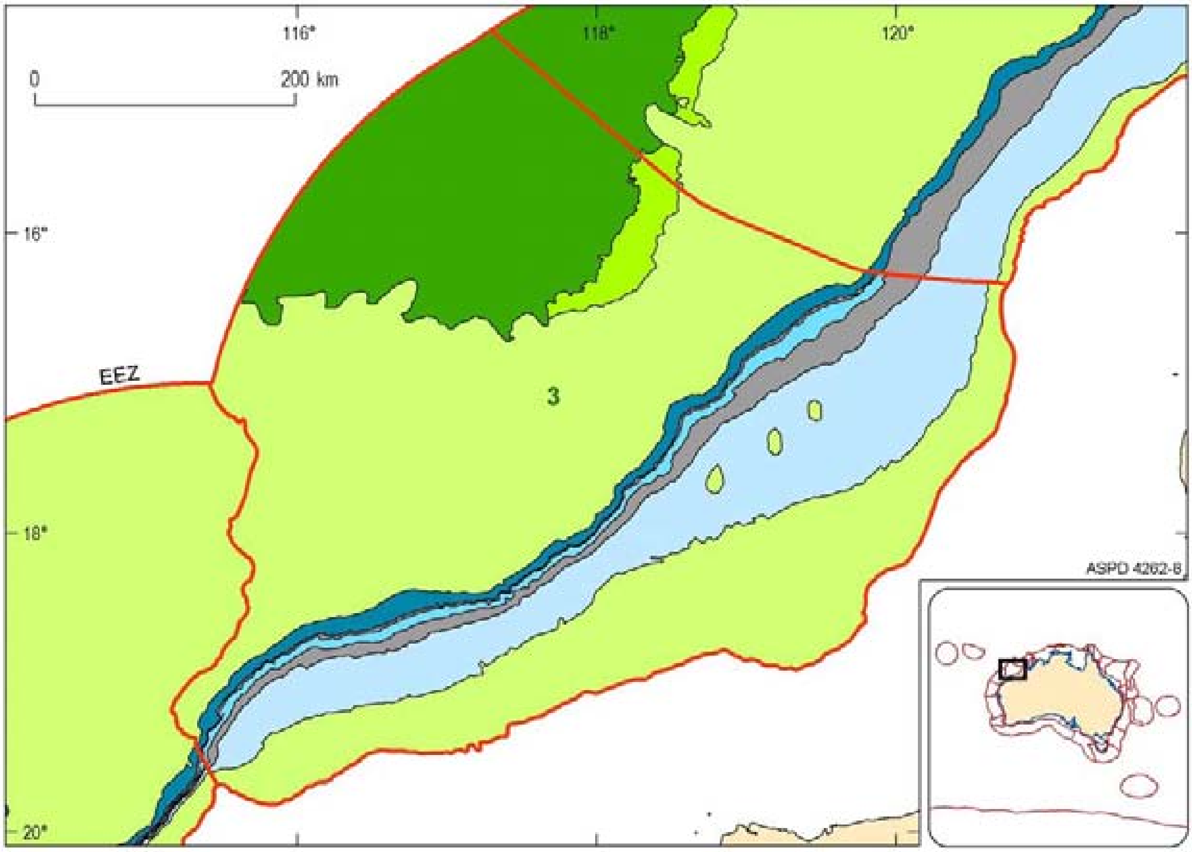

Figure C.3a. Map of Biomes in Provincial Bioregion 3 (PB3 – *Northwest Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

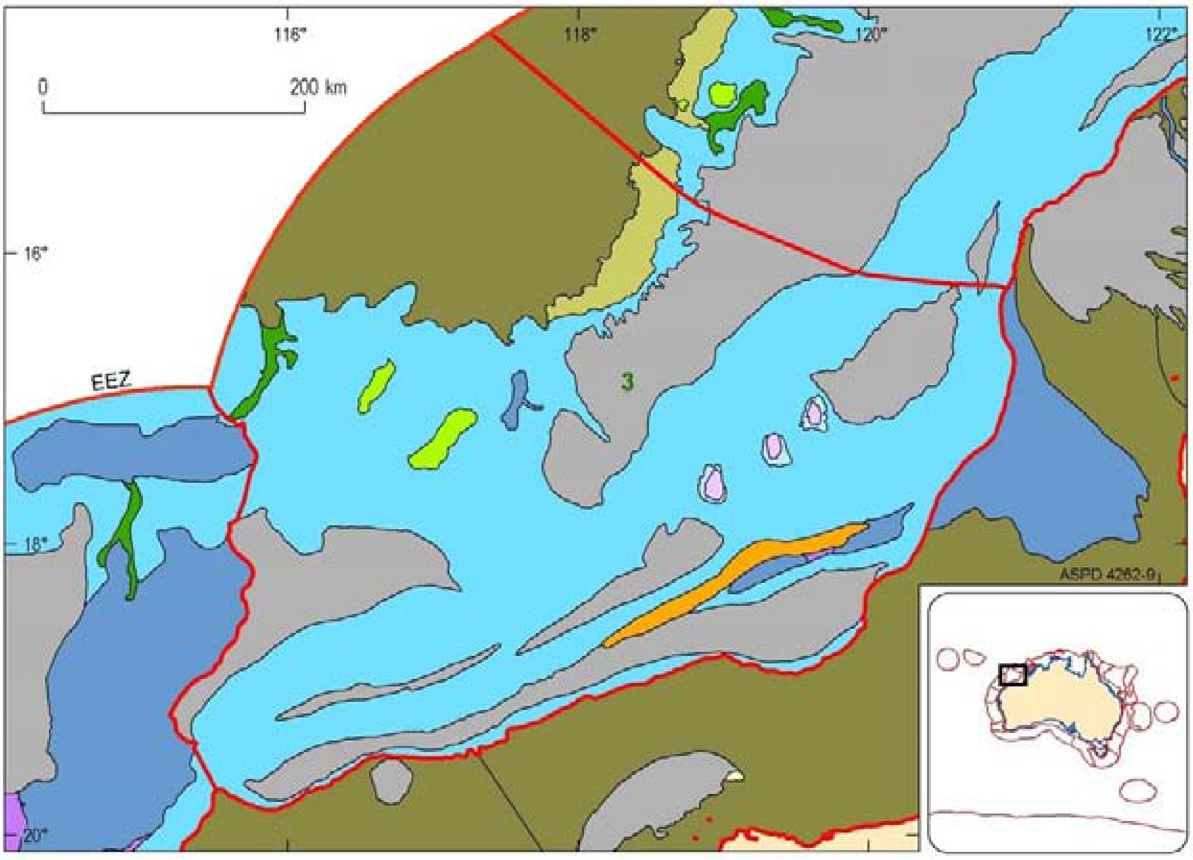

Figure C.3b. Map of Geomorphic Units in Provincial Bioregion 3 (PB3 – *Northwest Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB4 – Northwest Province

This bioregion is located on the northwest margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
188,730	-20	-5,133	-1,597	804

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 5		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
188,180	420	-	2,980	1,590	20,550

No. of Demersal Fish Species:	508 (8 string nodes)
Key Indicator Demersal Fish Species:	
Chaunax sp., *Dibranchus* sp., *Diplacanthopoma* sp., *Hime* sp., *Leptochilichthys microlepis*, *Parapercis* cf. *macrophthalma*, *Uranoscopus* sp.	
No. of Endemics:	76
Strength:	2.2 (weakly defined)

Geomorphic Units (km^2) *N* = 16													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	3	75,200	-	-	1	1,340	-	-	1	10,120	6	67,720
Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	170	1	700	-	-	-	-	3	33,090	-	-	-	-

Notes:

- This bioregion is one of 11 NBMB bioregions to cover two Primary Bathymetric Units, and one of only two to occur on the slope and rise.
- This bioregion contains the 2nd smallest area of rise of all the NBMB bioregions.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- The ratio of endemic species to total species is the highest for all the NBMB bioregions.
- Biomes defined by the demersal fish depth structure are the 11th largest in terms of their total area and cover the 10th largest area as a percentage of the bioregion area.
- This bioregion is one of four NBMB bioregions to contain seven classes of geomorphic units.
- Class 12 in this bioregion is the largest in area for all of the NBMB bioregions.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.

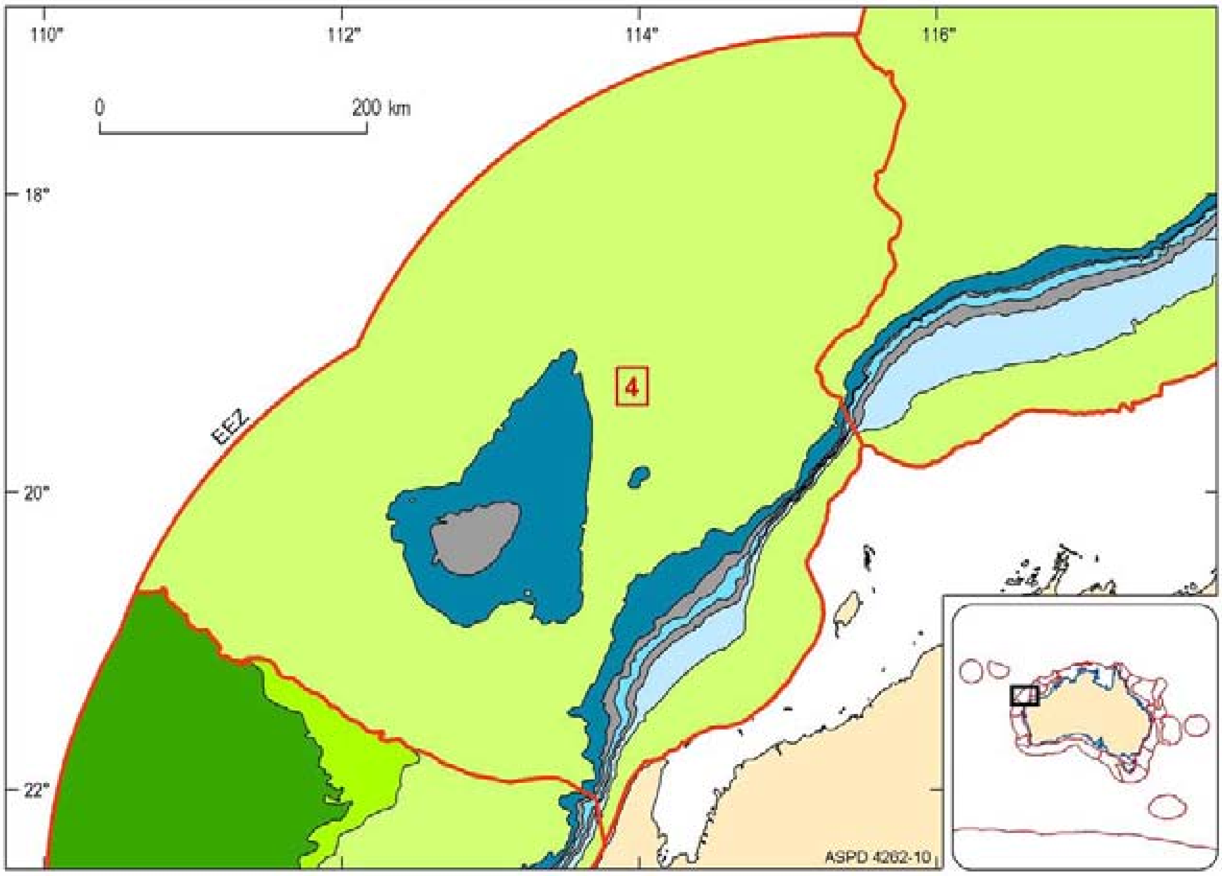

Figure C.4a. Map of Biomes in Provincial Bioregion 4 (PB4 – *Northwest Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

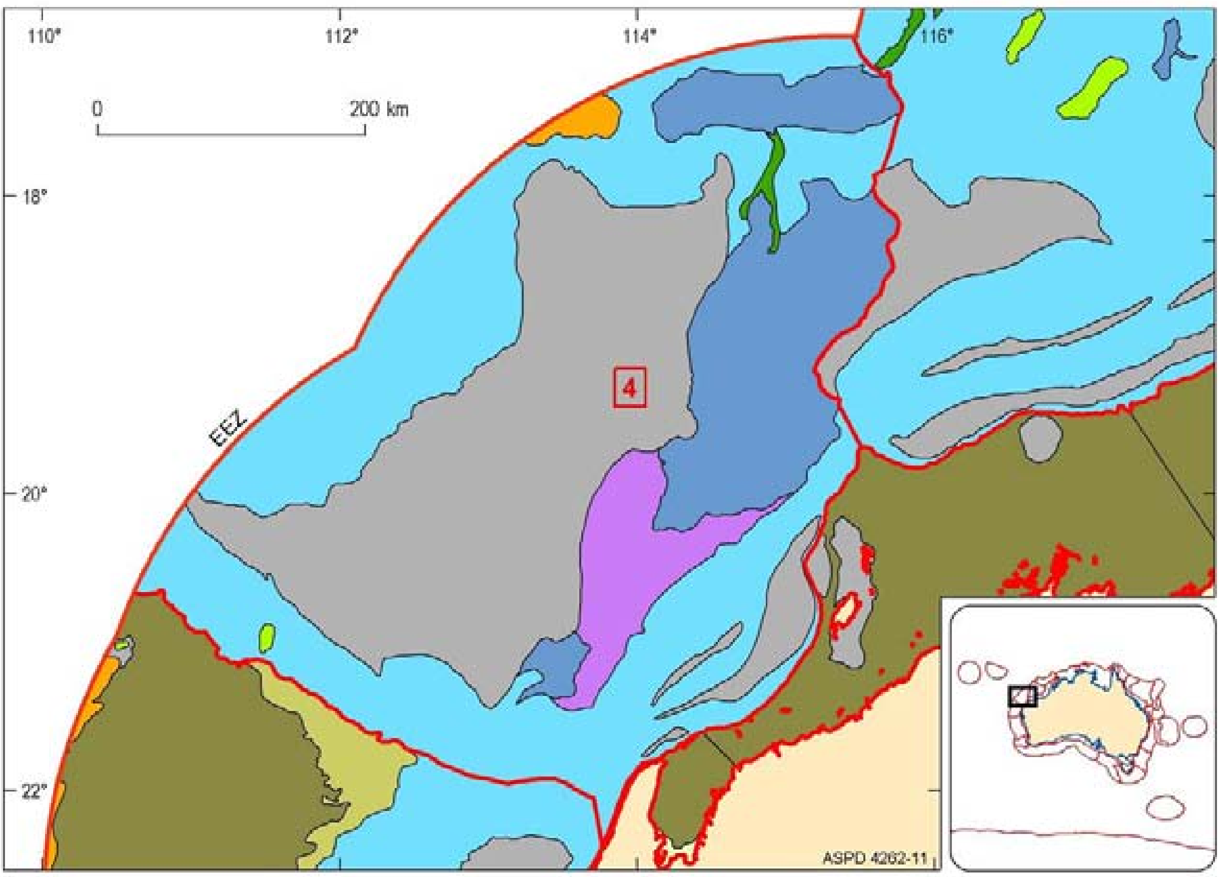

Figure C.4b. Map of Geomorphic Units in Provincial Bioregion 4 (PB4 – *Northwest Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB5 – Central Western Transition

This bioregion is located on the western margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
173,660	0	-5,325	-3,036	1,784

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 4		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
125,230	7,060	41,330	4,250	4,800	8,130

No. of Demersal Fish Species:	462 (10 string nodes)
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N./A

Geomorphic Units (km^2) *N* = 17													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	40,140	2	64,170	3	7,520	3	1,880	-	-	1	7,880	4	40,490

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	50	-	-	-	-	-	-	1	12,180	-	-	-	-

Notes:

- This bioregion is one of seven NBMB bioregions to cover all three Primary Bathymetric Units.
- This bioregion contains the 4th largest area of rise of all the NBMB bioregions.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- Biomes defined by the demersal fish depth structure are the 7th largest in terms of their total area and cover the 5th largest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is one of five NBMB bioregions to contain eight classes of geomorphic units.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.

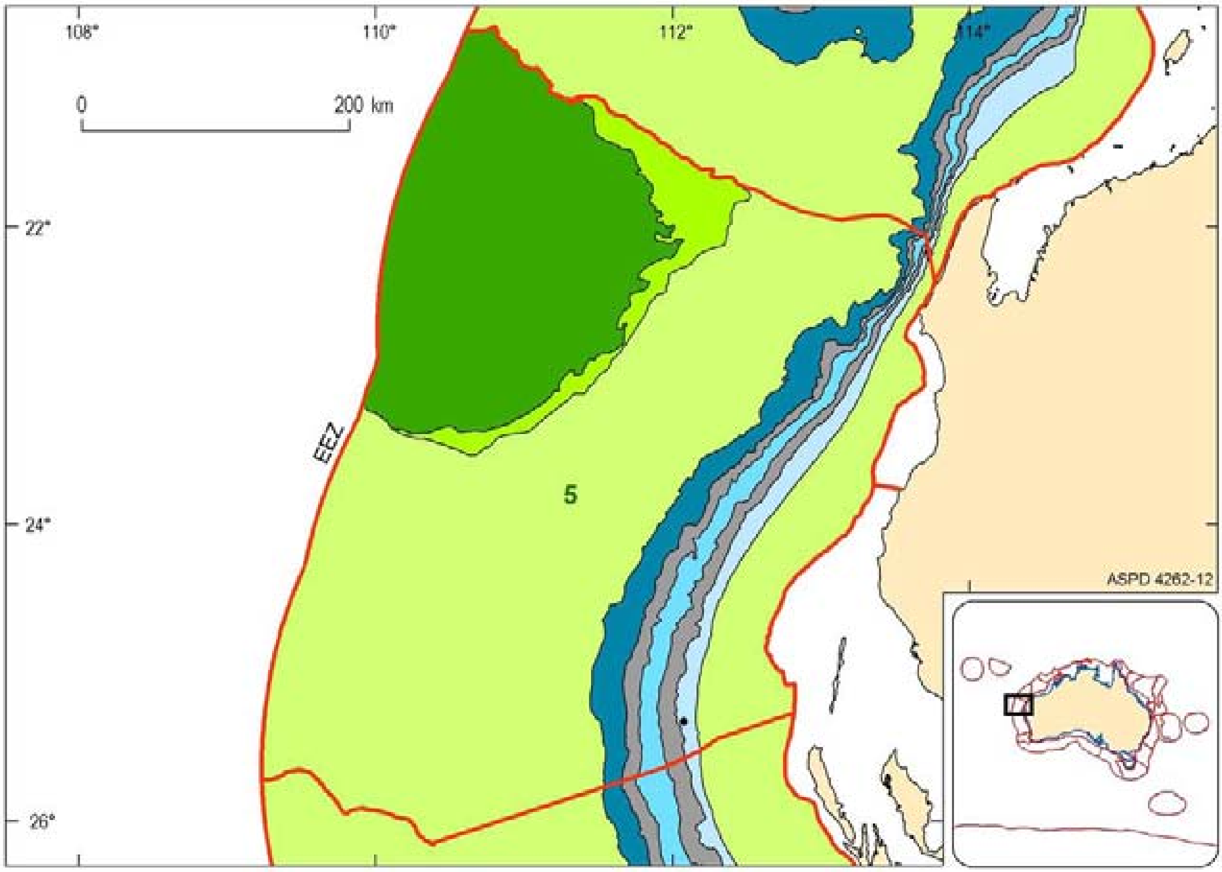

Figure C.5a. Map of Biomes in Provincial Bioregion 5 (PB5 – *Central Western Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

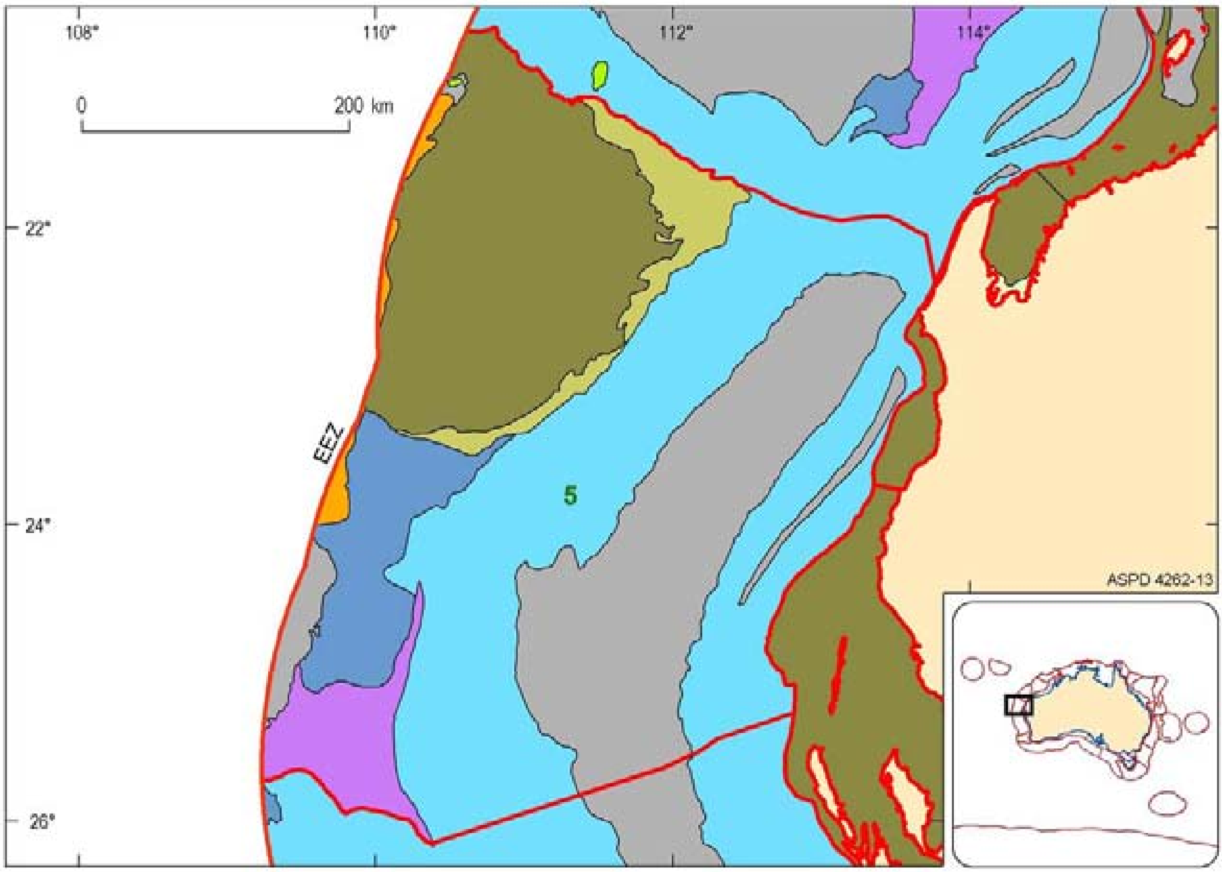

Figure C.5b. Map of Geomorphic Units in Provincial Bioregion 5 (PB5 – *Central Western Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB6 – Central Western Province

This bioregion is located on the western margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
286,730	-33	-6,001	-3,815	1,866

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 7		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
129,120	52,090	105,170	4,320	8,590	7,610

No. of Demersal Fish Species:	480 (15 string nodes)
Key Indicator Demersal Fish Species:	
Dicrolene sp., *Epigonus macrops*, *Monomitopus* sp., *Neomerinthe* cf *nielseni*, *Parascyllium sparsimaculatum*, *Dipturus* sp.	
No. of Endemics:	31
Strength:	1.7 (weakly defined)

Geomorphic Units (km^2) *N* = 11													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	103,910	6	107,630	1	52,240	-	-	-	-	-	-	2	21,110
Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	2	1,500	-	-	-	-

Notes:

- This bioregion is one of seven NBMB bioregions to cover all three Primary Bathymetric Units.
- This bioregion contains the largest area of rise of all the NBMB bioregions.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types
- The southern boundary of this bioregion is well-defined by Perth Canyon. This large submarine canyon is a significant geomorphic feature on the margin. Studies have shown that it represents a major faunal discontinuity for sponges, corals, decapods and xanthid crabs, as well as affecting the major ocean currents and associated water properties by being a conduit for significant upwelling.
- Biomes defined by the demersal fish depth structure are the 6th largest in terms of their total area and cover the 7th largest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is one of two NBMB bioregions to contain five classes of geomorphic units.
- Class 2 in this bioregion is the 4th biggest of all the NBMB bioregions
- Class 2 includes units defined by the spacing of submarine canyons on the slope.

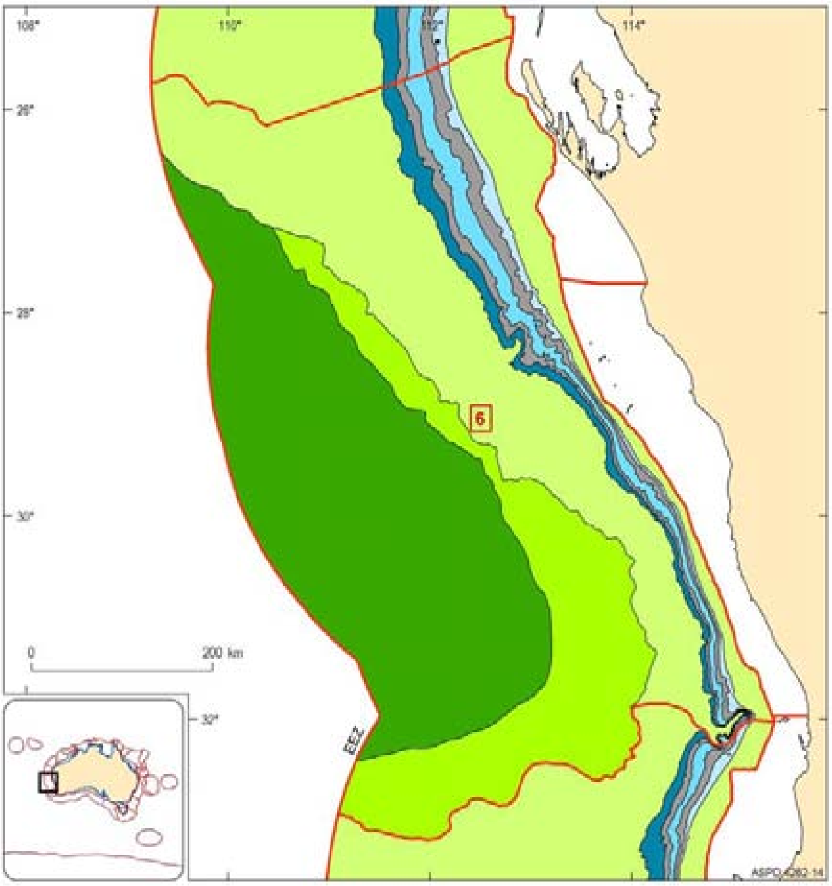

Figure C.6a. Map of Biomes in Provincial Bioregion 6 (PB6 – *Central Western Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

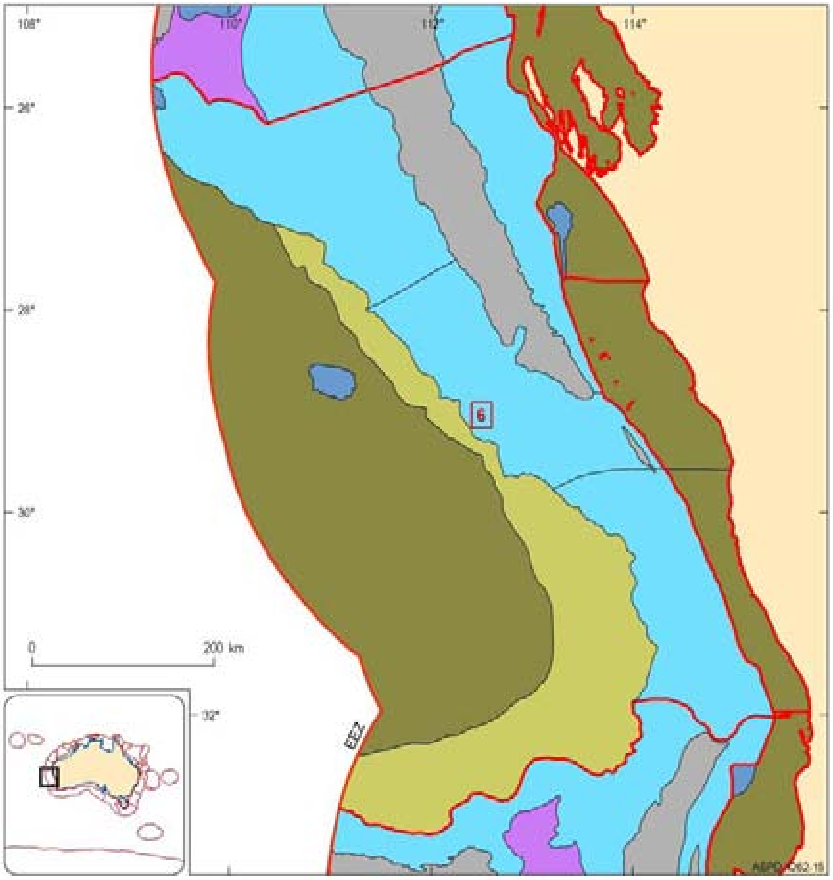

Figure C.6b. Map of Geomorphic Units in Provincial Bioregion 6 (PB6 – *Central Western Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB7 – Southwest Transition

This bioregion is located on the southwest margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
110,460	-48	-5,902	-2,414	1,287

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 6		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
109,830	-	-	1,770	2,440	4,390

No. of Demersal Fish Species:	398 (5 string nodes)
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 5													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	1	54,350	-	-	-	-	-	-	1	8,950	3	46,980
Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

- This bioregion is one of six NBMB bioregions to cover only one Primary Bathymetric Unit, and one of five to occur only on the slope.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- Biomes defined by the demersal fish depth structure are the 6th largest in terms of their total area and cover the 7th largest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is one of four NBMB bioregions to contain three classes of geomorphic units.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.
- This bioregion is centred on the Naturaliste Plateau, a 90,000 km^2 submerged continental fragment that rises from water depths of >5000 m to 2,000 m and surrounded by deep ocean floor. This bioregion represents a completely different environment from the surrounding seabed and adjacent Provinces.

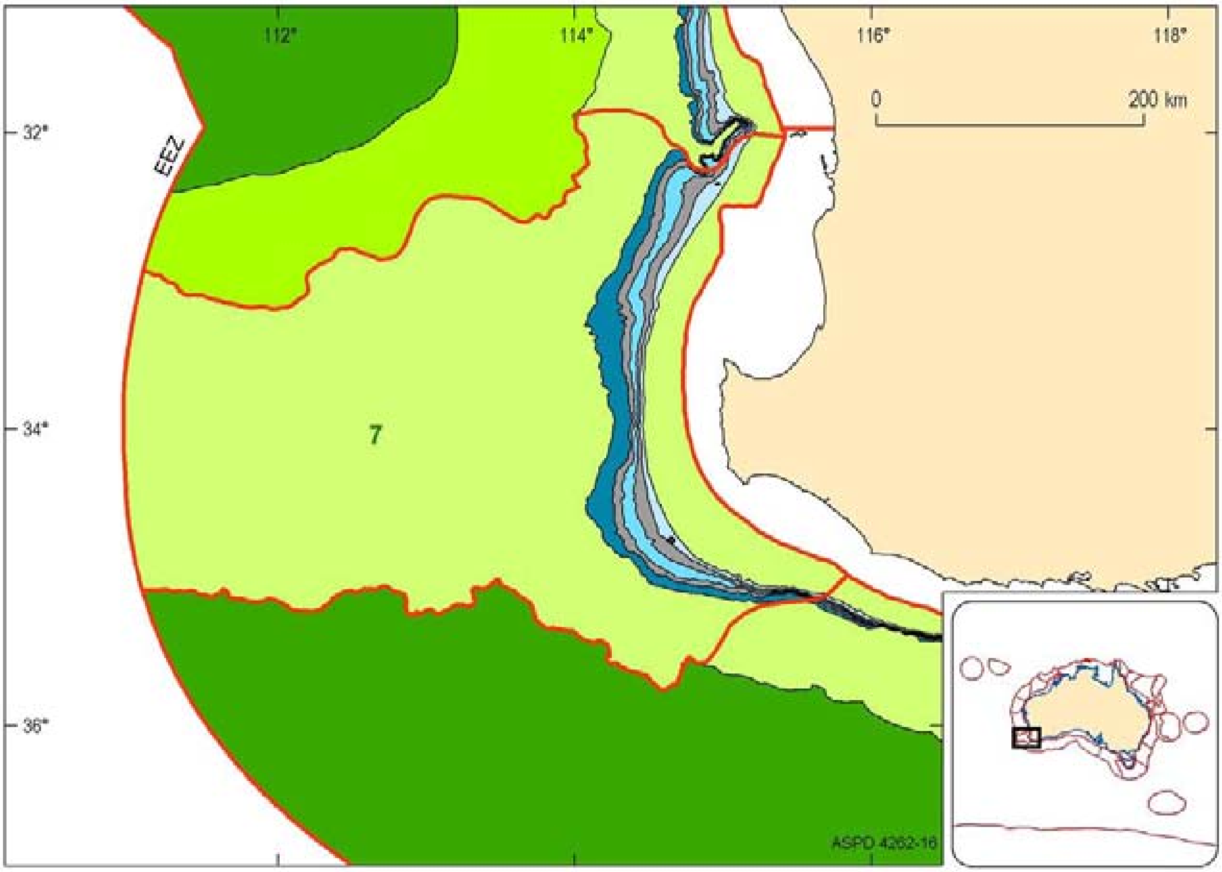

Figure C.7a. Map of Biomes in Provincial Bioregion 7 (PB7 – *Southwest Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for – legend.

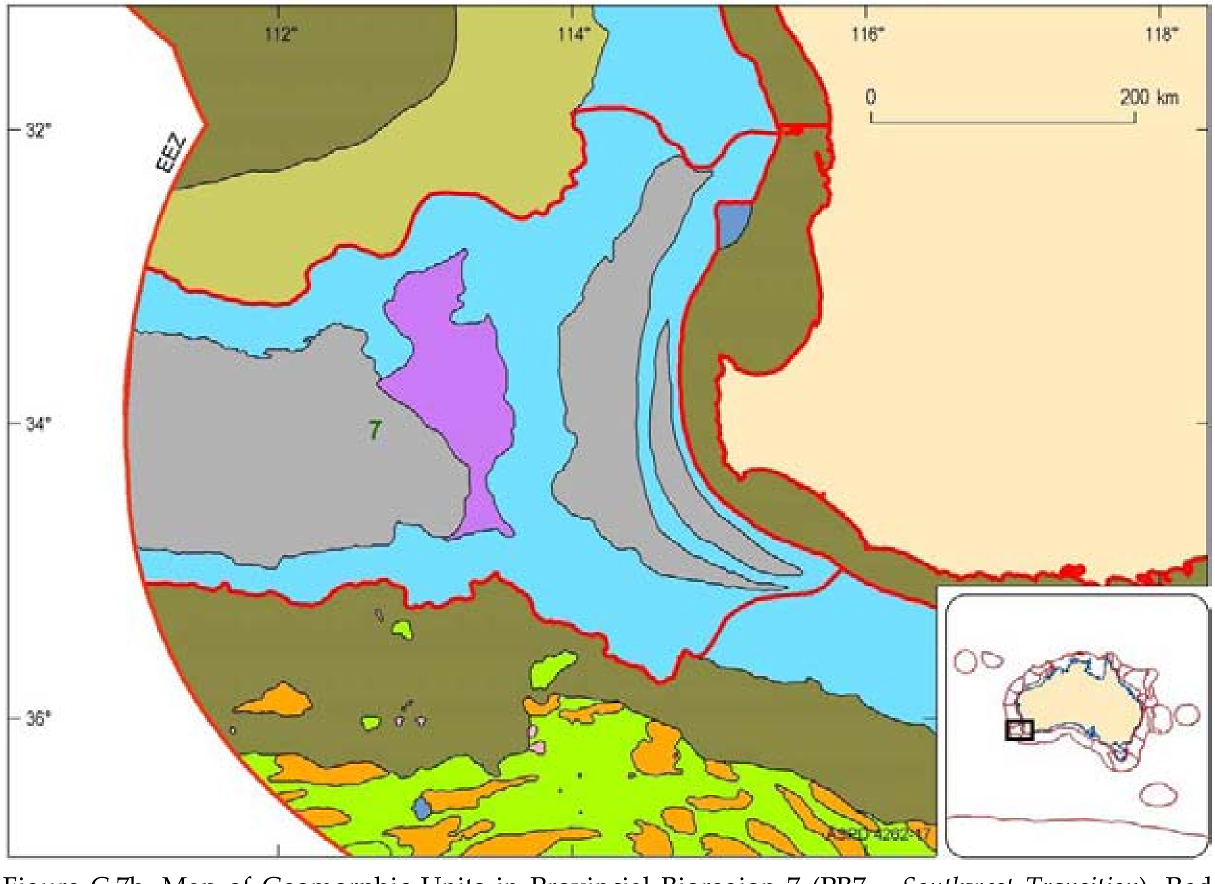

Figure C.7b. Map of Geomorphic Units in Provincial Bioregion 7 (PB7 – *Southwest Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB8 – Southern Province

This bioregion is located on the southern margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
774,120	N/C	N/C	N/C	N/C

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 21		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
362,020	-	412,000	10,310	5,950	21,510

No. of Demersal Fish Species:	463 (52 string nodes)
Key Indicator Demersal Fish Species:	
Bathyraja sp., *Centroberyx* sp., *Dicrolene* sp., *Notoraja* sp., *Nybelinella* sp., *Paraliparis australiensis*, *Paraliparis avellaneus*, *Pavoraja* sp.	
No. of Endemics:	26
Strength:	4.8 (strongly defined)

Geomorphic Units (km^2) *N* = 99													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
3	305,330	6	225,430	-	-	51	38,130	-	-	2	1,560	2	136,570

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
10	66,710	-	-	21	350	-	-	4	450	-	-	-	-

Notes:

- This bioregion is one of 11 NBMB bioregions to cover two Primary Bathymetric Units, and one of nine to occur on the slope and abyssal plain/deep ocean floor.
- This bioregion contains the 2nd largest area of abyssal plain/deep ocean floor and 4th largest slope area of all the NBMB bioregions.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- The ratio of endemics to total fish species is the lowest for all the NBMB bioregions.
- The central distribution of demersal fishes is located in the Great Australian Bight (Last *et al.*, 2005).
- Biomes defined by the demersal fish depth structure are the third largest in terms of their total area and cover the 11th largest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is one of five NBMB bioregions to contain eight classes of geomorphic units.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.
- This bioregion contains the largest Class 2, 2nd largest Class 1, and 5th largest Class 7 unit of all the NBMB bioregions.
- The province also contains the Diamantina Fracture Zone a region of very rugged seabed comprised of numerous deep-sea ridges and troughs which represents. This is a unique region of deep-sea habitats.

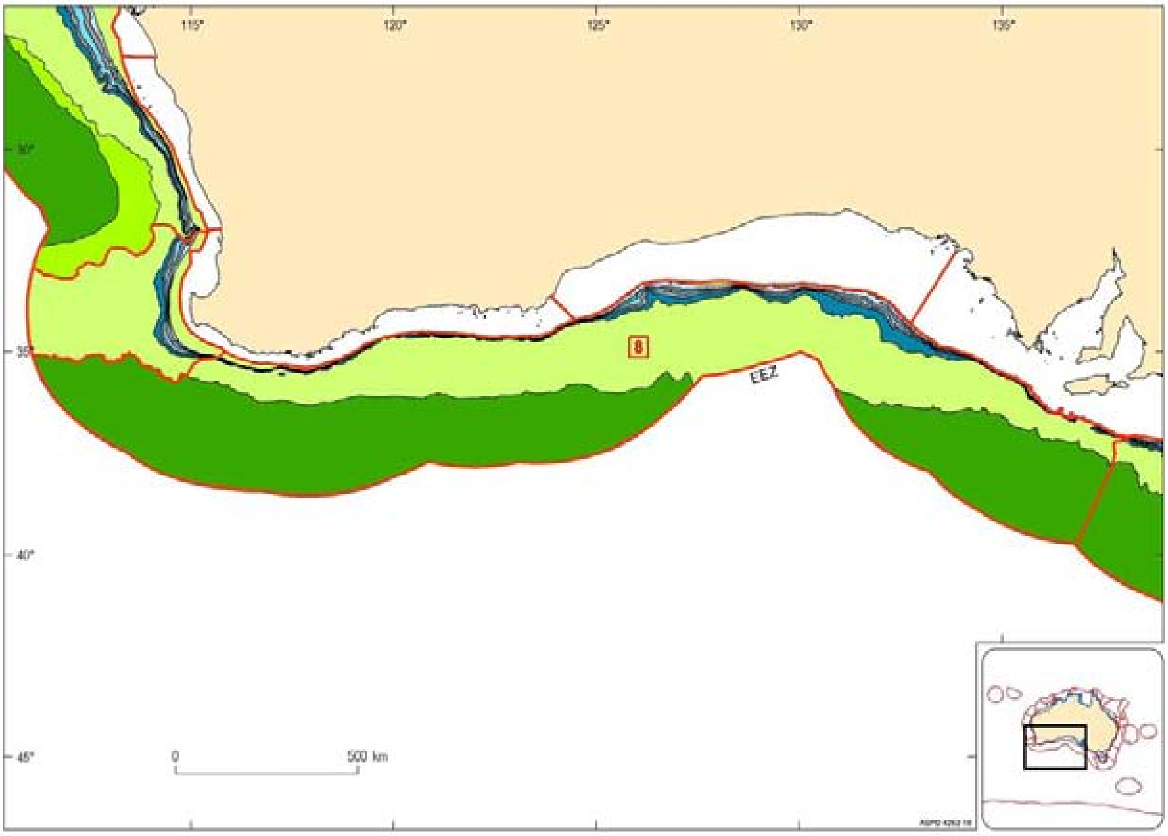

Figure C.8a. Map of Biomes in Provincial Bioregion 8 (PB8 – *Southern Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

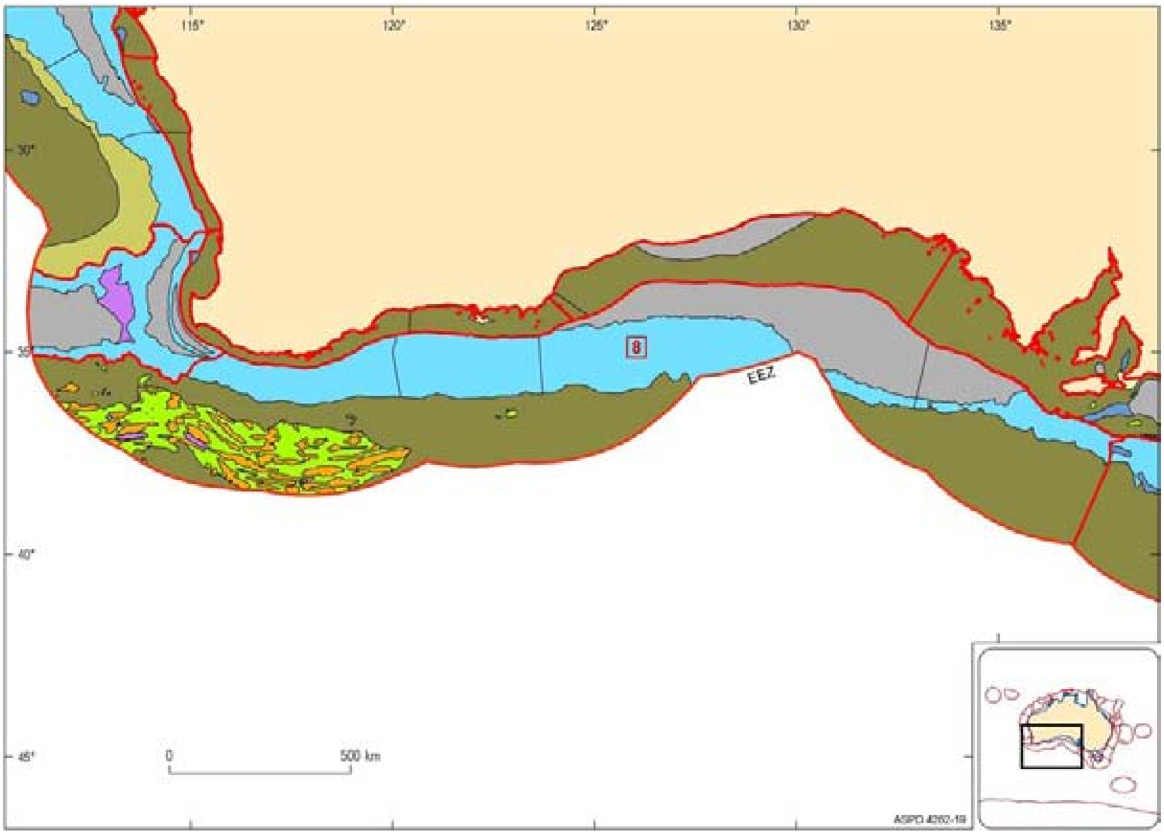

Figure C.8b. Map of Geomorphic Units in Provincial Bioregion 8 (PB8 – *Southern Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB9 – West Tasmania Transition

This bioregion is located west of Tasmania on the southeast margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
289,850	-36	-5,645	-3,918	1,482

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 4		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
89,980	-	10,460	2,690	1,100	2,820

No. of Demersal Fish Species:	456 (15 string nodes)
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 14													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	199,040	3	84,350	-	-	-	-	-	-	-	-	1	2,960

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
7	1,330	-	-	-	-	-	-	2	2,170	-	-	-	-

Notes:

- This bioregion is one of 11 NBMB bioregions to cover two Primary Bathymetric Units, and one of nine to occur on the slope and abyssal plain/deep ocean floor.
- This bioregion contains the 7th largest area of abyssal plain/deep ocean floor of all the NBMB bioregions.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- Biomes defined by the demersal fish depth structure are the 13th largest in terms of their total area and cover the 12th largest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is one of two NBMB bioregions to contain five classes of geomorphic units.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.

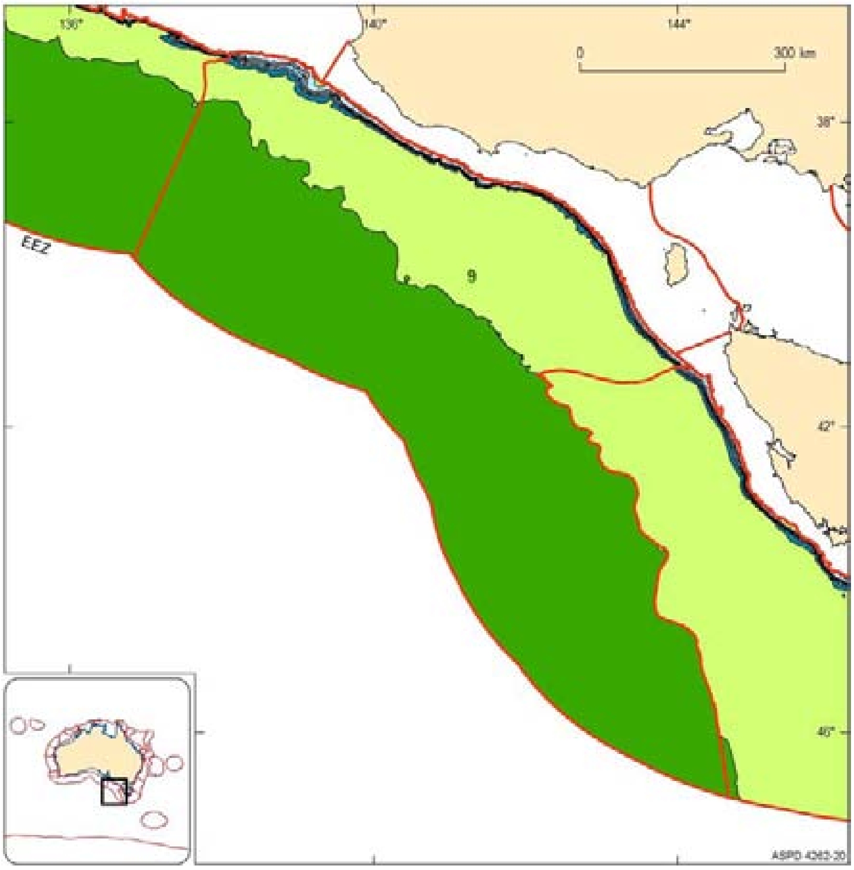

Figure C.9a. Map of Biomes in Provincial Bioregion 9 (PB9 – *West Tasmania Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

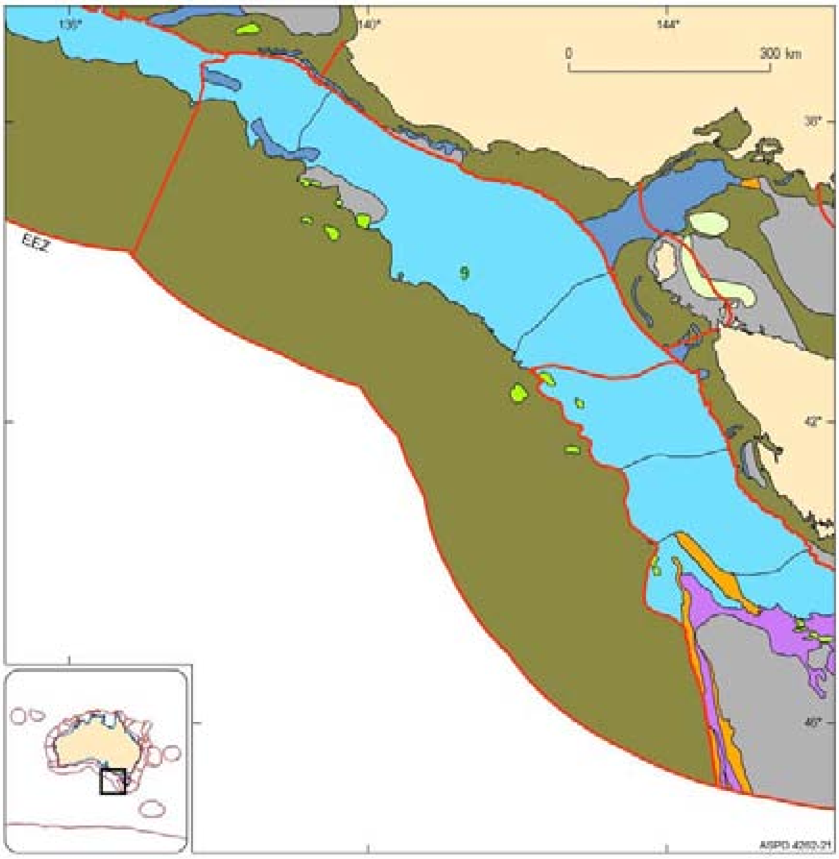

Figure C.9b. Map of Geomorphic Units in Provincial Bioregion 9 (PB9 – *West Tasmania Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB10 – Tasmania Province

This bioregion is located south of Tasmania on the southeast margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
300,190	-36	-5,584	-3,220	1,073

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 15		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
289,580	-	10,460	1,930	1,080	2,690

No. of Demersal Fish Species:	486 (23 string nodes)
Key Indicator Demersal Fish Species:	
Cataetyx spp, *Guttigadus* sp., *Monomitopus* cf *kumae*, *Paraliparis anthracinus*, *Paraliparis ater*, *Rhinochimaera africana*	
No. of Endemics:	52
Strength:	4.3 (strongly defined)

Geomorphic Units (km^2) *N* = 44													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	3,950	8	158,750	-	-	5	5,850	8	6,250	2	32,780	2	84,640

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
15	3,160	2	320	-	-	-	-	-	-	-	-	-	-

Notes:

- This bioregion is one of 11 NBMB bioregions to cover two Primary Bathymetric Units, and one of nine to occur on the slope and abyssal plain/deep ocean floor.
- This bioregion contains the 5th largest area of slope of all the NBMB bioregions.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- The demersal fish data indicate that the fish fauna in this bioregion may have some overlap with the demersal fish fauna of the PB8.
- Biomes defined by the demersal fish depth structure are the 14th largest in terms of their total area and cover the smallest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is one of five NBMB bioregions to contain eight classes of geomorphic units.
- Class 2 in this bioregion is the 2nd largest of all the NBMB bioregions and includes units defined by the spacing of submarine canyons on the slope.
- This bioregion is characterised by a large number of seamounts that contain endemic fishes. The Cascade Seamount is included because its fauna is more closely associated with fauna found on other seamounts in the Southern Ocean. Because of its shallow depth the South Tasman Rise contains species of fish otherwise found on the upper slope of the Tasmanian margin. Studies have shown that the benthic fauna at the foot of the slope and the abyssal plain in this bioregion are similar and distinct from benthic fauna on the top of the Cascade Plateau.

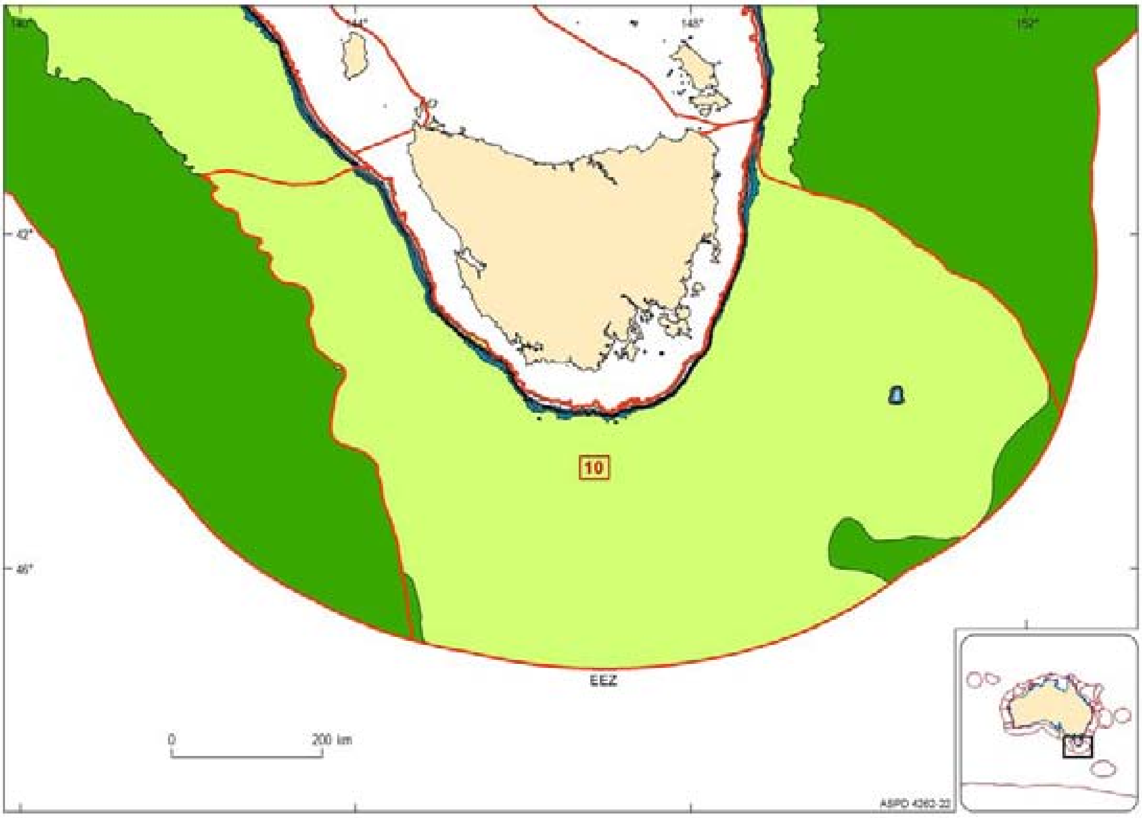

Figure C.10a. Map of Biomes in Provincial Bioregion 10 (PB10 – *Tasmania Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

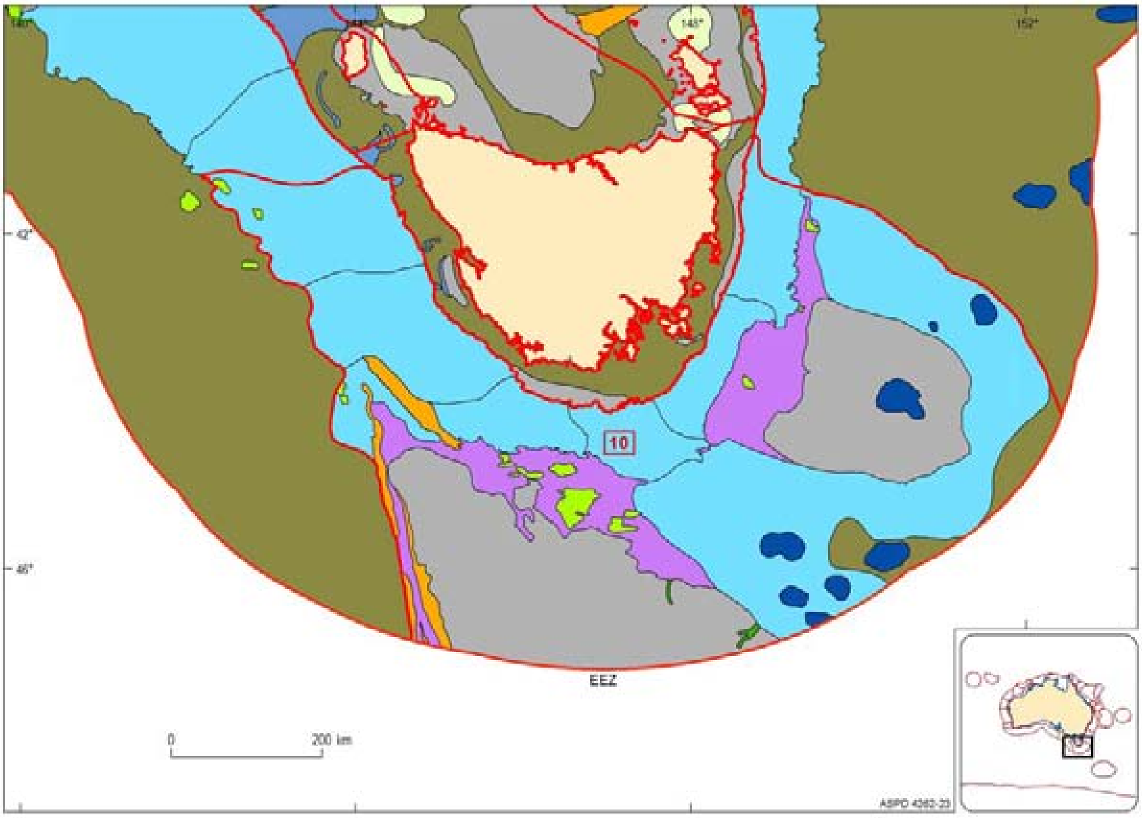

Figure C.10b. Map of Geomorphic Units in Provincial Bioregion 10 (PB10 – *Tasmania Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB11 – Southeast Transition

This bioregion is located on the southeast margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
241,940	-37	-5,534	-3,827	1,281

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 4		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
41,250	-	200,610	2,680	1,340	1,100

No. of Demersal Fish Species:	536 (21 string nodes)
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 8													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	202,340	4	41,270	-	-	-	-	3	2,840	-	-	-	-

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

- This bioregion is one of 11 NBMB bioregions to cover two Primary Bathymetric Units, and one of nine to occur on the slope and abyssal plain/deep ocean floor.
- This bioregion contains the 6th largest area of abyssal plain/deep ocean floor of all the NBMB bioregions.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- Biomes defined by the demersal fish depth structure are the smallest in terms of their total area and cover the 14th largest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is one of four NBMB bioregions to contain three classes of geomorphic units.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.

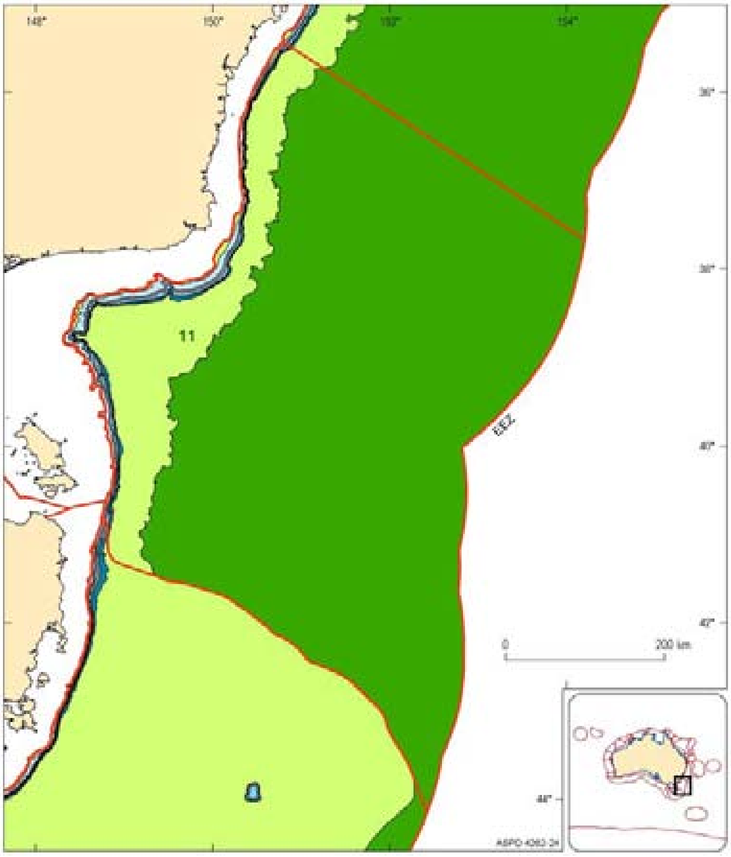

Figure C.11a. Map of Biomes in Provincial Bioregion 11 (PB11 – *Southeast Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

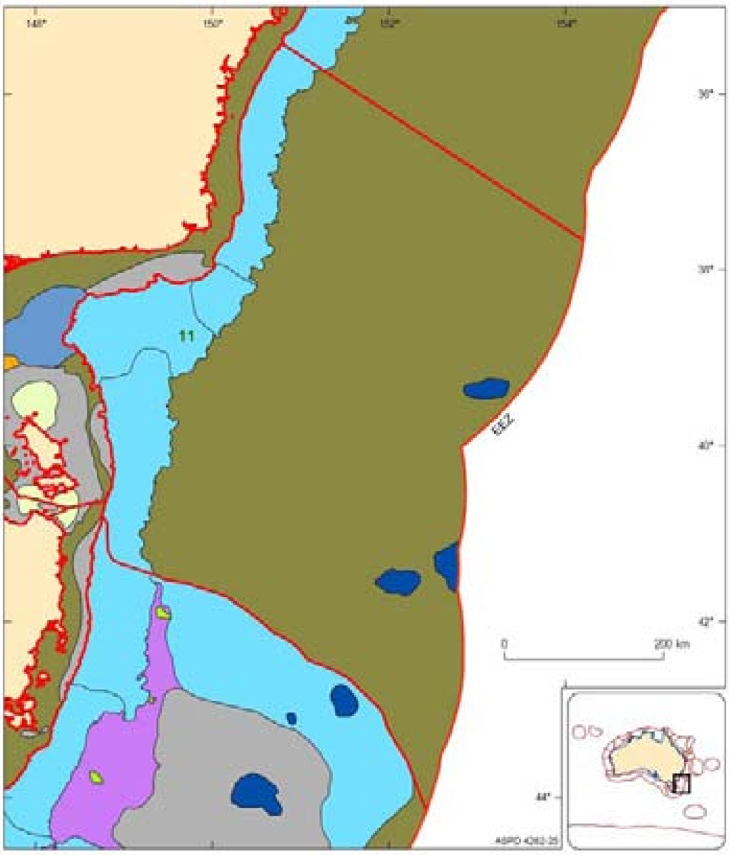

Figure C.11b. Map of Geomorphic Units in Provincial Bioregion 11 (PB11 – *Southeast Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB12 – Central Eastern Province

This bioregion is located on the eastern margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
268,850	-79	-5,590	-4,175	1,229

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 13		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
65,260	-	203,430	2,870	2,410	1,890

No. of Demersal Fish Species:	639 (17 string nodes)
Key Indicator Demersal Fish Species:	
Bembrops morelandi, *Chaunax* sp., *Halieutopsis* sp., *Lepidoperca magna*, *Malthopsis* sp., *Paraliparis eastmani*, *Paraulopus okamurai*, *Dupturus* sp. C, *Solocisquama* sp.	
No. of Endemics:	56
Strength:	3.4 (strongly defined)

Geomorphic Units (km^2) *N* = 5													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	203,430	3	64,170	-	-	-	-	-	-	-	-	1	2,280

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

- This bioregion is one of 11 NBMB bioregions to cover two Primary Bathymetric Units, and one of nine to occur on the slope and abyssal plain/deep ocean floor.
- This bioregion contains the 5th largest area of abyssal plain/deep ocean floor of all the NBMB bioregions.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- Biomes defined by the demersal fish depth structure are the 12th largest in terms of their total area and cover the 13th largest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is one of four NBMB bioregions to contain three classes of geomorphic units.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.
- This bioregion contains the 4th largest Class 1 unit for all the NBMB bioregions.

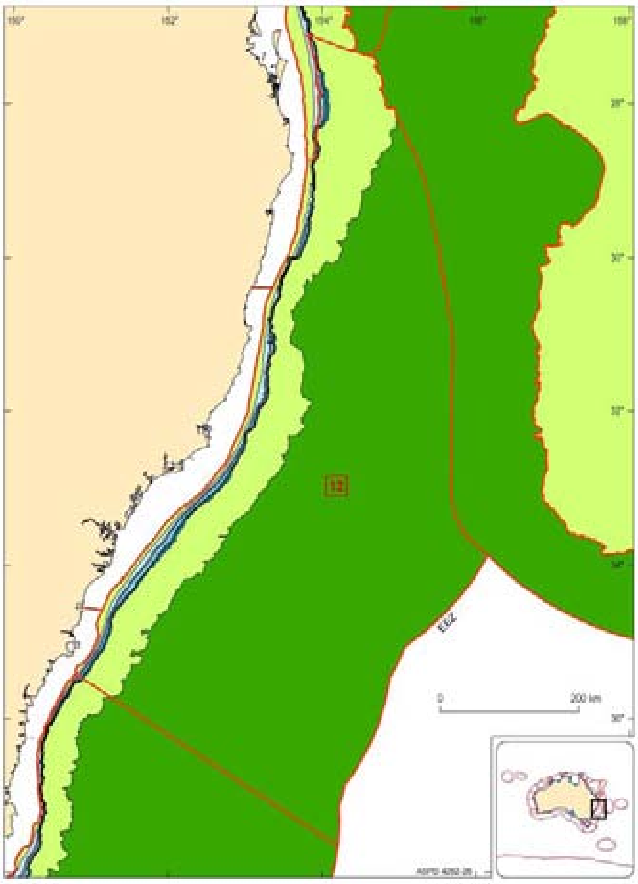

Figure C.12a. Map of Biomes in Provincial Bioregion 12 (PB12 – *Central Eastern Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

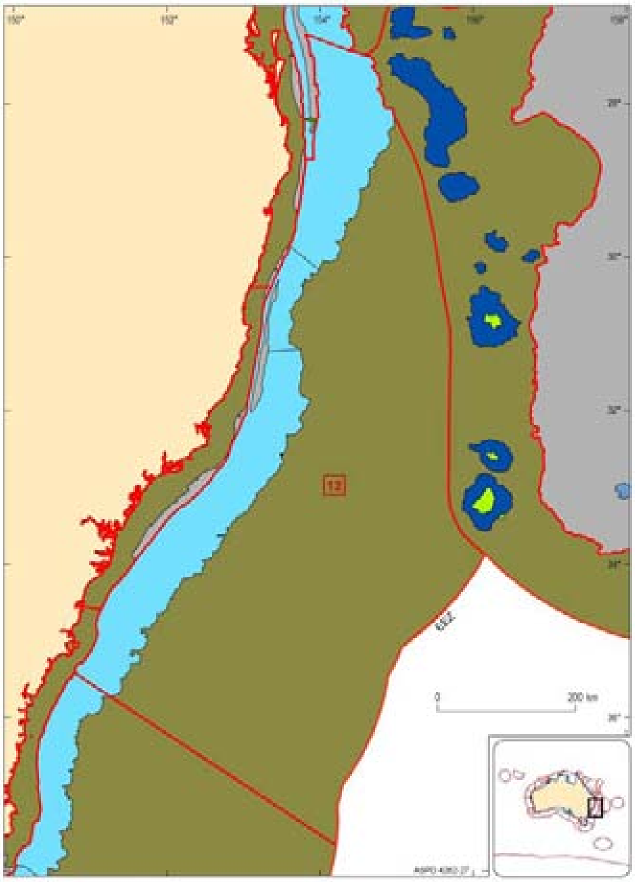

Figure C.12b. Map of Geomorphic Units in Provincial Bioregion 12 (PB12 – *Central Eastern Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB13 – Tasman Basin Province

This bioregion occurs in the Tasman Sea between the mainland and Lord Howe Island on the east margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
155,680	-71	-5,855	-4,420	782

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 0		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
-	-	154,780	-	-	-

No. of Demersal Fish Species:	N/A
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 15													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	136,840	-	-	-	-	-	-	10	18,530	-	-	-	-

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
4	1,050	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

- This is one of six NBMB bioregions to cover only one Primary Bathymetric Unit, and the only bioregion to occur only on the abyssal plain/deep ocean floor.
- This bioregion is one of nine NBMB bioregions to contain no Biomes.
- This bioregion does not correspond to any demersal fish province. Despite demersal fish data being relatively poor from this area, this bioregion specifically captures the assemblage of demersal fishes (and other biota) associated with extensive range of seamounts in the central Tasman Sea, which appears to be different from the coastal seas and Lord Howe Rise regions.
- Biomes defining the demersal fish depth structure as well as the rise do not occur in this province.
- This is one of four NBMB bioregions to contain three classes of geomorphic units.
- This bioregion contains the 2nd largest area of Class 5 units of all the NBMB bioregions.
- The seamounts are part of the Tasmantid Seamounts that form a near-continuous chain of high-relief steep-sided features extending right along the deep eastern margin of Australia (Fig. 2.1). Like their counterparts in the Southern Ocean, the well-developed and numerous seamounts in this bioregion are likely to have associated fauna, including many endemics. Because they are located in warm temperate waters, the fauna associated with the seamounts in this bioregion is likely to differ from the fauna associated with seamounts located in the warm tropical waters to the north (i.e., PB16).

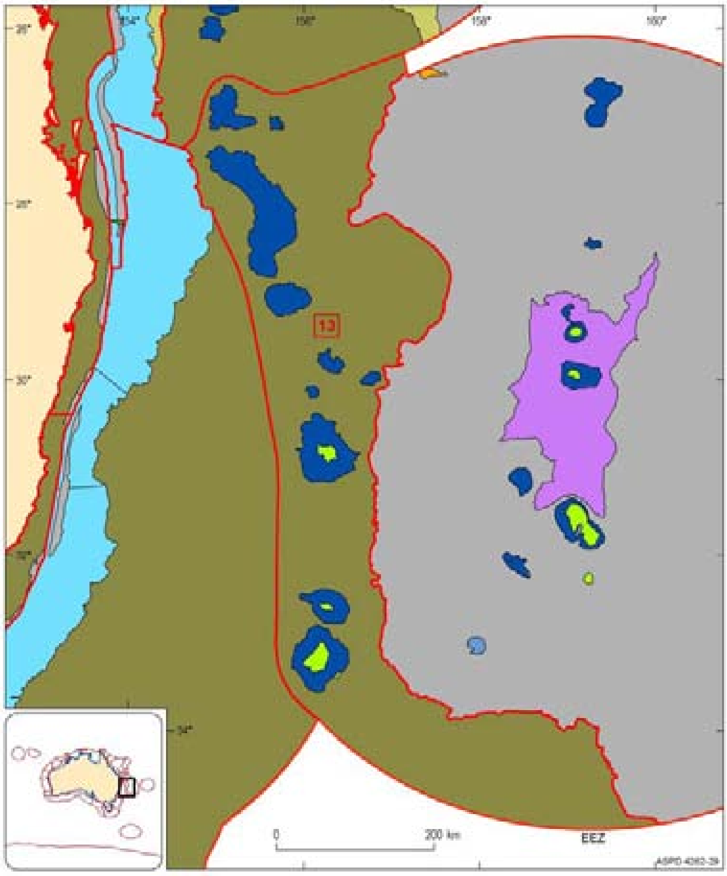

Figure C.13. Map of Geomorphic Units in Provincial Bioregion 13 (PB13 – *Tasman Basin Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB14 – Lord Howe Province

This bioregion surrounds Lord Howe Island in the Tasman Sea on the east margin of Australia.

Total Area	Water Depth (m)			
(km²)	Minimum	Maximum	Mean	Std Dev.
486,020	0	-5,025	-2,329	972

Primary Bathymetric Units (km²)			Biomes (km²) *N* = 0		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
484,540	-	-	-	-	-

No. of Demersal Fish Species:	N/A
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km²) *N* = 20													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	1	220	8	5,480	1	23,470	1	454,490

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
4	1,260	-	-	-	-	-	-	5	410	-	-	-	-

Notes:

- This bioregion is one of six NBMB bioregions to cover only one Primary Bathymetric Unit, and one of five to occur only on the slope.
- This bioregion contains the largest slope area of all the NBMB bioregions.
- This bioregion is one of nine NBMB bioregions not to contain any Biomes.
- This bioregion does not correspond to any demersal fish province but specifically captures endemic demersal fish species more closely associated with the Lord Howe Rise.
- This bioregion is the only NBMB bioregion to contain six classes of geomorphic units.
- This bioregion contains the largest Class 7 unit of all the NBMB bioregions.

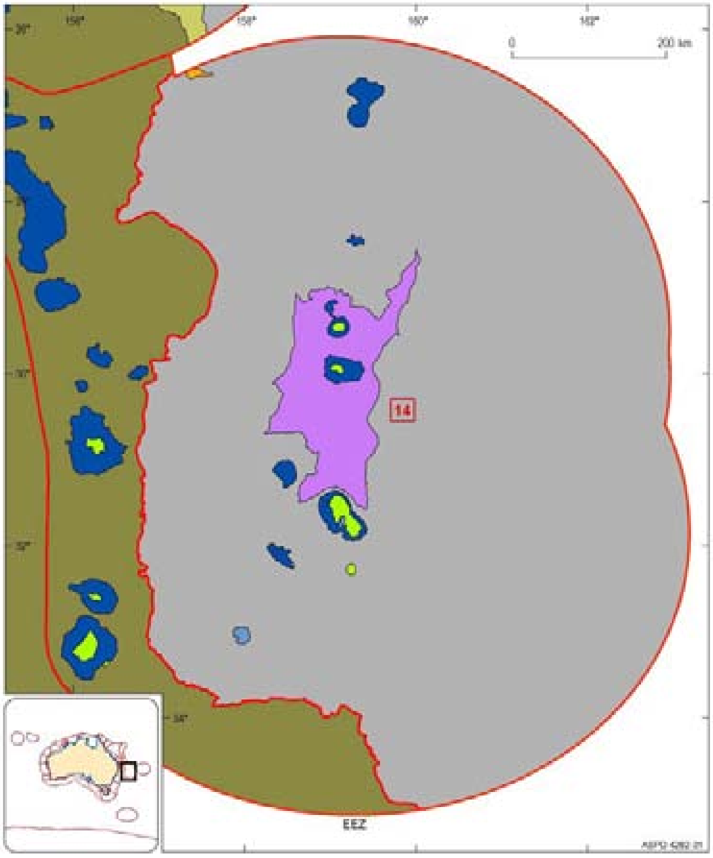

Figure C.14. Map of Geomorphic Units in Provincial Bioregion 14 (PB14 – *Lord Howe Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB15 – Central Eastern Transition

This bioregion is located on the east margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
74,020	-20	-4,867	-1,536	1,442

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 5		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
63,020	9,950	-	20,770	3,750	2,790

No. of Demersal Fish Species:	518 (14 string nodes)
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 72													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	4	48,210	1	10,050	-	-	-	-	-	-	6	14,840

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	1	60	-	-	-	-	-	-	-	-	-	-

Notes:

- This bioregion is one of 11 NBMB bioregions to cover two Primary Bathymetric Units, and one of two to occur only on the slope and rise.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- Biomes defined by the demersal fish depth structure are the 5th largest in terms of their total area and cover the largest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is the only NBMB bioregion to contain four classes of geomorphic units.
- This bioregion contains the 3rd largest area of Class 3 of all the NBMB bioregions. This class is the largest on the east margin.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.

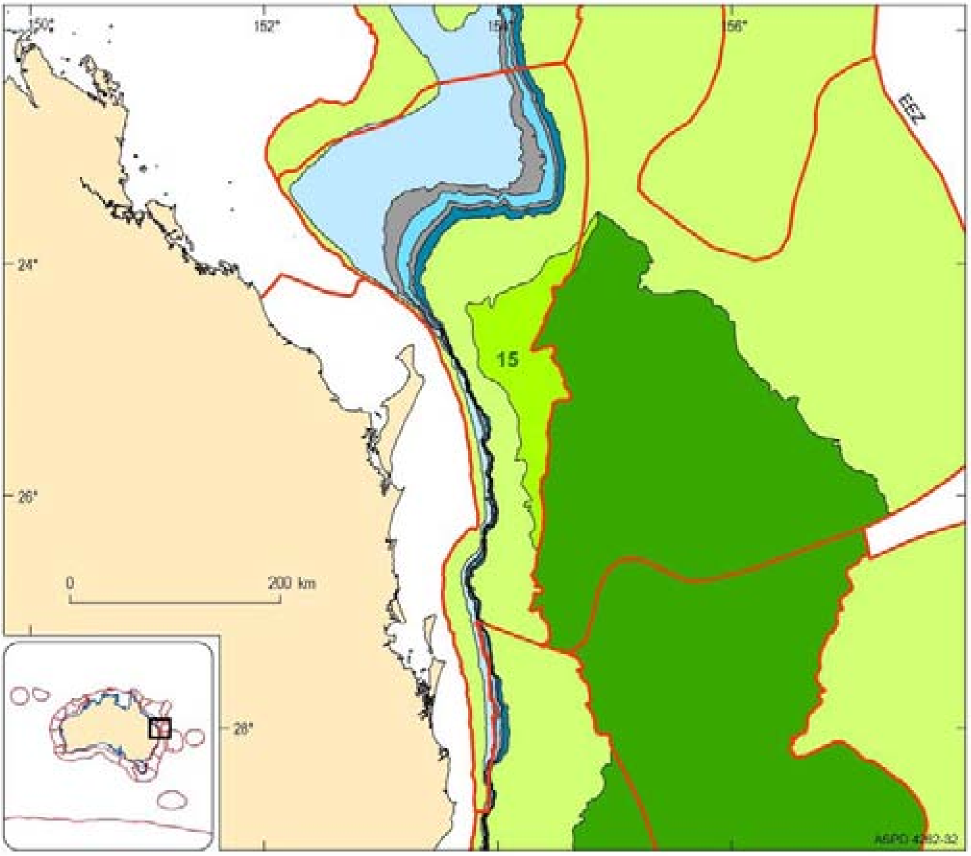

Figure C.15a. Map of Biomes in Provincial Bioregion 15 (PB15 – *Central Eastern Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

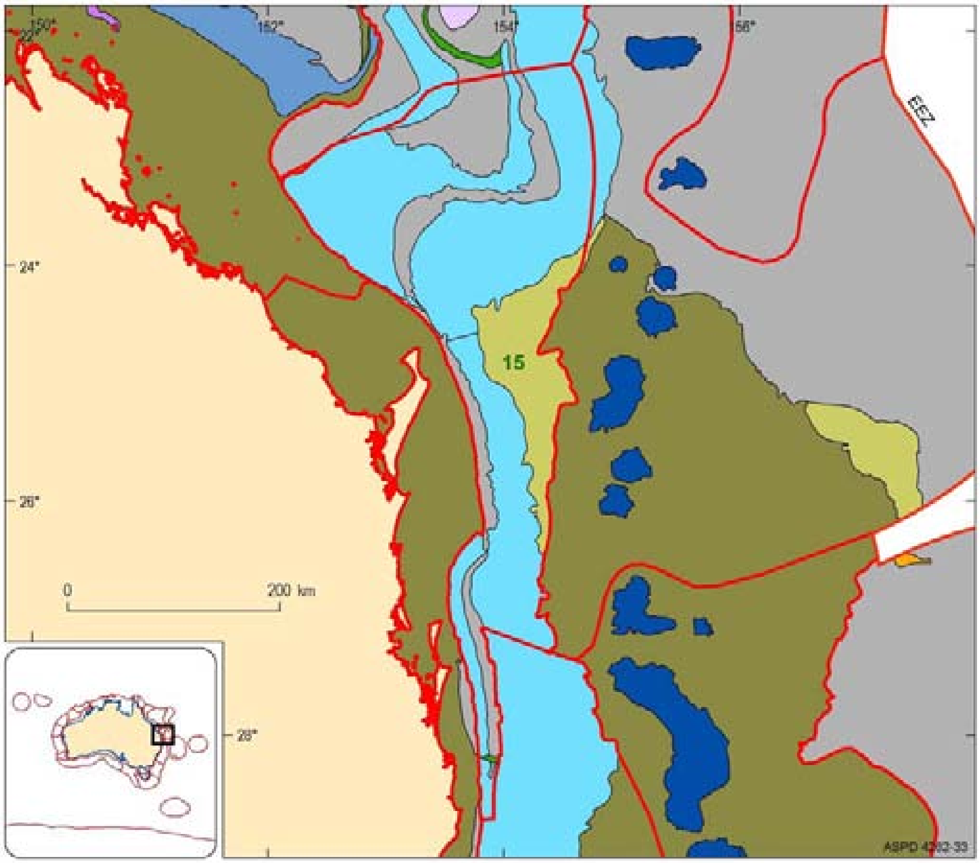

Figure C.15b. Map of Geomorphic Units in Provincial Bioregion 15 (PB15 – *Central Eastern Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB16 – Kenn Transition

This bioregion is located in the north Tasman Sea on the northeast margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
376,480	0	-5,106	-3,129	854

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 0		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
246,750	250	64,620	-	-	-

No. of Demersal Fish Species:	N/A
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 30													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	60,470	1	3,360	2	5,380	-	-	12	10,490	4	32,110	3	186,520

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	590	1	110	-	-	-	-	3	13,010	1	360	-	-

Notes:

- This bioregion is one of seven NBMB bioregions to cover all three Primary Bathymetric Units.
- This bioregion contains the smallest area of rise of all the NBMB bioregions.
- This bioregion is one of nine NBMB bioregions not to contain any Biomes.
- This deep-water bioregion specifically captures the mixing and heterogeneity between the demersal fish species that are endemic to both New Caledonia and Australia.
- This is bioregion defines a complex region that represents a transition zone between tropical and temperate fauna, as well as a transition zone between Australian and New Caledonian fauna. In the north, the fauna associated with the seamounts is likely to be dominated by tropical species (including coral reef species) that would be more similar to the eastern Australian margin than the Lord Howe Rise margin. The northern seamounts are also likely to contain endemic fauna that is different to fauna associated with seamounts in southern and temperate regions.
- This bioregion is one of three NBMB bioregions to contain 10 classes of geomorphic units.
- This bioregion contains the 4th largest Class 7 unit of all the NBMB bioregions.

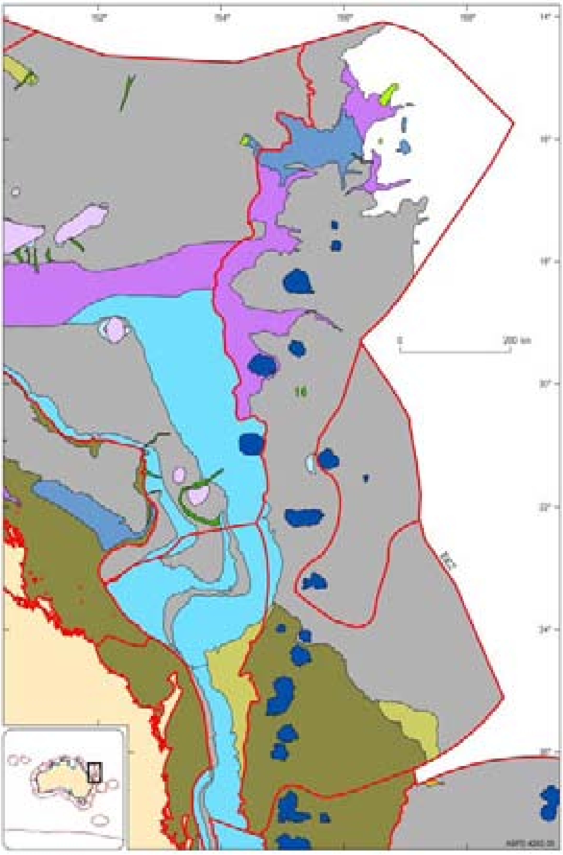

Figure C.16. Map of Geomorphic Units in NMB Bioregion 16 (PB16 – *Kenn Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB17 – Kenn Province

This bioregion is located on the Kenn Plateau (Tasman Sea) on the northeast margin of Australia.

Total Area	Water Depth (m)			
(km²)	Minimum	Maximum	Mean	Std Dev.
57,420	-20	-4,867	-1,536	1,442

Primary Bathymetric Units (km²)			Biomes (km²) *N* = 0		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
57,420	-	-	-	-	-

No. of Demersal Fish Species:	N/A
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km²) *N* = 4													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	3	1,750	-	-	1	55,670
Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

- This bioregion is one of six NBMB bioregions to cover only one Primary Bathymetric Unit, and one of five to occur only on the slope.
- This bioregion is one of nine NBMB bioregions not to contain any Biomes.
- This deep-water bioregion centered on the shallower regions of the Kenn Plateau does not correspond to any demersal fish province.
- It specifically captures endemic fish species that are more closely associated with New Caledonia fauna. The regions of deep ocean floor in the Tasman Sea and Cato Basin located in PB16 that separate the continental margin from the Kenn Plateau probably act as significant barriers to dispersal, with the 2,000 m bathymetric contour likely to be a major faunal boundary.
- This bioregion is the only NBMB bioregion to contain only two geomorphic unit classes, and it also contains the least number of geomorphic unit classes of all the NBMB bioregions.

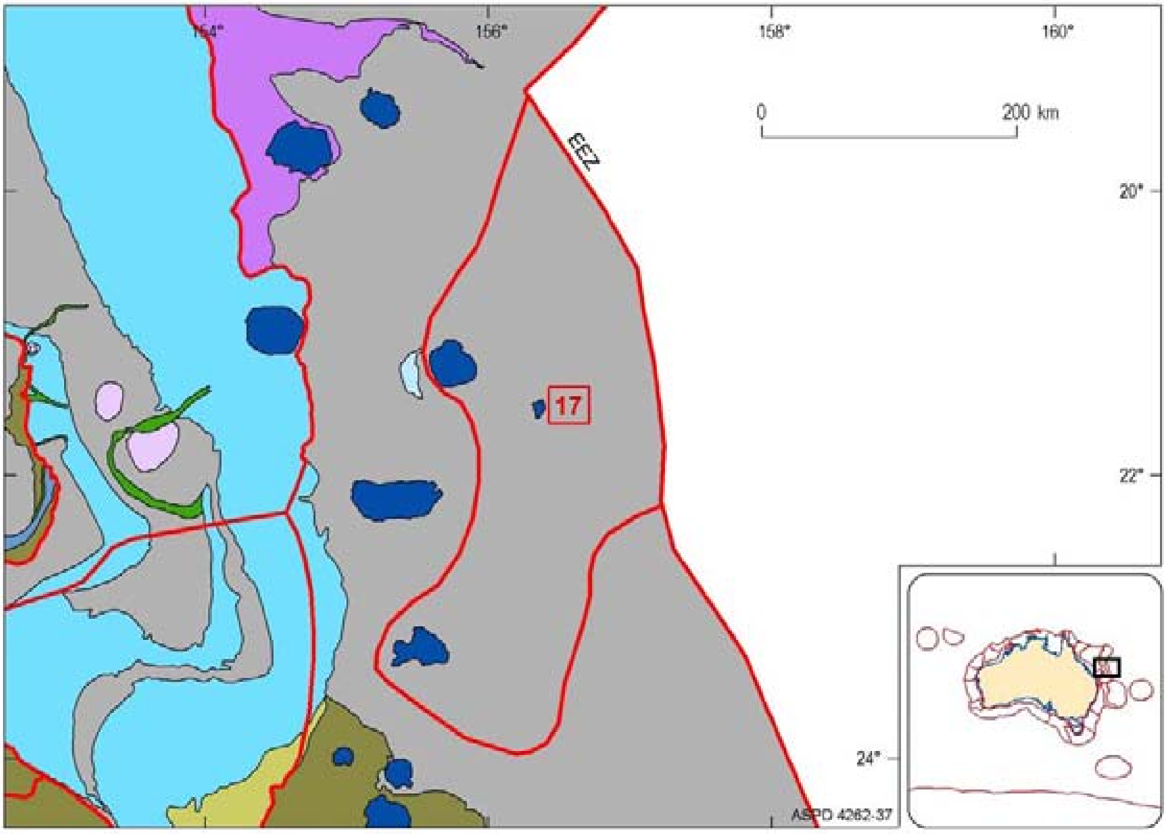

Figure C.17. Map of Geomorphic Units in Provincial Bioregion17 (PB17 – *Kenn Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB18 – Northeast Province

This bioregion is located in the southern Coral Sea on the northeast margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
454,990	0	-4,725	-1,640	1,341

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 40		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
384,710	2,440	67,840	60,940	21,510	68,420

No. of Demersal Fish Species:	441 (19 string nodes)
Key Indicator Demersal Fish Species:	
Arnoglossus nigrifrons, *Aulopus* sp., *Bembrops sp., Caelorinchus shcherbachevi*, *Halieutaea* spp, *Mastigopterus* sp., *Pterygotrigla robersti.*	
No. of Endemics:	70
Strength:	4.7 (strongly defined)

Geomorphic Units (km^2) *N* = 87													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	6	2,190	3	2,195	-	-	1	1,310	5	60,540	6	300,030

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	250	12	2,490	13	210	-	-	1	480	14	1,550	24	18,350

Notes:

- This bioregion is one of seven NBMB bioregions to cover all three Primary Bathymetric Units.
- This bioregion contains the 3rd largest area of slope of all the NBMB bioregions.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- This bioregion contains the highest ratio of endemic species to total fish species for all of the NBMB bioregions.
- Within this bioregion the assemblage of sponges associated with the coral reefs on the southern Queensland Plateau are distinct from the sponge assemblages associated with the coral reefs of the northern Queensland Plateau and GBR (Hooper & Ekins, 2004), which are contained in PB20 and PB40, respectively.
- Biomes defined by the demersal fish depth structure are the largest in terms of their total area and cover the second largest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is one of two NBMB bioregions to contain 11 classes of geomorphic units, along with PB3.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.
- This bioregions contains the largest units for Classes 6 and 14, and the 3rd largest unit for Class 7 for all the NBMB bioregions.

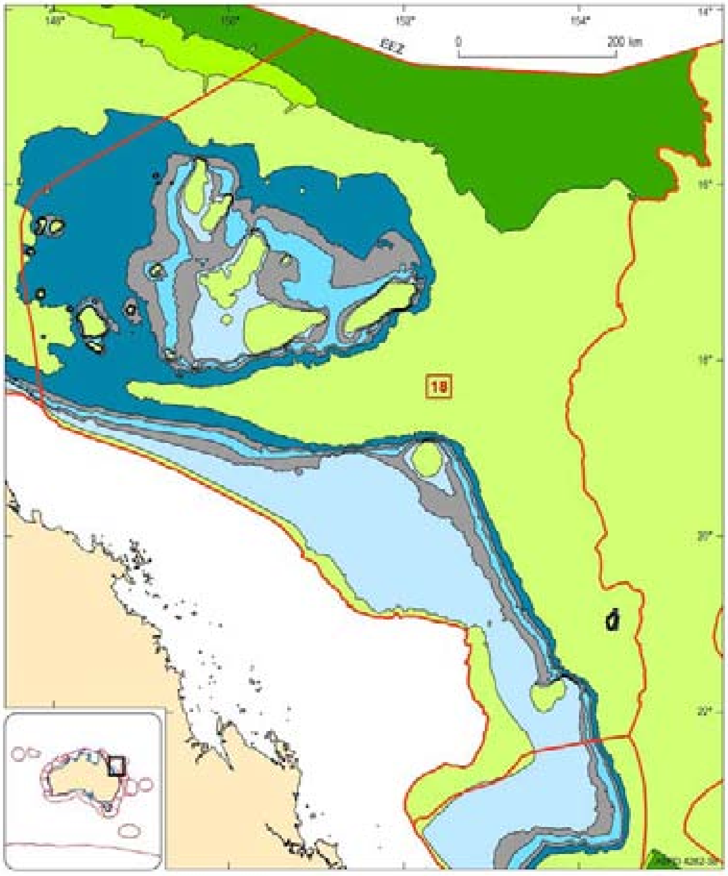

Figure C.18a. Map of Biomes in Provincial Bioregion18 (PB18 – *Northeast Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

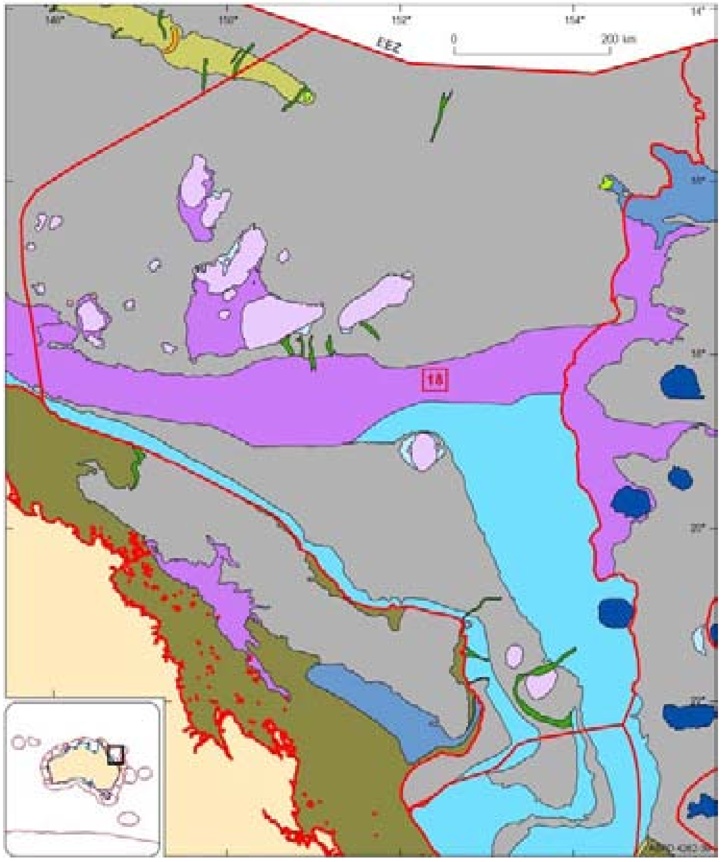

Figure C.18b. Map of Geomorphic Units in Provincial Bioregion18 (PB18 – *Northeast Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB19 – Northeast Transition

This bioregion is located in the central Coral Sea on the northeast margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
150,150	0	-4,719	-2,123	1,172

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 21		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
117,490	12,980	19,680	2,430	1,070	11,340

No. of Demersal Fish Species:	421 (8 string nodes)
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 27													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	2	6,600	3	11,970	2	440	-	-	1	27,030	3	102,200

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	10	770	-	-	-	-	-	-	2	790	4	480

Notes:

- This is one of seven NBMB bioregions to cover all three Primary Bathymetric Units.
- This bioregion contains the 2nd largest rise areas of all the NBMB bioregions.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- This bioregion specifically captures the effects of the westward flowing Coral Sea current that impinges on the northeast margin in the vicinity of Cairns.
- Studies have shown that the fauna on Osprey Reef located on the Queensland Plateau is genetically more closely related to coral reefs of the Great Barrier Reef than the coral reefs located on the southern Queensland Plateau. Other studies have shown that there is also a faunal gyre to the north of Osprey Reef. This makes Osprey Reef a strong biological boundary, although it does not represent a geomorphic boundary.
- Biomes defined by the demersal fish depth structure are the 8th largest in terms of their total area and cover the 8th largest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is one of five NBMB bioregions to contain eight classes of geomorphic units.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.
- This bioregion contains the 2nd largest Class 3 unit of all the NBMB bioregions.

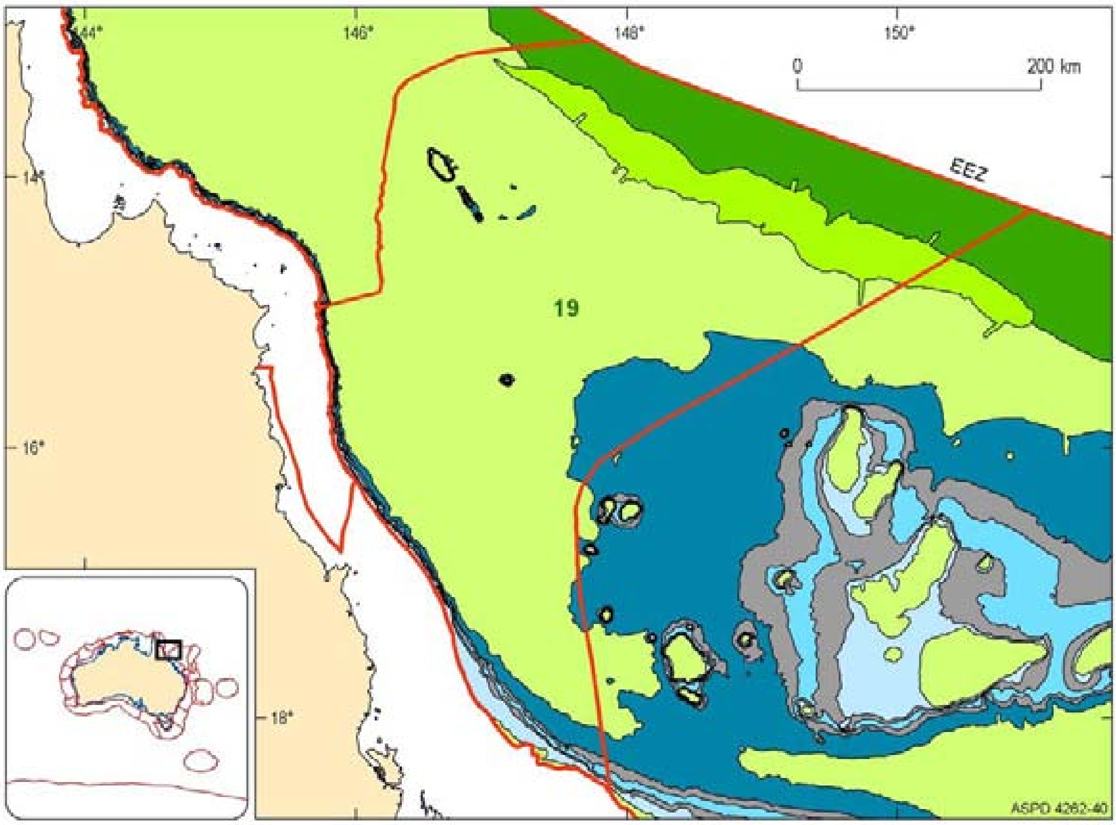

Figure C.19a. Map of Biomes in Provincial Bioregion19 (PB19 – *Northeast Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

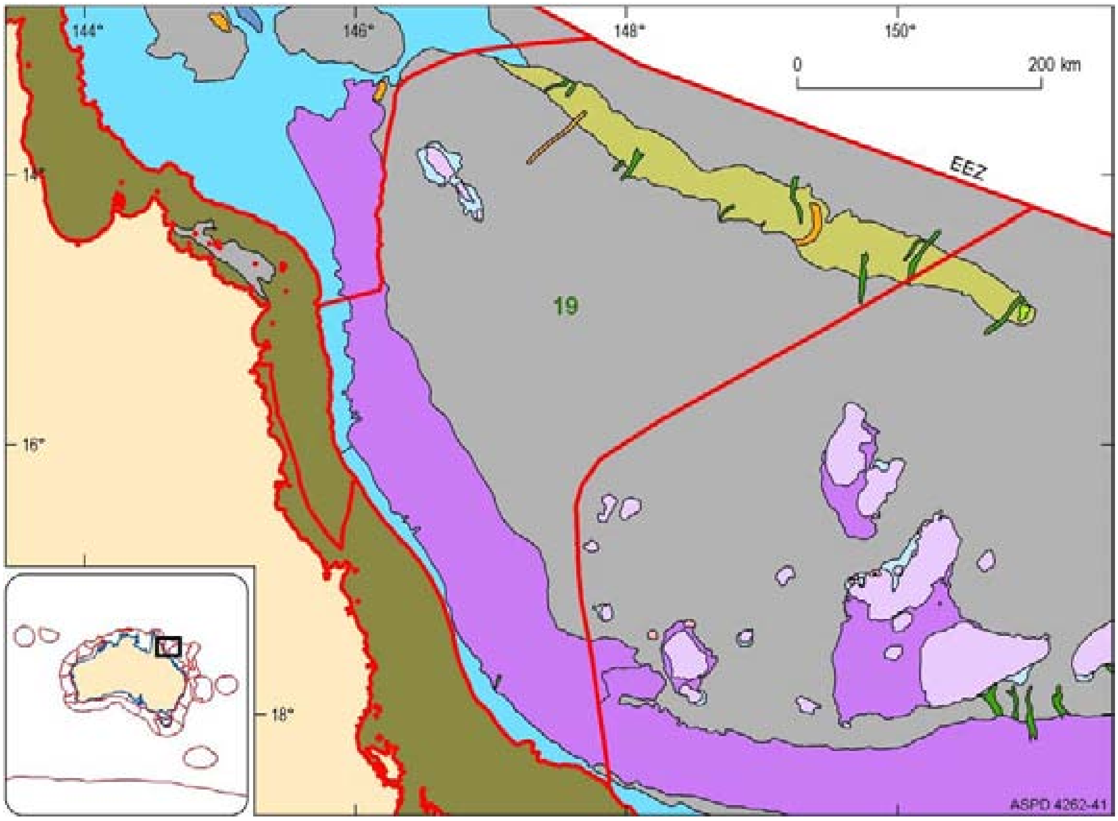

Figure C.19b. Map of Geomorphic Units in Provincial Bioregion19 (PB19 – *Northeast Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB20 – Cape Province

This bioregion is located in the western Coral Sea on the northeast margin of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
111,220	0	-4,186	-2,325	910

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 25		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
109,120	-	2,090	2,100	3,610	3,400

No. of Demersal Fish Species:	302 (10 string nodes)
Key Indicator Demersal Fish Species:	
Aulastomatomorpha phospherops, *Bassozetus compressus*, *Etmopterus dianthus*, *Halicmetus* sp., *Monomitopus garmani*, *Notoraja laxipell*	
No. of Endemics:	24
Strength:	0.9 (weakly defined)

Geomorphic Units (km^2) *N* = 18													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	1	83,330	-	-	2	240	-	-	3	8,620	5	12,440

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	2	280	-	-	-	-	1	5,210	-	-	4	1,030

Notes:

- This bioregion is one of 11 NBMB bioregions to cover two Primary Bathymetric Units and one of nine to occur on the slope and abyssal plain/deep ocean floor.
- This bioregion is one of 14 NBMB bioregions to contain all of the biome types.
- Biomes defined by the demersal fish depth structure are the 10th largest in terms of their total area and cover the 9th largest area as a percentage of the bioregion area for all the NBMB bioregions.
- This bioregion is one of four NBMB bioregions to contain seven classes of geomorphic units.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.

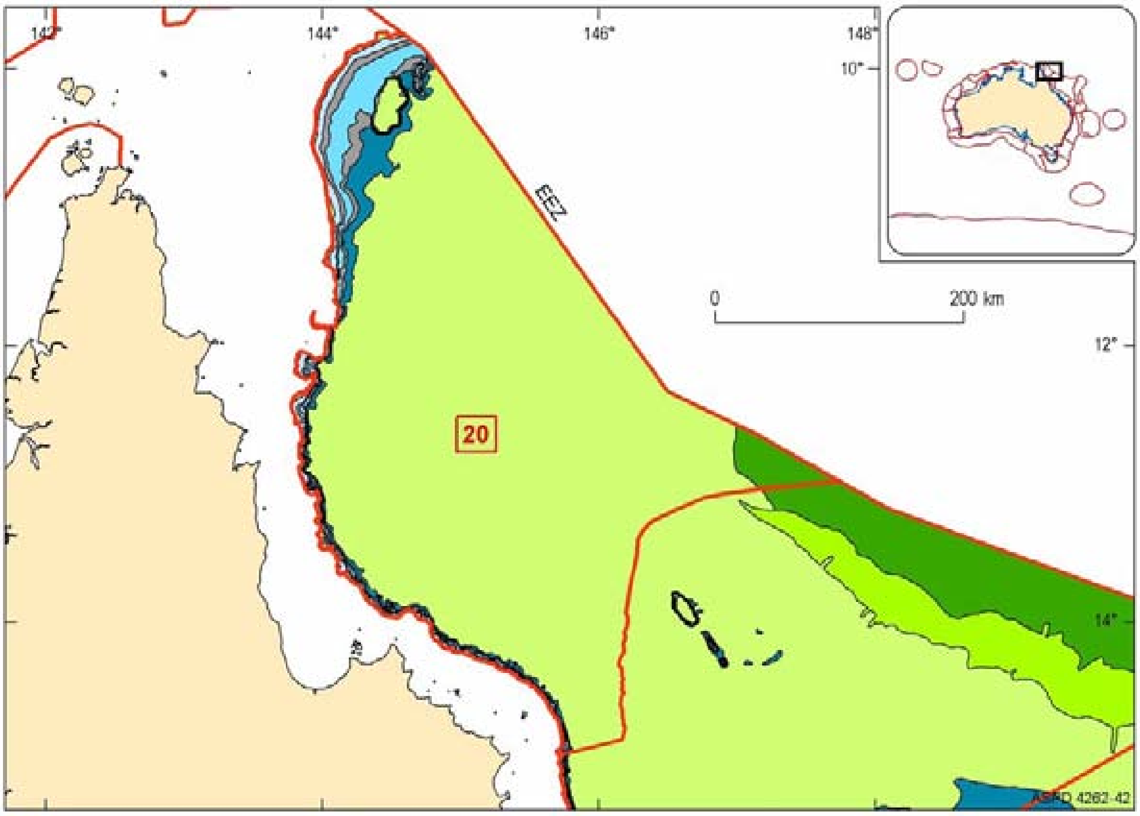

Figure C.20a. Map of Biomes in Provincial Bioregion20 (PB20 – *Cape Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

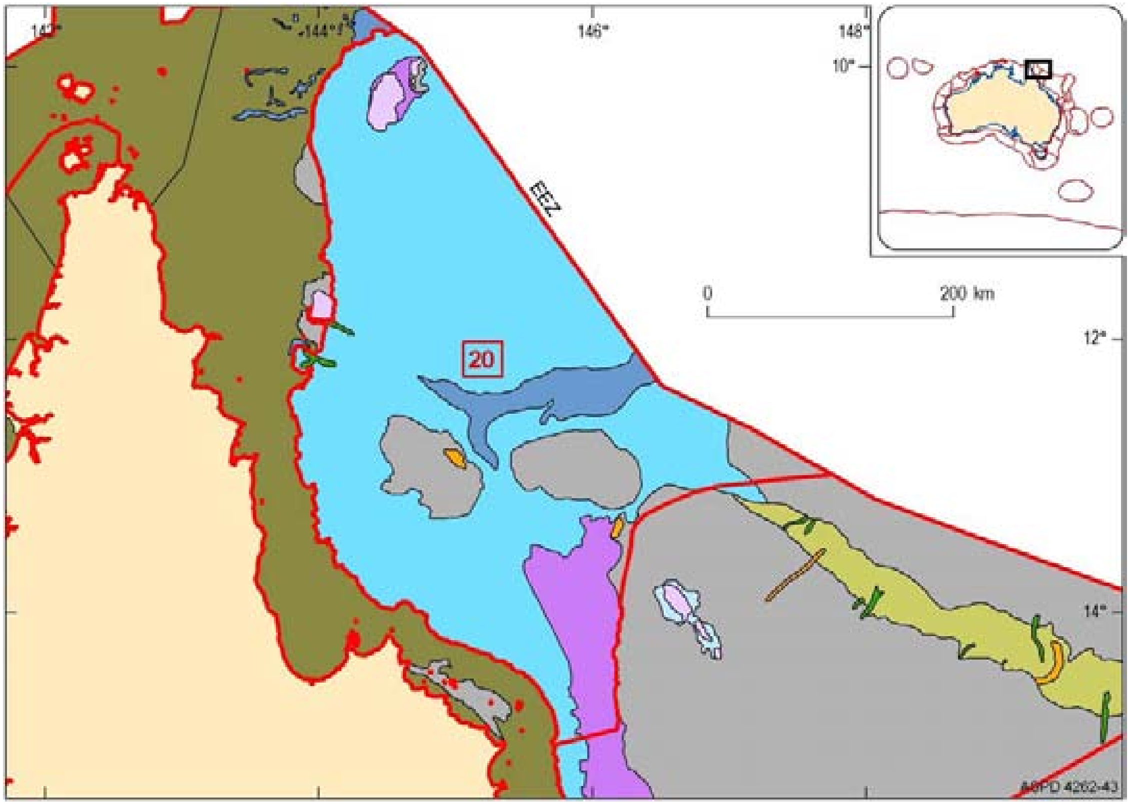

Figure C.20b. Map of Geomorphic Units in Provincial Bioregion20 (PB20 – *Cape Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB21 – Norfolk Island Province

This bioregion is surrounds Norfolk Island in the central Tasman Sea.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
431,160	-19	-4,827	-2,759	826

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 0		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
430,480	-	-	-	-	-

No. of Demersal Fish Species:	N/A
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 46													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	680	3	31,330	-	-	1	280	15	4,370	7	39,830	7	346,950

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
5	6,800	-	-	5	190	1	720	1	10	-	-	-	-

Notes:

- This bioregion is one of six NBMB bioregions to cover one Primary Bathymetric Unit and one of five to occur only on the slope.
- This bioregion contains the 2nd largest slope area of all the NBMB bioregions.
- This bioregion is one of nine NBMB bioregions not to contain any Biomes.
- This bioregion does not correspond to any demersal fish province, but specifically captures endemic fish species and other fauna more closely associated with the Norfolk Island region.
- The fauna associated with this bioregion are much different to the fauna associated with the mainland.
- This bioregion is one of three NBMB bioregions to contain 10 classes of geomorphic units.
- Class 2 includes units defined by the spacing of submarine canyons on the slope.
- This bioregion contains the 2nd largest Class 7 unit of all the NBMB bioregions.

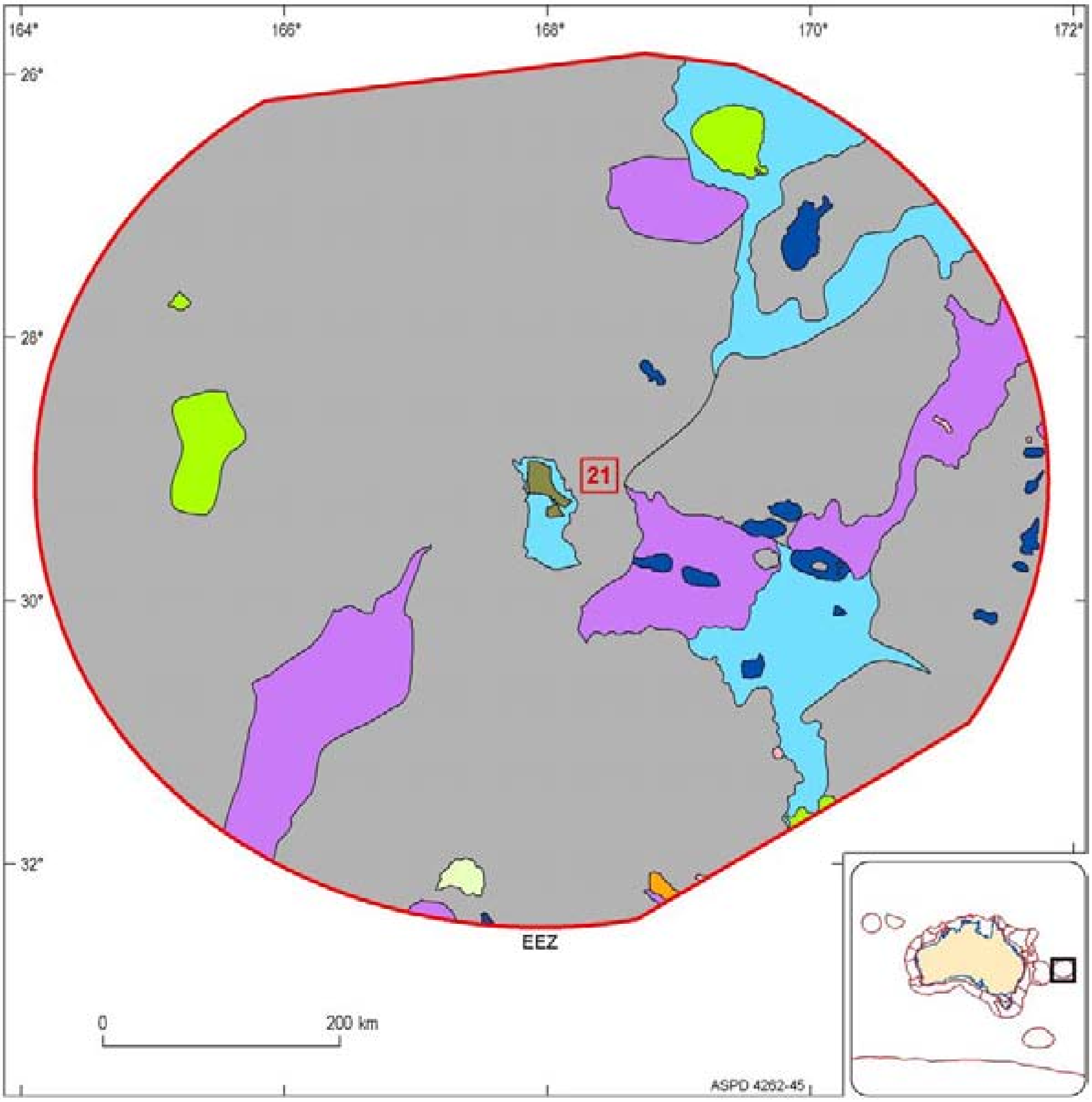

Figure C.21. Map of Geomorphic Units in Provincial Bioregion21 (PB21 – *Norfolk Island Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB22 – Cocos (Keeling) Island Province

This bioregion surrounds Cocos (Keeling) Island in the eastern Indian Ocean, northwest of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
467,260	0	-6,468	-4,988	686

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 0		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
35,140	-	432,030	-	-	-

No. of Demersal Fish Species:	N/A
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 99													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
4	291,380	1	24,140	-	-	1	18,310	22	14,900	3	16,100	28	94,420

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
40	8,010	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

- This bioregion is one of 11 NBMB bioregions to cover two Primary Bathymetric Units and one of nine to occur on the slope and abyssal plain/deep ocean floor.
- This bioregion contains the largest abyssal plain/deep ocean floor area of all the NBMB bioregions.
- This bioregion is one of nine NBMB bioregions not to contain any Biomes.
- This bioregion does not correspond to any demersal fish province, but specifically captures endemic fish species and other fauna associated with the Cocos (Keeling) Islands.
- This bioregion is the deepest NBMB bioregion on average due to the relatively large areas of abyssal plain/deep ocean floor.
- This bioregion is one of four NBMB bioregions to contain seven classes of geomorphic units.
- Due to the similar geomorphology and location adjacent to Indonesia in the tropical Indian Ocean, the fauna contained in this bioregion is probably similar or related to the fauna associated with the Christmas Island bioregion (PB23).
- This bioregion contains the 3rd largest Class 1 and Class 4 units of all the NBMB bioregions.

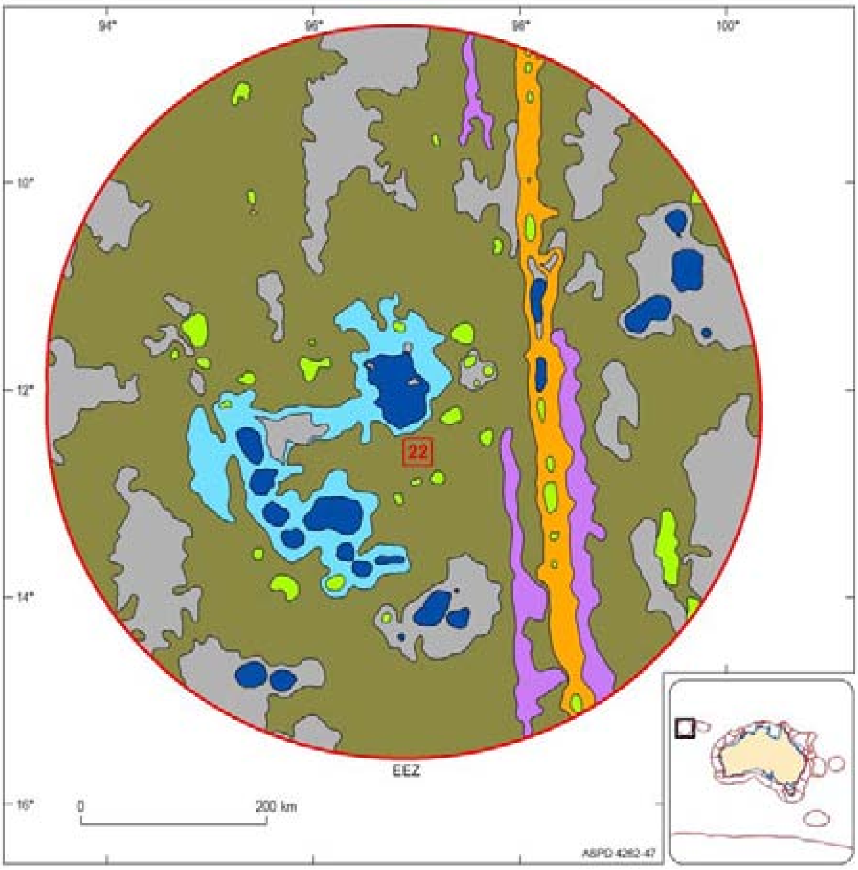

Figure C.22. Map of Geomorphic Units in Provincial Bioregion22 (PB22 – *Cocos (Keeling) Island Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB23 – Christmas Island Province

This bioregion surrounds Christmas Island in the eastern Indian Ocean, northwest of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
277,180	0	-6,545	-5,020	792

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 0		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
22,950	-	254,170	-	-	-

No. of Demersal Fish Species:	N/A
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 115													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
10	165,750	2	12,290	-	-	1	180	57	26,430	9	1,930	18	61,350

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
12	2,570	1	270	1	30	-	-	4	6,380	-	-	-	-

Notes:

- This bioregion is one of 11 NBMB bioregions to cover two Primary Bathymetric Units and one of nine to occur on the slope and abyssal plain/deep ocean floor.
- This bioregion contains the 4th largest abyssal plain/deep ocean floor area and smallest area of slope of all the NBMB bioregions.
- This bioregion is one of nine NBMB bioregions not to contain any Biomes.
- This bioregion does not correspond to any demersal fish province, but specifically captures endemic fish species and other fauna associated with Christmas Island.
- This bioregion is one of three NBMB bioregions to contain 10 classes of geomorphic units.
- Due to the similar geomorphology and location adjacent to Indonesia in the tropical Indian Ocean, the fauna contained in this bioregion is probably similar or related to the fauna associated with the Cocos (Keeling) Island bioregion (PB22).
- This bioregion contains the 7th largest Class 1 unit of all the NBMB bioregions.

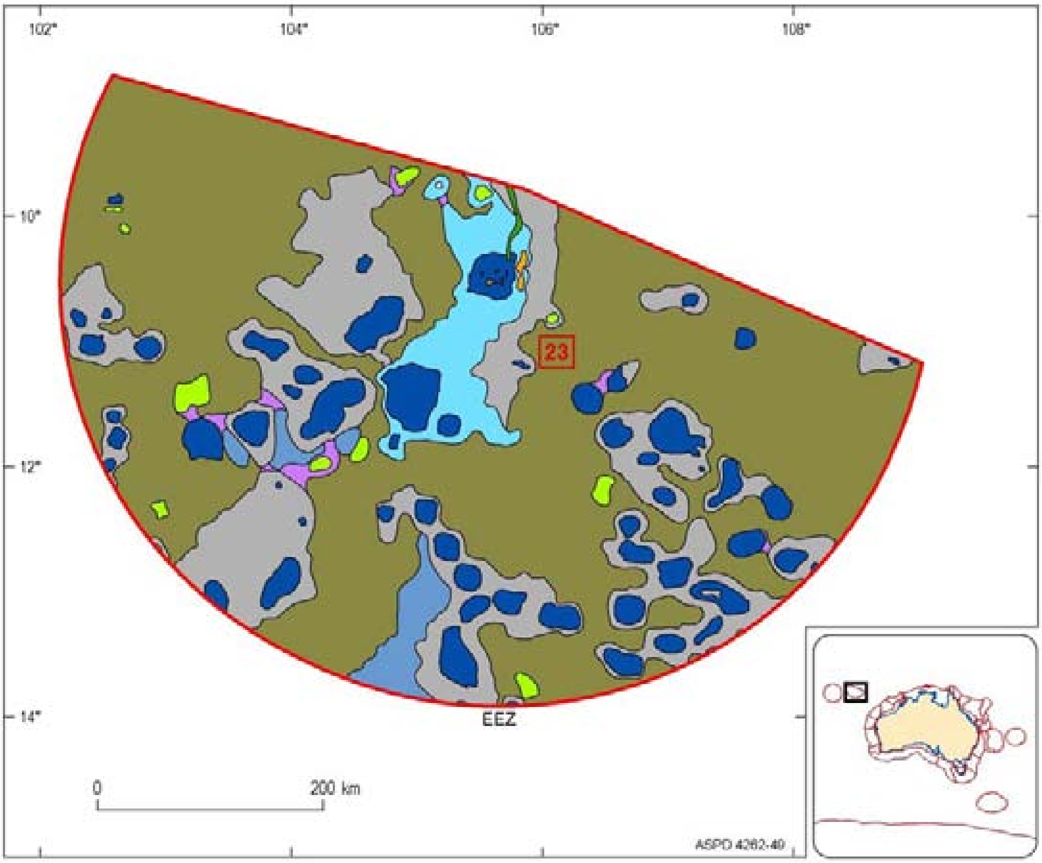

Figure C.23. Map of Geomorphic Units in Provincial Bioregion23 (PB23 – *Christmas Island Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB24 – Macquarie Island Province

This bioregion surrounds Macquarie Island in the Southern Ocean, southeast of Australia.

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
477,430	0	-6,737	-3,838	998

Primary Bathymetric Units (km^2)			Biomes (km^2) *N* = 0		
Slope	Rise	AP / DOF	Upper Slope	Mid-upper Slope	Mid Slope
64,590	-	411,330	-	-	-

No. of Demersal Fish Species:	N/A
Key Indicator Demersal Fish Species:	N/A
No. of Endemics:	N/A
Strength:	N/A

Geomorphic Units (km^2) *N* = 84													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
8	375,170	7	19,650	-	-	16	36,690	1	80	4	24,890	-	-

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
29	10,210	10	1,420	-	-	-	-	9	9,320	-	-	-	-

Notes:

- This bioregion is one of 11 NBMB bioregions to cover two Primary Bathymetric Units and one of nine to occur on the slope and abyssal plain/deep ocean floor.
- This bioregion contains the 3rd largest abyssal plain/deep ocean floor area of all the NBMB bioregions.
- This bioregion is one of nine NBMB bioregions not to contain any Biomes.
- This bioregion does not correspond to any demersal fish province, but specifically captures endemic fish species and other fauna associated with Macquarie Island.
- Analysis of fish data for the SE bioregionalisation (e.g., Butler *et al.*, 2001) indicated that the Macquarie Island margin should be considered a separate province from the continental margin.
- This bioregion contains the deepest seabed environments of the EEZ due to the presence of the well-developed trench system.
- This bioregion is one of five NBMB bioregions to contain eight classes of geomorphic units.
- This bioregion contains the largest Class 1 unit of all the NBMB bioregions.

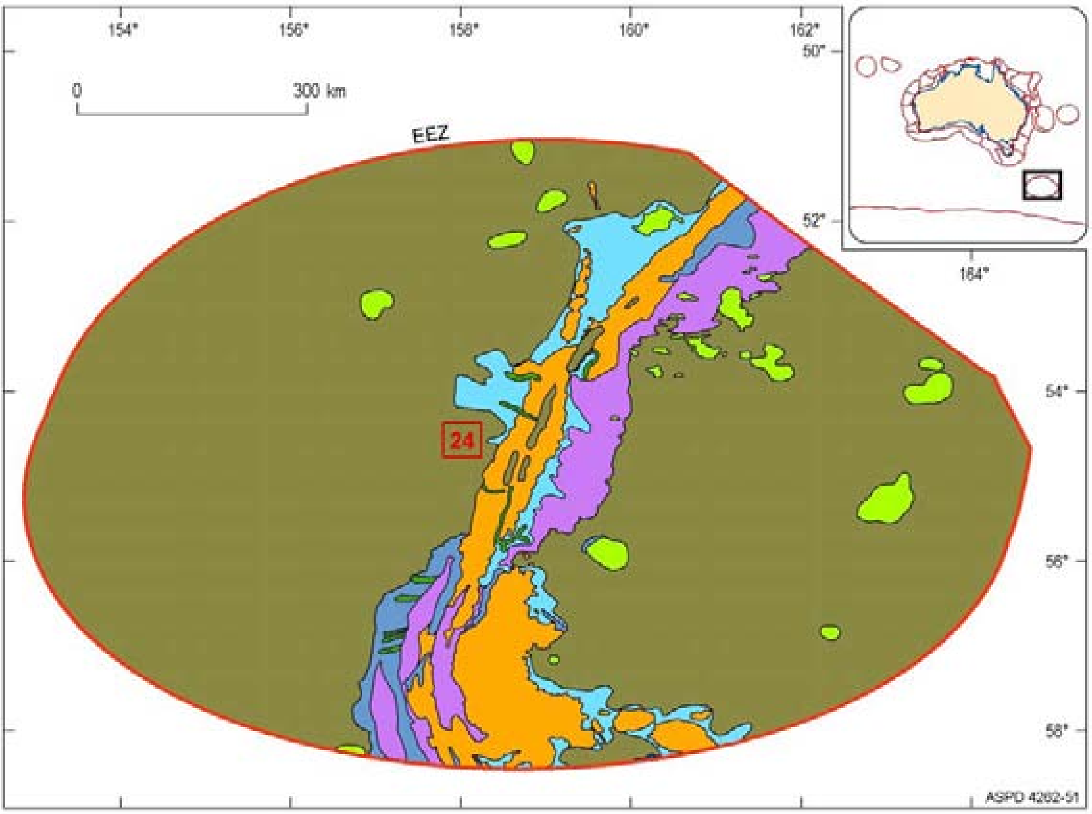

Figure C.24. Map of Geomorphic Units in Provincial Bioregion24 (PB24 – *Macquarie Island Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB25 – Northern IMCRA Province

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
556,350	0	-273	-44	27

Geomorphic Units (km^2) *N* = 92													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
9	303,410	-	-	-	-	6	11,930	-	-	1	500	13	222,990
Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	3	3,230	10	130	25	10,310	25	3,850	-	-	-	-

Notes:

- This bioregion is the largest of all the IMCRA shelf bioregions.
- Class 1 includes units defined by the distribution and abundance of pinnacles, banks, and sand banks.
- This bioregion contains the largest area of Class 1 units for all of the IMCRA shelf bioregions.
- This bioregion contains the largest area of Class 7 units of all IMCRA shelf bioregions, dominated by the low-gradient basin located in the Gulf of Carpentaria.
- This bioregion is the only IMCRA shelf bioregion to contain eight classes of geomorphic units.

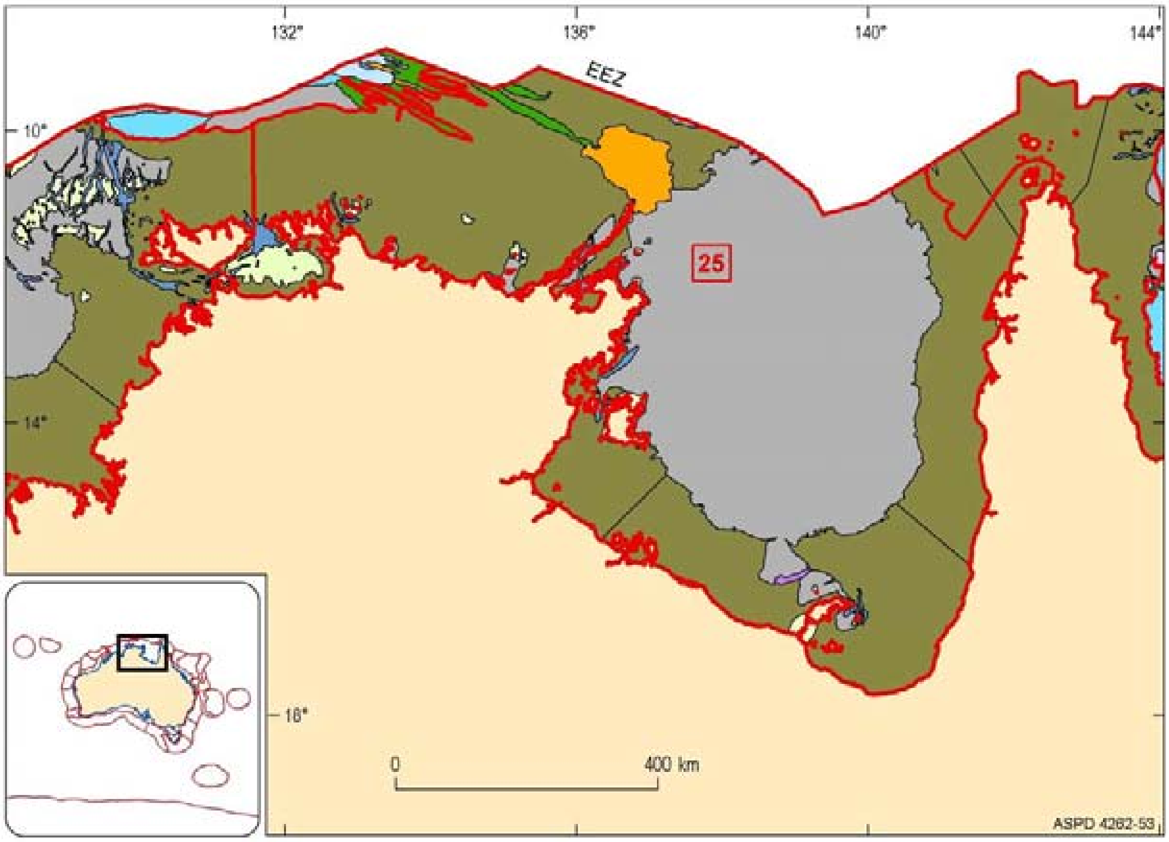

Figure C.25. Map of Geomorphic Units in Provincial Bioregion 25 (PB25 – *Northern IMCRA Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB26 – Northwest IMCRA Transition

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
305,550	0	-526	-70	41

Geomorphic Units (km^2) *N* = 121													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
16	125,290	-	-	-	-	1	3,730	-	-	-	-	15	126,770
Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	5	40	79	33,370	78	16,160	-	-	5	190

Notes:

- This bioregion is the 2nd largest of all the IMCRA shelf bioregions.
- Class 1 includes units defined by the distribution and abundance of pinnacles, banks, and sand banks.
- This bioregion contains the 3rd largest area of Class 1 units for all of the IMCRA shelf bioregions.
- This bioregion contains the 2nd largest areas of Class 7 units of all IMCRA shelf bioregions, dominated by broad shelf terraces, and the shallow basin located in the Joseph Bonaparte Gulf.
- This bioregion contains the largest area of Class 11 units of all IMCRA shelf bioregions, dominated by the extensive banks that make up the Sahul Banks and Van Diemen Rise.
- This bioregion also contains the 2nd largest area of Class 12 units of all IMCRA shelf bioregions.
- This bioregion is the only IMCRA shelf bioregions to contain seven classes of geomorphic units.

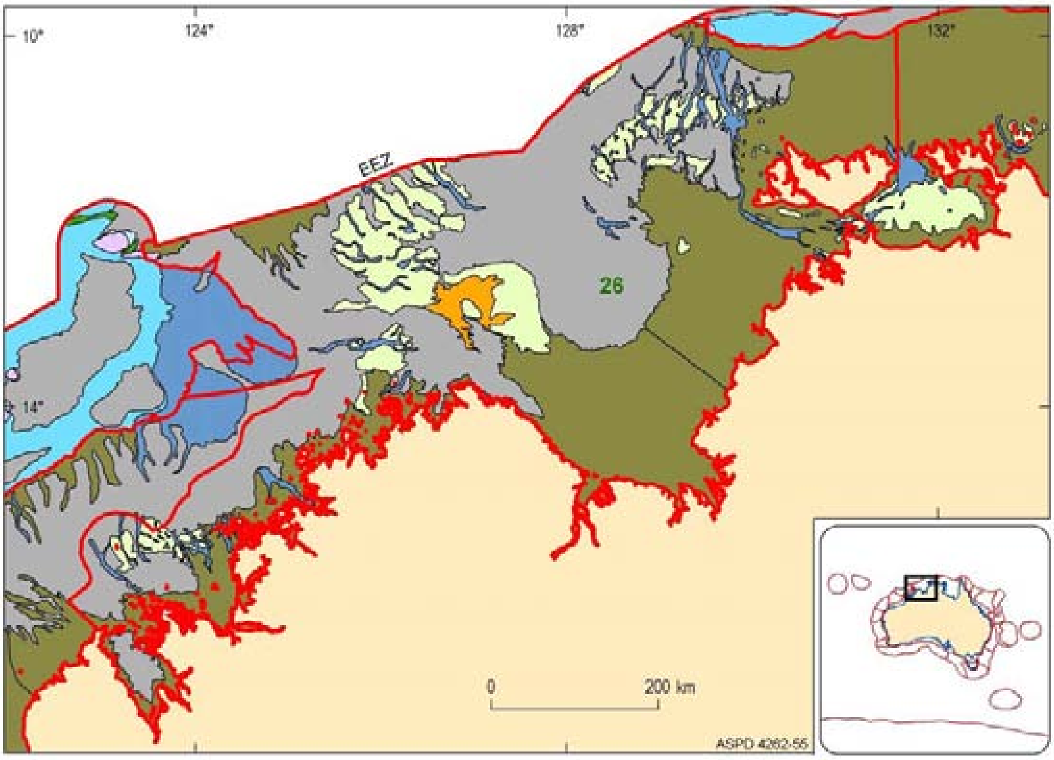

Figure C.26. Map of Geomorphic Units in Provincial Bioregion 26 (PB26 – *Northwest IMCRA Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB27 – Northwest IMCRA Province

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
193,480	0	-140	-49	32

Geomorphic Units (km^2) *N* = 23													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
5	130,030	-	-	-	-	-	-	-	-	-	-	7	43,260

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	3	680	8	19,510	-	-	-	-

Notes:

- This bioregion is the 3rd largest of all the IMCRA shelf bioregions.
- Class 1 includes units defined by the distribution and abundance of pinnacles, banks, and sand banks.
- This bioregion contains the 2nd largest area of Class 1 units of all the IMCRA shelf bioregions.
- This bioregion is one of four IMCRA shelf bioregions to contain five classes of geomorphic units.

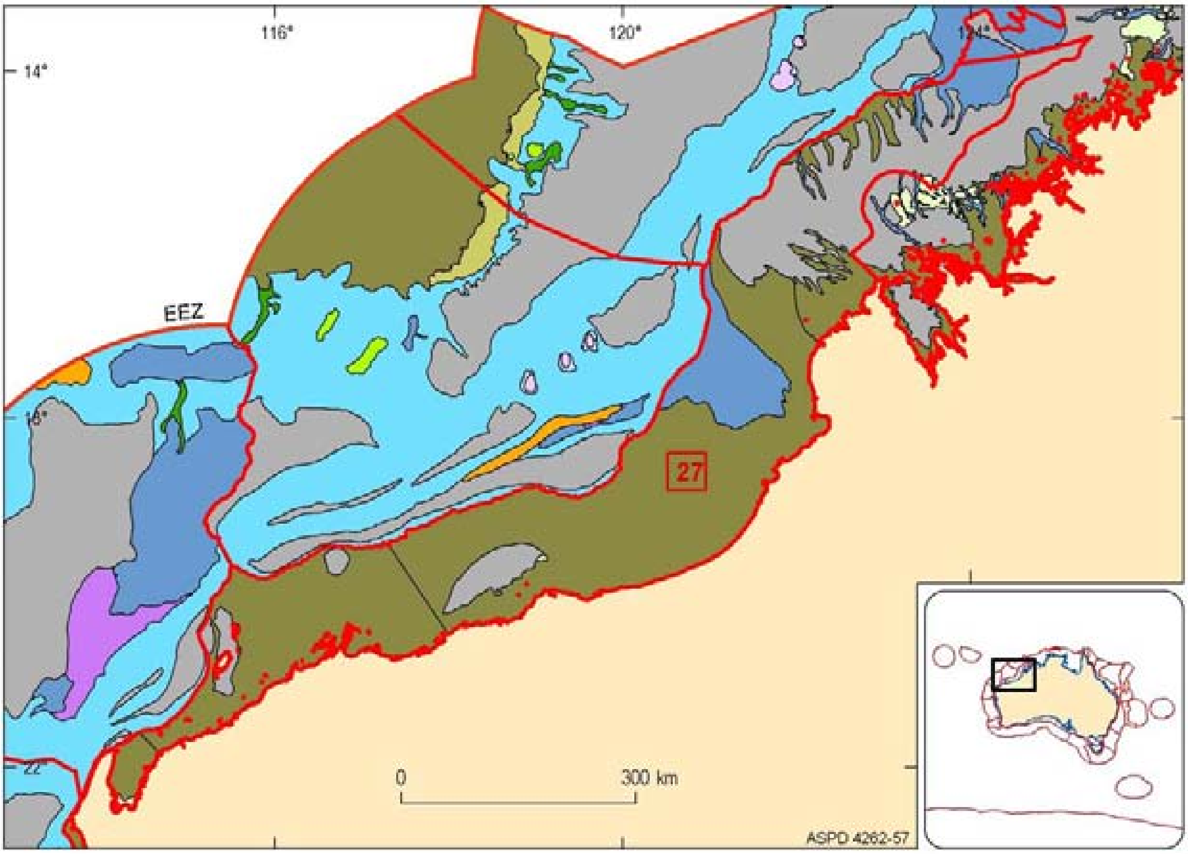

Figure C.27. Map of Geomorphic Units in Provincial Bioregion 27 (PB27 – *Northwest IMCRA Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB28 – Central Western IMCRA Transition

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
3,080	0	-106	-51	27

Geomorphic Units (km^2) *N* = 3													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	2,920	-	-	-	-	-	-	-	-	-	-	-	-
Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	-	-	-	-	1	160

Notes:

- This bioregion is the smallest of the IMCRA shelf bioregions.
- Class 1 units are overwhelmingly the dominant geomorphic class in this bioregion.
- This bioregion is one of six IMCRA shelf bioregions to contain two classes of geomorphic units.

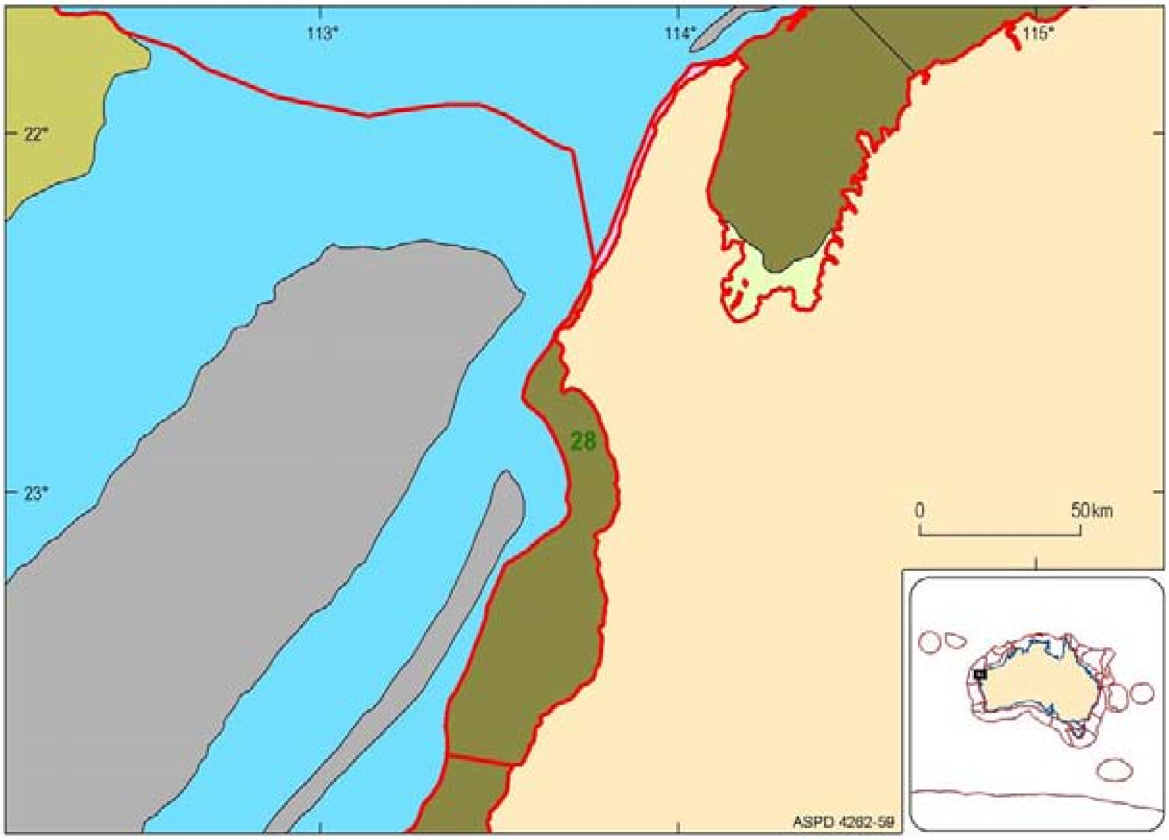

Figure C.28. Map of Geomorphic Units in Provincial Bioregion 28 (PB28 – *Central Western IMCRA Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB29 – Central Western IMCRA Province

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
32,680	0	-112	-38	37

Geomorphic Units (km^2) *N* = 3													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	31,890	-	-	-	-	-	-	-	-	-	-	-	-

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	1	790	-	-	-	-

Notes:

- This bioregion has the second shallowest mean water depth of all the IMCRA shelf bioregions.
- Class 1 units are overwhelmingly the dominant geomorphic class in this bioregion.
- This bioregion is one of six IMCRA shelf bioregions to contain two classes of geomorphic units.

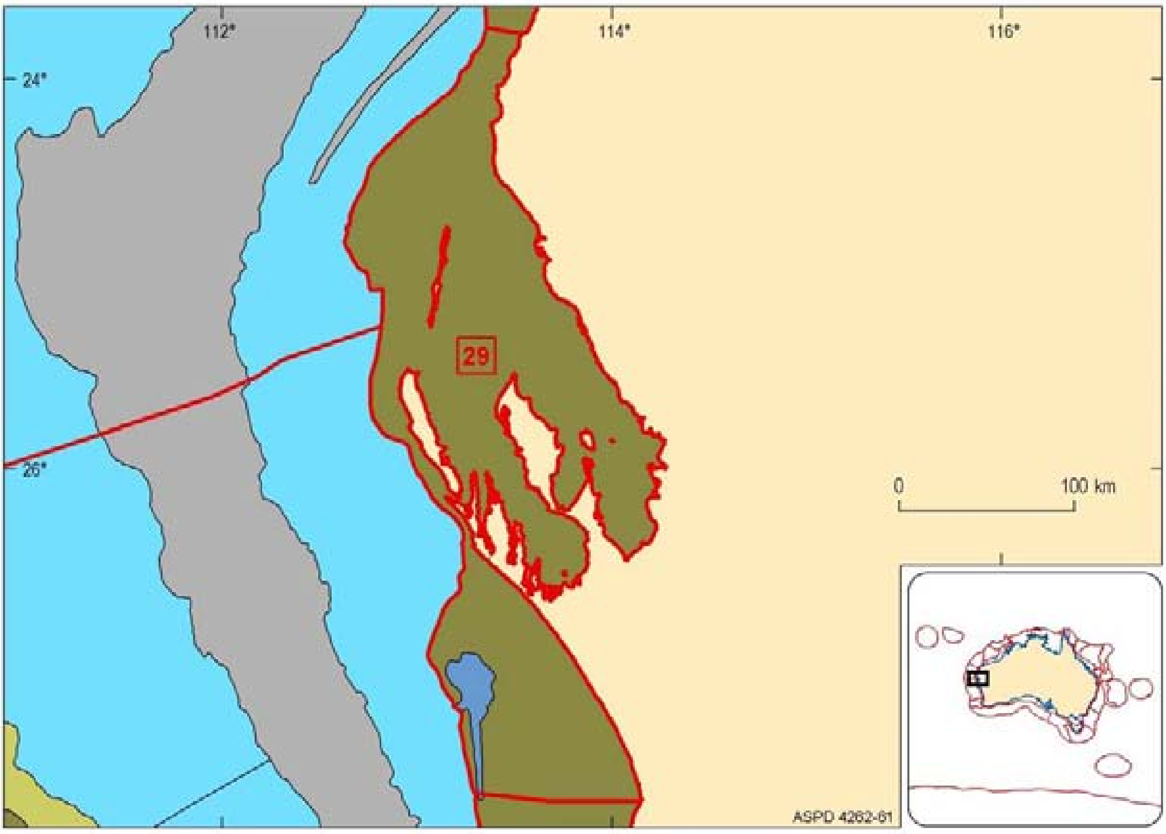

Figure C.29. Map of Geomorphic Units in Provincial Bioregion 29 (PB29 – *Central Western IMCRA Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB30 – Southwest IMCRA Transition

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
27,110	0	-296	-41	17

Geomorphic Units (km^2) *N* = 3													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	27,100	-	-	-	-	-	-	-	-	-	-	-	-
Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	1	10	-	-	-	-

Notes:

- This bioregion is the second smallest of all the IMCRA shelf bioregions.
- Class 1 includes units defined by the distribution and abundance of pinnacles, banks, and sand banks.
- This bioregion is one of six IMCRA shelf bioregions to contain only two classes of geomorphic units.

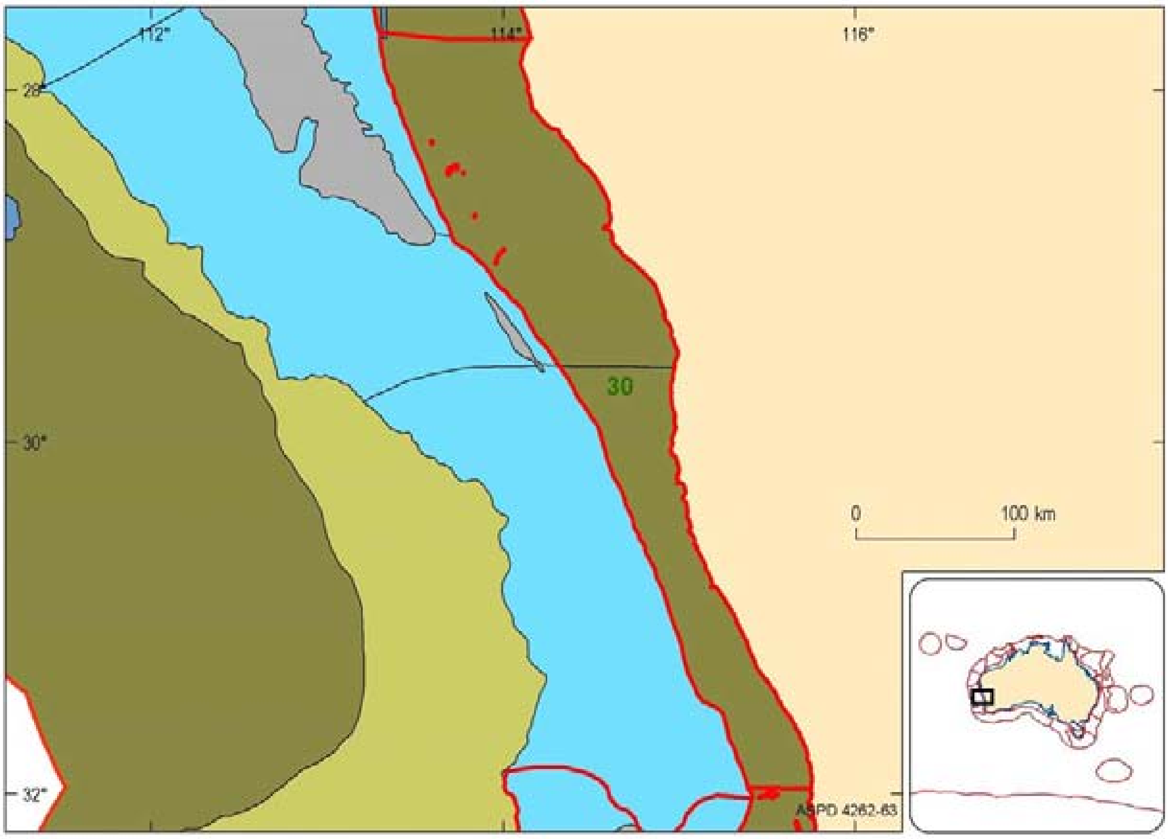

Figure C.30. Map of Geomorphic Units Provincial Bioregion 30 (PB30 – *Southwest IMCRA Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB31 – Southwest IMCRA Province

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
61,360	0	-600	-54	28

Geomorphic Units (km^2) *N* = 5													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
3	60,030	-	-	-	-	-	-	-	-	-	-	-	-

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	1	740	1	60	-	-	-	-

Notes:

- This bioregion contains the second deepest seabed habitats of all the IMCRA shelf bioregions.
- Class 1 includes units defined by the distribution and abundance of pinnacles, banks, and sand banks.
- This bioregion is only IMCRA shelf bioregion to contain three classes of geomorphic units.

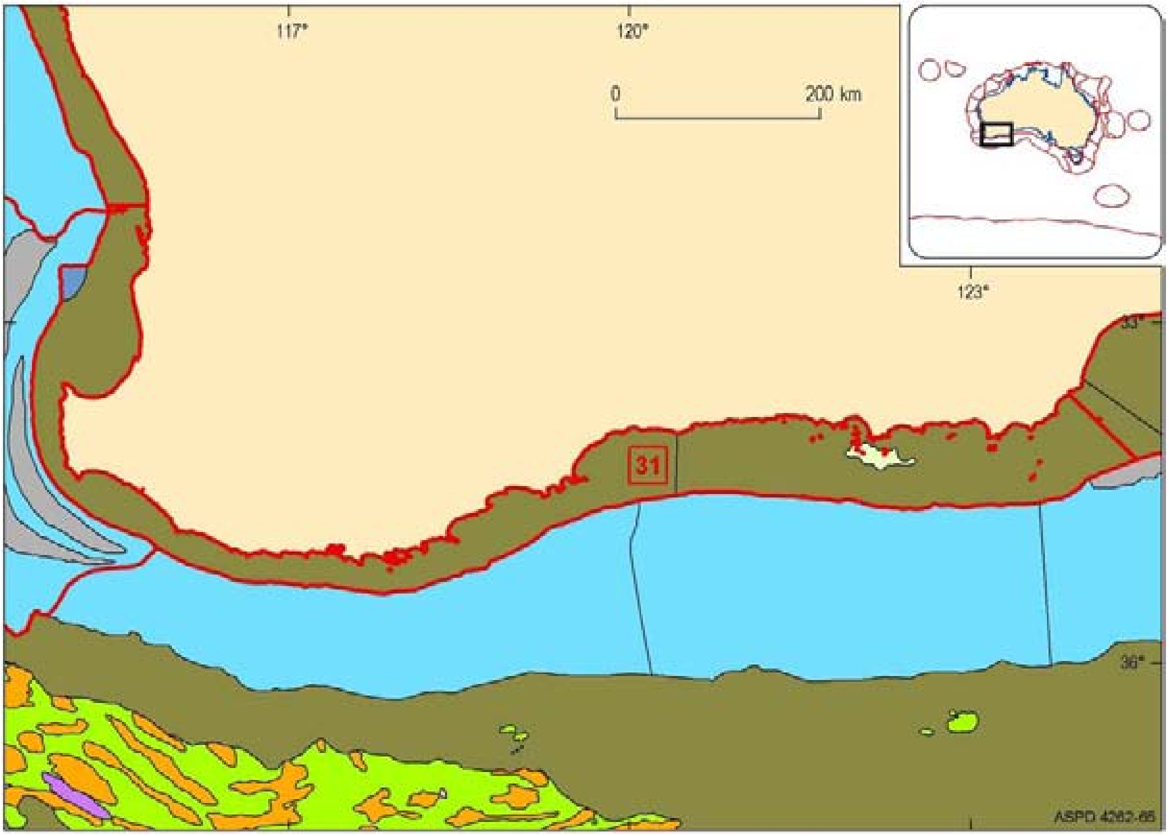

Figure C.31. Map of Geomorphic Units in Provincial Bioregion 31 (PB31 – *Southwest IMCRA Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB32 – Great Australian Bight IMCRA Transition

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
144,970	0	-354	-74	32

Geomorphic Units (km^2) *N* = 3													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	123,710	-	-	-	-	-	-	-	-	-	-	1	21,260
Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

- This bioregion is the 5th largest bioregion of the IMCRA shelf bioregions.
- Class 1 includes units defined by the distribution and abundance of pinnacles, banks, and sand banks.
- This bioregion contains the 4th largest area of Class 1 units and 6th largest area of Class 7 units of all the IMCRA shelf bioregions.
- This bioregion is one of six IMCRA shelf bioregions that contain two classes of geomorphic units.

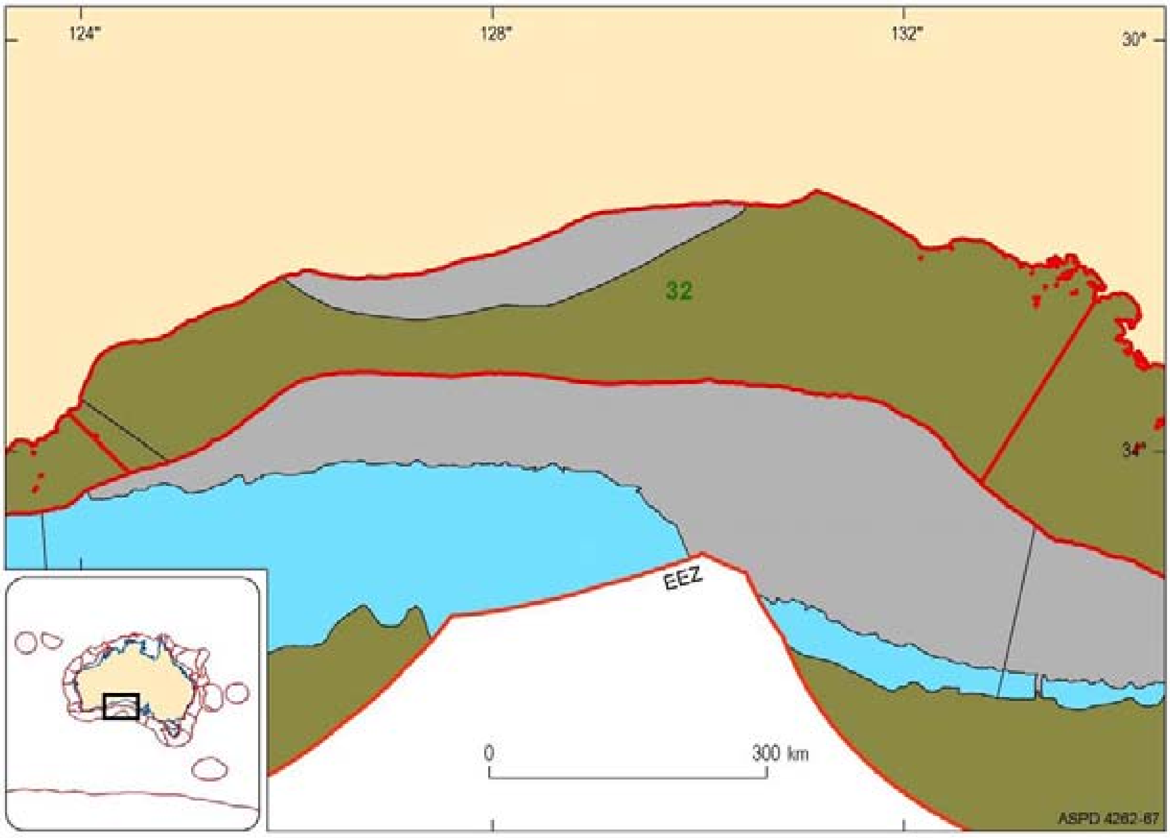

Figure C.32. Map of Geomorphic Units in Provincial Bioregion 32 (PB32 – *Great Australian Bight IMCRA Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB33 – Spencer Gulf IMCRA Province

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
132,860	0	-603	-60	50

Geomorphic Units (km^2) *N* = 13													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	115,340	-	-	-	-	-	-	-	-	-	-	3	11,940

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	510	-	-	-	-	2	1,370	4	3,700	-	-	-	-

Notes:

- This bioregion is the 6th largest bioregion of the IMCRA shelf bioregions.
- Class 1 includes units defined by the distribution and abundance of pinnacles, banks, and sand banks.
- This bioregion is one of four IMCRA shelf bioregions to contain five classes of geomorphic units.

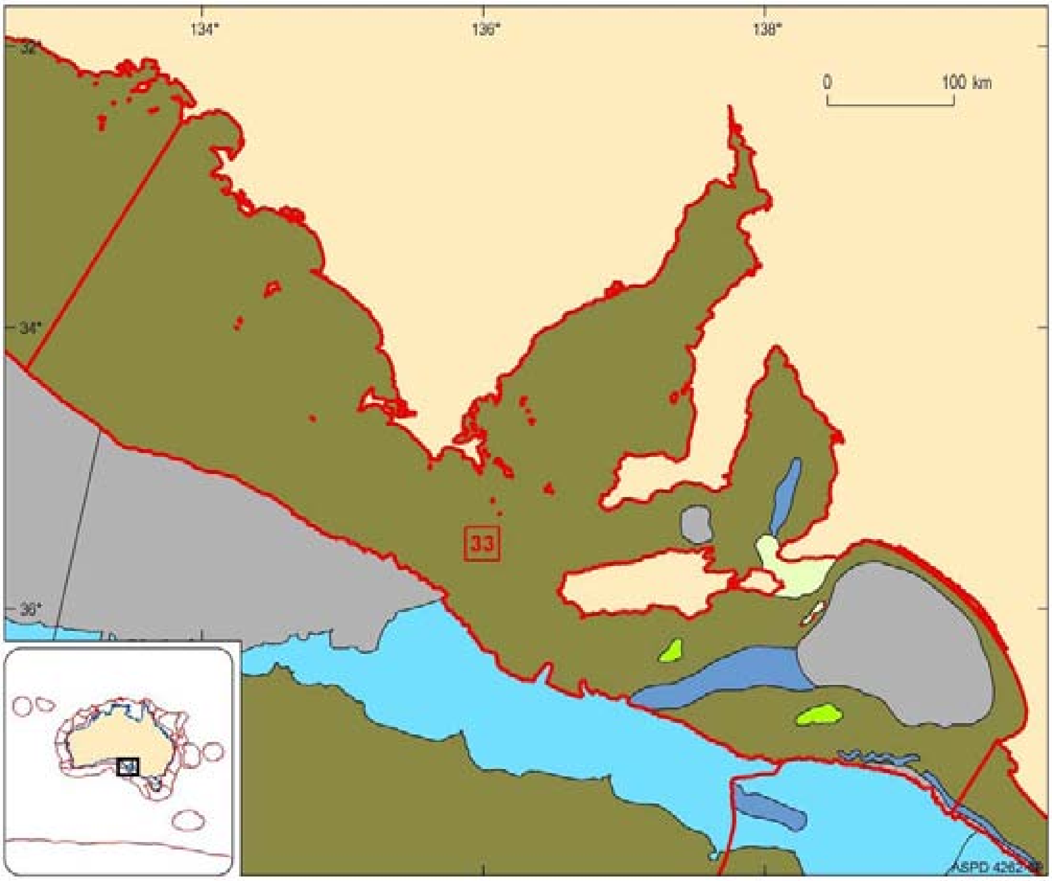

Figure C.33. Map of Geomorphic Units in Provincial Bioregion 33 (PB33 – *Gulf IMCRA Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB34 – Western Bass Strait IMCRA Transition

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
37,130	0	-272	-75	45

Geomorphic Units (km^2) *N* = 15													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
3	24,880	-	-	-	-	-	-	-	-	-	-	4	5,080

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	1	1,430	7	5,740	-	-	-	-

Notes:

- This bioregion is the 11th largest bioregion of the IMCRA shelf bioregions.
- This is one of four IMCRA shelf bioregions to contain four classes of geomorphic units.
- This bioregion contains the 5th largest area of Class 1 units of all the IMCRA shelf bioregions.

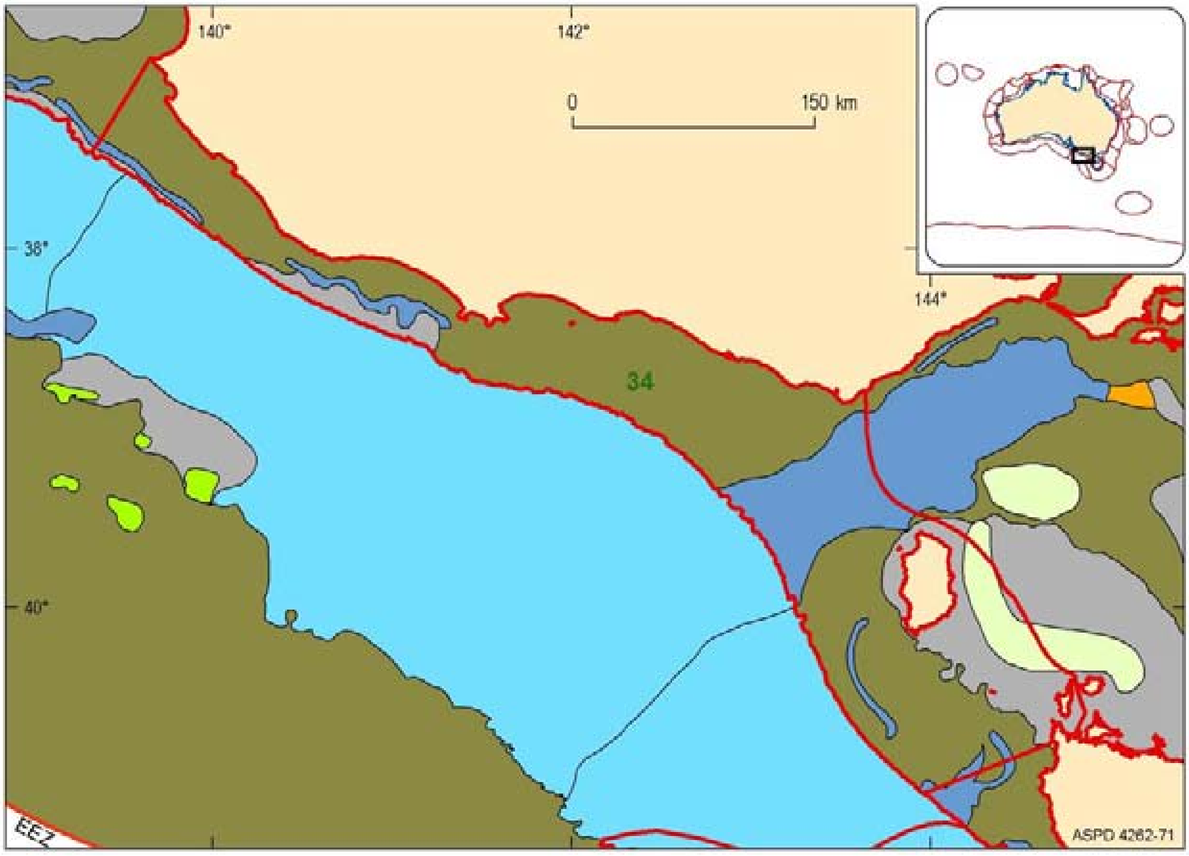

Figure C.34. Map of Geomorphic Units in Provincial Bioregion 34 (PB34 – *Western Bass Strait IMCRA Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB35 – Bass Strait IMCRA Province

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
96,670	0	-90	-61	23

Geomorphic Units (km^2) *N* = 18													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
2	27,600	-	-	-	-	1	280	-	-	-	-	8	26,410

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	4	3,180	3	7,110	-	-	-	-

Notes:

- This bioregion is the 8th largest bioregion of the IMCRA shelf bioregions.
- This bioregion contains the 5th largest area of Class 7 and 4th largest Class 12 units of all the IMCRA shelf bioregions.
- This bioregion is one of four IMCRA shelf bioregions to contain five classes of geomorphic units.

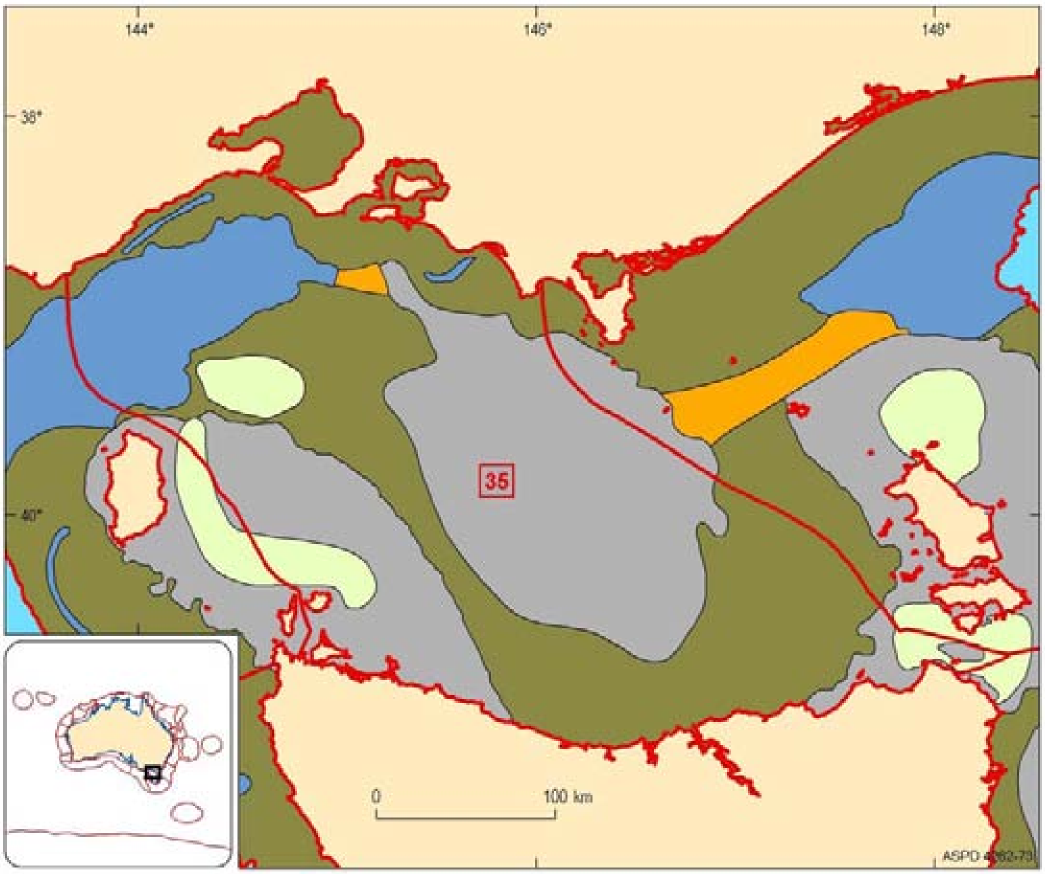

Figure C.35. Map of Geomorphic Units in Provincial Bioregion 35 (PB35 – *Bass IMCRA Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB36 – Tasmanian IMCRA Province

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
59,300	0	-834	-97	62

Geomorphic Units (km^2) *N* = 17													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
3	24,935	-	-	-	-	-	-	-	-	-	-	7	5,770

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	2	370	5	1,030	-	-	-	-

Notes:

- This bioregion is the 14th largest bioregion of the IMCRA shelf bioregions.
- This bioregion contains the deepest seabed habitats and is the deepest bioregion on average of all the IMCRA shelf bioregions.
- This bioregion is one of four IMCRA shelf bioregions to contain four classes of geomorphic units.

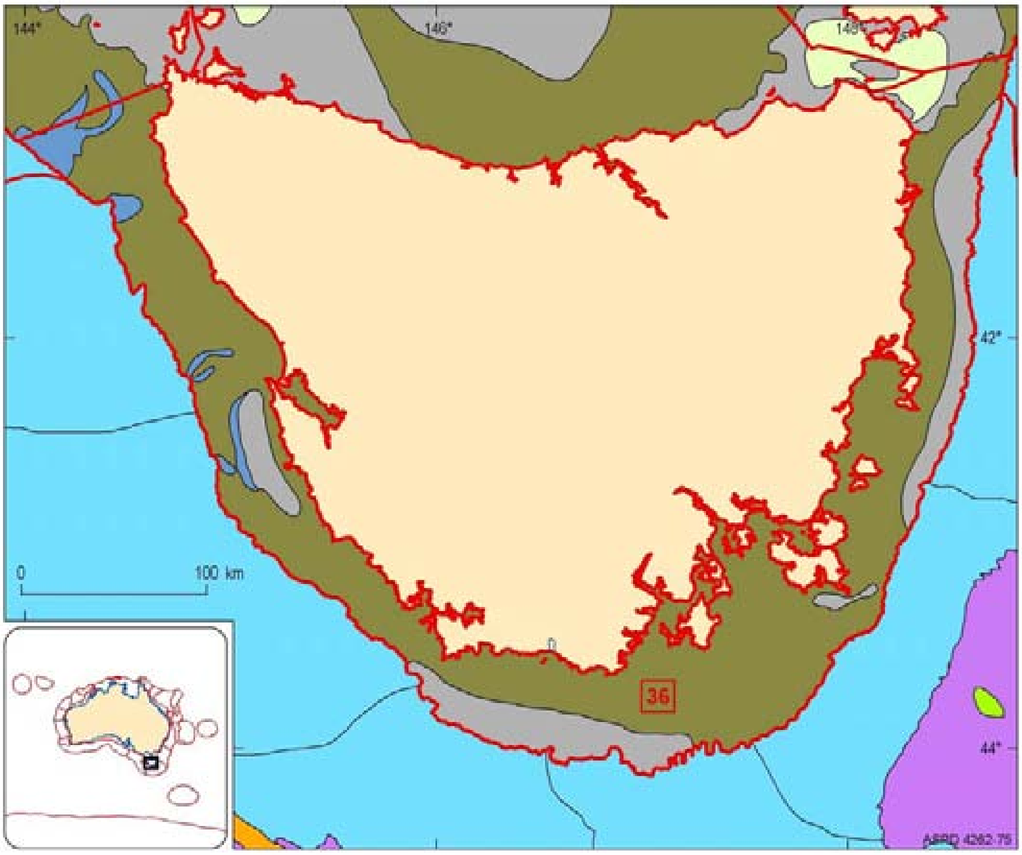

Figure C.36. Map of Geomorphic Units in Provincial Bioregion 36 (PB36 – *Tasmania IMCRA Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB37 – Southeast IMCRA Transition

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
175,540	0	-359	-64	50

Geomorphic Units (km^2) *N* = 13													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
4	31,240	-	-	-	-	1	2,510	-	-	-	-	5	16,370

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	2	2,970	1	6,210	-	-	-	-

Notes:

- This bioregion is the 10th largest bioregion of the IMCRA shelf bioregions.
- This bioregion is one of four IMCRA shelf bioregions to contain five classes of geomorphic units.
- This bioregion contains the 3rd largest Class 4 unit, 4th largest Class 11 unit and 5th largest Class 12 unit of all the IMCRA shelf bioregions.

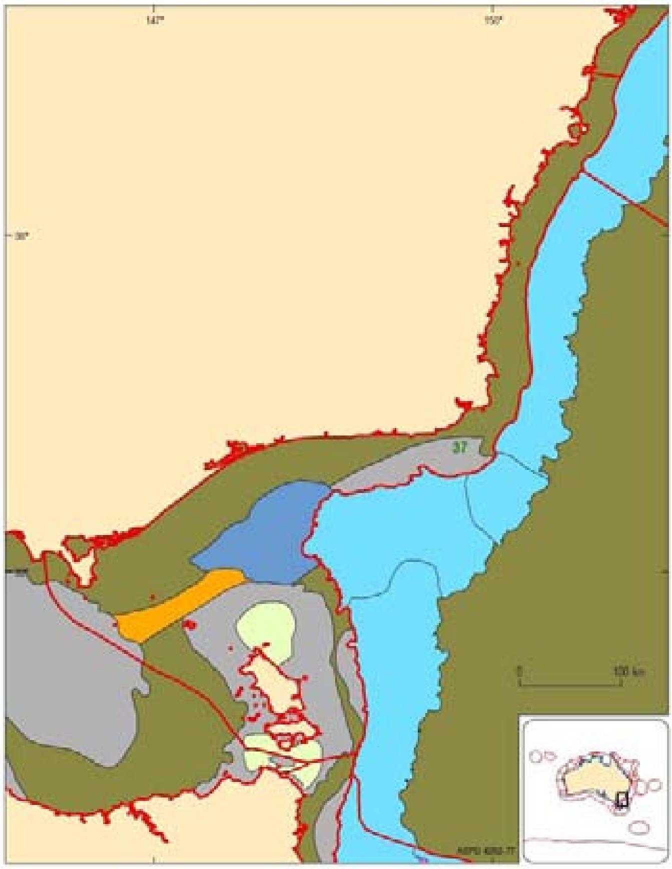

Figure C.37. Map of Geomorphic Units in Provincial Bioregion 37 (PB37 – *Southeast IMCRA Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB38 – Central Eastern IMCRA Province

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
36,180	0	-181	-83	44

Geomorphic Units (km^2) *N* = 4													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	15,230	-	-	-	-	-	-	-	-	-	-	3	2,310

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

- This bioregion is the 2nd smallest bioregion of the IMCRA shelf bioregions.
- This bioregion is the second deepest on average of all the IMCRA shelf bioregions.
- This bioregion is one of six IMCRA shelf bioregions that contains two classes of geomorphic units.

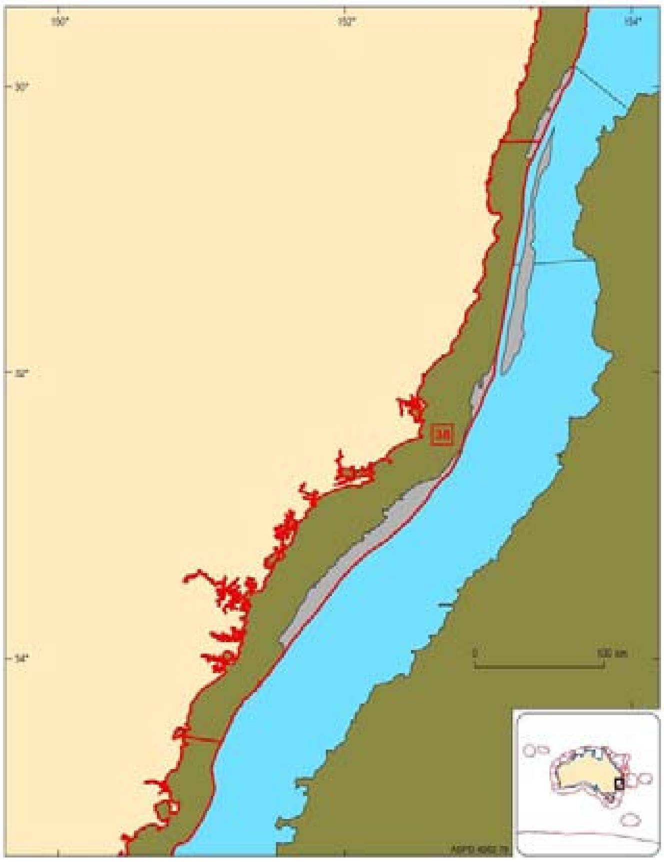

Figure C.38. Map of Geomorphic Units in Provincial Bioregion 38 (PB38 – *Central Eastern IMCRA Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB39 – Central Eastern IMCRA Transition

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
170,990	0	-114	-31	33

Geomorphic Units (km^2) *N* = 4													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1	34,590	-	-	-	-	-	-	-	-	-	-	3	1,590

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

- This bioregion is the 12th largest bioregion of the IMCRA shelf bioregions.
- This bioregion is the shallowest on average of all the IMCRA shelf bioregions.
- Class 1 includes units defined by the distribution and abundance of pinnacles, banks, and sand banks.
- This bioregion is one of six IMCRA shelf bioregions to contain two classes of geomorphic units.

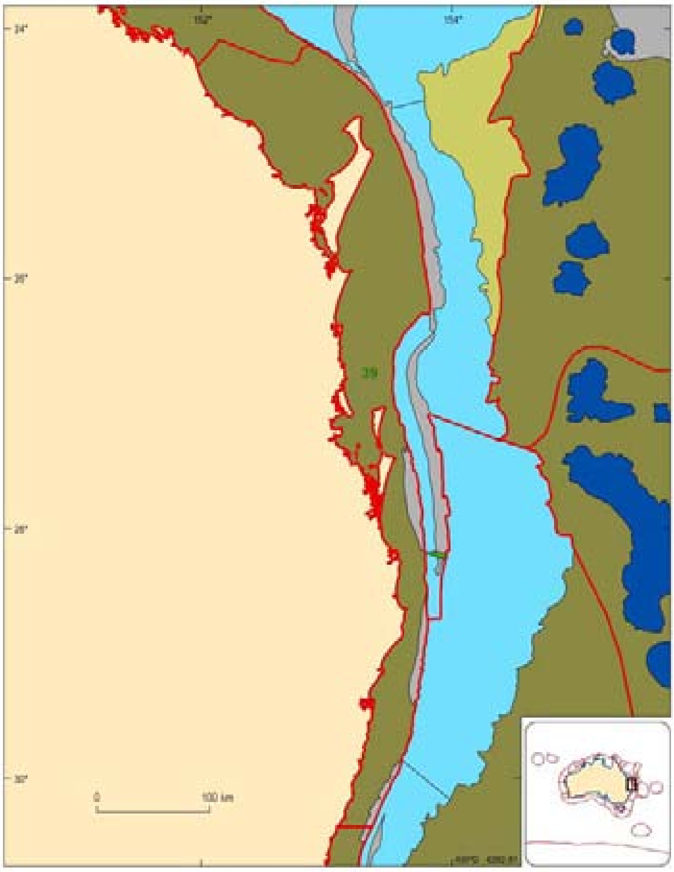

Figure C.39. Map of Geomorphic Units in Provincial Bioregion 39 (PB39 – *Central Eastern IMCRA Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB40 – Northeast IMCRA Province

Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
95,530	0	-314	-21	29

Geomorphic Units (km^2) *N* = 11													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
6	107,850	-	-	-	-	-	-	-	-	1	6,810	1	47,700

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	2	380	-	-	-	-	1	8,250	-	-	-	-

Notes:

- This bioregion is the 4th largest of all the IMCRA shelf bioregions.
- Class 1 includes units defined by the distribution and abundance of pinnacles, banks, and sand banks.
- This bioregion is one of four IMCRA shelf bioregions to contain five classes of geomorphic units.
- This bioregion contains the larges Class 6 unit, 6th largest Class 1 unit, and 3rd largest Class 7 and Class 12 units of all the IMCRA shelf bioregions.
- The bioregion is contains many coral reefs of the Great Barrier Reef.

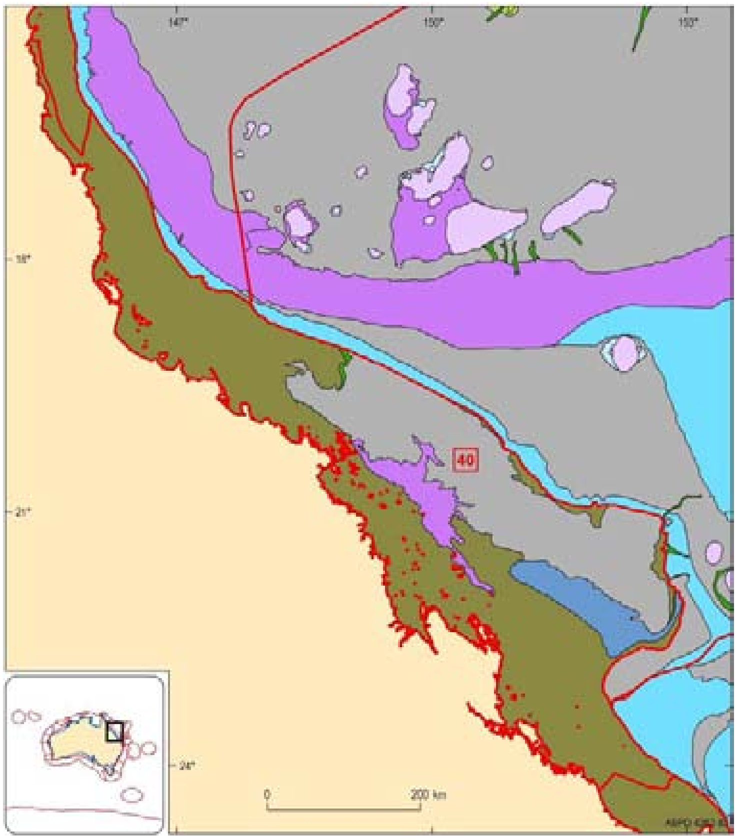

Figure C.40. Map of Geomorphic Units in Provincial Bioregion 40 (PB40 – *Northeast IMCRA Province*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

PB41 – Northeast IMCRA Transition

Type	Transition			
Total Area	Water Depth (m)			
(km^2)	Minimum	Maximum	Mean	Std Dev.
75,450	0	1184	-4	15

Geomorphic Units (km^2) *N* = 23													
Class 1		Class 2		Class 3		Class 4		Class 5		Class 6		Class 7	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
5	90,330	-	-	-	-	-	-	-	-	-	-	5	2,940

Class 8		Class 9		Class 10		Class 11		Class 12		Class 13		Class 14	
No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
-	-	-	-	-	-	-	-	12	1,870	-	-	1	390

Notes:

- This bioregion is the 7th largest bioregion of the IMCRA shelf bioregions.
- Class 1 includes units defined by the distribution and abundance of pinnacles, banks, and sand banks.
- This bioregion is one of four IMCRA shelf bioregions to contain four classes of geomorphic units.
- The bioregion contains many coral reefs of the Great Barrier Reef.

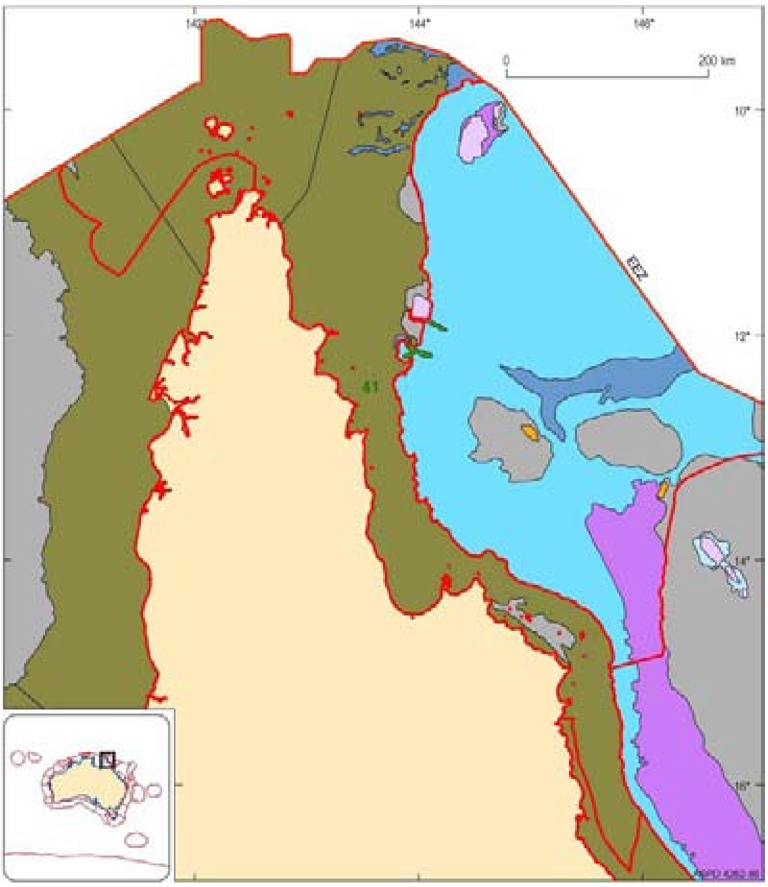

Figure C.41. Map of Geomorphic Units in Provincial Bioregion 41 (PB41 – *Northeast IMCRA Transition*). Red lines are Provincial Bioregion boundaries. See page 72 for legend.

APPENDIX D

Definitions of Patch Cohesion and Patch Connectance Indices

The following definitions and details of the patch cohesion and connectance are largely taken from the Fragstats® manual available on the web at the following url: http://www.umass.edu/landeco/research/fragstats/fragstats.html. They are presented here for completeness and as background information.

Patch Cohesion Index

- *Description*: — COHESION equals 1 minus the sum of the patch perimeter (in terms of number of cell surfaces) divided by the sum of the patch perimeter times the square root of the patch area (in terms of number of cells) for patches of the corresponding patch type, divided by 1 minus 1 over the square root of the total number of cells in the landscape, multiplied by 100 to convert to a percentage. Note, total landscape area (*A*) excludes any background present.
- *Units*:— Percent.
- *Range*:— 0 ≤ COHESION < 100. COHESION approaches 0 as the proportion of the landscape comprised of the focal class decreases and becomes increasingly subdivided and less physically connected. COHESION increases monotonically as the proportion of the landscape comprised of the focal class increases until an asymptote is reached near the percolation threshold. COHESION is given as 0 if the landscape consists of a single non-background cell.
- *Comments*:— Patch cohesion index measures the physical connectedness of the corresponding patch type. Below the percolation threshold, patch cohesion is sensitive to the aggregation of the focal class. Patch cohesion increases as the patch type becomes more clumped or aggregated in its distribution; hence, more physically connected. Above the percolation threshold, patch cohesion does not appear to be sensitive to patch configuration (Gustafson, 1998).

Connectance Index

- *Description*:— CONNECT equals the number of functional joinings between all patches of the corresponding patch type (sum of c_{ijk} where $c_{ijk} = 0$ if patch *j* and *k* are not within the specified distance of each other and $c_{ijk} = 1$ if patch *j* and *k* are within the specified distance), divided by the total number of possible joinings between all the patches of the corresponding patch type, multiplied by 100 to convert to a percentage.
- *Units*:— Percent.
- *Range*:— 0 ≤ CONNECT ≤ 100. CONNECT = 0 when either the focal class consists of a single patch or none of the patches of the focal class are "connected" (i.e., within the user-specified threshold distance of another patch of the same type). CONNECT = 100 when every patch of the focal class is "connected."
- *Comments*:— Connectance is defined on the number of functional joinings between patches of the corresponding patch type, where each pair of patches is either connected or not based on a user-specified distance criterion. Connectance is reported as a percentage of the maximum possible connectance given the number of patches. Note that connectance can be based on either

Euclidean distance or functional distance. Also, note that Euclidean distances are calculated from cell centre to cell centre. Thus, two patches that have 10 10-m cells between them have a computed distance of 110 m, not 100.