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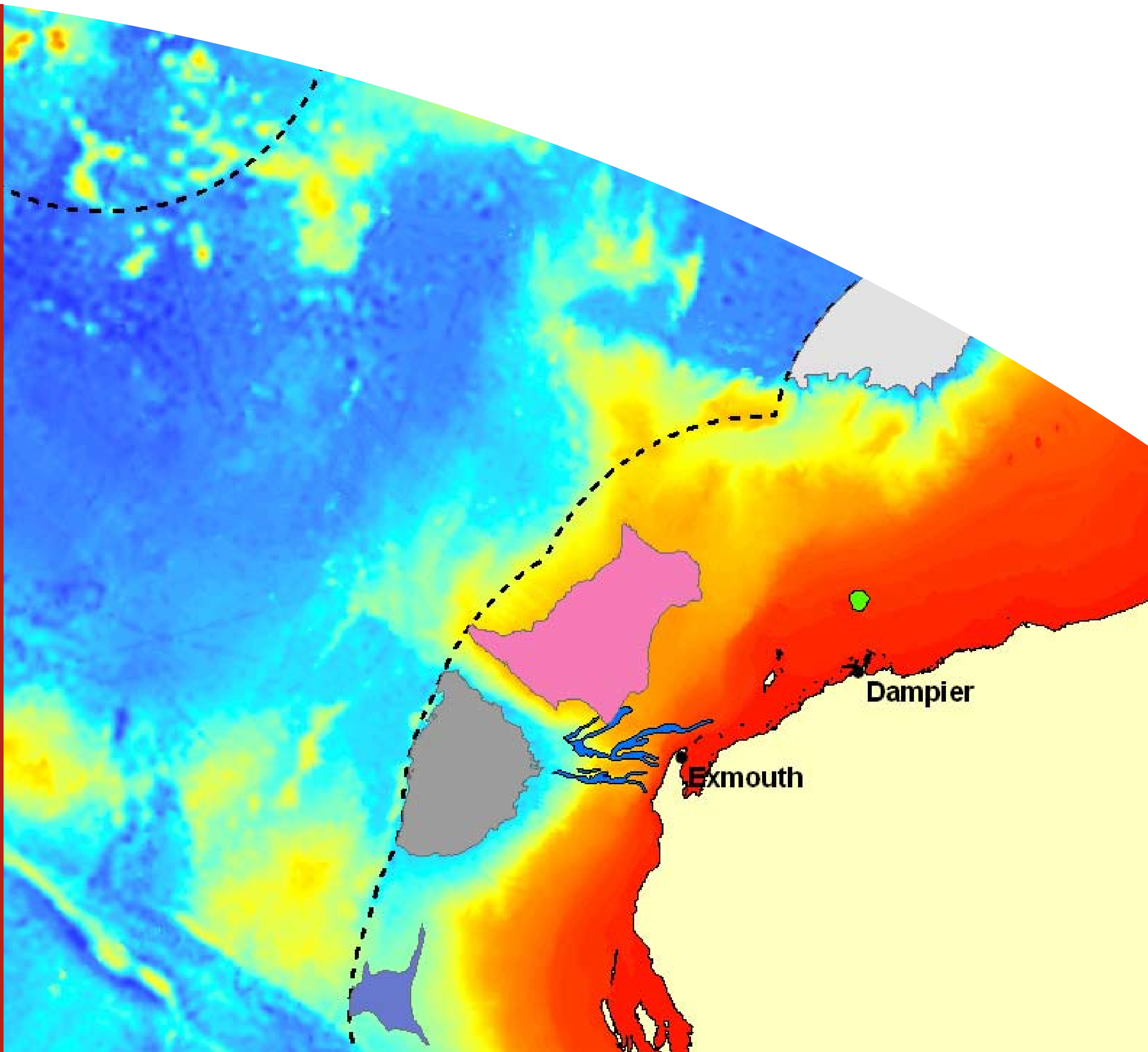
Review of Ten Key Ecological Features (KEFs) in the Northwest Marine Region

A report to the Department of the Environment, Water, Heritage and the Arts by Geoscience Australia

I. Falkner, T. Whiteway, R. Przeslawski & A.D. Heap

Record
2009/13
GeoCat # 68732



Review of Ten Key Ecological Features (KEFs) in the Northwest Marine Region

A REPORT TO THE DEPARTMENT OF THE ENVIRONMENT, WATER, HERITAGE AND THE ARTS BY GEOSCIENCE AUSTRALIA

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By

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ISSN 1448-2177

ISBN (print) 978-1-921498-66-4

ISBN (web) 978-1-921498-65-7

GeoCat # 68732

Bibliographic reference: Falkner, I., Whiteway, T., Przeslawski, R., Heap, A.D. 2009. Review of Ten Key Ecological Features (KEFs) in the North-west Marine Region. Geoscience Australia, Record 2009/13. Geoscience Australia, Canberra. 117pp.

Table of Contents

List of Figures

List of Tables

Executive summary

The Department of the Environment, Water, Heritage and the Arts (DEWHA) has identified as key ecological features (KEFs) numerous geomorphic features or regionally important species or habitats in the northwest marine region. This process supports the department's establishment of the development of Marine Bioregional Plans and a National Representative System of Marine Protected Areas (NRSMPA). A total of ten KEFs are included in this study of which seven lie in the deep-sea where information on biodiversity and ecosystems is scarce. The ten KEFs are: Wallaby Saddle, Cuvier Abyssal Plain, Cape Range Canyons, Exmouth Plateau, Argo Abyssal Plain, Bowers and Oates Canyons, Scott Plateau, Scott Reef, the Holocene Coastline, and Glomar Shoals. Geoscience Australia was engaged to investigate habitat heterogeneity of these KEFs utilising its existing expertise in habitat mapping and surrogacy.

The principal aims of this study were: (1) to confirm the biological and physical data available for ten KEFs, and (2) to use the biophysical data to derive 'seascapes'. This approach is designed to identify whether the KEFs represent one or more habitat types and whether these habitat types are environmentally significant in the region. According to the NRSMPA, several criteria including representativeness, uniqueness, productivity, vulnerability, and ecological importance are used to select MPAs, and each KEF was also therefore evaluated according these criteria.

Biological information for the KEFs beyond the shelf was anecdotal and mostly consisted of museum records of a few invertebrate and fish species at a small number of locations. With the exception of Glomar Shoals, these data were not consistent, and their coverage inadequate for a complete surrogacy analysis. Physical data coverage was more comprehensive, with hydrology data and data from a conductivity, temperature, and depth (CTD) recorder yielding the best results. Sediment data were less frequent in some areas off the shelf.

The seascapes and focal variety analyses for the North-west Marine Region gave the following results:

- The **Argo and Cuvier Abyssal Plains** may represent a unique habitat type which is not found anywhere else in the North-west Marine Region (Table 1).

- The **Exmouth and Scott Plateaus** represent different habitat types that potentially support different communities. The habitat types found on the plateaus, however, were also found among other geomorphic features in the region (Table 1).
- Abyssal plains and plateaus were identified as areas of low habitat diversity while the margins of plains and plateaurs were identified as areas of greater habitat diversity.
- The **Cape Range Canyons and Bowers/Oates Canyons** coincided with several seascapes which were not found at the other KEFs. However, our analysis also showed that the same seascapes were found close to the canyons indicating that these habitat types are not 'canyon specific' or unique to the region. In addition, both canyon systems appear to represent different habitat types. The two canyon areas coincided with high focal variety indices indicating high habitat heterogeneity (Table 1).
- The **Wallaby Saddle** is a unique geomorphic feature in the North-west Marine Region, and, according to our analysis, it also represents a unique habitat type that neither occurs anywhere else within hundreds of kilometres, nor with as large an area in the entire North-west Marine Region. Habitat diversity, however, was lowest on the saddle as the margins coincided with the same seascape as the saddle itself (Table 1).
- **Scott Reef** coincided with one seascape which was only found much further onshelf, supporting previous findings that the reef is an ecosystem vastly different from its surroundings. Interestingly, the reef coincided with a seascape which was characterised by high primary productivity in an area that is otherwise defined by low to moderate primary production values. Based on the focal variety analysis, Scott Reef also represents an area of high habitat diversity which confirms previous findings that described discreet reef habitats supporting different communities (Table 1).
- The **Holocene coastline** can be separated into a northern section (north of Broome) characterised by low primary production and a southern section characterised by high primary production. Based on the focal variety analysis, habitat diversity is moderate along this feature. However, areas adjacent to the coastline are high in habitat diversity, particularly in the area between Exmouth and Broome where there are an abundance of shoals, banks and terraces (Table 1).

- The seascape and focal variety analysis of the entire on-shelf North-west Marine Region showed that **Glomar Shoals** represents the same habitat type as the surrounding areas. In two additional analyses focusing only on Glomar Shoals and its immediate surrounds (with and without demersal fish data incorporated), Glomar Shoals coincided with a single seascape that did not occur anywhere else in the surrounding area. This indicates that Glomar Shoals represents a habitat type that is locally not found anywhere else. On a regional scale, however, this habitat type may not be unique. Interestingly, in all three analyses, Glomar Shoals was an area of increased habitat diversity compared to surrounding areas. (Table 1)

Table 1. Regional assessment summary for KEFs in the North-west marine region

Geomorphic feature	Representativeness	Uniqueness
Argo Abyssal Plain	YES	NO[1]
Cuvier Abyssal Plain	YES	NO[1]
Exmouth Plateau	YES	NO
Scott Plateau	YES	NO
Bowers & Oates Canyons	YES	NO
Cape Range, Cloates & Mermaid Canyons	YES	NO
Wallaby Saddle	YES	YES[2]
Scott Reef	YES	YES[3]
Holocene coastline	YES	NO
Glomar Shoals	YES	YES[4]

[1] Together, these KEFs represent a unique habitat, as they occur within the same seascape which is found nowhere else in the North-west Marine Region.
[2] Considered unique because the associated seascape is found nowhere else within hundreds of kilometres.
[3] Considered unique because the associated seascape is found nowhere else this far off shelf
[4] Local seascape analysis suggests that Glomar Shoals is unique among surrounding areas, but regional seascape analysis lumps Glomar Shoals into the same habitat type as surrounding areas, likely due to lower resolution at the coarser spatial scale used

This study represents the first time seascapes have incorporated biological data as an additional spatial layer. The results indicate that the addition of biological data may add some additional spatial complexity to the classification. The statistical analysis of demersal fish assemblages and environmental properties at Glomar Shoals, however, revealed only a very weak correlation.

On a regional level the seascapes analysis successfully identified different habitat types for the KEFs. The seascapes coincided particularly well with some of the large KEFs in the deep-sea such as the abyssal plains and the marginal plateaus which are considered to be relatively homogenous environments. Here, coverage of the seascapes data was sufficient to produce a reliable result. Insufficient data coverage may have been the reason why smaller, more diverse KEFs such as the submarine canyons and Glomar Shoals coincided with the same seascapes as the surrounding areas. Here the interpolation of the seascapes data may have resulted in the masking of existing differences between KEFs and surrounding areas.

1 Introduction

The Department of Environment, Water, Heritage and the Arts (DEWHA) is developing marine bioregional plans under the Environmental Protection and Biodiversity (EPBC) Act. The North-west Marine Bioregional Plan is one of five regional plans that aim to identify the conservation values of Australian waters, to develop conservation strategies and to commend areas that should to be included in a network of Marine Protected Areas (MPAs). Numerous key ecological features (KEFs) have been identified by the DEWHA in the North-west Marine Region. Many of these KEFs are in the deep-sea where information on biodiversity and ecosystems is scarce.

One of the major goals of Australia's Oceans Policy is to establish a National Representative System of Marine Protected Areas (NRSMPA) to ensure the protection and maintenance of Australia's marine biodiversity and natural resources. The NRSMPA is guided by nine principles: incorporation of a regional framework, comprehensiveness, adequacy, representativeness, inclusion of highly protected areas, precautionary principles, consultation, indigenous involvement, and the integration of both short- and long-term considerations in decision-making (Australian and New Zealand Environmental and Conservation Council 1998). One of the ways that the Australian Government is incorporating a regional framework into the NRSMPA is through marine bioregional planning. The plans will also provide guidance for decision-making in the North-west Marine Region under the EPBC Act, such as considering whether an action is likely to have a significant impact on the Commonwealth marine area.

1.1 Aims of this study

The principal aims of the present work are to confirm the biological and physical data available for 10 of the 14 KEFs in the North-west Marine Region and to use the biophysical data to derive 'seascapes' for each of these KEFs that provide information on potential biodiversity. In deeper waters, abiotic factors such as bathymetry are recommended as appropriate data sources to map ecosystems and marine habitats and meet NRSMPA principles (Harris *et al.,* 2008; NRSMPA Strategic Plan of Action: Review of Methods for Ecosystem Component Mapping, 2000). Seascapes incorporate multiple physical parameters and can therefore assist in the characterisation of the candidate MPAs for the North-west Marine Region. This study was not aimed at describing physical datasets, as this has been done in other reports (*e.g.* Baker *et al.,* 2008).

To achieve these aims, Geoscience Australia has sourced, collated and analysed all biological and physical data available for the KEFs. Fine-scale focal variety analyses were conducted to assess habitat heterogeneity of each KEF which will assist DEWHA in marine bioregional planning. Results from the current study will assist policy-makers and managers to identify conservation strategies, inform decision-making, and address the first two steps of MPA establishment: 1) Gather baseline data, and 2) Identify a list of candidate areas within bioregions to represent major ecosystems using critera for the identification of MPAs (*e.g.* vulnerability, productivity, ecological importance, representativeness, and uniqueness) (ANZECC, 1998).

1.2 Key Ecological Features in the North-west Marine Region

Ten KEFs are located in Commonwealth waters between Ningaloo Reef in the south to Joseph Bonaparte Gulf in the north (Table 1.1; Fig. 1.1).

Table 1.1. KEFs of the North-west Marine Region examined in this study. [a] Located at the centre of the feature (Heap & Harris 2008). [b] Obtained from Australian Hydrographic Service.

Geomorphic feature	Lat./Long.[a]	Area (km^2)	Feature type
Off-shelf			
Wallaby Saddle	-25.44 / 109.43	7,880	Saddle
Cuvier Abyssal Plain	-22.17 / 110.85	40,140	Abyssal plain
Cape Range Canyons			
Cape Range Canyon	-21.91 / 113.34	660	Canyon
Cloates Canyon	-22.25 / 112.90	1,260	Canyon
Mermaid Canyon			Canyon
Exmouth Plateau	-17.41 / 116.42	49,310	Plateau
Argo Abyssal Plain	-15.27 / 117.46	58,970	Abyssal plain
Bowers/Oates Canyons			
Bowers Canyon	-14.38 / 119.37	550	Canyon
Oates Canyon			Canyon
Scott Plateau	-13.49 / 120.81	43,370	Plateau
Scott Reef	-14.11 / 121.83	540	Reef
Shelf break			
Holocene strandline (125 m isobath)			Ancient strandline
On-shelf			
Glomar Shoals	-19.55 / 116.80[b]	~200	Shoal

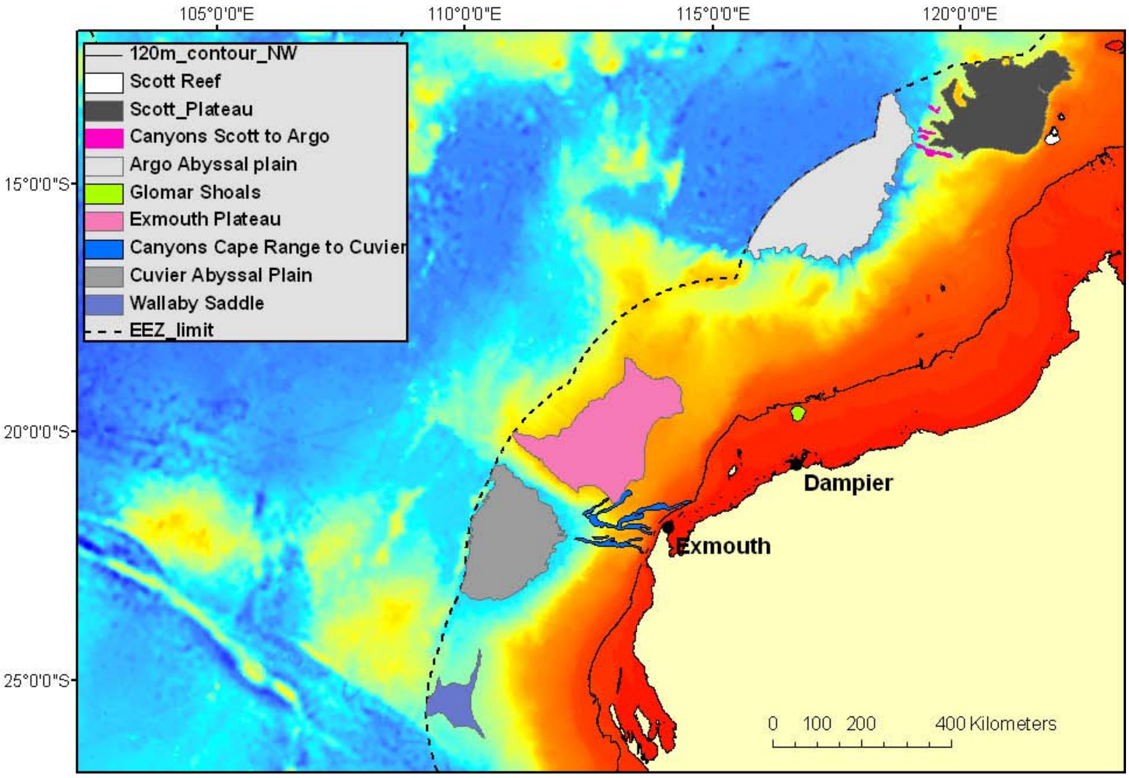

Figure 1.1. KEFs of the North-west Marine Region examined in this study.

These KEFs investigated in this report include mostly deep-sea geomorphic features, namely: abyssal plains, marginal plateaus, and submarine canyons. Seven of these KEFs occur in the deep-sea (>200 m) (Gage & Tyler 1992) (Table 2.1) and are characterised by a relative lack of publicly available biological information. In the absence of biological information, habitat heterogeneity (as defined by seascapes) is a major consideration in both conservation initiatives and ecological studies, with areas of higher complexity often containing higher abundances and numbers of species than more homogenous regions (Vetter & Dayton, 1998). Thus, a promising approach to biodiversity-focused conservation in the absence of robust biological data is to identify potential habitat and biodiversity hotspots based on physical datasets.

1.3 Seascapes

1.3.1 Characterisation of habitat and species diversity

Traditionally the characterisation of seafloor habitats and species communities has relied on intensive sampling efforts mainly using grabs, trawls and/or video. Data from such surveys are subsequently extrapolated to a broader spatial scale to predict the spatial distribution of habitats or communities (Eleftheriou & McIntyre, 2005). If a broad spatial coverage is intended, this approach is likely to be both time-consuming and costly. Even when sampling is accomplished successfully, the relatively few taxonomists able to identify organisms to species level often preclude a timely identification of most samples (Ponder *et al.,* 2002). These constraints are reflected in the lack of available comprehensive biological data from most of Australia's marine regions, especially the deep sea.

In recent years, scientists have used sophisticated remote sensing systems such as multibeam or side scan sonar to map seafloor habitats in great detail (*e.g*., Brown *et al.,* 2004a, b; Mayer, 2006). In combination with field samples, mapping seafloor habitats using acoustic remote sensing technology has greatly contributed to marine management and planning. While field validation is required, samples can only be spatially interpreted by setting them in the broader context achieved from the remotely sensed data. Hence, both approaches complement each other in describing distribution patterns of biota and habitat heterogeneity across a range of spatial scales (Foster-Smith & Sotheran, 2003).

Underwater video footage has confirmed that acoustic data can reliably predict seafloor habitats in certain environments (Brown & Collier, 2008; Rooper & Zimmermann, 2007). These studies presume a link between benthic community structure and habitat-defining physical parameters, which has been shown in several studies (Etter & Grassle, 1992; Levin & Gage, 1998). Sediment characteristics are emerging as particularly important determinants of infaunal communities, as infauna rely on the sediment for nutrition and habitat. For example, grain size is positively correlated to crustacean species richness in the Indo-Pacific (Levin & Gage, 1998), and sediment characteristics and macrobenthic diversity are correlated in the western North Atlantic (Etter & Grassle, 1992). In the deep-sea, other physical parameters such as depth, sediment organic carbon and bottom oxygen content are significantly correlated with macrobenthic species diversity (Levin *et al.,* 1991; Levin & Gage, 1998). Although sediment characteristics and other abiotic factors may affect certain taxa, the influence of different physical parameters may vary among taxonomic groups (Levin & Gage, 1998).

It seems likely that, rather than one single physical factor influencing species distributions and community composition, multiple factors interact and influence distribution, abundance and diversity of marine organisms (Post *et al.,* 2006; Przeslawski *et al.,* 2008; Snelgrove & Butman, 1994). Sediment grain size and organic and microbial content, for example, are strongly correlated, as all three are influenced by the local current flow regimes (Snelgrove & Butman, 1994).

1.3.2 National seascapes

Lambshead (1993) estimate that approximately 5 km^2 of the ocean bottom has been sampled for macrofauna and meiofauna- a very small area considering the vastness of the deep-sea. An alternative approach to direct biologically sampling is to classify biophysical parameters into distinct classes to define benthic habitats. The biophysical parameters comprise biologically meaningful datasets such as depth, sediment grain size, and primary production, which are combined to create large-scale seafloor habitat maps termed seascapes (Roff & Taylor, 2000; Roff *et al.,* 2003; Whiteway *et al.,* 2007). Each seascape coincides with an area of seafloor that is characterised by a similar suite of biophysical properties indicating similarities in habitat types and ecosystems. Hence seascapes can be used to determine different habitat types and communities and to identify areas of biological significance based on habitat heterogeneity and structure (Roff & Taylor, 2000; Roff *et al.,* 2003; Whiteway *et al.,* 2007). Geoscience Australia has adapted this seascapes approach for a national classification of the entire Australian Exclusive Economic Zone (EEZ), off-shelf (Fig. 1.2) and on-shelf (Fig. 1.3), and the Northern and the Southwest Planning Regions (Whiteway *et al.,* 2007).

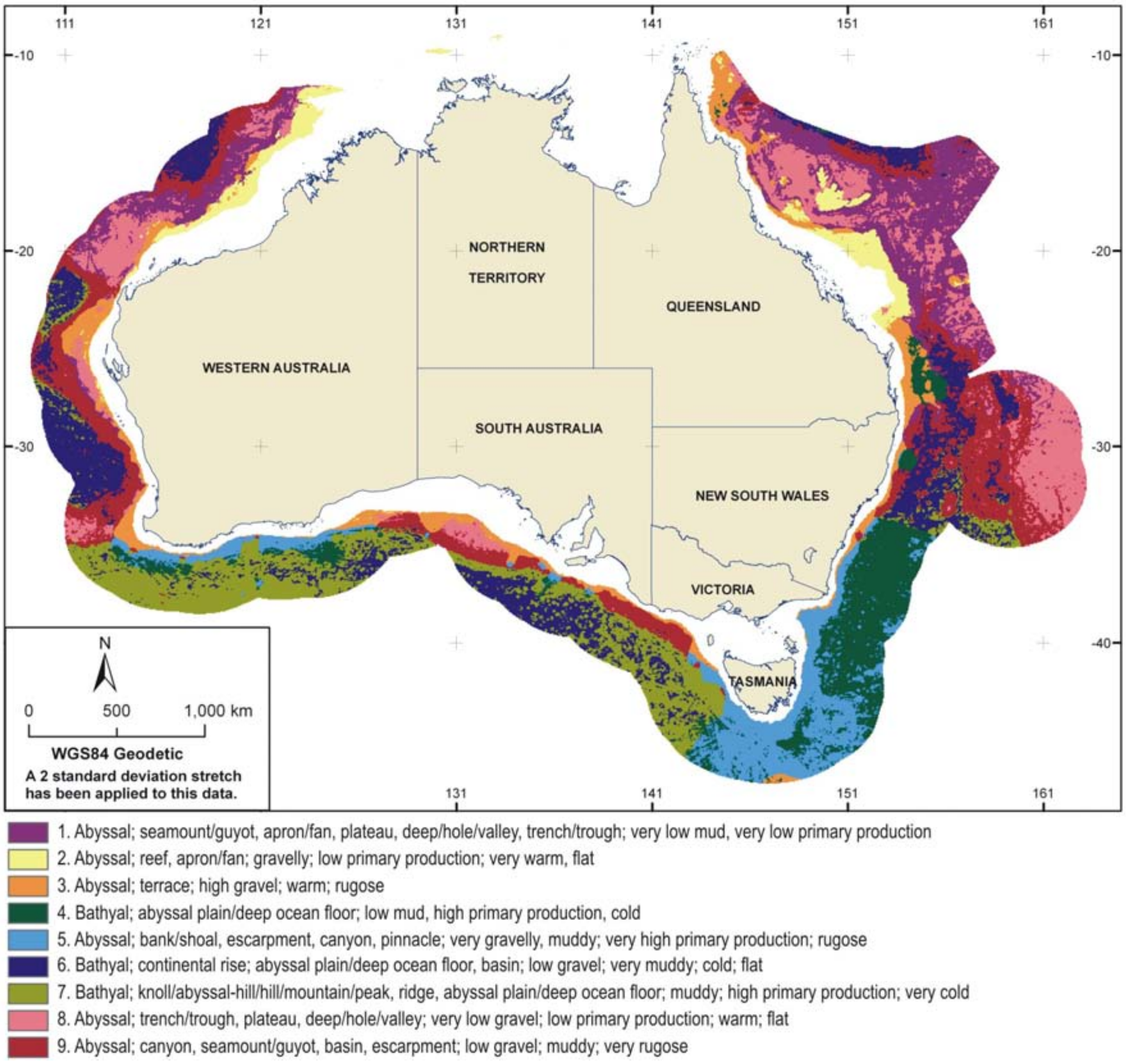

Figure 1.2. National seascape map for the off-shelf region of Australia.

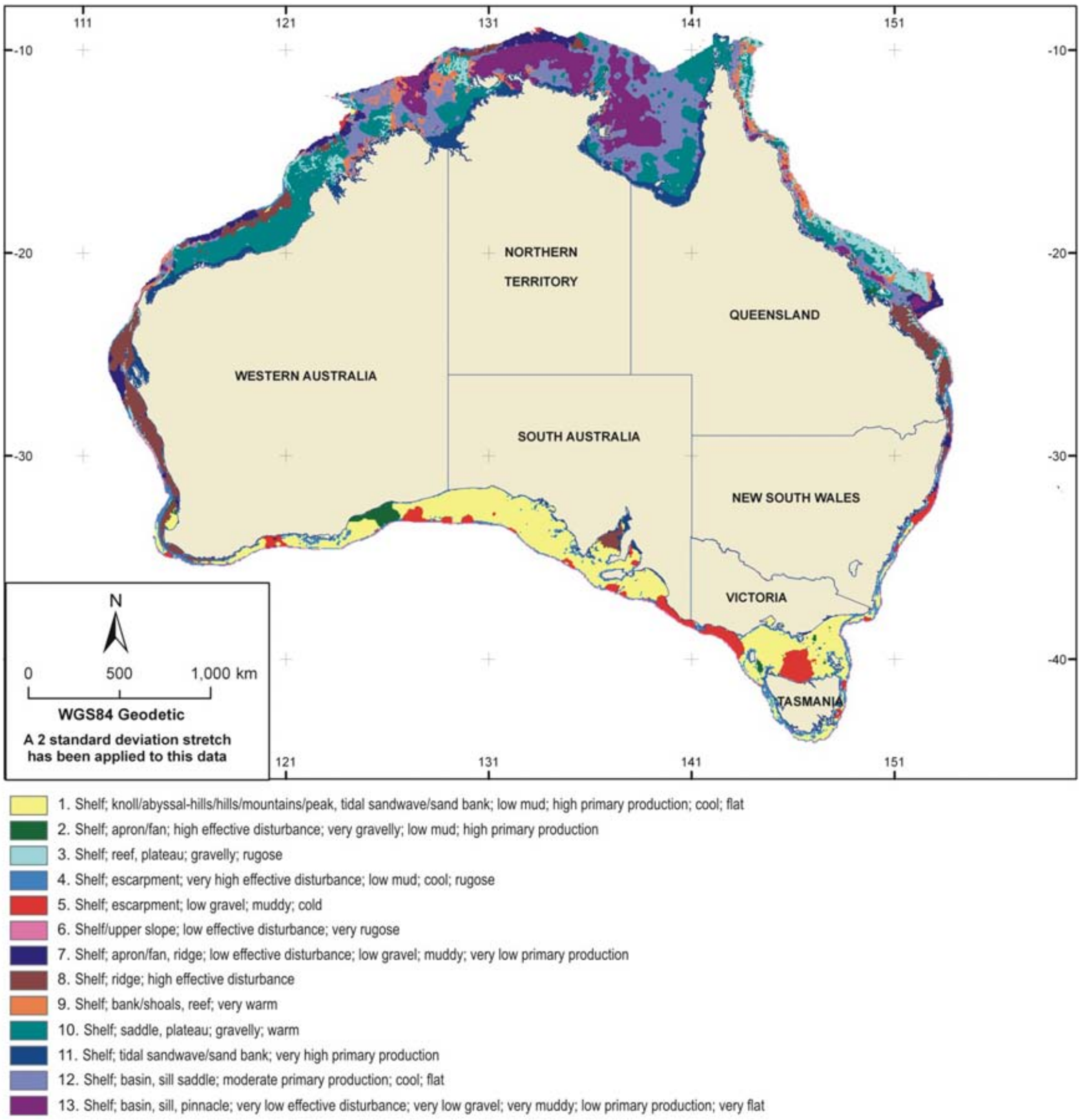

Figure 1.3. National seascapes for the on-shelf region of Australia.

1.4 The deep-sea environment

More than 80% of the Australian EEZ is deeper than 200 m and is ecologically defined as the ‘deep-sea’ (Gage & Tyler 1992). The associated ecological depth zones are:

(i) *subtidal* – low water mark to 200 m

(ii) *bathyal* – 200 to 2,000 m

(iii) *abyssal* – 2,000 to 6,000 m

(iv) *hadal* – > 6,000 m

The northwest Australian EEZ, the area of focus of this report, is comparatively shallow with more than 40% in water depths of less than 200 m and less than 15% of the total area deeper than 4,000 m (Baker *et al.,* 2008). Despite occupying a large area of the

Australian EEZ, deep-sea habitats and their associated biota are virtually unknown, particularly in the northwest (Ponder *et al.,* 2002).

1.4.1 The physical environment of the deep-sea

Beyond the shelf break, the seafloor slopes down for thousands of metres until it extends into the continental rise and abyssal plain/deep ocean floor at >4,000 m (Gage & Tyler, 1992; Thistle, 2003). With the exception of hydrostatic pressure and current energies, most physical parameters vary little over large distances in these environments. The deep-sea is thus considered a relatively uniform and constant environment compared to coastal waters (Gage & Tyler, 1992; Levin *et al.,* 2001). Deep-sea water generally ranges from 4 to -1 ºC and is separated from shallow waters by the permanent thermocline which lies between 800 and 1,300 m water depth. Oxygen concentrations are almost at the saturation point in most regions, but decrease slightly as deep water masses move away from their origin. Salinity is also relatively constant at 34.8‰ ± 0.3 ‰ (Gage & Tyler, 1992; Thistle, 2003).

Despite the notion of relative homogeneity in the deep-sea, it is now known that deep-sea sediments are dynamic and richly textured environments shaped by physical and biological processes (Levin *et al.,* 2001). Turbidity currents, sediment slides and slumps, and debris flows move sediments from the slope onto the continental rise and abyssal plains, scarring the sediment surface and carving out canyons (Thistle, 2003). Periodic changes in bottom currents, benthic storms and seasonality in the vertical flux of organic matter add to spatial and temporal variation in the deep-sea environment (Levin *et al.,* 2001; Thistle, 2003). Hard substrates are relatively uncommon in the deep-sea, being found on the steep continental slopes, seamounts and along mid-ocean ridges. Coarse sediments of terrigenous origin are found on the continental slopes or rises, transported in the past by turbidity currents and sediment slumps through submarine canyons. Vast areas, of the abyssal plains are covered by fine biogenic sediments and clay (Gage & Tyler, 1992; Thistle, 2003). These biogenic sediments may contain skeletal material composed of silicon, calcium carbonate or aragonite. Near the continental margin these sediments can be thick, particularly on abyssal plains adjacent to passive margins such as the Western Australian continental margin (Gage & Tyler, 1992; Thistle, 2003).

1.4.2 Deep-sea biodiversity

It is now well-established that the seemingly monotonous deep-sea floors provide a habitat for many different invertebrate species and that deep-sea communities may be more diverse than shallow water environments (Gage, 1996; Sanders & Hessler, 1969; but see Gray *et al.,* 1997). Estimates for the number of species living in the deep-sea world-wide range from 500,000 to 10^7 (Butler *et al.,* 2001). Deep-sea species diversity may even be comparable to that of coral reefs and tropical rain forests (Grassle & Maciolek,1992). Diversity appears to be parabolically related to depths, with highest species diversity found on the slope in 1,000-3,000 m depths (Baguley *et al.,* 2006; Etter & Grassle, 1992; Paterson & Lambshead, 1995; Rex, 1981; Rex *et al.,* 1993). A latitudinal gradient has also been described in the North Atlantic, with higher diversity associated with low latitudes. This pattern appears less obvious in the southern hemisphere (Rex *et al.,* 1993; Stuart *et al.,* 2003). The number of large benthic animals living on the deep-sea floor (megabenthos) may be low, and the vast majority of deep-sea animals are small invertebrates living in the sediment (Sanders & Hessler, 1969; Lambshead, 1993). The dominant taxa of deep-sea soft bottoms are polychaetes, nematodes and foraminifers followed by crustaceans and bivalves (Thistle, 2003). Other invertebrates that occur in significant numbers are worms belonging to the phyla Pogonophora and Sipunculida (Miller, 2004). On hard bottoms, sponges, gorgonians, and black corals (antipatharians) dominate (Thistle, 2003).

Food availability is one of the most important limiting factors in the deep-sea. All life in the deep-sea, with the exception of hydrothermal vent and cold seep communities, is directly or indirectly dependent on the transport of organic matter to the ocean floor (Miller, 2004; Sokolova, 1997). Since the pelagic and benthic community share the same food source, the amount of food sinking to the ocean floor ultimately depends on the feeding rate in the water column. Hence there is a general trend towards a decrease in biomass and size with increasing depth (Miller, 2004; Sanders *et al.,* 1965). Globally, primary productivity and terrestrial run-off contribute significant amounts of carbon to the deep-sea which decreases significantly with increasing distance from land. On the Australian slope, however, there is a relatively low terrestrial run-off. The lowest benthic biomass is thus found on abyssal plains far from shore where surface productivity is very low (Miller, 2004; Thistle, 2003).

1.4.3 Threats to the deep-sea environment

Anthropogenic activities impact the deep sea environment in a variety of ways (Gage & Tyler, 1992; Thiel, 2003). Extensive deposits of commercially important minerals (e.g. Ferro-manganese nodules containing Co, Ni, Mn) can be found on the abyssal plains of all oceans (Gage & Tyler 1992; Baker *et al.,* 2001). Deep-sea mining for mineral deposits has been seriously considered, and exploratory mining has been conducted in the Atlantic and Pacific (Gage & Tyler, 1992; Thiel, 2003). So far there have been no mining efforts for minerals in the deep-sea within the Australian Exclusive Economic Zone (Ponder *et al.,* 2002). Mineral mining may have a greater effect on deep-sea biological communities compared to communities in shallow water due to their slow growth and re-colonisation rates.

In other parts of the world the deep-sea environment has already been exploited as a dump for industrial wastes. Deep-sea dumping is currently not standard practice in Australia, although some dumping of dredge spoil does occur (Ponder *et al.,* 2002).

Although the deep-sea fish diversity appears to be high along the northwest slope, the long-lived, slow-growing and late maturing fish community does not support a high productivity and is thus not likely to be exploited commercially. Commercial fishing of orange roughy, blue grenadier, oreos, and gemfish has been mainly conducted along the upper and mid-slope of southeast Australia and the Great Australian Bight (Williams *et al.,* 1996, 2001).

We now know that due to its high degree of endemism and low growth, reproduction and re-colonisation rates, the deep-sea is a fragile environment that recovers very slowly after disturbance. The KEFs included in this report have been chosen based on their representation of several major deep-sea geomorphic features, such as submarine canyons, abyssal plains and plateaus, some of which are considered to be of high conservation value and deserve adequate protection (Gage & Tyler, 1992; Newton, 1999; Schlacher *et al.,* 2007).

1.5 Regional background

1.5.1 Geology

The western Australian continental margin is a passive margin that is drifting away from the spreading centre in the Indian Ocean (Falvey & Veevers, 1974; Powell, 1976; Veevers, 1986). The margin extends from Cape Leuwin in the south to the northwest shelf in the north and represents an area of approximately 1,239,690 km^2. The overall morphology of the region, e.g. the development of the plateaus, owe its origins to the rifting of Australia and the opening of the Indian Ocean after the initial break-up of Gondwana between 95 and 83 Ma ago (Veevers, 1986). A complete geological history of the margin is outside the scope of this report but is summarised in Stagg *et al.* (1999).

Seafloor sediments range from sand and gravel on the shelf to mud on the slope and abyssal plain (Baker *et al.,* 2008; van Andel & Veevers, 1967). Calcium carbonate is the dominant constituent of the seafloor sediments and is abundant both on the shelf and the slope. Terrigenous sediments are a minor component and mostly occur on the inner shelf close to river mouths (Colwell & Von Stackelberg, 1981).

1.5.2 Local oceanography

The Eastern Indian Ocean along the northwestern Australian coast is dominated by a tropical equatorial climate north of 25°S (Reddy, 2007). Surface currents in this region include the Indonesian Throughflow, Leeuwin Current and Undercurrent, South Equatorial current, and the West Australian Current (Reddy, 2007). The Indonesian Throughflow and the Leeuwin Current flow poleward and carry warm, low-salinity tropical water into the region. The Leeuwin Current is the only example of a southward flowing eastern boundary current, and it has a major influence on the regional ocean climatology, sedimentology, and biota. Significant upwelling of nutrient-rich deep water does not occur along much of the Western Australian coastline, and biological productivity in the region is relatively low (Demopoulos *et al.,* 2003; Reddy, 2007). The South Equatorial Current starts around longitude 110°E and moves towards the west away from the Australian continent. It is generated by the southeast trade winds. The West Australian Current is a derivate of the circumpolar Westwind Drift and transports cold water north along the west coast of Australia towards the equator. At latitudes of

16-20°S, it joins the South Equatorial current. Opposing undercurrents are the Leeuwin Undercurrent and the West Australian Current.

Like the Atlantic and Pacific Oceans, the deep water masses in the Indian Ocean below 3,800 m consist mostly of cold Antarctic Bottom Water. Antarctic Bottom Water fills the Great Australian Bight and then moves west and north into the Indian and Pacific Oceans. The oxygen concentration follows this flow pattern, with the concentration in the bottom water decreasing towards the north. From a depth of 1,500 to 3,800 m, the Indian Ocean is dominated by Indian Ocean Deep Water formed from North Atlantic Deep Water (Demopoulos *et al.,* 2003).

Sediment transport on the shelf is largely influenced by tidal currents while on the slope and abyssal plains sediment transport is mostly influenced by large ocean currents and slope processes (Baker *et al.,* 2008).

1.5.3 Provincial bioregions of the North-west Marine Region

The Integrated Marine and Coastal Regionalisation of Australia (IMCRA v. 4.0) identified eight bioregions for the North-west Marine Region; four transitions and four provinces (Fig. 1.4). The bioregions are defined by demersal fish data and geomorphology, the latter particularly important in deep waters. Transitions are areas of mixed faunas and species overlap, while provinces are areas of high endemism and distinct fish communities. With respect to the KEFs - the plateaus, canyons, Glomar Shoals and the ancient strandline fall into provinces while the two abyssal plains and the Wallaby Saddle fall into transitions. This would indicate that KEFs located within provinces (e.g. plateaus and canyons) may be characterised by distinct fauna compared to the KEFS located in transitions (e.g. abyssal plains and the Wallaby Saddle) which may be characterised by species with a broader range.

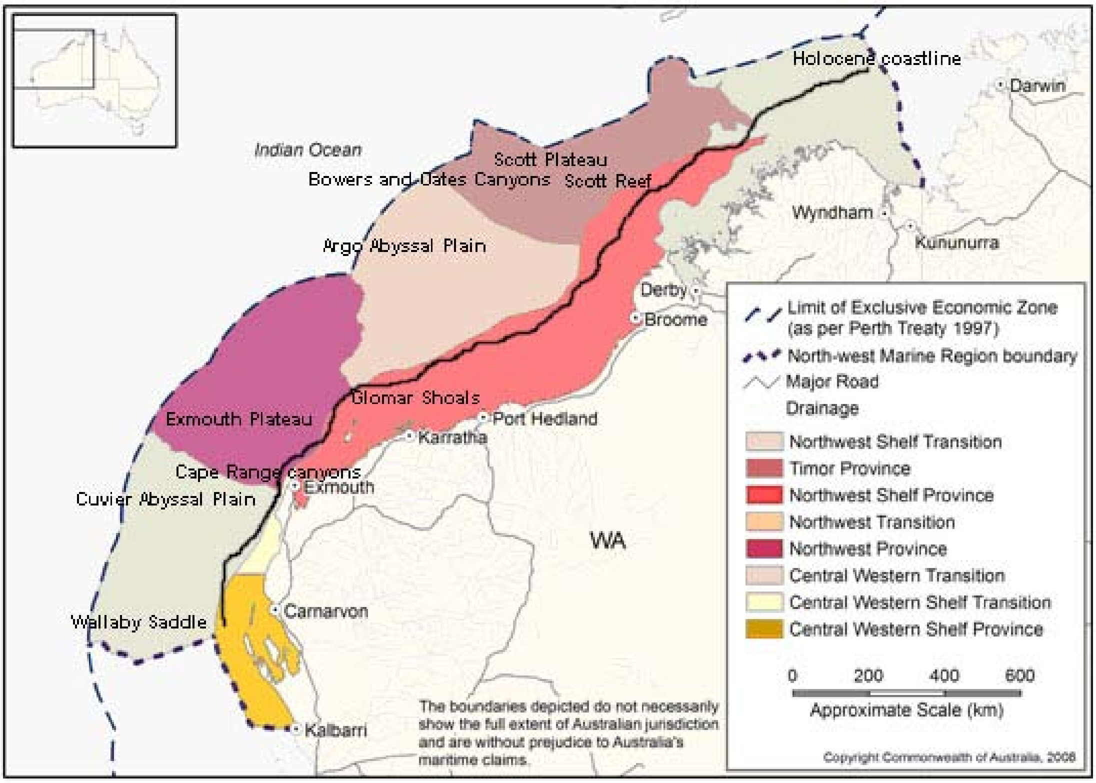

Figure 1.4. Provincial bioregions of the North-west Marine Region. The shape of the Holocene coastline is an approximation.

1.5.4 Commercial and Industrial Development

The northwest shelf and slope are used by many different stakeholders. The Shark Bay Prawn, Exmouth Gulf Prawn and Shark Bay Scallop Fisheries are the main commercial fisheries in the region. More recently a small fishery of deep-water goldband snapper has developed. The Exmouth Gulf is the location of a highly productive and profitable prawn industry as well as a growing ecotourism industry based on the Ningaloo Reef and the seasonal presence of whale sharks. Recreational fishing is a major tourist attraction and aquaculture developments are of economic importance (Fletcher & Santoro, 2007).

The northwest shelf is also a region of significant oil and gas reserves, with more than 65 active fields on the shelf and upper slope (Petroleum and Royalties Division, 2007, 2008). Given the combination of high oil prices and increased demand, surveys are regularly undertaken to discover new petroleum provinces in deeper waters (Petroleum and Royalities Division, 2007).

2 Methods

2.1 Data collection and reporting

2.1.1 Biological data

Biological data were obtained from several publicly available databases, museum databases and individual researchers (Tables 2.1 & 2.2). In most cases, a spatial search was conducted using a bounding box with the coordinates for each KEF or a 5 x 5° grid search encompassing each KEF.

Table 2.1. List of databases searched for biological data

Database	Web address	Data available
World porifera database	http://www.marinespecies.org/porifera/	all sponge species recorded for the Australian EEZ/ Indian ocean, but no regional search possible
Fishbase (fishbase.org)	http://www.fishbase.org	Deep water fish for Australia (n = 734), but no individual collection data
Global biodiversity Information facility	http://data.gbif.org/welcome.htm	Fish / invertebrate data (species names and location) for Cape Range canyons
Ocean Biogeographic Information Systems	http://www.iobis.org/OBISWEB/OBIS.jsp	Geographic search leads to species list, but no individual collection data
Integrated Taxonomic Information System	www.itis.gov	Search by species name only
Marine and Coastal Data Directory of Australia	http://www.marine.csiro.au/cgi-bin/mcdd_spatial/spatial_MBR.pl	None (Internal Server Error message appeared when region was defined)
CSIRO Marine and Atmospheric research	http://www.marine.csiro.au/marlin/csq-chooser.htm	Survey information and phytoplankton bioregion map
CSIRO Data Trawler	http://www.marine.csiro.au/warehouse/jsp/loginpage.jsp	CTD, hydrology and species data of individual surveys

Species data obtained from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) mostly contains fish records and the occasional invertebrate record. Museum data largely consists of invertebrate records. Additionally a map of Australia's marine phytoplankton bioregions was obtained from MarLIN, the CSIRO – Marine and Atmospheric Research Laboratories Information Network (Table 2.1). Records from the Oceanographic Biogeographic Information Systems were obtained from 0.05 – 5.0° grids overlapping each KEF, depending on the size of the KEF. The 125 m isobath was not included in this search due to the lack of specificity of the grids for this particular feature. OBIS records are listed in the Appendix but are not included in the biological samples presented below due to the lack of station locations from which each specimen was collected.

Table 2.2. List of scientists and institutions that provided data for this study

Data source	Contact	email	Data provided
Australian Museum	Mark McGrouther	Mark.McGrouther@austmus.gov.au	Fish data (resolution: species or genus level)
	Dr Stephen Keable	Stephen.Keable@austmus.gov.au	Invertebrate data (resolution: species or family level)
	Ian Loch	Loch@austmus.gov.au	Mollusc data (resolution: mostly species level)
CSIRO Division of Fisheries	Dr Alan Williams	Alan.Williams@csiro.au	Fish data (species composition and abundance)
Queensland Museum	Dr Merrick Ekins	MerrickE@qm.qld.gov.au	Invertebrate data (resolution: species level)
Northern Territory Museum	Gavin Dally	Gavin.Dally@nt.gov.au	Fish and invertebrate data (resolution: species and genus level)
Museum of Victoria	Dr Gary Poore Dr Joanne Taylor	gpoore@museum.vic.gov.au	Invertebrate data (resolution: species or family level)

Increasing pressure from development has resulted in considerable research into marine ecosystems of the northwest shelf since the 1990s. Significantly, scientists from the Australian Institute of Marine Science (AIMS) have established collaborative research with the offshore oil and gas industry, the fishing and aquaculture industry, and the State Government (*e.g.* Batterham, 2001; Heyward *et al.,* 2006). Despite these fruitful collaborations, there has been little examination of the benthic biota from the deep sea environments of Western Australia. Studies that do exist for these environments include those conducted by CSIRO between 1960 and1980 (Williams *et al.,* 2001), by AIMS at the Vincent-Enfield drilling site in 2001 and 2002, and at Pluto Field (Fromont *et al.,* 2006). More recently, CSIRO conducted regional biogeographic surveys along the shelf and upper slope from Albany to Darwin to obtain a species inventory of the region (G. Poore, pers. comm.). Data obtained from these research projects are currently being analysed and will be used by State and Federal Governments for management and planning but were unfortunately unavailable for inclusion in the present study.

2.1.2 Physical data

Physical data were sourced as follows:

- Harris *et al.* (2004) and Heap & Harris (2008) provide the most comprehensive bathymetric dataset based on Geoscience Australia's bathymetry data, Royal Australian Navy data and data obtained from numerous surveys undertaken on the RV *Franklin* and RV *Southern Surveyor*. The data were combined to produce a bathymetric map with 100 % coverage and a 250 m horizontal resolution.
- Sediment data were obtained from Baker *et al.* (2008) which contains the most complete and up-to-date dataset of sediment texture and composition (percent sand, gravel, and mud) and carbonate content of the area, based primarily on data from Geoscience Australia's marine samples database MARS (www.ga.gov.au/oracle/mars).
- Effective disturbance data, an estimation of sediment exposure to mobilising forces, was derived from Hemer (2006).
- A primary productivity dataset produced by CSIRO in 2004 based on satellite imagery was also used in the analysis.
- The CSIRO MarLIN research vessel and mooring database lists all the survey data available from 1959 to present (Table 2.1). The data was searched in 5 x 5° grids using the c-squares spatial search. Surveys that had potential samples for any of the KEFs were recorded, and the data downloaded using the CSIRO Marine Data Trawler application. Data downloaded from the CSIRO database comprised conductivity, temperature and oxygen concentration measurements from a conductivity, temperature and depth recorder (CTD) and some ocean chemistry data including measurements of phosphate, oxygen, and nitrate concentrations. Some hydrology data also included temperature and salinity records.

Both physical and biological data are described, listed and mapped to determine data coverage for each KEF.

2.2 Seascapes analysis for the North-west Marine Region

Seascapes were derived for the North-west Marine Region at a resolution of 0.01 decimal degrees. These new seascapes are at a finer resolution than those previously derived in the national assessment (Fig. 1.2 and 1.3) (DEH, 2005; Whiteway *et al.* 2007) but are not necessarily nested within them. Seascapes were created using the software package ERMapper following the data sources and method outlined in Whiteway *et al.* (2007). The final seascape classification for the North-west Marine Region was divided into an on-shelf and off-shelf zone in order to incorporate the effective disturbance data. The following data were used for the seascape analysis:

- bathymetry
- % gravel
- % mud
- seafloor temperature
- slope
- primary production
- effective disturbance (on-shelf only).

The distance ratio was used to determine the optimal number of classes in each analysis. The distance ratio is the ratio of the average of the mean distance of each class member from its class mean to the overall average distance of each member from the overall mean. The smaller the ratio the closer on average the class members are to their class means. Distance ratios were plotted versus the number of classes (3 to 20 classes) and the local minimum used to determine the optimal number of classes (Whiteway *et al.,* 2007).

The seascapes were first characterised by their mean depth. Seascapes with a mean depth of <200 m were classified as subtidal, from 200 – 2,000 m depth as bathyal and from 2,000 – 6,000 m as abyssal (Gage & Tyler, 1992). After depth, the seascapes were characterised by ranking the mean values of the remaining physical properties for each seascape. The three top and bottom values of each physical property were used to further characterise the respective seascape (Fig. 2.1) (Whiteway *et al.,* 2007).

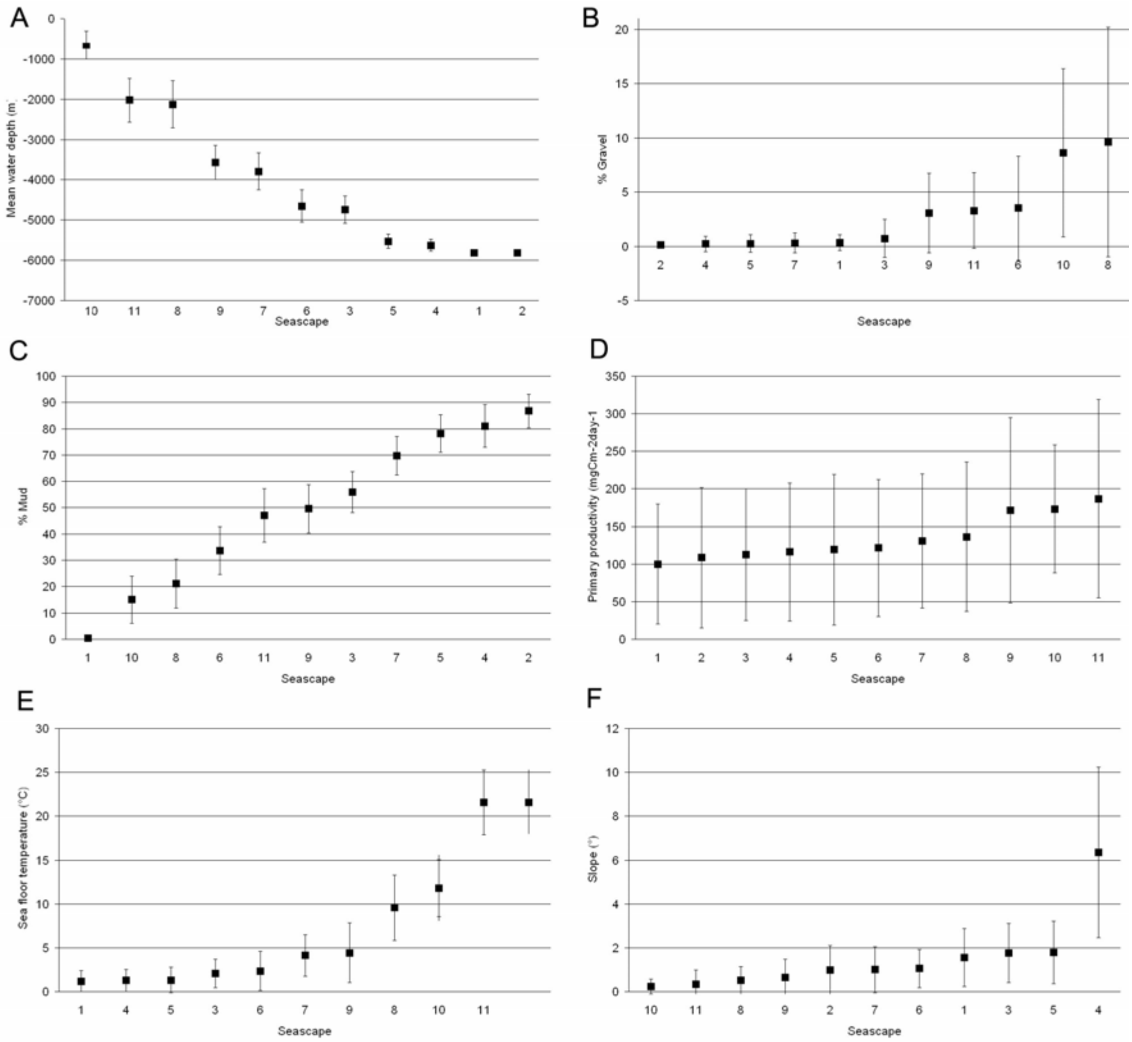

Figure 2.1. Graphs of seascape versus abiotic factors: (A) water depth; (B) gravel content; (C) mud content; (D) primary production; (E) seafloor temperature; (F) slope for the off-shelf seascapes of the North-west Marine Region. Physical properties with the three highest and lowest mean values are used as distinguishing properties in naming each of the seascapes. Plots show means and limits of one standard deviation.

2.3 Focal variety analysis

The focal variety analysis provides a spatial representation of seafloor habitat heterogeneity based on the final seascape classification for the on-shelf and off-shelf northwest region and the geomorphology classification for the same regions. Areas of high seascape and geomorphic diversity were identified using Spatial Analyst Tools in ArcGIS. The focal variety tool determines the number of different seascapes within a specified radius on an input raster and sends the result (named focal variety index) to a corresponding cell on an output raster (Fig. 2.2). The number of neighbouring cells was determined to be 20 (equivalent to ~ 25 km^2) for the analysis of the entire North-west Marine Region (Section 2.2) and 10 (~ 12.5 km^2) for the detailed analysis of Glomar

Shoals and surrounds (Section 2.4). Areas of high seascape diversity are represented by a high focal variety index while areas of low seascape diversity are represented by a low focal diversity index.

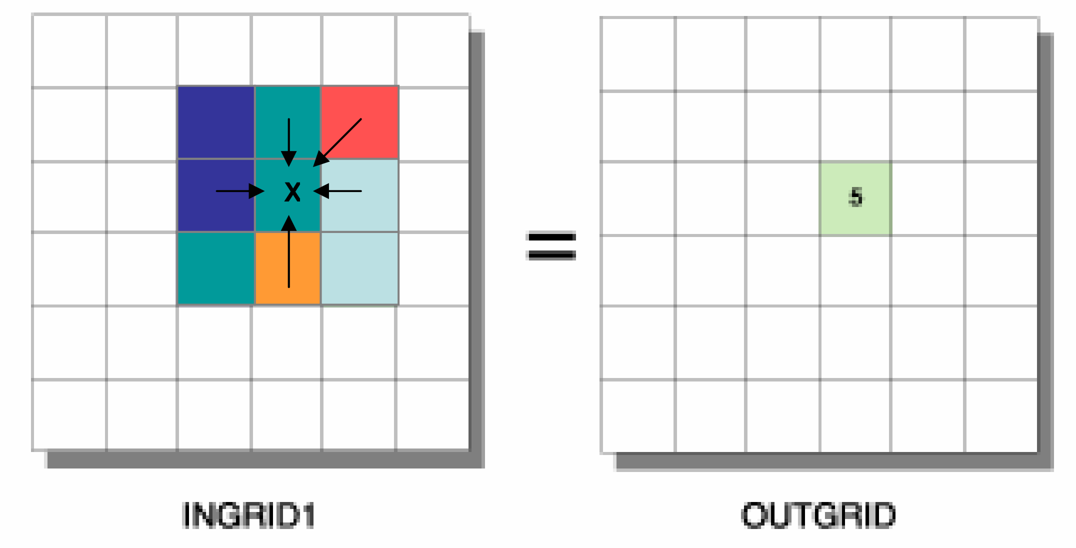

Figure 2.2. Methodology for calculating the focal variety index for individual cells based on the final seascape analysis of the North-west Marine Region (Whiteway et al., 2007).

2.4 Seascape analysis for Glomar Shoals

Seascapes were created on a local scale for Glomar Shoals and its immediate surrounds with and without the integration of biological data to investigate whether biological data contributes to the identification of seascapes. Seascapes were created without biological data using the methods in Section 2.2. Seascapes were created with biological data by adding a layer that includes univariate biodiversity data to the analyses. The biological dataset comprised demersal fish catch compositions and trawl locations from a cruise of the Russian fishery research vessel *Berg-3* carried out in Australian waters between May and July 1967. Of a total of 354 trawls from the northwest shelf, 113 trawls covering Glomar Shoals and surrounds were chosen for the analysis (Fig. 2.3). Most records included catch composition by species (presence/absence), some data on length frequency, maturity and diet of commercially important species and the collection coordinates. The 113 samples comprised 152 fish species of which 106 occurred in numbers of <100 individuals and a further 33 species of <1,000 individuals.

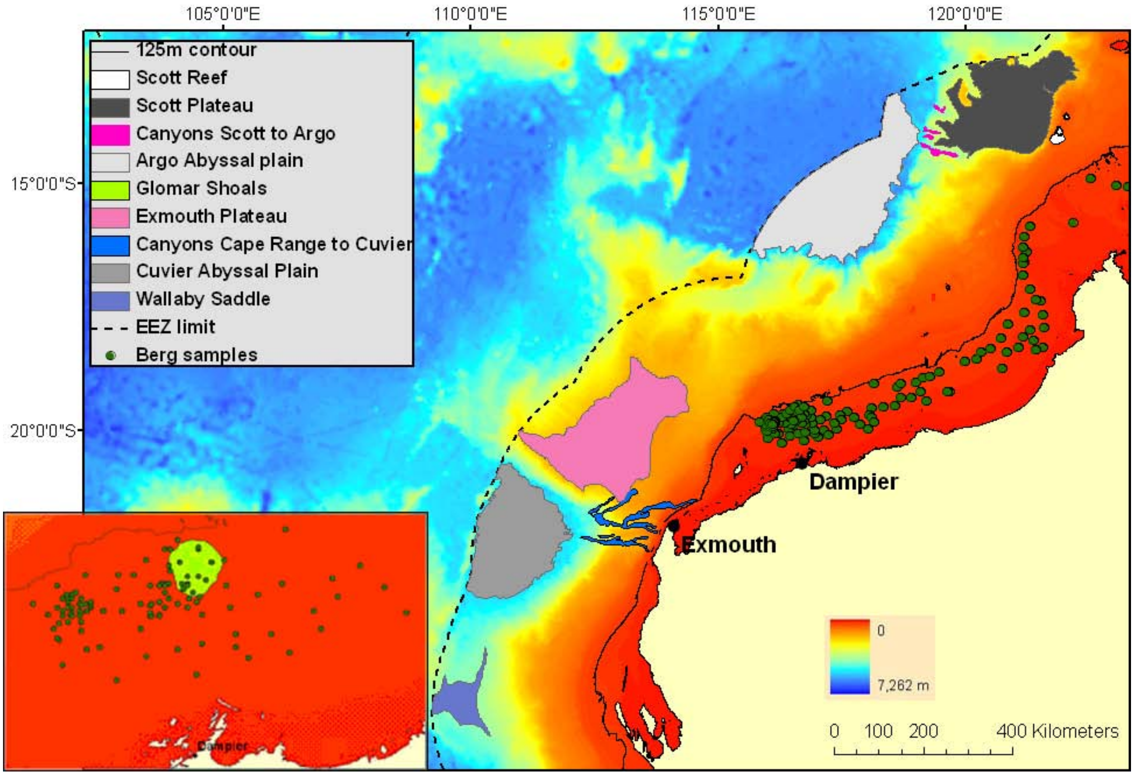

Figure 2.3. Biological samples covering Glomar Shoals and immediate surrounds from the Berg-3 1967 survey. Biological samples shown as green points. The inset map shows the area for which biological data was integrated into seascapes.

The multivariate assemblage data was reduced into a single diversity index using the statistical package PRIMER v.5. The Shannon diversity index (*H′*) was used as a measure of diversity in terms of species richness and abundance distribution. The resulting diversity indices were then interpolated as a spatial layer in ArcGIS. The result of this interpolation is shown in Fig. 2.4. Areas coinciding with a high *H′* are represented in red and areas coinciding with a low *H′* are represented in green. Glomar Shoals is characterised by high *H′* values. Interestingly, the area adjacent to the western Glomar Shoal margin is characterised by very low *H′* values (Fig. 2.4).

Seascapes and focal variety analyses of Glomar Shoals and its immediate surrounds were performed both with and without the integration of biological data as described in Sections 3.8.1 and 3.8.2 respectively.

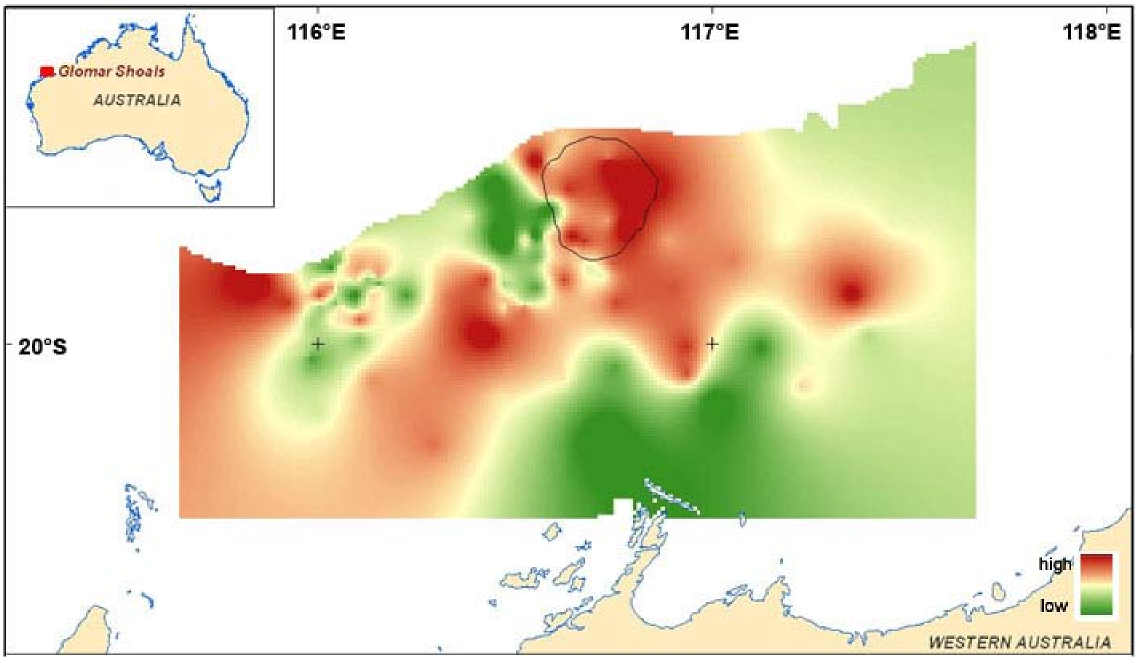

Figure 2.4. Shannon diversity indices interpolated as spatial layer to include into seascapes analysis. Glomar Shoals is outlined with the black line.

2.5 Fish assemblages of Glomar Shoals area

Demersal fish assemblages at Glomar Shoals were compared to those of surrounding areas using multivariate procedures to investigate whether they would be significantly different. We performed the Analysis of Similiarities (ANOSIM) to test the null hypothesis that there are no differences in fish assemblages between Glomar Shoals and adjacent areas, and we used non-metric multidimensional scaling plots to visualise similarities between sites. All multivariate analyses were conducted in Primer v. 5.

Prior to statistical analysis, rare species were removed from the original dataset to increase the chances of an interpretable ordination result. Species were considered rare when they contributed less than 4 % of the total abundance of any sample. The resulting data matrix consisted of 69 species (instead of the 152 species in the original dataset), which is comparable to the recommended number of 50-60 species for this type of analysis (Clarke & Warwick, 2001). The abundance data of the remaining species were square-root transformed to allow stronger weighting of the remaining rarer species.

Similarities between sites were based on the abundance of the remaining fish species and determined using the Bray-Curtis similarity coefficient. This coefficient provides good results for ecological data since it does not measure the absence of species which may be due to the distribution limits of the species (Clarke & Warwick, 2001).

The resulting rank similarity matrix is the basis for the calculation of the global *R* statistic, which is a measure of the degree of separation of sites and lies in the range from -1 to 1. *R* is approximately zero if the null hypothesis is true and differences between and within sites are the same on average. $R = 1$ only if all samples within Glomar Shoals are more similar to each other than any samples from the surrounding sites. If the probability of *R* occurring is less than 5 % (<0.05) if H_0 is true then the null hypothesis is rejected indicating that fish assemblages at Glomar Shoals are different from those of the surrounding areas.

The similarity between sites based on their fish assemblages was visualised by non-metric multidimensional scaling (nMDS). Distances between sites in this ordination represent their similarities in species presence and abundance. Thus sites that cluster on the nMDS plot have similar fish assemblages, sites further apart have fish assemblages that are less similar in species composition and abundance.

The importance of individual species to the entire fish assemblage similarities between Glomar Shoals samples was investigated using the SIMPER routine (Clarke & Warwick, 2001). This routine converts Bray-Curtis similarities between all pairs of samples into percentage contributions from each species.

2.6 Linking fish diversity to environmental variables at Glomar Shoals

To examine to what extent the physical data “explain” the observed biological pattern, namely the similarity of fish assemblages between sites, the biological and physical data were analysed using the BIO-ENV procedure in PRIMER v.5.

The analysis of the biological pattern was based on the reduced, square-root transformed fish dataset as described in the previous section to reduce the chance of unpredictable relationships to the environmental variables. The environmental data were extracted from the respective spatial layers of the on-shore seascapes analysis using the Hawths Tools in ArcGIS. Hence the environmental data available for the statistical analysis were: bathymetry, % gravel, % mud, seafloor temperature, slope, primary production, and effective disturbance. All environmental data except the bathymetry data were ln(x+1) transformed to achieve a normal distribution, and all data were standardised to give each variable equal weighting (Clarke & Warwick, 2001).

The BIO-ENV procedure is outlined in Fig. 2.5. The basis for the analysis is similarity matrices underlying both datasets which differ to match the respective form of data. Bray-Curtis similarity coefficients were used for the biological data, and Euclidean distances were used for the environmental data (Clarke & Warwick, 2001). Their similarity ranks, however, can be compared through a rank correlation coefficient ρ. In this analysis the Spearman coefficient was used as it is appropriate for comparing similarity matrices derived from different types of coefficients (Bray-Curtis versus Euclidean distance).

The Spearman coefficient ρ lies in the range of -1 to 1 with the extremes of ρ corresponding to the cases where the two sets of ranks are in complete opposition (-1) or complete agreement (1). Values of ρ around zero correspond to the absence of any match between the two similarity matrices. Subsequently ρ is maximised for a certain combination of environmental variables.

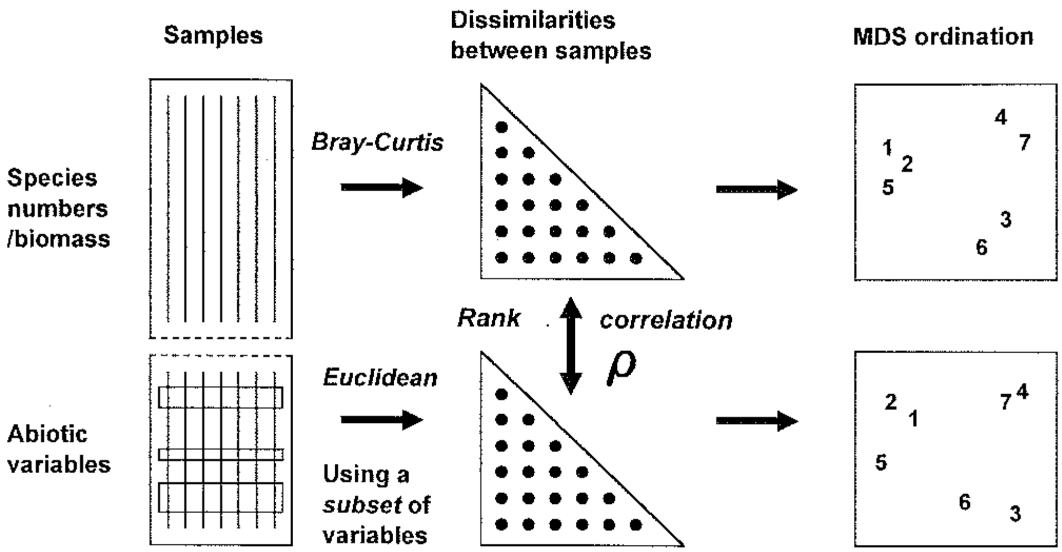

Figure 2.5. Schematic diagram of the BIO-ENV procedure in PRIMER v.5 (from Clarke & Warwick 2001).

3 Results

Data collation and seascape results are presented according to each broader geomorphic feature associated with each KEF since geomorphology was used as the basis for defining most of the KEFs in this report. For each KEF, the following are presented unless otherwise specified:

- A general description of the relevant geomorphologic feature (except Scott Reef)
- A general description of the KEF.
- Synthesis of available physical data (except Scott Reef).
- Synthesis of available biological data (except Scott Reef).
- Results of high resolution seascape analysis for each KEF.
- Integration of biological data into seascapes analysis (Glomar Shoals only).
- Statistical analysis of fish assemblage data to a) reveal similarities between KEF and surrounding areas; b) investigate correlation between environmental properties and fish assemblages (Glomar Shoals only).

More information about Scott Reef's role as a KEF can be found in Donovan *et al.* 2008.

3.1 Abyssal plains

Abyssal plains are the most extensive geomorphic features of the seafloor. They are generally defined as deep-sea areas of flat, relatively homogeneous ocean floor in depths of greater than 4,500 m (Blondel & Murton, 1997, Newtown, 1999). The homogenous seafloor is created by accumulation of material either transported from the continental margins (e.g. through submarine canyons) or raining down from the water column. Blanketing of geomorphic features on the seafloor contributes to the uniformity of the seafloor. Few systematic investigations of abyssal plains have been undertaken due to the great difficulty and cost in investigating the deep-sea floor. Consequently abyssal plains have remained largely unexplored and uncharacterised.

The size of abyssal plains implies that these areas potentially harbour huge numbers of species (Grassle, 1989; Grassle & Maciolek, 1992). High species richness coupled with low abundances and high local diversity has been found on three abyssal plains in the eastern Atlantic and the Clipperton-Clarion Fracture Zone in the equatorial Pacific. However, whether the diversity resembles real faunistic provinces or gradual changes in species composition still needs to be determined (Hessler & Jumars, 1974; Paterson *et al.,* 1998).

Abyssal plain/deep ocean floor environments comprise 2.8 million km^2 or 32.2% of the Australian margin and adjacent seafloor (Heap & Harris, 2008). Compared to the rest of the Australian EEZ, the North-west Marine Region has a low percentage of abyssal plain/deep ocean floor (9.4%), which accounts for only 3.5 % of the total area of deep ocean floor in the entire Australian EEZ. The Cuvier and Argo Abyssal Plains are the two abyssal plains on the northwest margin, extending well beyond the outer boundary of the Australian EEZ.

3.1.1 The Argo Abyssal Plain

3.1.1.1 General description

The Argo Abyssal Plain is located between the Scott Plateau to the northeast and the Exmouth Plateau to the south and covers an area of approximately 58,970 km^2 (15.27˚S / 117.46˚E) (Heap & Harris, 2008) (Fig. 3.1). While bathymetry data are sparse, the abyssal plain is characterised by a smooth, featureless seafloor at approximately 5,700 m depth, rising gently in the north to form the outer ridge of the Java Trench. Swales have been recognised in the southwest regions of the plain, while the western margin contains small hills (Falvey & Veevers, 1974). The tectonic development is described in several publications (Buffler, 1994; Falvey & Veevers, 1974; Gopala Rao *et al.,* 1994). According to Colwell & von Stackelberg (1981) sediments in the Argo and Cuvier Abyssal Plains mainly consist of siliceous clays composed of radiolarians, diatoms, silico-flagellates and coccoliths. Thin layers of foraminifera-rich sand are locally present. Infaunal organisms rework the sediments as indicated by the large number of burrows.

3.1.1.2 Physical data

A total of 36 samples were obtained containing physical data. The majority of physical data available for the Argo Abyssal Plain (20 samples) are hydrology data from CSIRO surveys (Fig. 3.1; Table 3.1). On some of these surveys, CTD samples were also taken.

Fig. 3.1 shows that most samples are concentrated in the margin of the Argo Abyssal plain and that there are only a few additional samples available outside the Australian EEZ. Only four sediment samples were recorded from four different surveys (Table. 3.1).

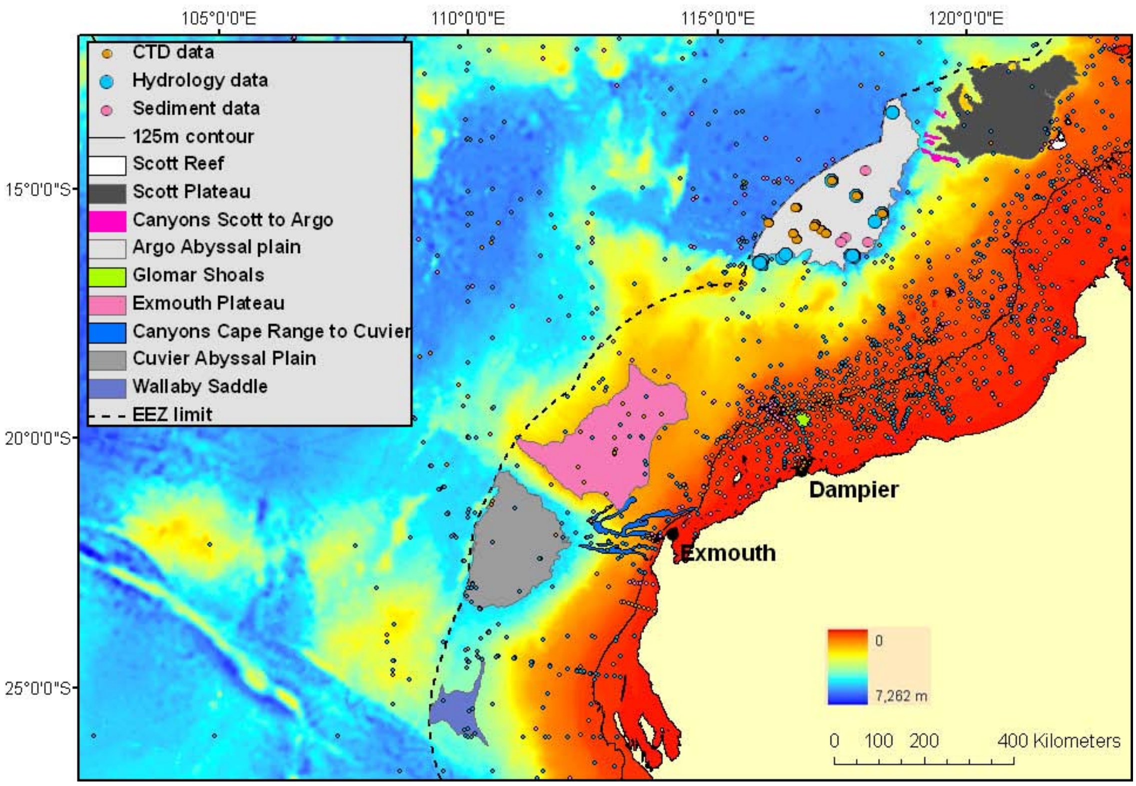

Figure 3.1. Location of physical samples from the Argo Abyssal Plain with sample locations shown by larger points.

Table 3.1 Metadata for hydrology, CTD and sediment samples from the Argo Abyssal Plain.

Data Source	Vessel	Collection year	Data Type	No. of Samples
CSIRO 'Marine Data Trawler'	HMAS *Diamantina*	1961	Hydrology data	1
	HMAS *Diamantina*	1969	Hydrology data	1
	RV *Soela*	1976	Hydrology data	1
	RV *Franklin*	1987	Hydrology data	13
	RV *Soela*	1987	Hydrology data	4
	RV *Soela*	1987	CTD data	9
	RV *Franklin*	1987	CTD data	3
Lamont Doherty Earth Observatory	*Vema*	1971	Sediment data	1
Geomar (Germany)	RV *Sonne*	1978	Sediment data	1
Geoscience Australia	Rig Seismic	1986	Sediment data	1
Ocean Drilling Program	Joides Resolution	1988	Sediment data	1

3.1.1.3 Biological data

The data search for the Argo Abyssal Plain generated no results. However, there is biological data available from three locations on the Argo Abyssal Plain outside the Australian EEZ (Fig.3.2; Table 3.2). The Northern Territory Museum holds one fish record and two echinoderm records. Curiously, the echinoderm records are from very shallow depths, 30 and 60 m respectively. There are currently insufficient data available for the Argo Abyssal Plain to provide an accurate depiction of its fauna.

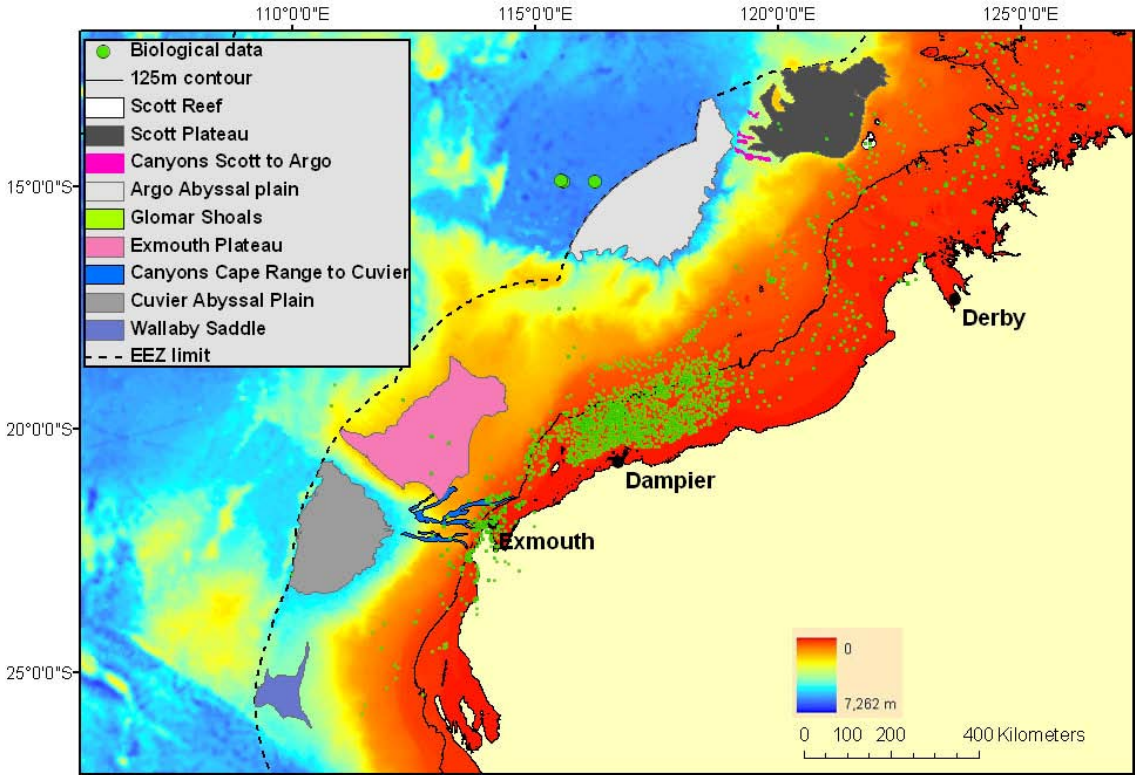

Figure 3.2. Location of biological samples from the Argo Abyssal Plain shown in larger green points.

Table 3.2. Metadata for biological samples from the Argo Abyssal Plain.

Data Source	Vessel	Collection year	Data Type	No. of Samples
NT Museum		1982	Fish data	1
		1975/1986	Echinoderm data	2

3.1.1.4 Seascapes and focal variety analysis

The Argo Abyssal Plain largely coincides with a single seascape in the offshore seascape analysis of the North-west Marine Region (Seascape 2) (Fig. 3.3). This seascape has a depth range of 4,215 – 5,977 m with a mean of 5,350 m which puts it into the abyssal zone of Australia's margin (Gage & Tyler, 1992). It is the seascape with the deepest depth range and mean depth. Seascape 2 is also characterised by the lowest gravel content and seafloor temperatures and the highest mud content. These characteristics correspond well to the general description of abyssal plains as uniformly cold and muddy environments.

In contrast, the abyssal plain margin coincides with two other seascapes; Seascape 1 along the southern margin and Seascape 4 along the Northern margin (Fig.3.3). Seascape 1 mainly coincides with the Wallaby Saddle and hence will be described in detail in Section 3.4.1.3. Seascape 4 has the largest depth range of all seascapes with a range of 1,729 – 5,480 m. Its mean depth is 3,856 m which puts it into the abyssal zone (Gage & Tyler 1992). It is also characterised by the 2nd-lowest gravel content and primary production values, the 2nd-highest mud content, the highest slope values and the 3rd-lowest seafloor temperatures. Not surprisingly, seascape 4 is only found along the abyssal plain and plateau margins where the slope drops deeply into the abyss (Fig.3.3).

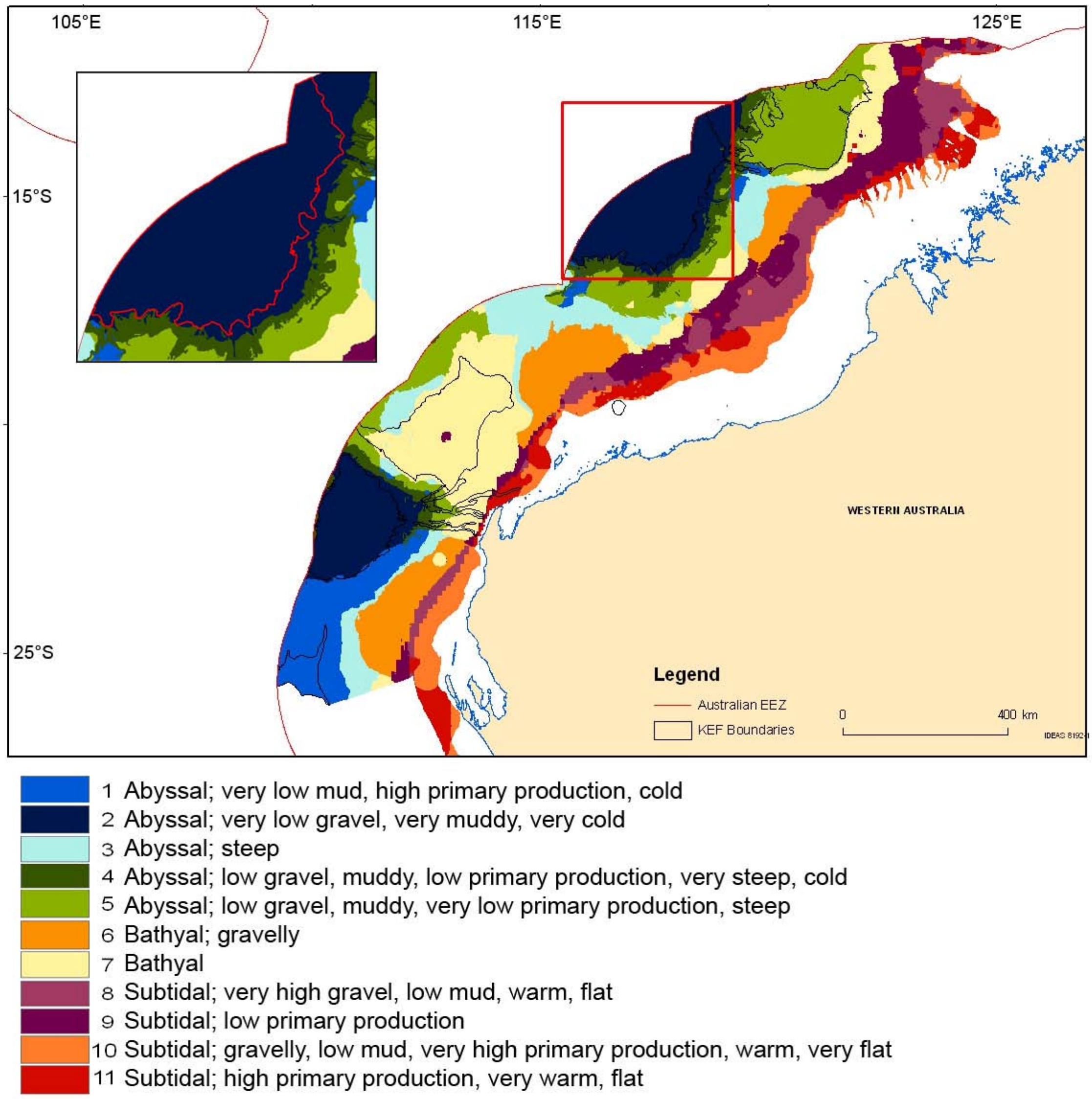

Figure 3.3. Map of seascapes for the Argo Abyssal Plain.

Almost the entire Argo Abyssal Plain coincides with one seascape indicating that it is a physically homogenous environment (Fig. 3.4). This is further supported in the focal variety analysis, a spatial representation of habitat diversity, which shows a low focal variety index for most of the plain and higher indices for the plain margin (Fig. 3.4).

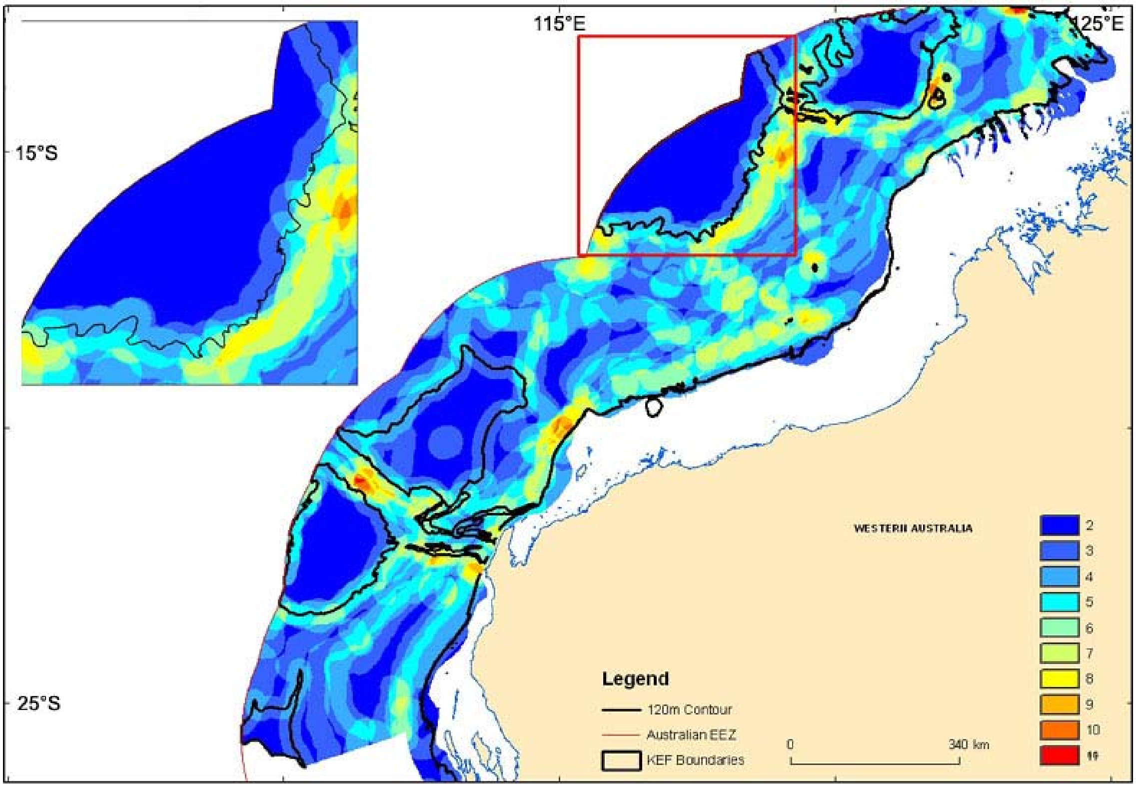

Figure 3.4. Map of focal variety indices for the Argo Abyssal Plain.

3.1.2 The Cuvier Abyssal Plain

3.1.2.1 General description

The Cuvier Abyssal Plain is located southwest of Exmouth Plateau and north of the Wallaby Plateau, covering an area of approximately 40,140 km^2 within the Australian EEZ (22.17˚S / 110.85˚E) (Heap & Harris, 2008). At a mean depth of 5,070 m, it is shallower than the Argo Abyssal Plain which may due to the greater deposition of terrigenous material from the continent (Falvey & Veevers, 1974). The plain deepens to the northwest to form a possible drainage system into the deeper Wharton Basin. Two high (>2,000 m) ridges reach northwards into the plain from the south separating it from the Wallaby Plateau. Similar to the Argo Abyssal Plain, abyssal hills occur on the western margin (Falvey & Veevers, 1974).

3.1.2.2 Physical data

A total of 28 samples were obtained containing physical data, including 17 CSIRO hydrology and seven CTD data records (Fig. 3.5; Table 3.3). Data from 10-15 sites outside the Australian EEZ were also recorded. Similar to the Argo Abyssal Plain, most samples appear to be taken from the margin. On three RV *Franklin* surveys CTD data was also collected. Two locations were sampled for sediment analyses in consecutive years by the German research vessel RV *Sonne* (Table 3.3).

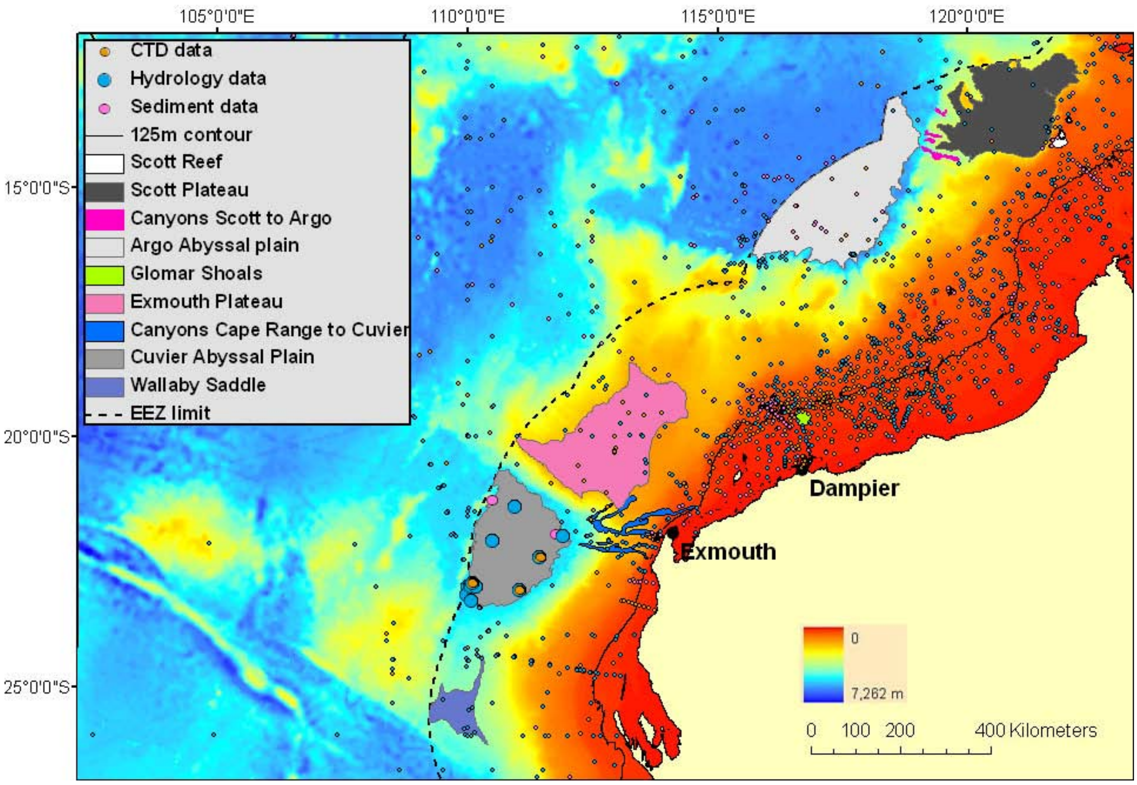

Figure 3.5. Location of physical samples from the Cuvier Abyssal Plain with sample locations shown by larger points.

Table 3.3. Metadata for hydrology, CTD and sediment samples from the Cuvier Abyssal Plain.

Data Source	Vessel	Collection year	Data Type	No. of Samples
CSIRO 'Marine Data Trawler'	HMAS *Diamantina*	1959	Hydrology data	1
	HMAS *Diamantina*	1961	Hydrology data	1
	HMAS *Diamantina*	1962	Hydrology data	2
	HMAS *Diamantina*	1963	Hydrology data	1
	Gascoyne	1963	Hydrology data	1
	HMAS *Diamantina*	1971	Hydrology data	3
	RV *Franklin*	1987	Hydrology data	6
	RV *Franklin*	1995	Hydrology data	1
	RV *Franklin*	2000	Hydrology data	1
	RV *Franklin*	1987	CTD data	4
	RV *Franklin*	1995	CTD data	2
	RV *Franklin*	2000	CTD data	1
Geomar (Germany)	RV *Sonne*	1978	Sediment data	2
	RV *Sonne*	1979	Sediment data	2

3.1.2.3 Biological data

The search for biological data for the Cuvier Abyssal Plain yielded only two crustacean records from one location in the Australian Museum (Fig 3.6; Table 3.4). Given this sparse data set, no accurate information can be provided on the biodiversity of the Cuvier Abyssal Plain.

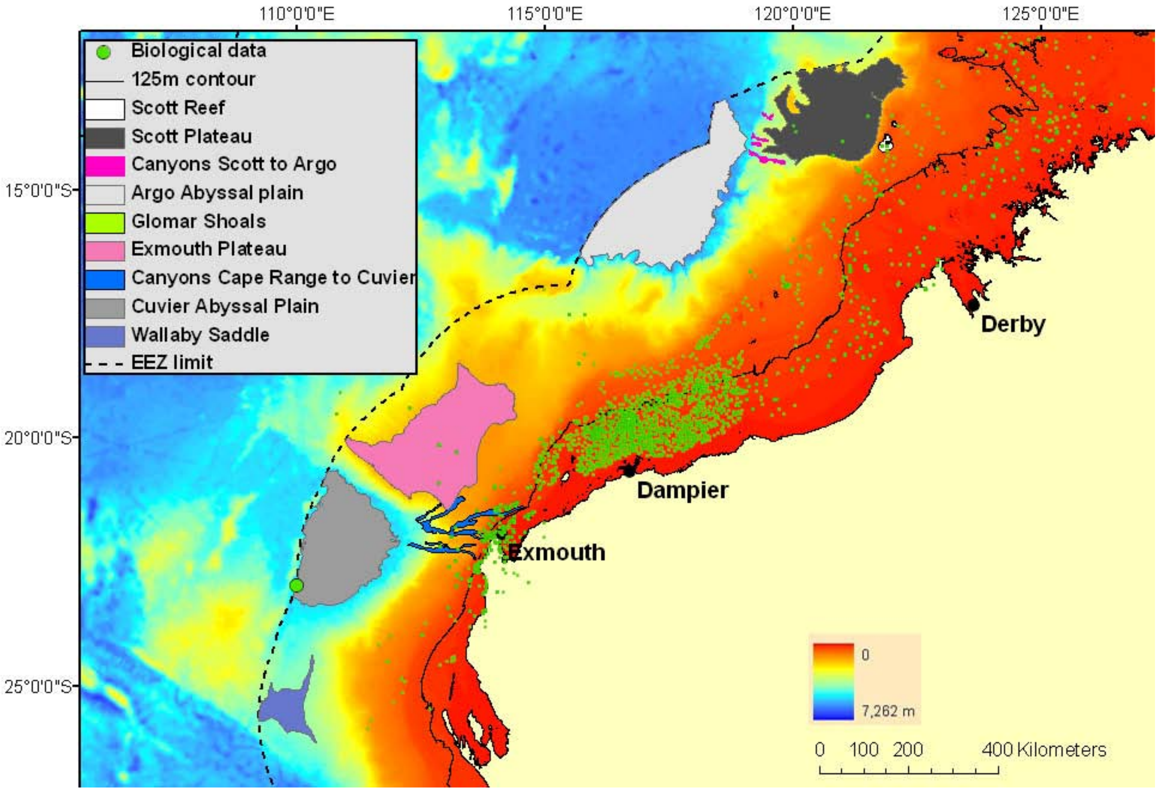

Figure 3.6. Location of biological samples from the Cuvier Abyssal Plain with sample locations shown as larger green points.

Table 3.4. Metadata for biological samples from the Cuvier Abyssal Plain.

Data Source	Vessel	Collection year	Data Type	No. of Samples
Australian Museum	HMAS *Diamantina*	1962/1963	Crustacean data	2

3.1.2.4 Seascapes and focal variety analysis

The Cuvier Abyssal Plain is largely covered by a single seascape (Seascape 2), the same seascape coinciding with the Argo Abyssal Plain, indicating that both abyssal plains represent similar physical habitats (Fig. 3.7). These results also confirm previous findings that abyssal plains are homogenous environments (Fig. 3.7). Within the offshore region, Seascape 2 only coincides with the two abyssal plains which makes these plains unique as ecosystems not found anywhere else in the region. The abyssal plain margin where the slope drops steeply into the abyss largely coincides with Seascape 4 which is accordingly characterised by high slope values.

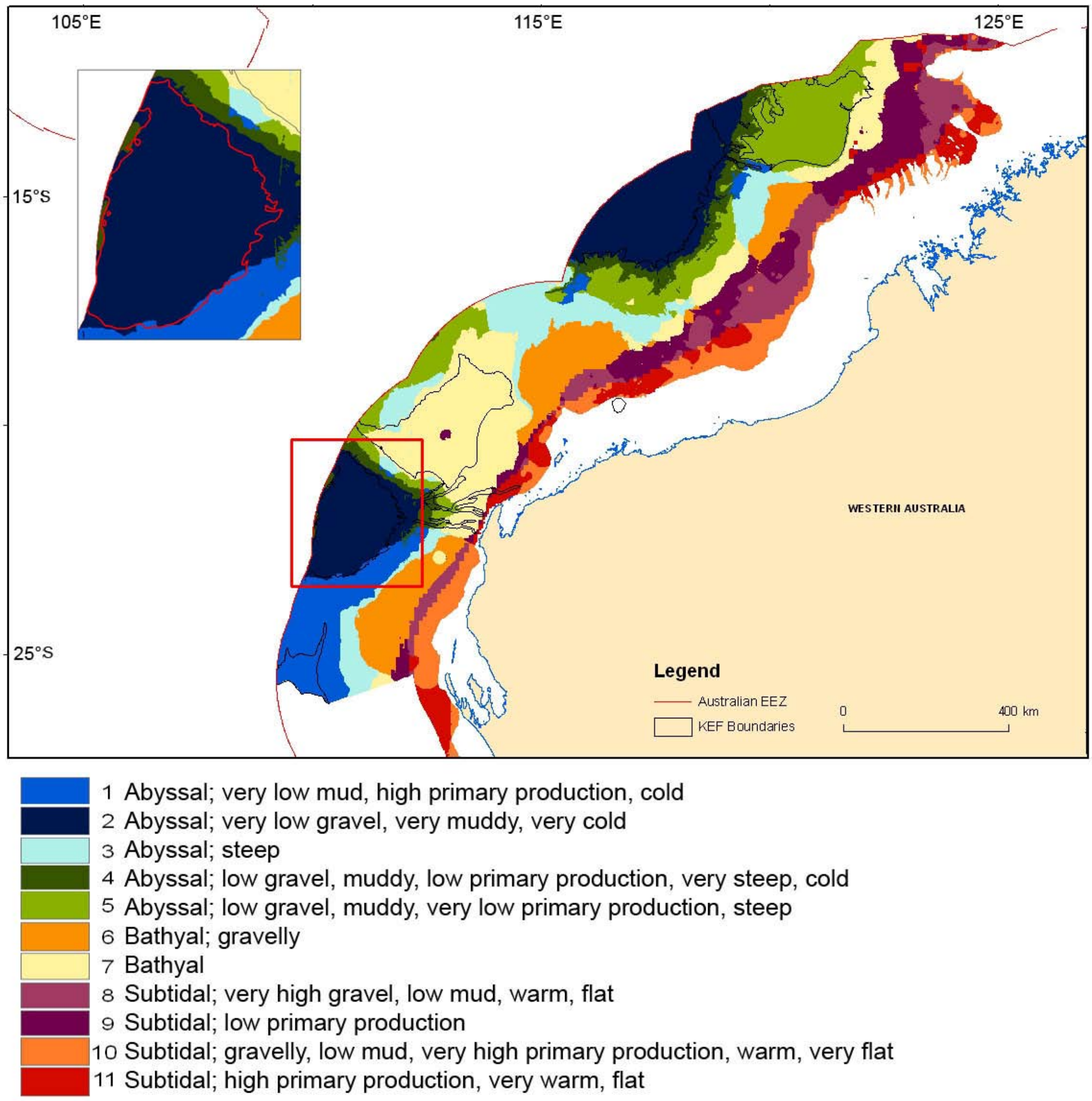

Figure 3.7. Map of seascapes for the Cuvier Abyssal Plain.

The Cuvier Abyssal Plain is an area of low habitat heterogeneity as suggested by the lowest focal variety index. The plain margin is slightly more diverse with higher focal variety indices (Fig. 3.8).

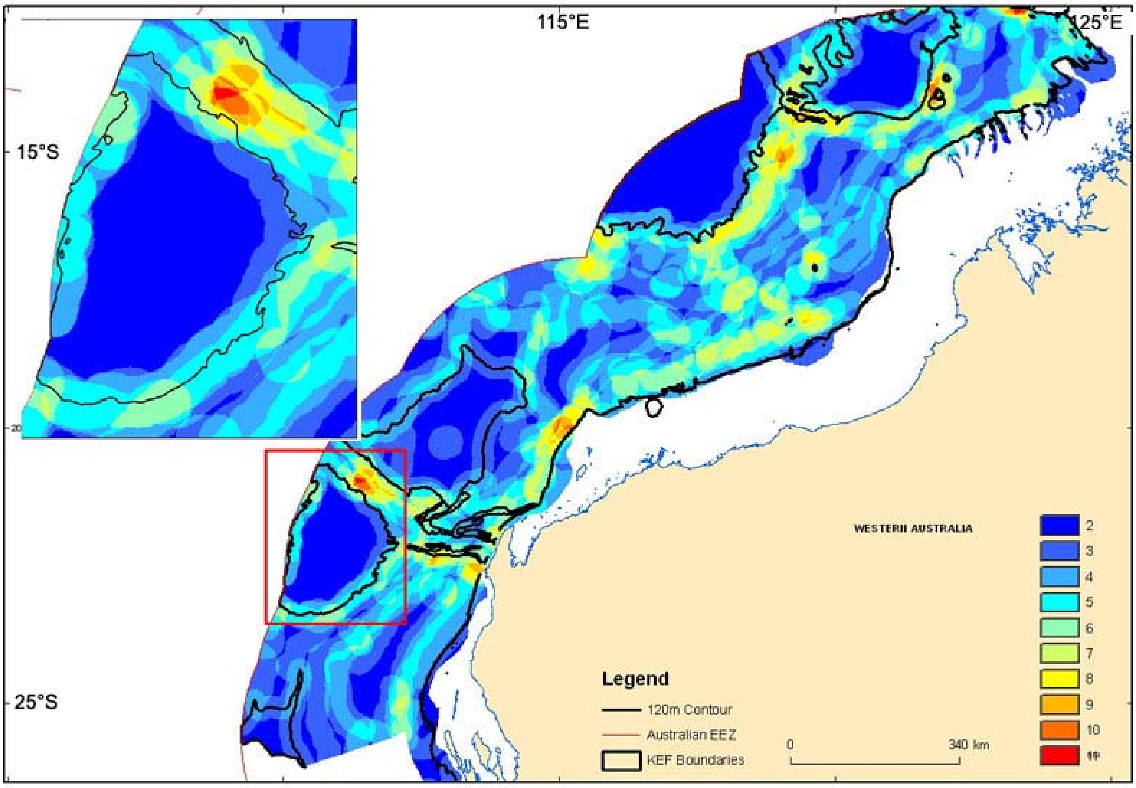

Figure 3.8. Map of focal variety indices for the Cuvier Abyssal Plain.

3.2 Marginal Plateaus

Most plateaus are steplike interruptions of the continental slopes and appear to be downwarped or downfaulted blocks of former continental shelves that subsided after rifting associated with seafloor spreading. Hence they are flat or nearly flat areas of elevation which drop off abruptly on one or more sides. Around the Australian margin, 61 plateaus have been identified, with Exmouth and Scott Plateaus being two prominent plateaus on the northwest slope (Heap & Harris, 2008). Plateaus are a distinctive feature of the Australian margin and cover the largest surface area totalling >1.4 million km^2 (16.54 %) of Australia's EEZ. Australia's marginal plateaus contribute 20 % to the area covered by marginal plateaus globally (Heap & Harris, 2008).

3.2.1 Exmouth Plateau

3.2.1.1 General description

The Exmouth Plateau is located approximately 250 km offshore of the Western Australian coast and generally trends NE-SW (17.41˚S / 116.42˚E) (Fig. 3.9). It covers 49,310 km^2 and occurs in water depths of 800 to 4,000 m (Exon & Willcox, 1980; Heap

& Harris, 2008). The geological development, stratigraphy and structure of the Exmouth Plateau have been well-described in numerous studies (*e.g.*, Exon *et al.,* 1982; Exon & Willcox 1978, 1980; Falvey & Veevers 1974; Heggie *et al.,* 1993; Willcox & Exon 1976).

The plateau surface is relatively rough and undulating, lying in 900 and 1,000 m water depth (Falvey & Veevers, 1974). The northern margin is steep and intersected by large canyons (e.g., Montebello Canyon, Swan Canyon) with relief of >500 m and spurs (Platypus Spur, Wombat Plateau, Echidna Spur, Emu Spur) (Exon *et al.,* 1982; Exon and Willcox, 1980; Ramsay & Exon, 1994). The western margin is moderately steep and relatively smooth. The southern margin is gently sloping and virtually free of canyons (Exon *et al.,* 1982).

Surface sediments are dominated by calcareous oozes (sediment containing 30 % skeletal material by weight) of foraminiferal origin and sands containing pteropod material. Sediment is composed of 20 – 60 % sand and 5 – 10 % silt, and calcium carbonate content attains 75 %. Sediments are increasingly dominated by siliceous clays with increasing water depth. Exmouth Plateau sediments contain very little terrigenous material, indicating that the surrounding abyssal plains and Montebello Canyon constitute a physical barrier for sediment transport (Colwell & von Stackelberg, 1981).

Hydrocarbons and deep-sea mineral deposits have been discovered on the Exmouth Plateau. Until recently, the most important discovery had been the Scarborough gas field on the central part of the plateau. In 2000, the Io/Jansz gas field was discovered and has since been developed, overlapping the easternmost edge of Exmouth Plateau. It is likely that other significant hydrocarbon discoveries will be made in the future, especially on the deep-water outer margin (Stagg *et al.,* 2004).

3.2.1.2 Physical data

Physical data for the Exmouth Plateau was obtained from two data sources: the CSIRO database and the sediment data collated in Baker *et al.* (2008) (Fig. 3.9; Table 3.5). In total, 24 samples were collated from physical datasets, and hydrology data were available for nine stations sampled during five independent surveys. Additional CTD measurements were collected by CSIRO on one RV *Franklin* cruise in 1987. The remaining physical data comprise sediment data from 14 samples collected during surveys undertaken by Germany's geology institute Geomar and Geoscience Australia. Sediment data for two additional locations were found in the Ocean Drilling Program records from the area (Table 3.5).

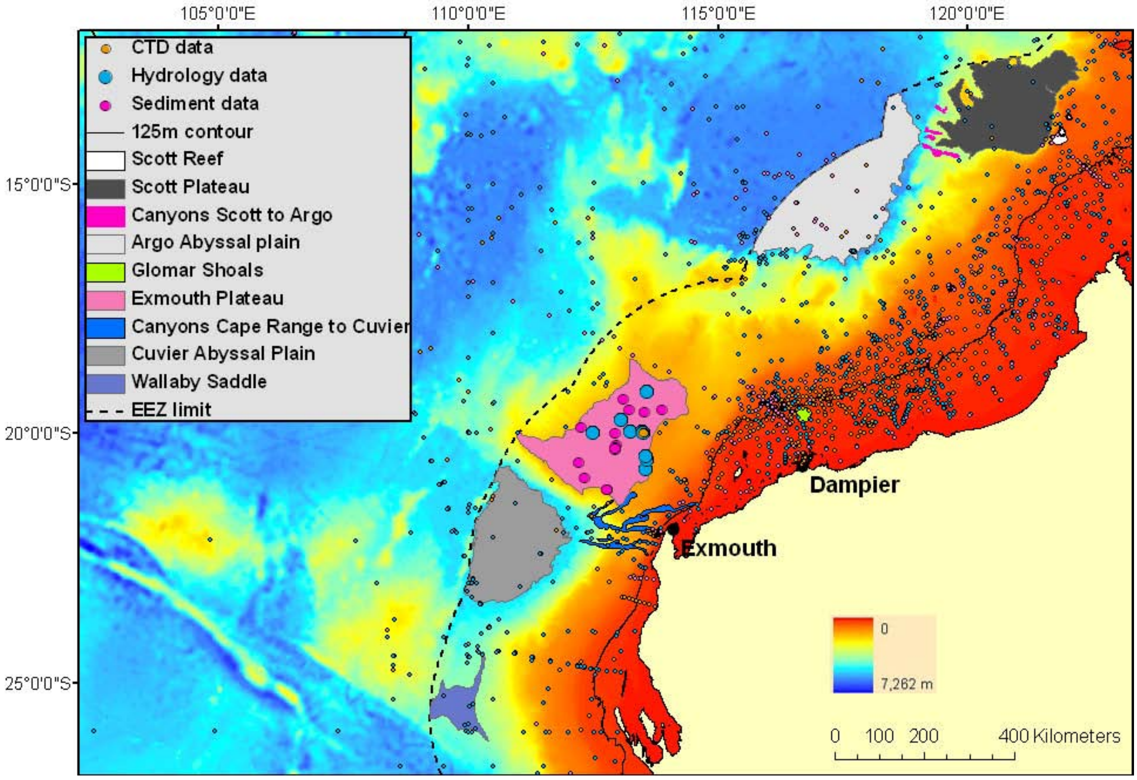

Figure 3.9. Location of physical samples from the Exmouth Plateau with sample locations shown by larger points.

Table 3.5. Metadata for hydrology, CTD and sediment samples from the Exmouth Plateau

Data Source	Vessel	Collection year	Data Type	No. of Samples
CSIRO 'Marine Data Trawler'	HMAS *Diamantina*	1960	Hydrology data	2
	HMAS *Diamantina*	1961	Hydrology data	1
	HMAS *Diamantina*	1962	Hydrology data	1
	HMAS *Diamantina*	1971	Hydrology data	4
	RV *Franklin*	1987	Hydrology data	1
	RV *Franklin*	1987	CTD data	1
Geomar (Germany)	RV *Sonne*	1978	Sediment data	5
	RV *Sonne*	1979	Sediment data	1
Geoscience Australia	Rig Seismic	1986	Sediment data	6
Ocean Drilling Program, Leg 122 & 123	Joides Resolution	1988	Sediment data	2

3.2.1.3 Biological data

Data for 14 samples from eight locations on the plateau and one location in similar depths off the western border were recorded (Fig. 3.10). The Northern Territory Museum holds records of 13 crustacean and 13 fish families from seven samples ranging from 300-1,200 m depth (Table 3.6). All invertebrates have been identified to genus level, and all fish have been identified to species level. Four samples from the Exmouth Plateau are recorded at the Australian Museum (Table 3.6). Three of the four samples from the Australian Museum are from the same locations as those of the NT Museum because the specimens were collected during the same survey (RV *Southern Surveyor* in 1991). However, two additional crustacean species, four echinoderm species and 21 fish families were recorded from all four locations. A complete dataset of fish composition and abundance from three locations on the Exmouth Plateau was provided by Dr Alan Williams from research cruise SS01/91 (Williams *et al.,* 1996; Williams *et al.,* 2001) (Table 3.6). Again, the three samples were part of the same survey which provided most of the material for the museums and hence does not provide data for new locations. Both data coverage and quality are insufficient for a statistical or spatial analysis for this KEF. The majority of the data consist of anecdotal museum records which cannot be considered a true representation of the species diversity of the Exmouth Plateau.

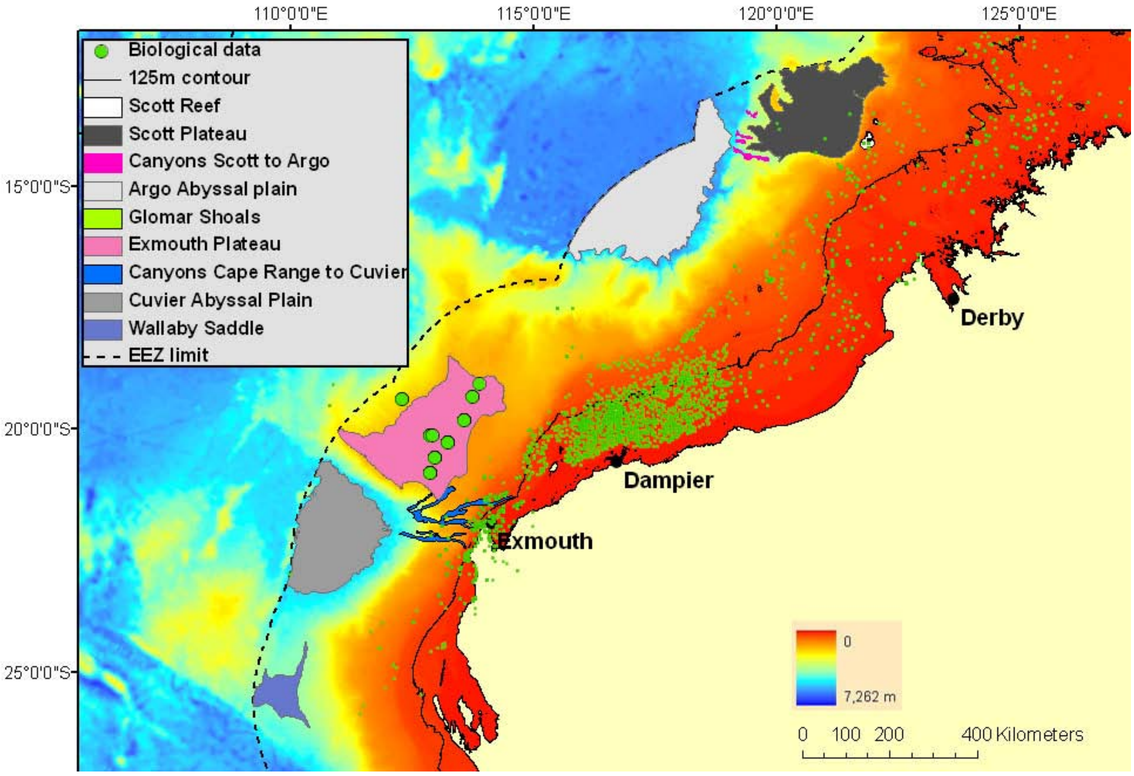

Figure 3.10. Location of biological samples from the Exmouth Plateau with sample locations shown as larger green points.

Table 3.6. Metadata for biological samples from the Exmouth Plateau.

Data Source	Vessel	Collection year	Data Type	No. of Samples
Northern Territory Museum	RV *Southern Surveyor*	1991	Crustacean data	3
	FV South Passage	1990	Crustacean & Fish data	1
	RV *Courageous*	1990	Crustacean & Fish data	1
	RV *Soela*	1983/1984	Crustacean data	2
CSIRO Division of Fisheries	RV *Southern Surveyor*	1991	Fish data	3
Australian Museum	RV *Soela*	1980	Invertebrate data	1
	RV *Southern Surveyor*	1991	Crustacean & Fish data	1
	RV *Southern Surveyor*	1991	Fish data	2

3.2.1.4 Seascapes and focal variety analysis

The Exmouth Plateau mostly coincides with Seascape 7 which ranges in depth from 3 – 1,929 m with a mean depth of 1,219 m and includes the bathyal zone (Gage & Tyler, 1992) (Fig. 3.11). Seascape 7 is defined by moderate physical properties compared to the other seascapes and extends beyond the plateau. It also coincides with other geomorphic features on the slope such as trenches or pinnacles. A very small area at the centre of the plateau coincides with Seascape 9 which is defined by moderate mud, gravel, and slope values, moderate seafloor temperatures and low primary productivity values (Fig. 3.11). Very small portions of the western margin of the plateau are covered by Seascapes 3 and 5 which cover larger areas on the lower slope. Seascape 3 ranges in depth from 1,164-3,156 m with a mean of 2,176 m which puts it into shallow abyssal depths on the margin. It is a seascape mostly characterised by moderate physical properties with the exception of high slope values. Hence we find Seascape 3 mostly at the outer margin where the slope descends into the abyss (Fig. 3.11). Seascape 5 coincides almost entirely with the Scott Plateau and hence will be discussed in the next section (3.2.2.4).

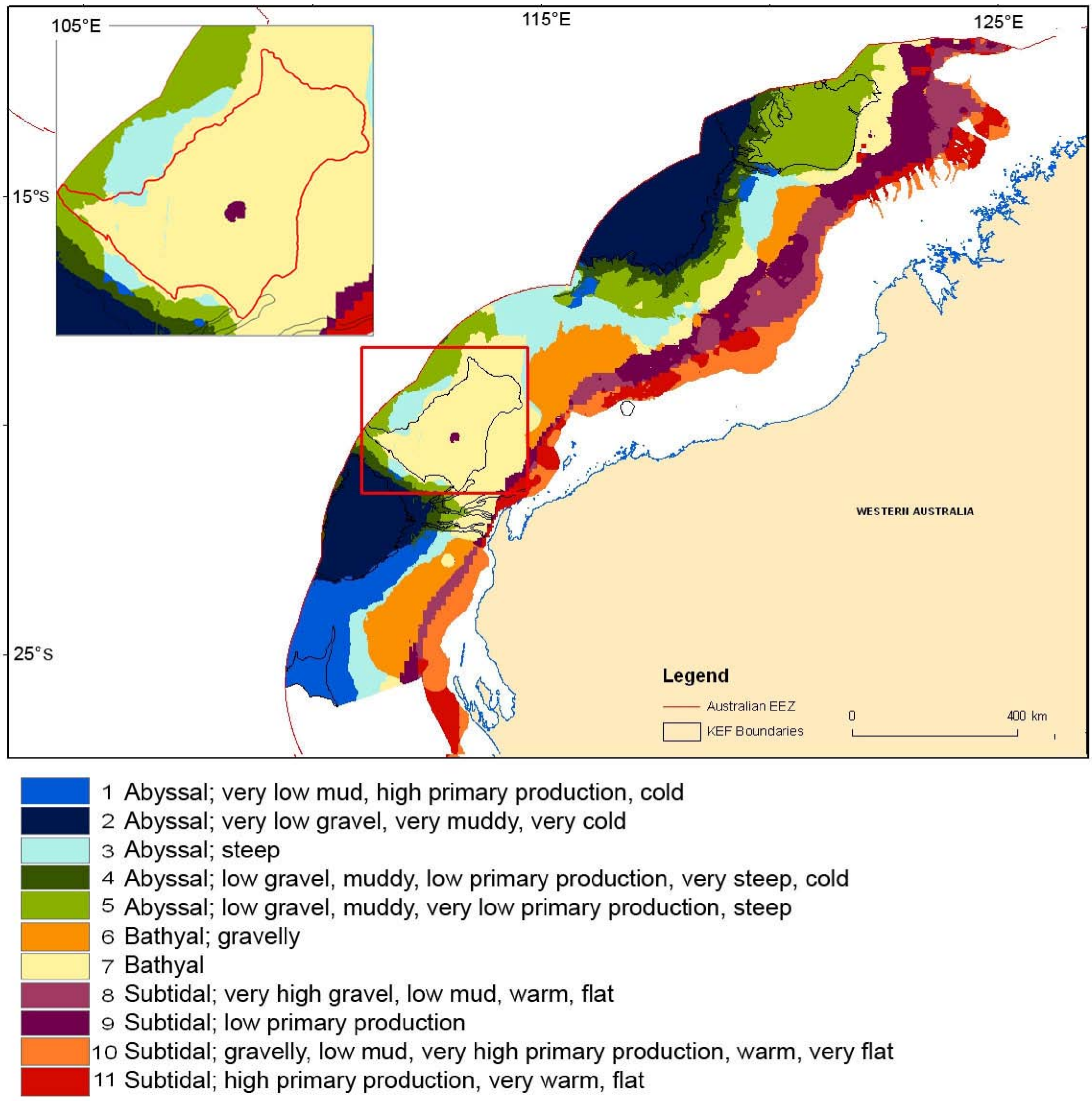

Figure 3.11. Map of seascapes for the Exmouth Plateau.

The focal variety analysis indicates that the Exmouth Plateau is an area of low habitat heterogeneity with indices ranging from 1 to 3 (Fig. 3.12). An area of very high diversity is the southwest plateau margin which includes some canyons and spurs (Fig. 3.12).

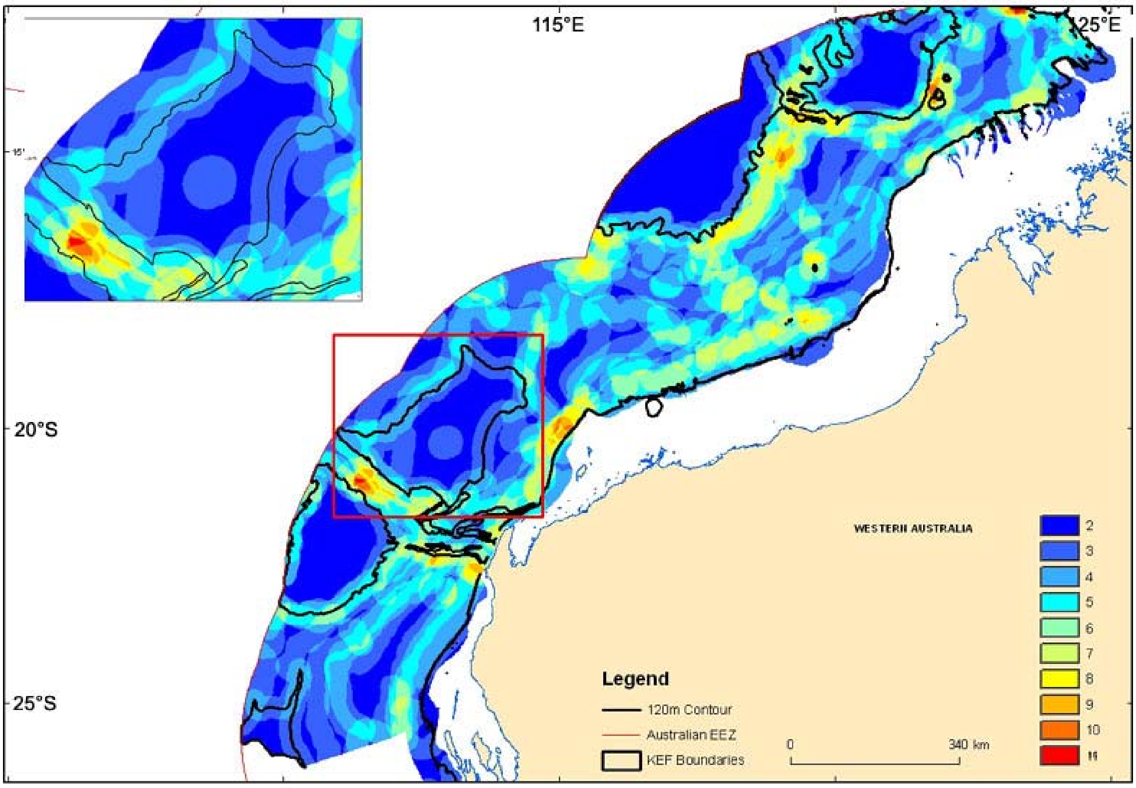

Figure 3.12. Map of focal variety indices for the Exmouth Plateau.

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3.2.2 Scott Plateau

3.2.2.1 General description

Scott Plateau is the most northerly of the marginal plateaus in Western Australia (13.49˚S / 120.81˚E). It covers approximately 80,000 km^2 although only 43,370 km^2 occur in the Australian EEZ (Exon & Willcox, 1980; Heap & Harris, 2008; Stagg and Exon, 1981) (Fig. 3.13). It lies primarily in water depths of 2,000 and 3,000 m, with a maximum depth of about 3,600 m occurring on the western edge (Falvey and Veevers, 1974; Stagg & Exon, 1981). The geological evolution, stratigraphy and structure of the plateau have been described in Stagg (1978) and Stagg & Exon (1981), with the petroleum potential of the Scott Plateau rated as low (Stagg, 1978).

The plateau culminates in a broad dome (Scott Plateau Dome) at water depths of <2,000 m and Wilson Spur at water depths of <1,800 m (Falvey & Veevers, 1974; Stagg, 1978). Numerous spurs and valleys of varying orientations characterise the top of the dome. Scott Plateau Saddle, a NNE-SSW trending depression (~2,000 m water depth), extends to the Bowers Canyon to the southwest (Falvey & Veevers, 1974; Stagg, 1978).

The Bowers and Oats Canyons cut deep into the western plateau margin and debouch onto the Argo Abyssal Plain at depths >5,500 m (Stagg, 1978).

Sediments from the Scott Plateau contain a lower proportion of biogenic sands than sediments at similar depths (~3,200 m) from the Exmouth Plateau. Sediments collected from northern Scott Plateau contain a significant amount of terrigenous material (mostly clay) transported to the plateau from the Timor Sea, Kimberley Block and Indonesian volcanoes. Hence, compared to Exmouth Plateau, the Scott Plateau appears to have a more active depositional system of terrigenous material (Colwell & von Stackelberg, 1981).

3.2.2.2 Physical data

A total of 18 samples from physical datasets were obtained. The CSIRO hydrology and CTD data comprise the largest dataset for the Scott Plateau with 14 samples from different locations (Fig. 3.13; Table 3.7). Salinity was also recorded. Four additional sediment samples were taken during three surveys in the 1970s and in 1996, respectively (Table 3.7).

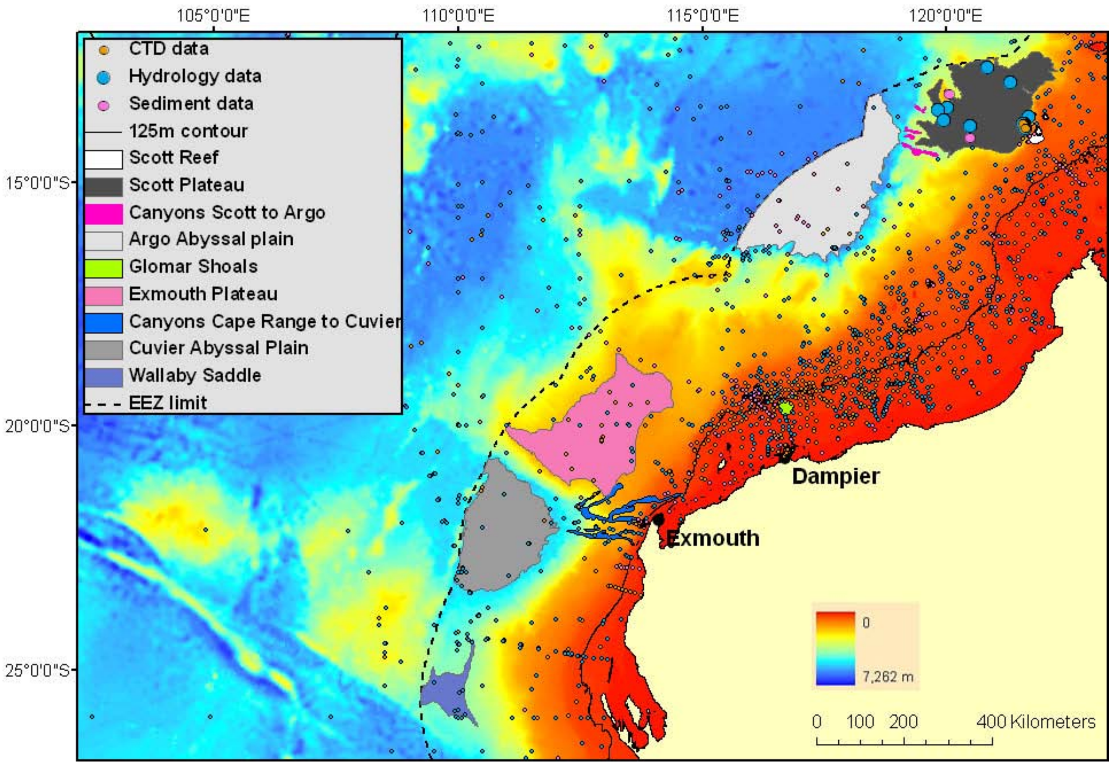

Figure 3.13. Location of physical samples from the Scott Plateau with sample locations shown by larger points.

Table 3.7. Metadata for hydrology, CTD and sediment samples from the Scott Plateau.

Data Source	Vessel	Collection year	Data Type	No. of Samples
CSIRO 'Marine Data Trawler'	HMAS *Diamantina*	1960	Hydrology data	1
	HMAS *Diamantina*	1961	Hydrology data	1
	HMAS *Diamantina*	1969	Hydrology data	1
	RV *Sprightly*	1976	Hydrology data	3
	RV *Franklin*	1987	Hydrology data	2
	RV *Franklin*	1996	Hydrology data	3
	RV *Franklin*	1996	CTD data	3
Lamont Doherty Earth Observatory	*Vema*	1971	Sediment data	1
BGR (Germany)	*Valdivia*	1977	Sediment data	1
ANU	RV *Franklin*	1996	Sediment data	2

3.2.2.3 Biological data

Data for five locations on the Scott Plateau were collated for this study (Fig. 3.14). The data consist of anecdotal museum records of specimens donated from various research cruises (Table 3.8). Four samples held by the Australian Museum include seven fish families. The Queensland Museum holds an additional sample of one crustacean species (Table 3.8). Overall, no datasets have been recorded for the Scott Plateau which could provide the basis for a conclusive statistical or spatial analysis of the seabed communities.

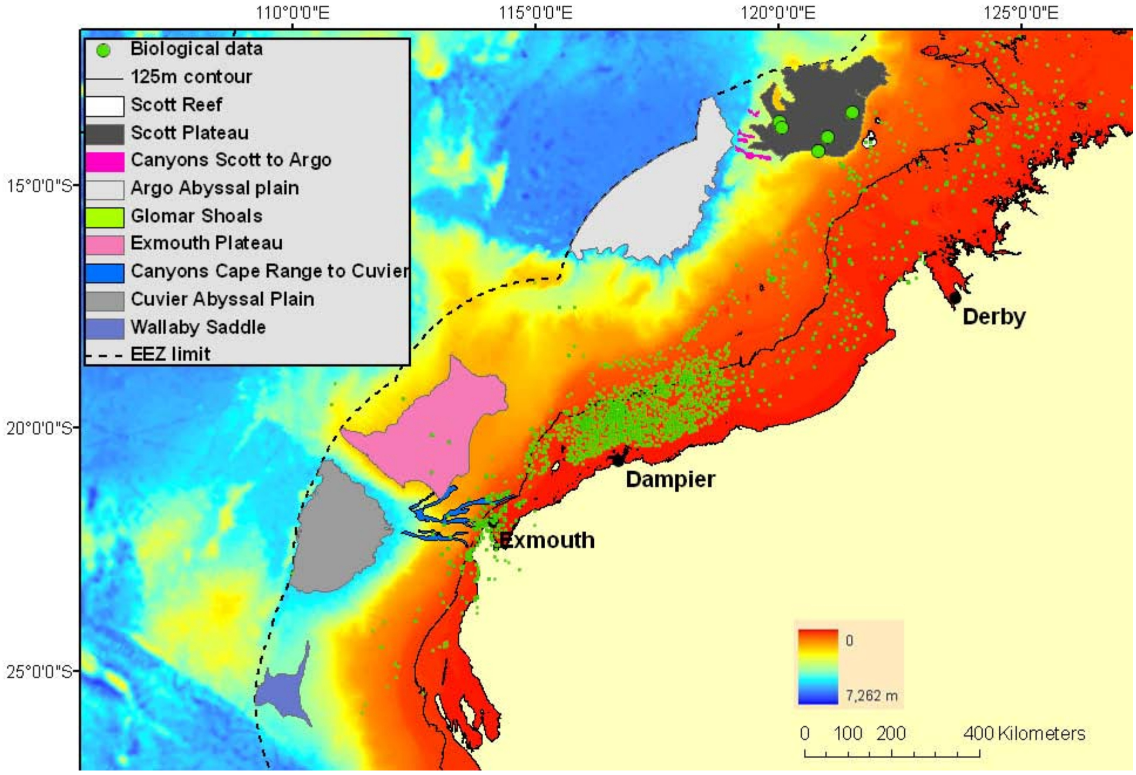

Figure 3.14. Location of biological samples from the Scott Plateau with sample locations shown as larger green points.

Table 3.8 Metadata for biological samples from the Scott Plateau.

Data Source	Vessel	Collection year	Data Type	No. of Samples
Australian Museum		1996	Fish data	1
		1969	Fish data	1
		1978	Fish data	1
		2002	Fish data	1
Queensland Museum		1976	Crustacean data	1

3.2.2.4 Seascapes and focal variety analysis

The Scott Plateau almost entirely coincides with Seascape 5 which has a depth range of 1,331 – 3,501 m and a mean depth of 2,399 m which puts it into the shallow abyssal zone of the margin (Gage & Tyler, 1992) (Fig. 3.15). It is also characterized by the 3rd-lowest gravel content, the 3rd-highest mud content, the lowest primary productivity and the 2nd-highest slope values. The high slope values may represent the relief of the actual plateau which culminates in a central dome. At the western margin of the plateau Seascape 5 borders onto Seascape 4 which marks the steep entry of the slope into the

Argo Abyssal Plain (Fig. 3.15). Hence Seascape 4 is mainly characterised by the highest slope values.

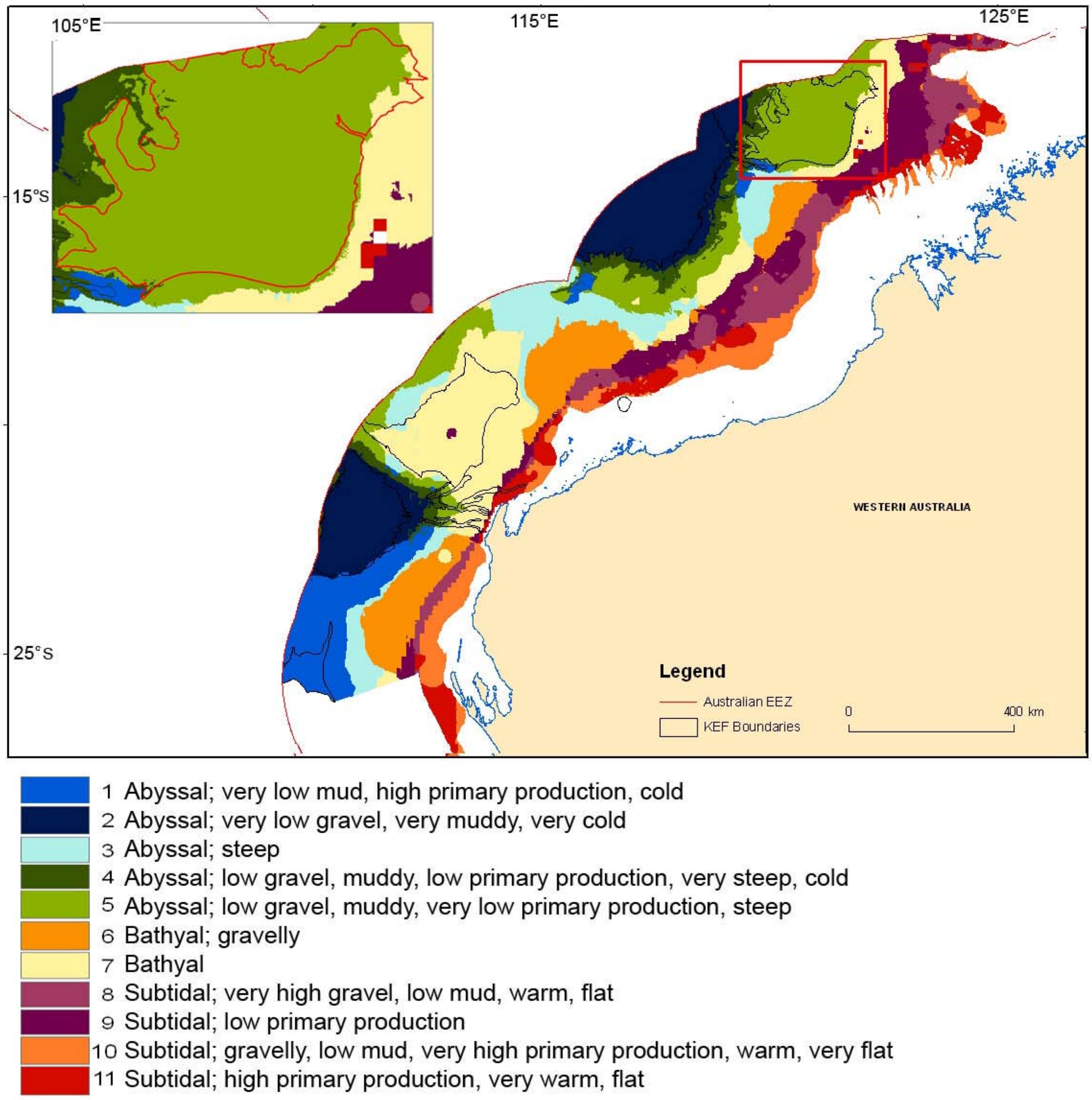

Figure 3.15. Map of seascapes for the Scott Plateau.

As expected the focal variety analysis suggests that the Scott Plateau is an area of low seascape diversity (Fig. 3.16). The plateau itself is the most homogenous environment while the plateau margins are somewhat more diverse. The southwest margin, where the Bowers and Oates Canyons occur, is an area of relatively high habitat diversity (Fig. 3.16). This margin will be discussed in more detail in Section 3.3.2.

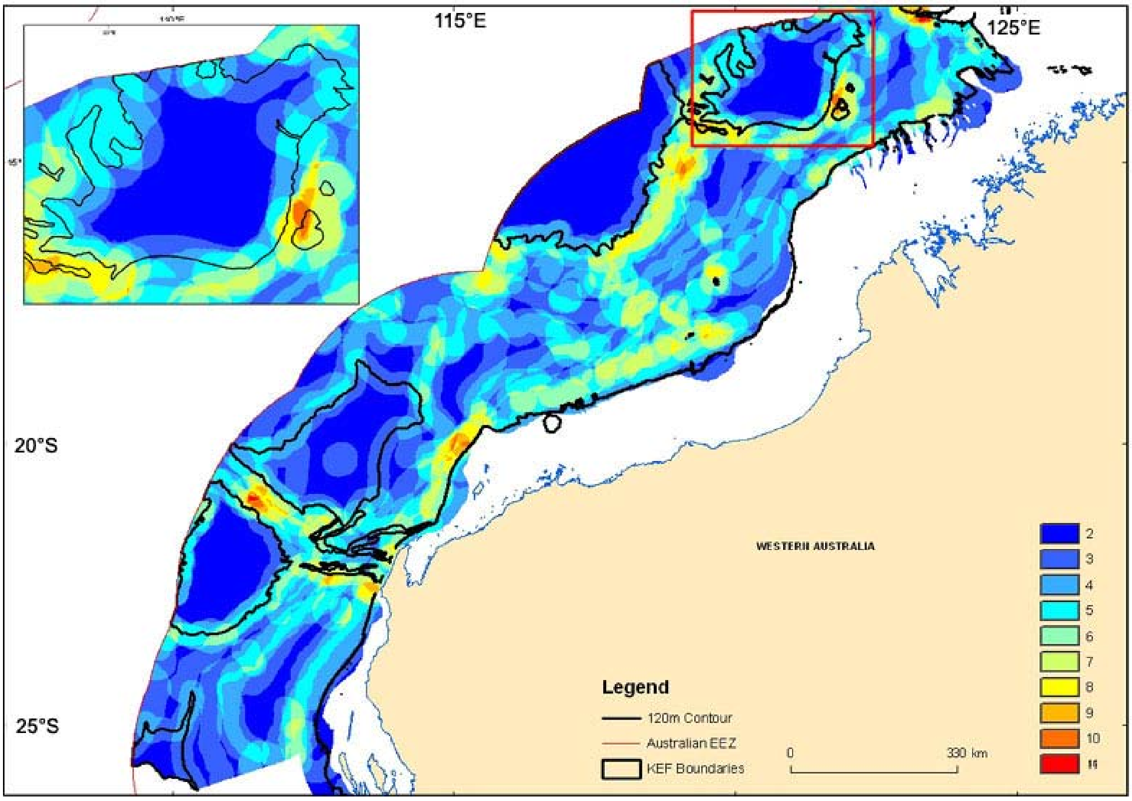

Figure 3.16. Map of focal variety indices for Scott Plateau.

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3.3 Submarine canyons

Submarine canyons are steep-sided, U- or V-shaped features that cut across the continental slope along most continental margins (Blondel & Murton, 1997). They are created through erosion and transport of sediments by currents or sediment slumps (Blondel & Murton, 1997; Thurman, 1997). Each canyon is uniquely characterised by its shape, depth, flow regime, sediment type and other physical properties (Thurman, 1997). Due to their complex topography, they provide numerous habitats for benthic organisms (Alves *et al.,* 2006; Ingels & Vanreusel, 2006). Canyons have enhanced organic matter deposition and are associated with increased carbon transport from the shelf to deep sea basins due to the unstable sediments, unique hydrodynamics and slowed processing of organic matter (Gardner, 1989; Granata *et al.,* 1999; Mullenbach & Nittrouer, 2000; Vetter & Dayton, 1998). This aggregation of organic matter on canyon floors contributes to a highly diverse and abundant macrobenthic invertebrate community (Levin & Gage, 1998; Rowe *et al.,* 1982; Schlacher *et al.,* 2007). In addition, canyons form a natural break in flow along the continental slope which may result in larvae being funnelled up or down the canyon, away from their ambient environment (Tyler, 1995). Submarine canyons are more likely to contain endemic fauna than nearby non-canyons at similar depths (Vetter and Dayton, 1998; 1999), due to these geographic barriers to recruitment and evolutionary isolation.

Submarine canyons are considered “hot–spots” for secondary production and biodiversity, supporting higher abundances and biomass than surrounding non-canyon regions at similar depths (Thurman, 1997; Vetter, 1994; Vetter & Dayton, 1998). Unfortunately, detailed data on faunal compositions are sparse (Schlacher *et al.,* 2007; Vetter & Dayton, 1998). Recently, Schlacher *et al.* (2007) identified a rich sponge fauna in five canyons off the southeast Australian margin. Sponge assemblages differed between sites in individual canyons and between canyons indicating that each canyon system was characterised by a unique benthic faunal community.

Across the Australian margin, 423 submarine canyons were identified covering an area of 106,540 km^2 or 1.19% of the total area (Heap & Harris, 2008). Most of Australia's canyon systems are comparatively small with few exceptions such as Bass Canyon, Perth Canyon, and Albany Canyons. Most of the canyons of the Australian margin have been mapped to some degree, but very few have been sampled (Schlacher *et al.,* 2007).

3.3.1 Cape Range, Cloates and Mermaid Canyons

3.3.1.1 <u>General description</u>

The canyons between Cape Range and the Cuvier Abyssal Plain are named Cape Range (21.91˚S / 113.34˚E), Cloates (22.25˚S / 112.90˚E), and Mermaid Canyons (Jongsma *et al.,* 1990; Jongsma & Johnston, 1993). Falvey & Veevers (1974) describe these canyons as low-relief and broad with smooth floors, indicating that they are old and inactive. They were probably created by buckling of continental crust associated with northward drift of the continent.

3.3.1.2 <u>Physical data</u>

In total, 12 samples from eight locations were recorded for the Cape Range canyon system (Fig. 3.17; Table 3.9). The four CTD and hydrology data samples taken on the RV Franklin in 1987, 1996 and 1999 were taken from the same location and are visualised by CTD samples (pink points) only (Fig. 3.17). The two CTD and hydrology samples from 1996 were taken at very close proximity and thus appear as one sample point on the map (Fig. 3.17). An additional hydrology sample was taken on the RV Franklin in 1995 (Table 3.9). There were three sediment samples taken from these canyons in 1967 and 2005 respectively (Fig. 3.9; Table 3.9).

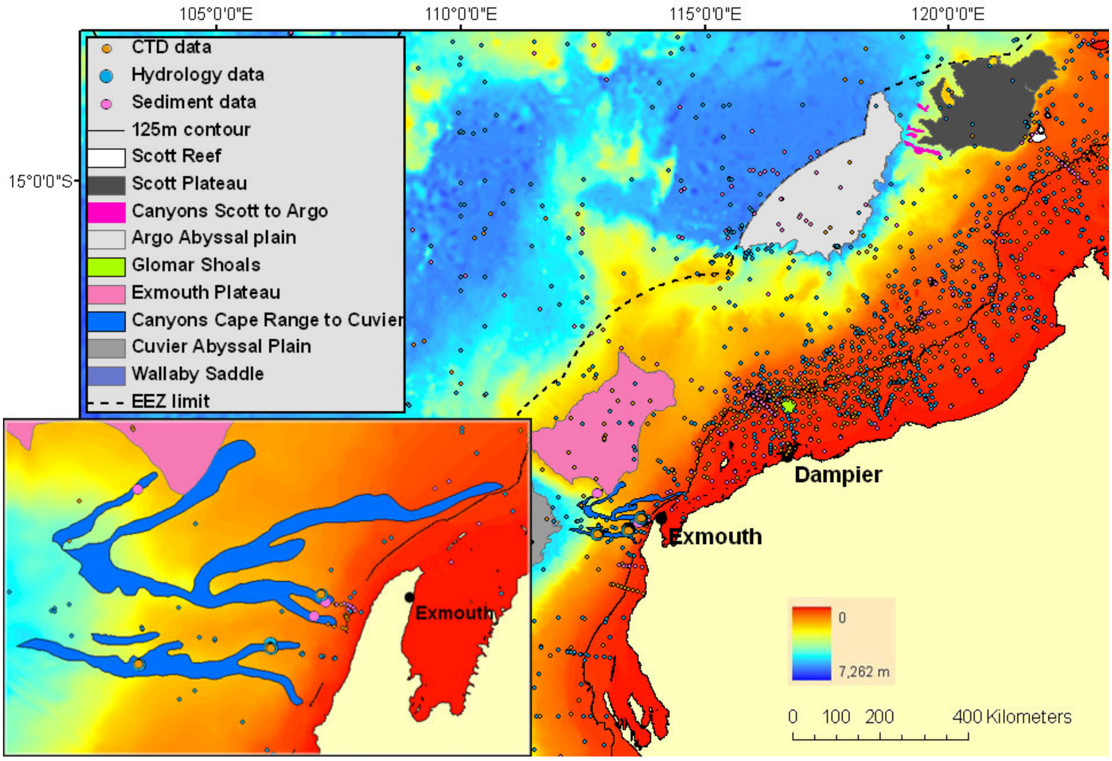

Figure 3.17. Location of physical samples from the Cape Range, Cloates, and Mermaid Canyons with sample locations shown by larger points.

Table 3.9. Metadata for hydrology, CTD and sediment samples from Cape Range canyons

Data Source	Vessel	Collection year	Data Type	No. of Samples
CSIRO 'Marine Data Trawler'	RV *Franklin*	1987	Hydrology data	1
	RV *Franklin*	1995	Hydrology data	1
	RV *Franklin*	1996	Hydrology data	2
	RV *Franklin*	1999	Hydrology data	1
	RV *Franklin*	1987	CTD data	1
	RV *Franklin*	1996	CTD data	2
	RV *Franklin*	1999	CTD data	1
Lamont Doherty Earth Observatory	*Robert D Conrad*	1967	Sediment data	1
CSIRO	RV *Southern Surveyor*	2005	Sediment data	2

3.3.1.3 Biological data

In total, data for 9 locations covering the Cape Range canyons have been recorded (Fig. 3.18; Table 3.10). These consist of museum records and one record derived from the public database GBIF (Global Biodiversity Information Facility) (Table 3.10). Data published on GBIF comprise 20 fish and eight coral species, but contain no collection details (e.g., depth or date). The Australian Museum holds records for five samples in the area including 14 invertebrate and 17 fish species (Table 3.10). Four echinoderm species were recorded from one sample at water depths of 680–750 m, suggesting that these species may be 'canyon fauna' while samples from the other three locations are from shallower waters on the adjacent slope. Similarly, the invertebrate species recorded at the Queensland Museum were collected in shallow waters (6–7m) at the canyon margin. However, the five mollusc species from one sample held at the Northern Territory Museum were collected at 430 m water depth and can therefore also be considered 'canyon fauna'.

Overall, the samples collected in the Cape Range canyon system are extremely heterogenous in respect to taxonomic group recorded and collection depth and therefore cannot be compared to determine trends in species composition. A systematic study of one taxonomic group for a range of water depths (e.g. <100, 200, 400, and 750 m) would be desirable for this purpose. However, such a study has so far only been conducted for five canyons off southeast Australia (Schlacher *et al.,* 2007) and the results are not transferable to the Cape Range Canyons.

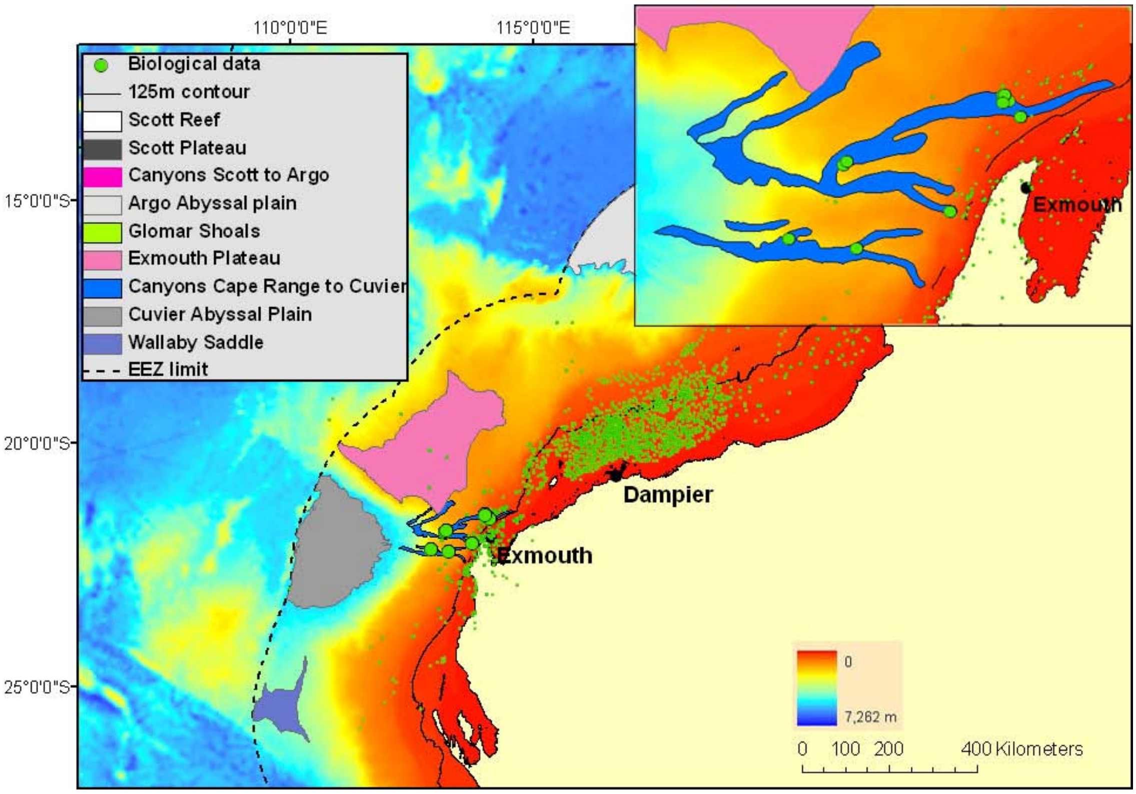

Figure 3.18. Location of biological samples from the Cape Range canyons with sample locations shown as larger green points.

Table 3.10 Metadata for biological samples from the Cape Range canyons.

Data Source	Vessel	Collection year	Data Type	No. of Samples
Global Biodiversity Information Facility			Fish data	1
Australian Museum			Mollusc data	2
	RV *Southern Surveyor*	2005	Echinoderm data	1
	Australian Museum / Crustacean Dept Western Australia Exp 1983-84	1984	Crustacean, Polychaete & Fish data	1
	RV *Soela*	1979	Fish data	1
Queensland Museum		1988	Invertebrate data	2
Northern Territory Museum	AIMS Northwest Cape Survey II	2002	Mollusc data	1

3.3.1.4 Seascapes and focal variety analysis

The canyon system adjacent to the Cape Range Peninsula is covered by several seascapes (Seascapes 4, 5, 7, 9 and 11) (Fig. 3.19). The shallower parts of the canyons coincide with seascapes that are mainly found on the upper slope (Seascapes 9 and 11) (Fig. 3.19). Seascape 9 has a depth range of 0 – 1,133 m with a mean of 428 m which puts it into the bathyal range of the margin (Gage & Tyler, 1992). It is also characterised by low primary productivity values. A larger area of the canyon entrances, however, coincides with Seascape 11 which has a depth range of 0 – 663 m with a mean of 140 m. This seascape also coincides with 3rd-highest primary productivity values, highest seafloor temperatures and 2nd-lowest slope values. High primary productivity values at the entrance to the canyons and surrounding areas supports previous findings of local upwelling of nutrient rich deep waters through the canyons. Deeper sections of the canyons coincide with seascape 7 which is characterised by moderate environmental properties (Fig. 3.19). The deepest sections of the canyons coincide with Seascapes 4 and 5 (Fig. 3.19). Seascapes 4 and 5 are characterised by high slope values and are mainly found in areas where the slope descends into the abyss.

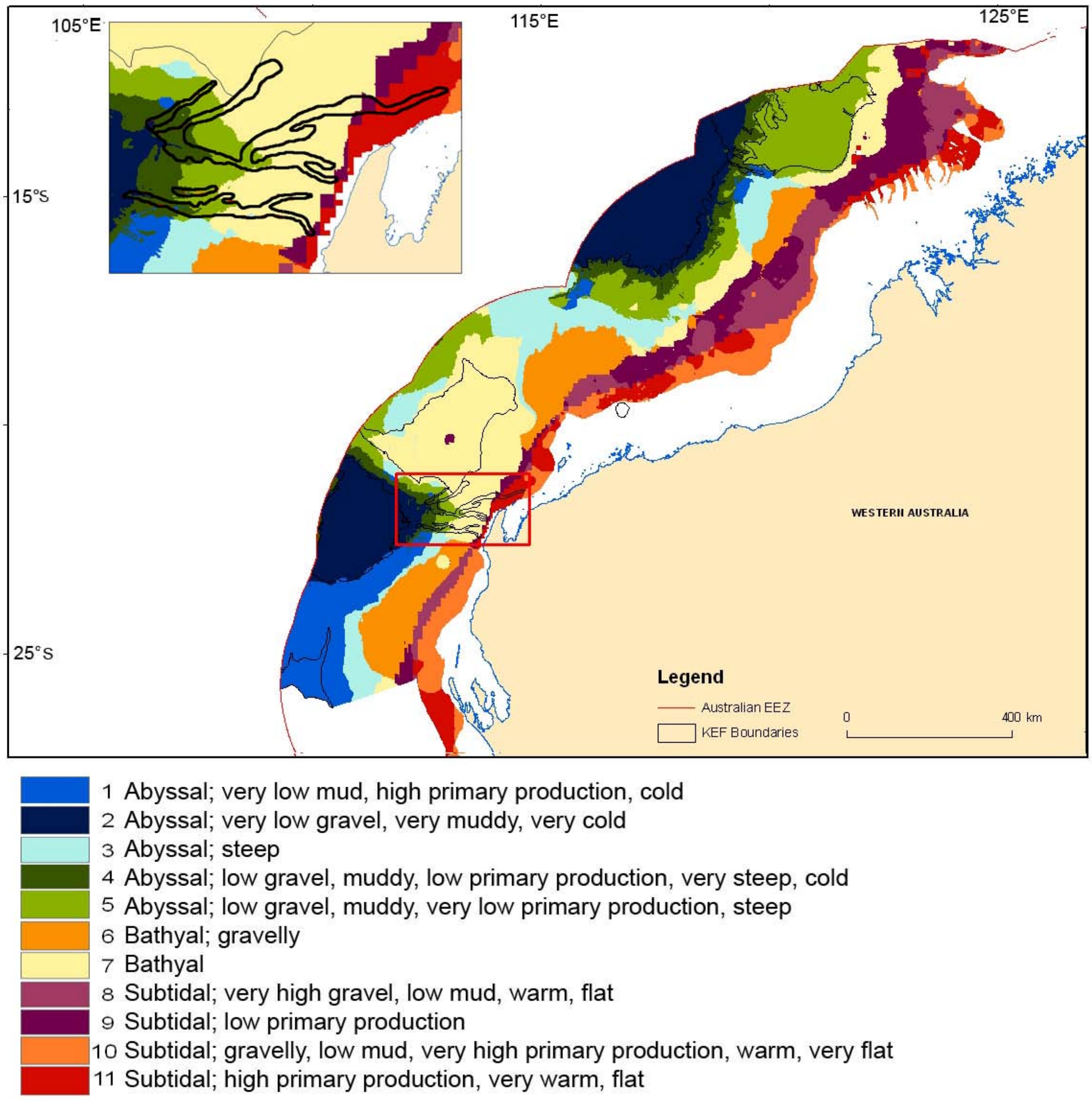

Figure 3.19. Map of seascapes for Cape Range canyons.

Overall, the seascapes coinciding with the canyons are also found in the surrounding areas indicating that the density of the seascapes data available for the canyons may not be high enough to allow a distinction between canyon and non-canyon areas. However, the fact that these canyons reach from the upper slope to abyssal plain depths and coincide with numerous seascapes suggests that they are areas of high habitat diversity. This is supported by the focal variety analysis which indicates that Cape Range, Cloates and Mermaid Canyons are areas of moderate to high habitat diversity (Fig. 3.20).

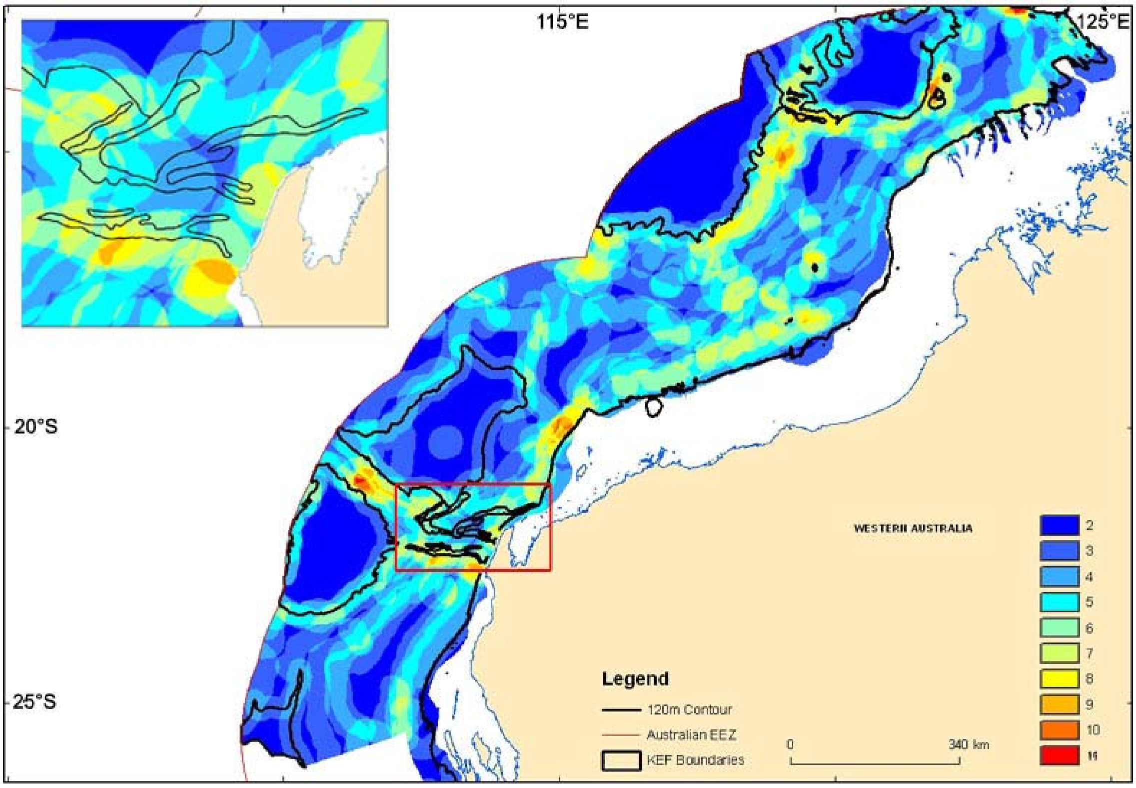

Figure 3.20. Map of focal variety indices for Cape Range canyons.

3.3.2 Bowers and Oates Canyons

The canyons connecting the Scott Plateau and Argo Abyssal Plain, named Bowers (14.38˚S / 119.37˚E) and Oates Canyons are mentioned briefly in Falvey & Veevers (1974) and Stagg (1978). These canyons cut deeply into the southwest margin of Scott Plateau and transport sediments to greater depths (~5,500 m) onto the Argo Abyssal Plain (Stagg 1978). This canyon system is probably of similar age to the Cape Range canyon system (Falvey & Veevers, 1974).

3.3.2.1 Physical data

No hydrology and CTD data could be found for these canyons in the CSIRO database. There were also no sediment samples available specifically for the canyons. However, bathymetry, slope, seafloor temperature and primary productivity data were available for the following seascapes and focal variety analysis.

3.3.2.2 Biological data

No biological data could be found for these canyons. No direct insight into the species richness can be ascribed to the canyons.

3.3.2.3 Seascapes and focal variety analysis

The Bowers and Oates Canyons coincide with three different seascapes (seascape 1, 2 and 4) (Fig. 3.21). The upper part of Bowers Canyon is covered by Seascape 1 which will be discussed in more detail in Section 3.4.1.3. The deeper parts of the canyons coincide with Seascapes 2 and 4 which characterize the lower slope and abyssal plains. The Bowers and Oates canyons contain fewer seascapes than the Cape Range canyon system, but data coverage of the canyons may not be sufficient to identify the canyons as unique ecosystems. However, these canyons connect the mid slope to the abyssal plain and hence represent a range of different habitats, as confirmed by the high values in the focal variety analysis (Fig. 3.22).

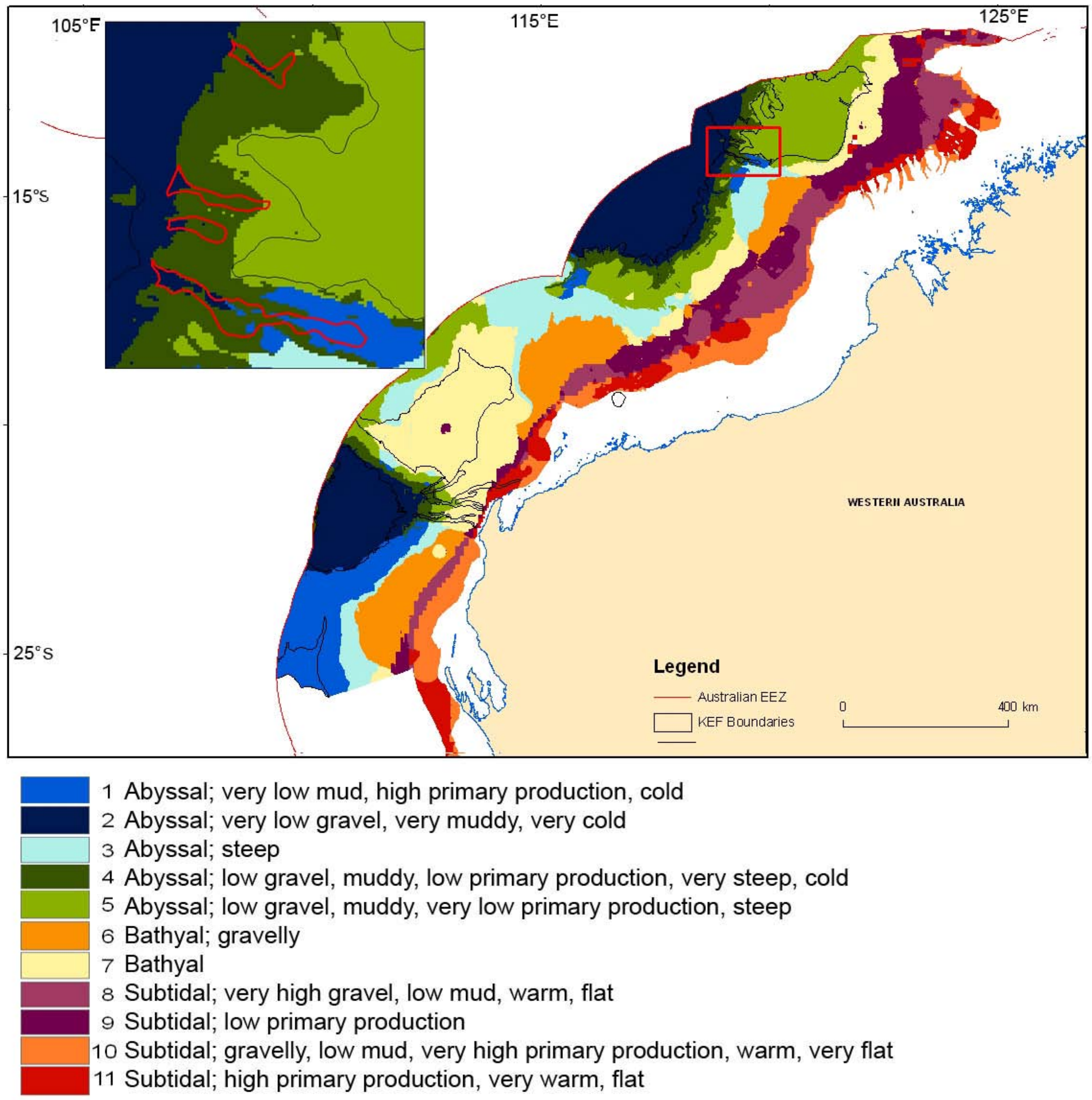

Figure 3.21. Map of seascapes for Bowers and Oates canyons.

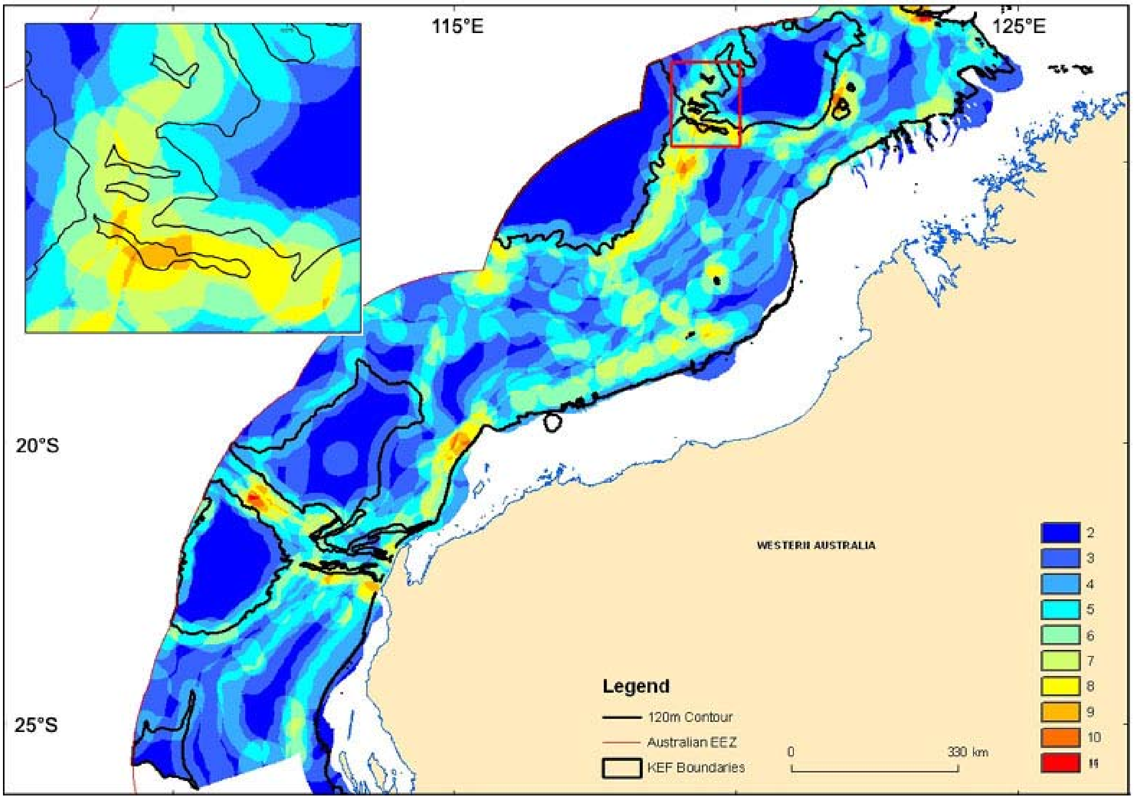

Figure 3.22. Map of focal variety indices at Bowers and Oates Canyons.

3.4 Saddles

Saddles are defined by an elevated area of regional extent separating two or more regions of deeper seafloor. They resemble broad passes in the shape of a riding saddle and around the Australian margin join marginal plateaus with the slope and shelf. Within the Australian margin, 36 saddles have been identified, covering an area of 146,240 km^2 or 1.62% of the total area (Heap & Harris, 2008).

3.4.1 Wallaby Saddle

Wallaby Saddle has only been described briefly in Symonds & Cameron (1977). It forms a broad (100 km) area of seafloor in 4,000-4,700 m water depth that connects the northwest margin of the Wallaby Plateau with the outboard margin of the Carnarvon Terrace on the upper continental slope (25.44˚S / 109.73˚E) (Symonds & Cameron, 1977) (Fig. 3.23). It covers 7,780 km^2 and is the only saddle in the western margin (Heap & Harris, 2008).

3.4.1.1 Physical data

Physical data available for the Wallaby Saddle comprise six hydrology samples from five locations and one CTD sample from the CSIRO database (Fig. 3.23; Table 3.11). The two hydrology samples from 1961 and 1996 were taken at the same location. However, the samples cover mostly the margin of the saddle and are concentrated in three areas (Fig. 3.23). No sediment data exist for this area according to Baker *et al.* (2008).

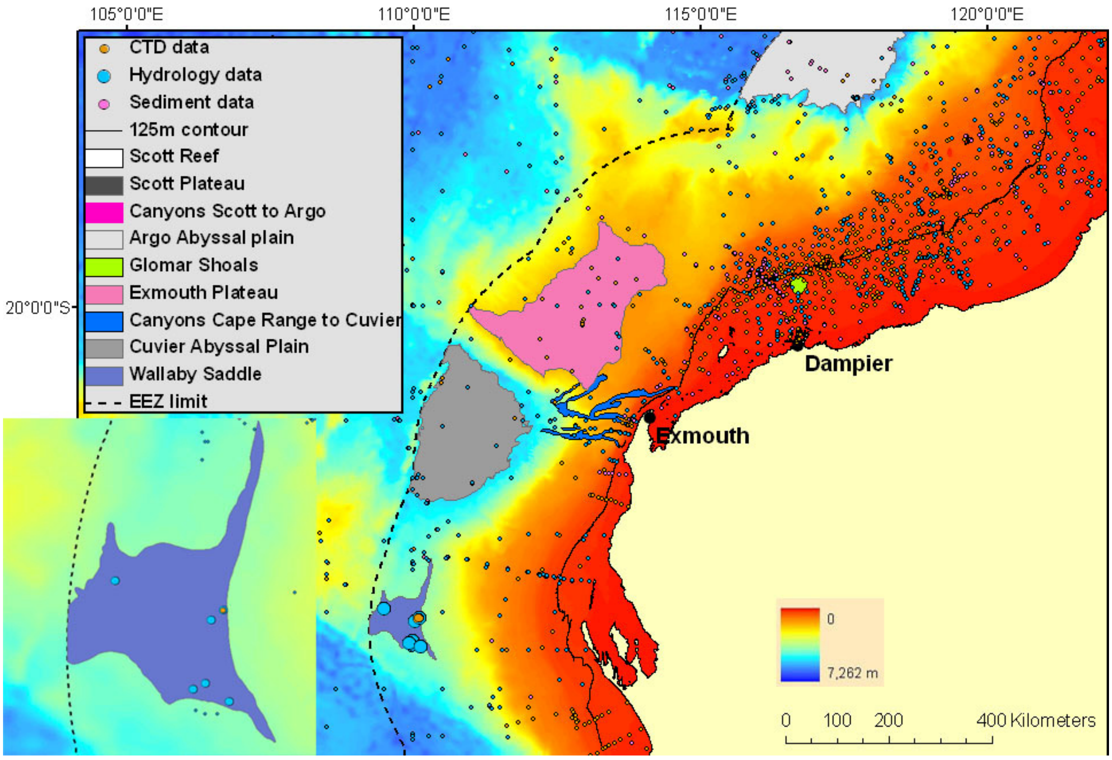

Figure 3.23. Locations of physical samples on the Wallaby Saddle with sample locations shown by larger points.

Table 3.11. Metadata for hydrology, CTD and sediment samples from the Wallaby Saddle.

Data Source	Vessel	Collection year	Data Type	No. of Samples
CSIRO 'Marine Data Trawler'	HMAS *Diamantina*	1961	Hydrology data	1
	HMAS *Diamantina*	1962	Hydrology data	1
	HMAS *Diamantina*	1963	Hydrology data	1
	HMAS *Diamantina*	1967	Hydrology data	1
	HMAS *Diamantina*	1971	Hydrology data	1
	RV *Franklin*	1996	Hydrology data	1
	RV *Franklin*	1996	CTD data	1

3.4.1.2 Biological data

No data from biological samples were found for these canyons. However, an underwater video camera was deployed for an hour along the seafloor of the Wallaby Saddle during a marine reconnaissance survey to the western Australian margin in January 2009 (Geoscience Australia GA-2476). No epibenthic animals were identified on the transect, although some infaunal tracks were observed, indicating low abundance of biota.

3.4.1.3 Seascapes and focal variety analysis

The Wallaby Saddle and the adjacent area coincide with Seascape 1 which has a depth range of 3,013 – 5,262 m and a mean of 3,964 m which is the 2nd-deepest mean depth of all seascapes which puts it into the abyssal depth zone of the margin (Gage & Tyler, 1992) (Fig. 3.24). Seascape 1 is also characterized by the lowest mud content, the 2nd-highest primary production values and the 2nd-lowest seafloor temperatures, supporting previous studies that identified the Wallaby Saddle as an area of increased primary production. Interestingly, Seascape 1 is found almost exclusively at the Wallaby Saddle and surrounds (Fig. 3.24).

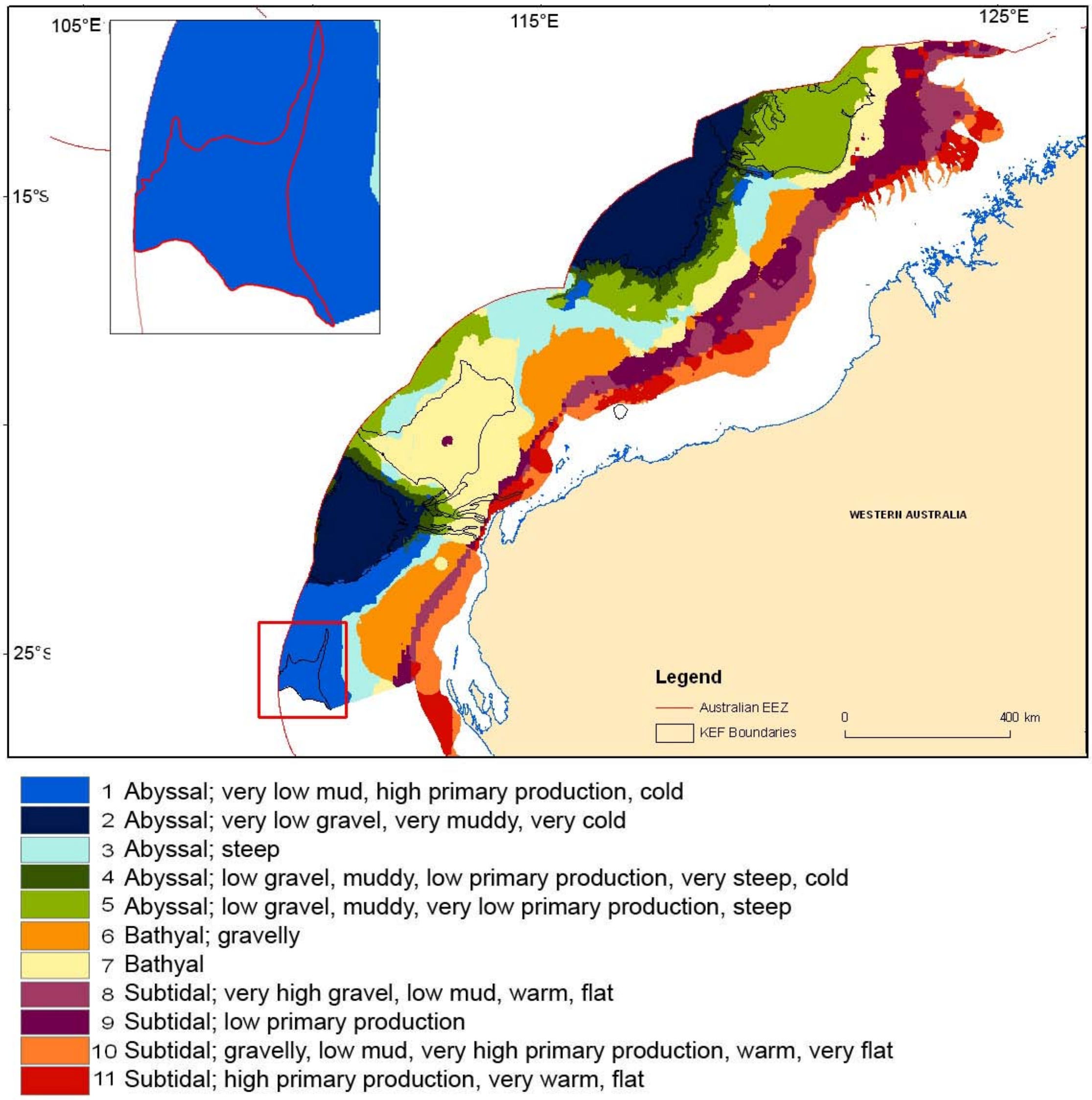

Figure 3.24. Map of seascapes for the Wallaby Saddle.

As expected from the seascapes analysis results, the focal variety analysis suggests that the Wallaby Saddle is an area of low habitat diversity (Fig. 3.25).

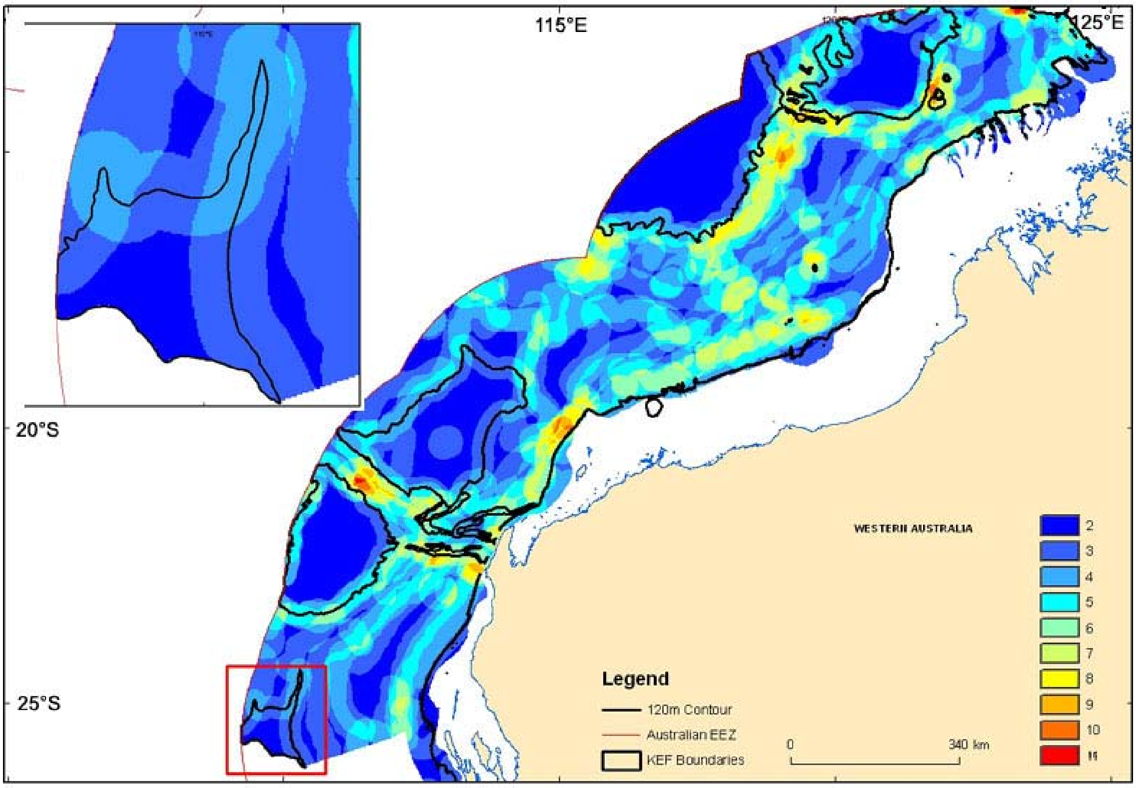

Figure 3.25. Map of focal variety indices for the Wallaby Saddle.

3.5 Holocene coastline at the 125m isobath

3.5.1.1 General description

The submerged strandline at a depth of about 125 m can be traced as a notch or scarp on the northwest shelf from North West Cape to the Bonaparte Gulf. It coincides with the well documented world-wide eustatic sea-level stillstand at about 130 m which preceded the Holocene transgression about 17,000 years ago (Jones, 1973).

3.5.1.2 Physical data

In total, 198 physical data samples were recorded for the ancient coastline between the 120 and 140 m isobath (Fig. 3.26; Table 3.12). We identified 81 hydrology samples from 16 different surveys starting from the 1960s to 2000. A further 88 sediment samples from different locations were collected by several institutions, and 29 CTD data samples were collected on three RV *Franklin* cruises in 1987, 1995 and 1999 respectively (Table 3.12).

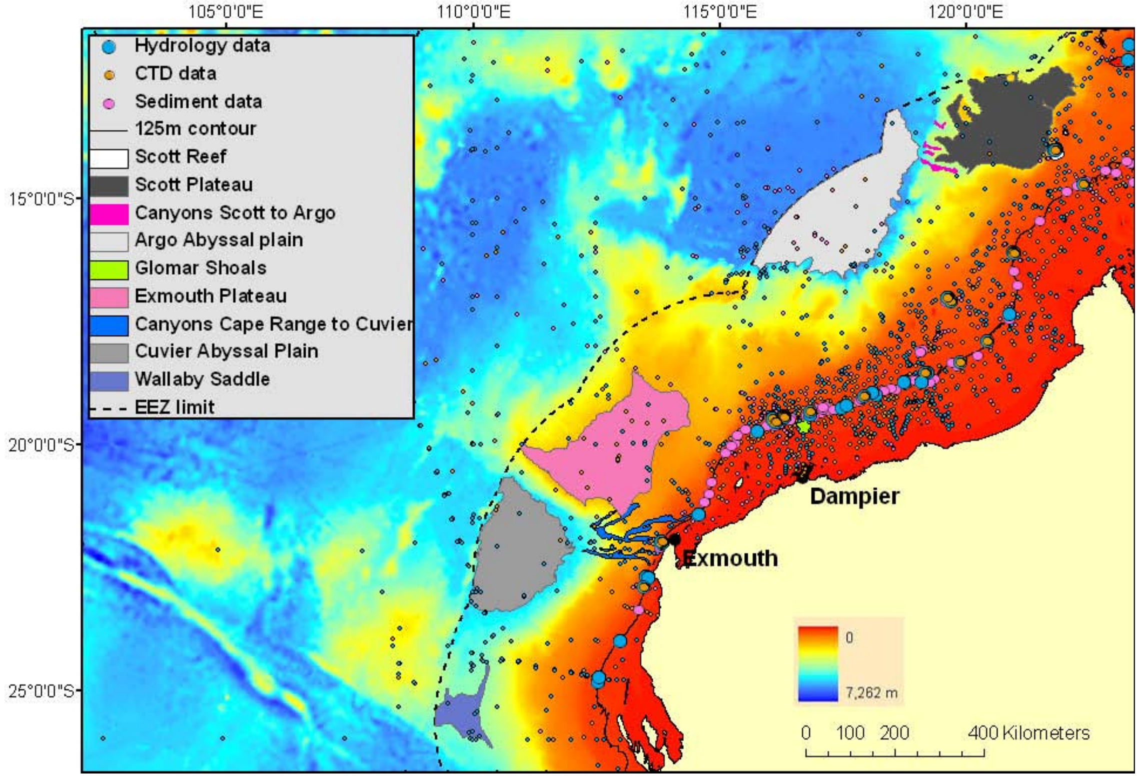

Figure 3.26. Locations of physical samples near the Holocene coastline (125 m contour) with sample locations shown by larger points.

Table 3.12. Metadata for hydrology, CTD and sediment samples from the Holocene coastline (120 – 140 m contour).

Data Source	Vessel	Collection year	Data Type	No. of Samples
CSIRO 'Marine Data Trawler'	HMAS *Diamantina*	1960	Hydrology data	2
	HMAS *Diamantina*	1961	Hydrology data	1
	HMAS *Diamantina*	1967	Hydrology data	5
	HMAS *Diamantina*	1971	Hydrology data	3
	RV *Sprightly*	1976	Hydrology data	4
	RV *Courageous*	1978	Hydrology data	6
	RV *Soela*	1979	Hydrology data	1
	RV *Courageous*	1979	Hydrology data	5
	RV *Soela*	1980	Hydrology data	2
	RV *Soela*	1982	Hydrology data	3
	RV *Soela*	1983	Hydrology data	6
	RV *Franklin*	1987	Hydrology data	12
	RV *Franklin*	1995	Hydrology data	17
	RV *Franklin*	1996	Hydrology data	2
	RV *Franklin*	1999	Hydrology data	11
	RV *Franklin*	2000	Hydrology data	1
	RV *Franklin*	1987	CTD data	9
	RV *Franklin*	1995	CTD data	8
	RV *Franklin*	1999	CTD data	12
Geoscience Australia	*Kos II*	1967	Sediment data	13
	Espirito Santo	1968	Sediment data	26
	RV *Soela*	1982	Sediment data	21
	Rig Seismic	1990	Sediment data	5
	RV *Franklin*	2000	Sediment data	4
GEOMAR (Germany)	RV *Sonne*	1978	Sediment data	2
	RV *Sonne*	1979	Sediment data	2
ANU	RV *Franklin*	1996	Sediment data	5
University of Adelaide	RV *Franklin*	1999	Sediment data	3
CSIRO	RV *Southern Surveyor*	2005	Sediment data	7

3.5.1.3 Biological data

In total, we found 131 biological samples for the ancient coastline between the 120 and 140 m contours (Fig. 3.27; Table 3.13). The majority of the samples (104) are comprised of demersal fish assemblages obtained from the CSIRO data base 'Marine Data Trawler'. These samples were collected on 14 different cruises from 1979 to 1997. The remaining 26 samples are comprised of museum records. The Australian Museum holds 19 samples that coincide with the ancient coastline (Table 3.13). Seven samples included only mollusc data with 51 mollusc species in total. Another 18 invertebrate and 5 fish species were recorded in the remaining 13 samples. The Northern Territory

Museum holds records from four samples (Table 3.13). These samples contained seven crustacean species. Finally, the Queensland Museum holds two more samples which list one polychaete and one crustacean species (Table 3.13).

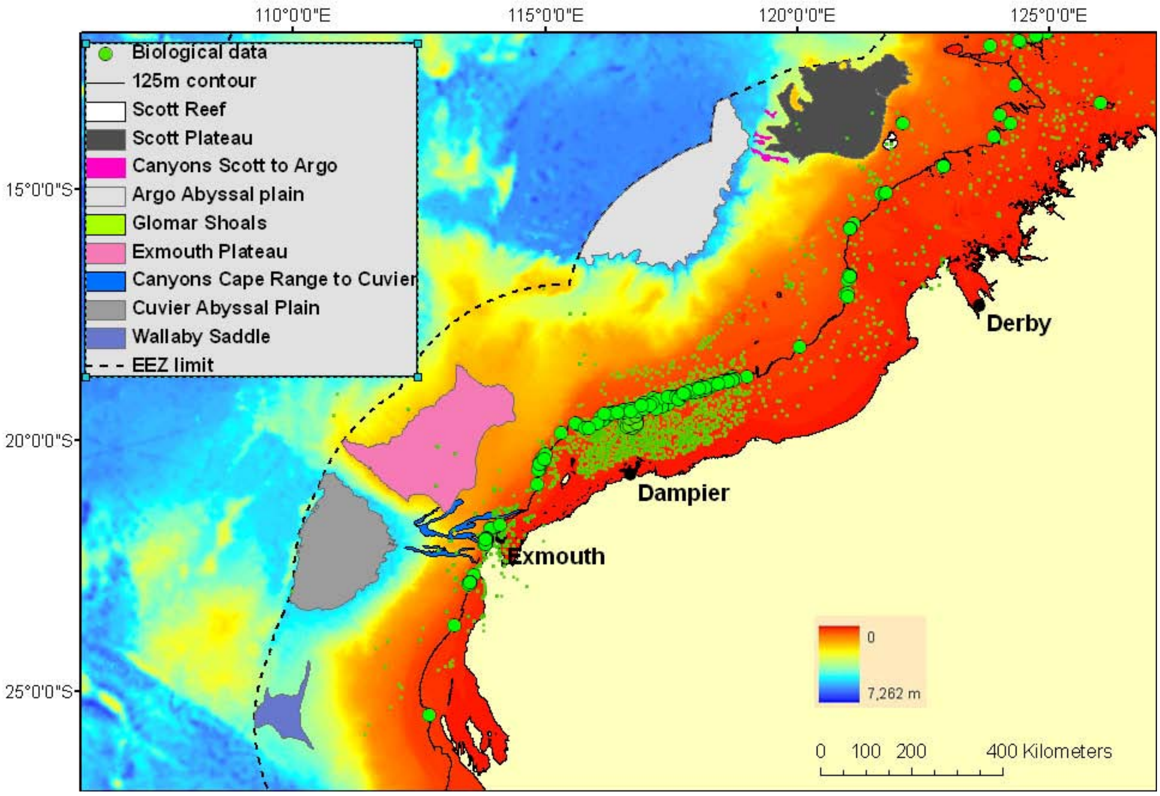

Figure 3.27. Location of biological samples near the Holocene coastline (125 m contour) with locations shown as larger green points.

Table 3.13. Metadata for biological samples from the Holocene coastline (120 – 140 m contour).

Data Source	Vessel	Collection year	Data Type	No. of Samples
CSIRO 'Marine Data Trawler'	RV *Courageous*	1979	Fish data	6
	Prometey	1968	Fish data	4
	RV *Courageous*	1978	Fish data	3
	Shantar	1974	Fish data	2
	FV Pride of Eden	1989	Fish data	6
	RV *Soela*	1982	Fish data	4
	RV *Soela*	1983	Fish data	9
	RV *Soela*	1986	Fish data	10
	RV *Soela*	1987	Fish data	4
	RV *Soela*	1988	Fish data	9
	RV *Southern Surveyor*	1990	Fish data	10
	RV *Southern Surveyor*	1991	Fish data	15
	RV *Southern Surveyor*	1995	Fish data	10
	RV *Southern Surveyor*	1997	Fish data	12
Australian Museum			Mollusc data	7
			Invertebrate data	12
			Fish data	1
Northern territory Museum	RV *Soela*	1982	Crustacean data	1
	RV *Soela*	1983	Crustacean data	3
		1986	Crustacean data	1
Queensland Museum		1963	Invertebrate data	1
		2007	Invertebrate data	1

3.5.1.4 Seascapes and focal variety analysis

Along its entire length the ancient coastline coincides mostly with two onshore seascapes, Seascape 10 and 11, which are characteristic for the upper slope (Fig. 3.28). Seascape 10 has a depth range of 11 – 528 m with a mean of 136 m and represents the seascape with the lowest mean depth on the slope. This puts it into the subtidal depth zone on the margin (Gage & Tyler, 1992). It is also characterised by the highest primary productivity values, 2nd-lowest mud content, the 2nd-highest gravel content and seafloor temperature and the lowest slope values. Seascape 11 is also characterised by high primary productivity values, warm seafloor temperatures and low slope values. North of 17˚S the ancient coastline is in close vicinity to two additional seascapes (Seascapes 8 and 9) which are characteristic of this Northern area (Fig. 3.28). Seascape 8 ranges in depth from 0 – 884 m with a mean of 325 m. It is also characterised by the highest gravel content, 3rd-lowest mud content, 3rd-highest seafloor temperatures and 3rd-lowest slope values while Seascape 9 is characterised by low primary productivity values.

Overall, in its southern parts (south of ~ 17˚S) the coastline coincides with seascapes that are characterised by high primary productivity while further north the strandline lies adjacent to areas which are characterised by low primary productivity. Low primary productivity and high seafloor temperatures may be due to the effects of the Indonesian Throughflow which carries warm and nutrient-poor water from the Pacific.

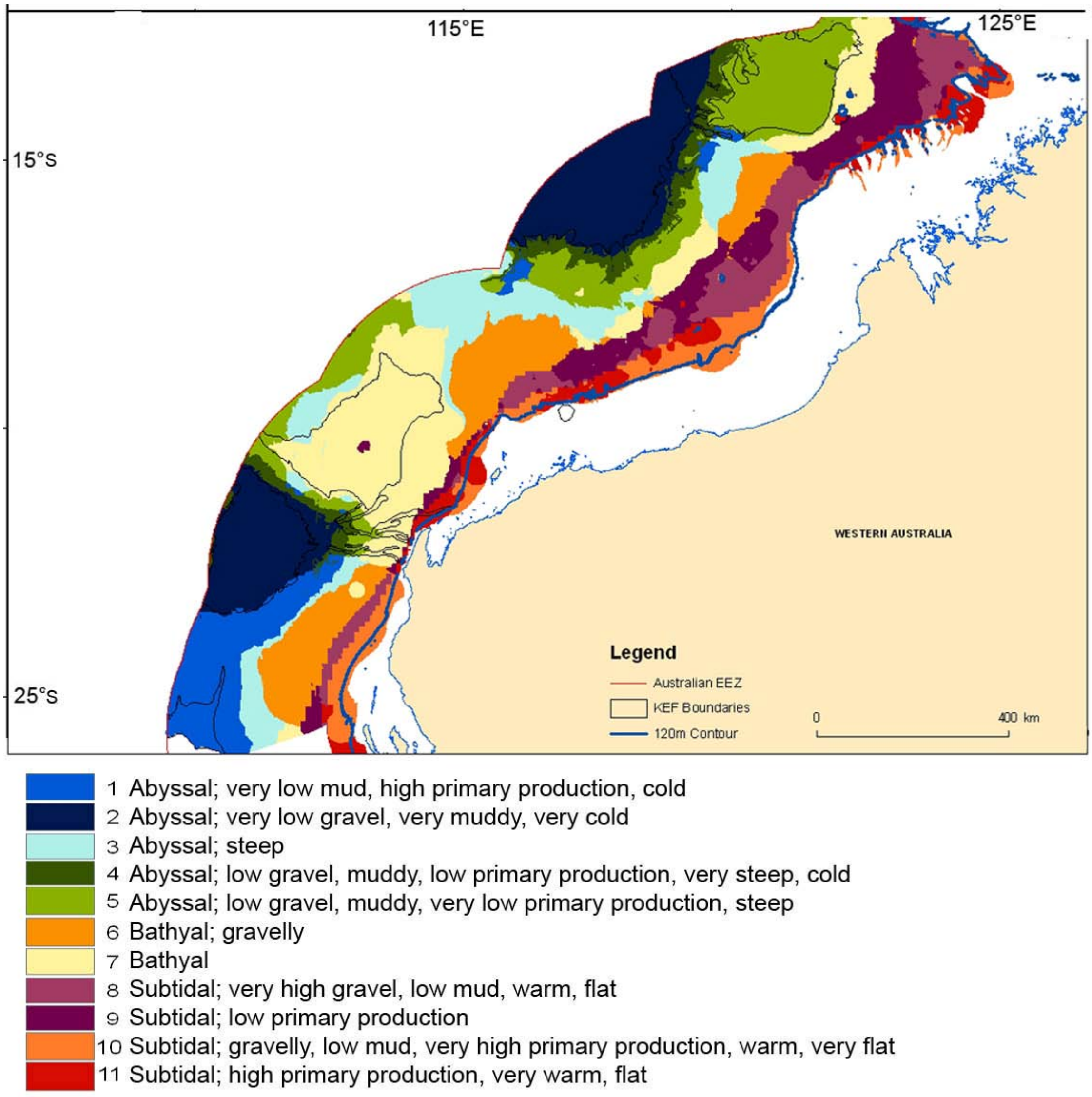

Figure 3.28. Map of seascapes for the Holocene coastline.

Based on the focal variety analysis, habitat diversity is moderate along the strandline (Fig. 3.29). However, the strandline runs adjacent to areas of high habitat diversity coinciding with several shoals, banks and terraces on the upper slope between Exmouth and Broome (Fig. 3.29).

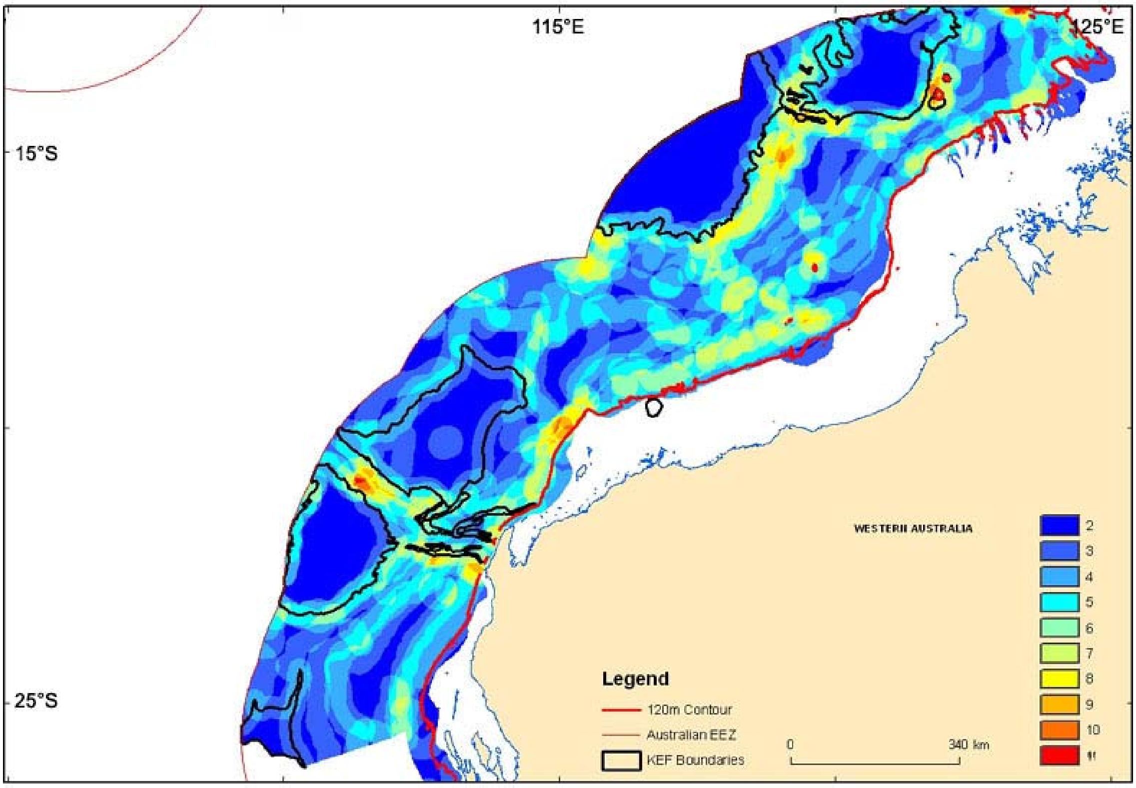

Figure 3.29. Map of focal variety indices for the Holocene coastline.

3.6 Shoals

Shoals are defined as areas of elevated seafloor composed of unconsolidated material and thus present a hazard to surface navigation. In Australia 488 banks/shoals have been identified covering a total area of 51,010 km^2 or 0.57% of the total area (Heap & Harris, 2008). The northwest margin contains by far the largest number of banks and shoals with 276, and the single most extensive shoal/bank region, the Sahul Banks (Heap & Harris, 2008).

3.6.1 Glomar Shoals

3.6.1.1 General description

Glomar Shoals are situated approximately 150 km north of Dampier on the Rowley Shelf (Jones 1973). It is a submerged littoral feature 26-70 m below the present sea level (littoral = the shore zone between high and low watermarks). Hence sediments mostly consist of skeletal material of marine organisms and are characterised by a relatively high (>90 %) carbonate content. Sediment samples from Glomar Shoals are distinguished from surrounding areas by a much higher gravel content and presence of coarse sands of weathered coralline algal and shell material. The accumulation of coarse shelly sand at Glomar Shoals indicates a high energy environment subjected to strong seafloor currents (McLoughlin & Young, 1985).

3.6.1.2 Physical data

There are only three hydrology samples and two sediment samples recorded for Glomar Shoals (Fig. 3.30; Table 3.14). This is a surprising result given the shallow depth of this KEF and comparative ease regarding sampling.

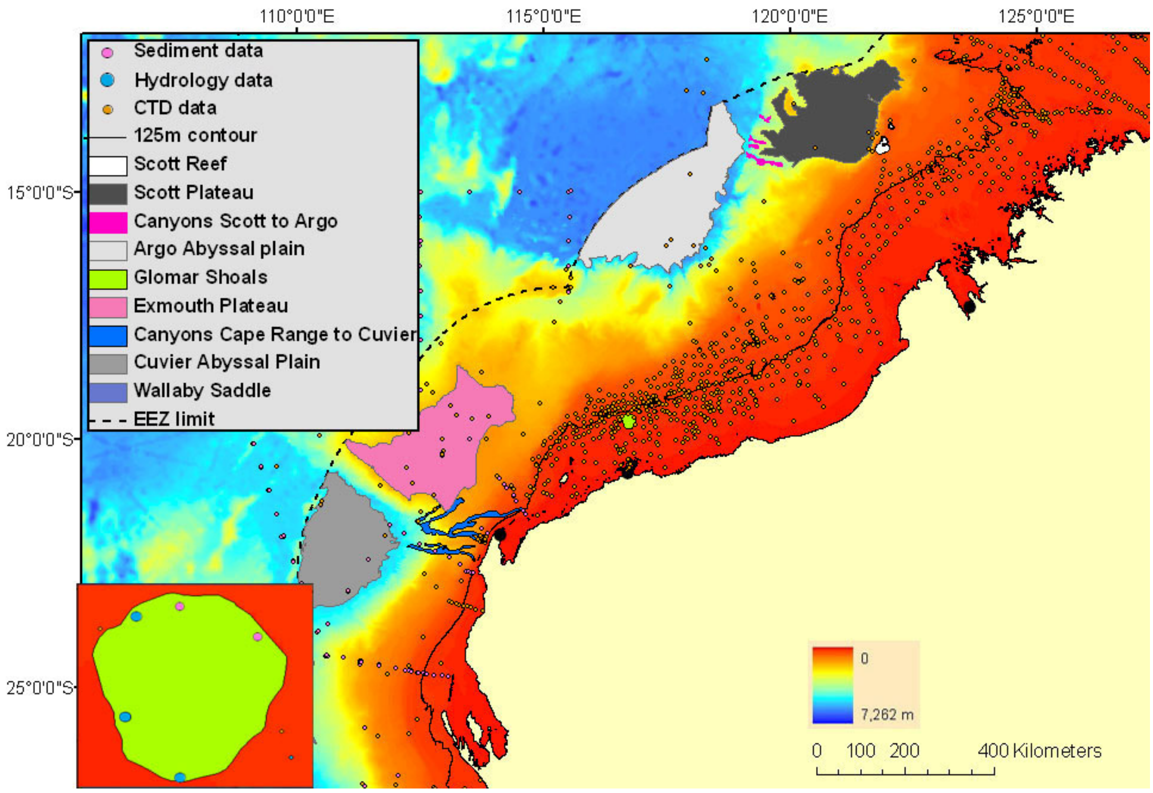

Figure 3.30. Location of physical samples for the Glomar Shoals with sample locations shown as larger points.

Table 3.14. Metadata for hydrology, CTD and sediment samples from the Glomar Shoals.

Data Source	Vessel	Collection year	Data Type	No. of Samples
CSIRO 'Marine Data Trawler'	RV *Sprightly*	1976	Hydrology data	1
	RV *Courageous*	1978	Hydrology data	2
Geoscience Australia / Northwest Shelf Sampling	*Kos II*	1967	Sediment data	2

3.6.1.3 Biological data

Glomar Shoals contains the best biological data coverage for all KEFs. A total of 44 samples were recorded for Glomar Shoals, of which 38 were recorded in the CSIRO database 'Marine Data Trawler' (Fig. 3.31; Table 3.15). The CSIRO records consist entirely of demersal fish composition data from depths of 50–70 m. The *Berg-3* 1967 survey data included species composition and abundance data of 87 demersal fish species and is a small subset of a large survey where more than 100 stations were sampled. This dataset was integrated in an additional seascapes analysis of Glomar Shoals and surrounds (Section 3.8.2). The remaining surveys included species composition data of demersal fish species only. The sponge and fish records from the Northern Territory and Queensland Museums were collected during the same survey in 50–80 m water depths.

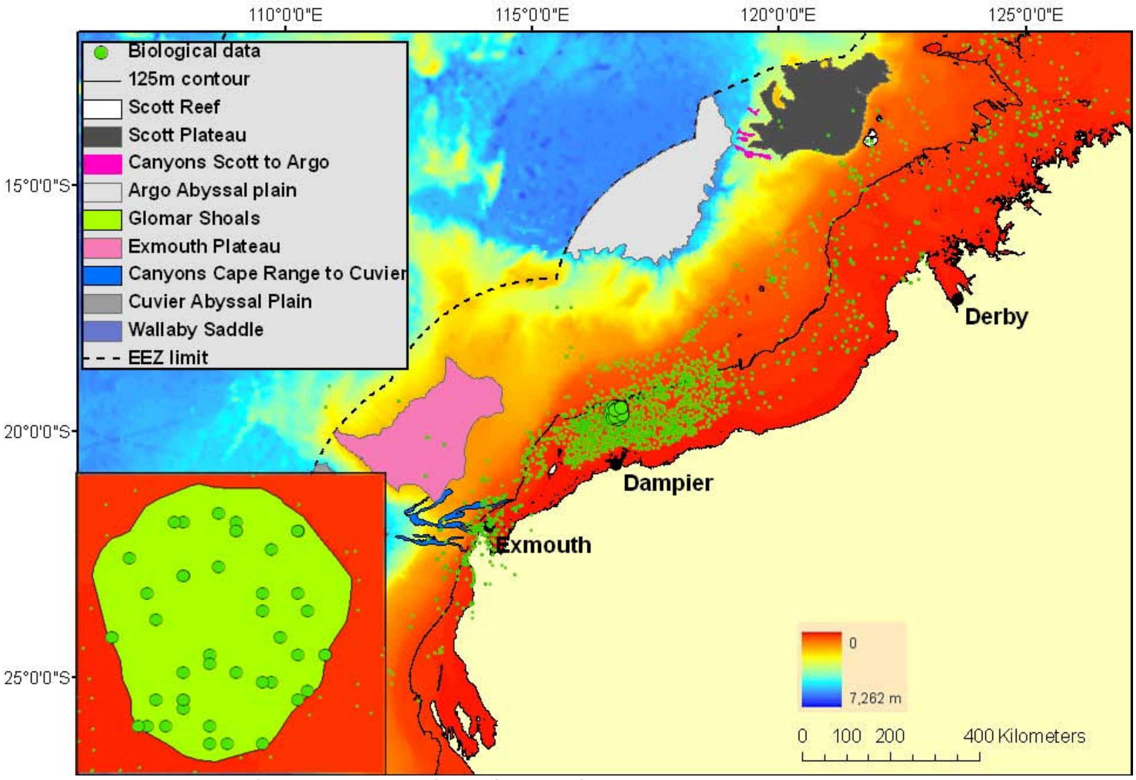

Figure 3.31. Location of biological data from Glomar Shoals with sample locations shown as larger green points.

Table 3.15. Metadata for biological samples from the Glomar Shoals on the northwest shelf.

Data Source	Vessel	Collection year	Data Type	No. of Samples
CSIRO 'Marine Data Trawler'	*Berg-3*	1967	Fish data	13
	Prometey	1968	Fish data	3
	Prometey	1970	Fish data	3
	Shantar	1974	Fish data	1
	RV *Soela*	1983	Fish data	5
	RV *Soela*	1987	Fish data	3
	FV Pride of Eden	1989	Fish data	2
	RV *Southern Surveyor*	1990	Fish data	2
	RV *Southern Surveyor*	1991	Fish data	1
	RV *Southern Surveyor*	1995	Fish data	2
	RV *Southern Surveyor*	1997	Fish data	3
Queensland Museum		1982	Sponge data	2
Northern Territory Museum		1982	Fish data	2
		1982	Sponge data	2

3.6.1.4 Seascapes and focal variety analysis

Glomar Shoals mostly coincides with one seascape in the seascape analysis for the North-west Marine Region, namely Seascape 9, which also occurs in the vicinity. Seascape 9 ranges in depth from 11.5 – 179.5 m with a mean of 112.6 m. Interestingly, this seascape is further characterised by very low primary productivity values which is contrary to the observed high biological productivity of the area. The southern shoal margin coincides with Seascape 2 which is characterised by the lowest mud content and the second lowest slope values. Seascape is 1 characterised by the 2nd-lowest gravel content and seafloor temperatures and the 3rd-lowest mud content. A small area on the northern margin coincides with seascape 3 which is defined by high gravel contents.

The results of smaller-scale seascapes and focal analyses of the Glomar Shoal region are described in Section 3.8.

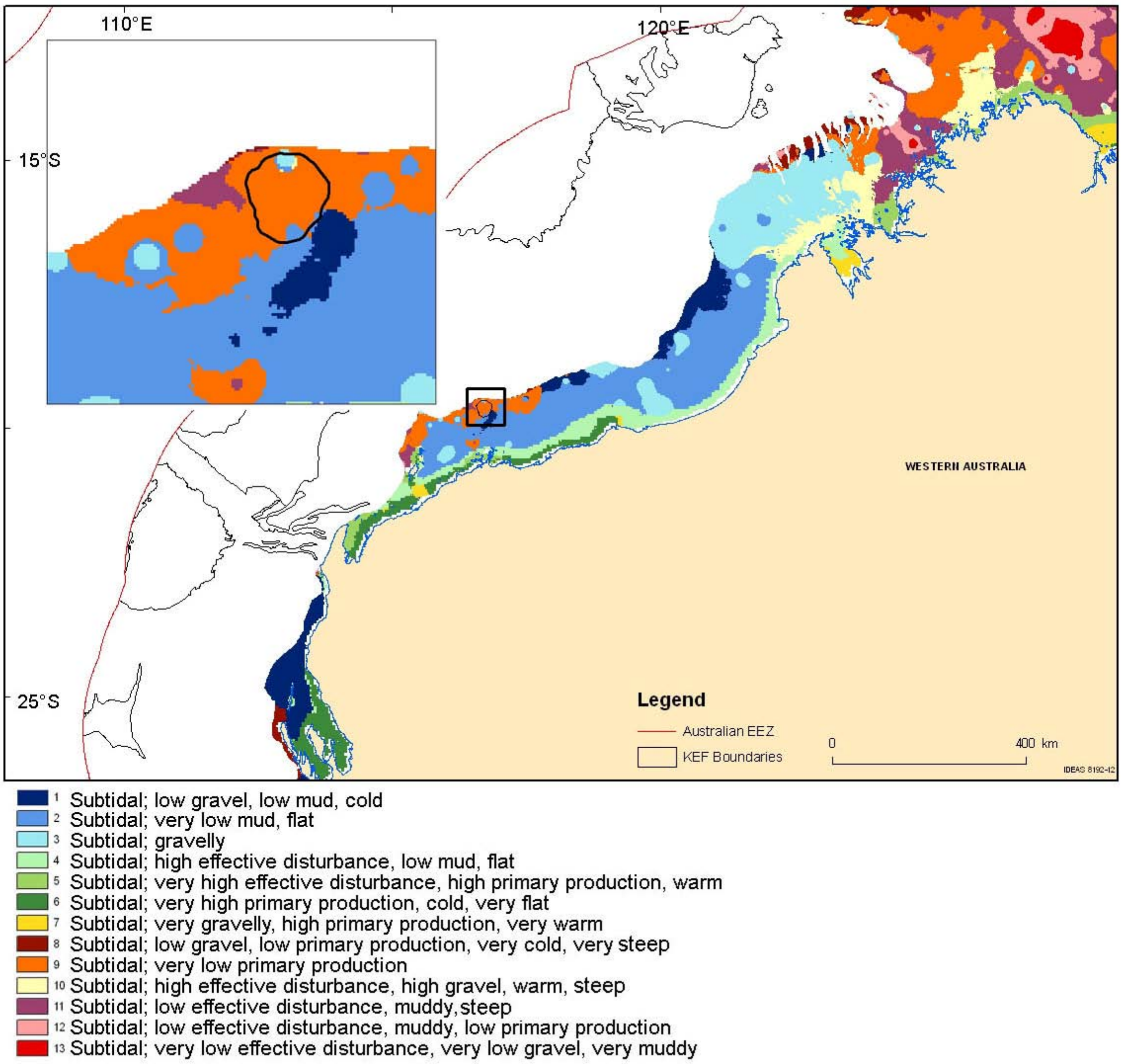

Figure 3.32. Map of seascapes for Glomar Shoals.

The resulting focal variety analysis indicates that Glomar Shoals is an area of moderate to higher seascapes diversity compared to its surroundings (Fig. 3.33). This can be largely attributed to the relatively large number of seascapes (4) in the vicinity.

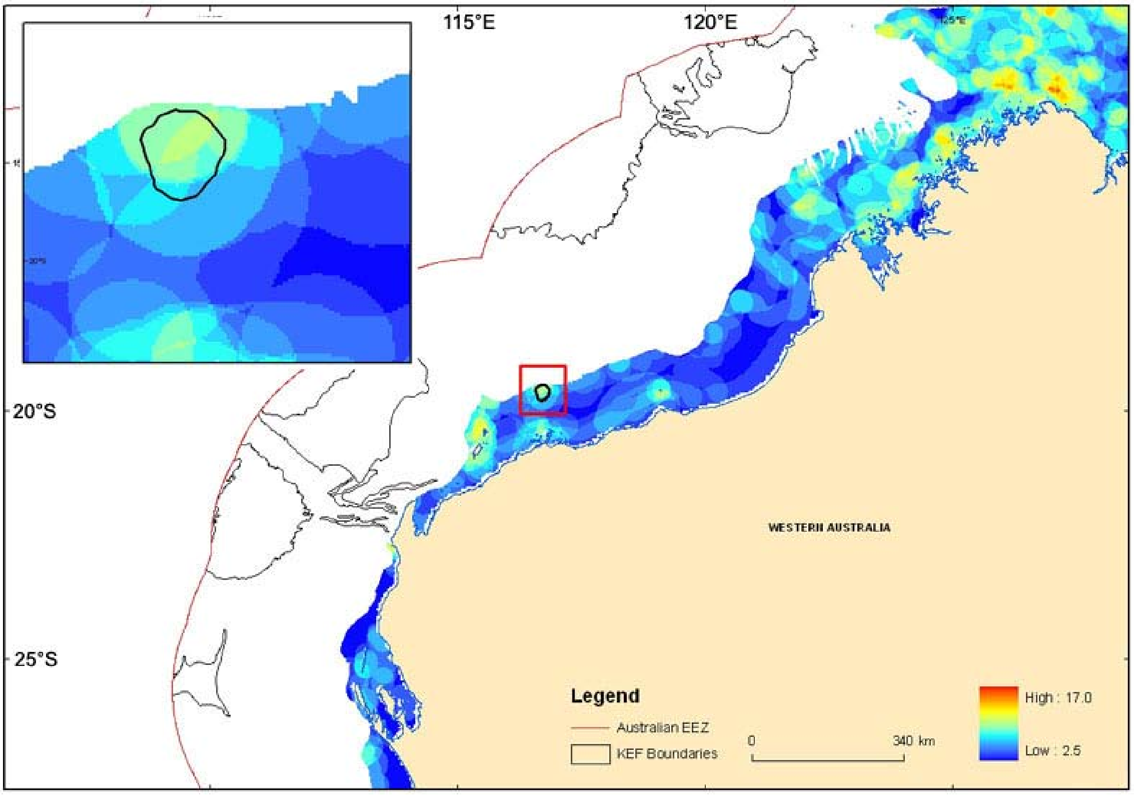

Figure 3.33. Map of focal variety indices for Glomar Shoals.

3.7 Scott Reef

3.7.1 General description

Scott Reef is part of a series of submerged annular reefs rising between the 300 and 700 m contours on the northwest continental slope (14.11˚S / 121.83˚E). Scott Reef consists of two separate reef formations, North Reef and South Reef. North Reef is an annular reef approximately 16 km long and 14 km wide. It encloses a deep central lagoon (max. depth ~21 m) which is connected to the open ocean by a passage to the northeast and southwest. South Reef is crescent-shaped with the opening facing North Reef. It isseparated by North Reef through a 400 – 700 m deep channel. The approximate width of the reef is 27 km and the length 17 km. The open lagoon of South Reef is 35-55 m deep.

The position of Scott Reef on one of the widest continental shelves in the world and its proximity to deep oceanic water makes it similar to oceanic atolls characterised by deep, clear oceanic water and low tidal ranges. However, Scott Reef is subjected to considerably higher tidal exchanges, similar to shelf atolls (Berry 1986).

3.7.2 Biological information for Scott Reef

In 1984 staff from the Western Australian Museum spent nine days on Scott Reef collecting the fauna of reef flats, lagoons and outer reef slopes. The survey conducted by the Western Australian Museum revealed that overall the reef fauna of Scott Reef is considerably different from near-shore reef areas and is characteristic of oceanic reefs. Overall more than 200 reef-building coral species and other cnidarians, almost 400 mollusc species, more than 50 crustacean, 100 echinoderm and 600 fish species were collected (Allen & Russell, 1986; Marsh, 1986; Veron, 1986; Wells & Slack-Smith, 1986).

In the 1990s the Australian Institute of Marine Science (AIMS) established a Scott Reef Long Term Monitoring project with 13 monitoring sites on different reef habitats (Heyward *et al.,* 1995). A first assessment indicated that benthic diversity differed significantly between monitoring sites depending on swell and current exposure. Sheltered sites such as patch reef areas in the lagoon exhibited a rich coral community while high energy zones such as outer reef slopes exhibited sparse coral growth. Overall, the abundance of live corals was comparable or higher to similar areas on the Great Barrier Reef (GBR). In contrast, fish communities differed between Scott Reef and similar areas on the GBR (Heyward *et al.,* 1995). The monitoring program is on-going, but no new findings have been published since.

More recently, the Western Australian Museum sponsored by Woodside Offshore Petroleum PTY LTD have conducted additional surveys at Scott Reef. Although some of the general findings have recently been published by the Department of Environment and Conservation, Western Australia (Huisman & Morrison, 2007), the raw data are not publicly available and were therefore unable to be incorporated in the present study.

3.7.3 Seascapes and focal variety analysis

Unfortunately, no biological data could be sourced within the short time-frame of the study. Thus, seascape and focal variety analyses of Scott Reef includes only the high resolution analyses from the North-west Marine Region, as per all other KEFs in this report, with the exception of Glomar Shoals.

Interestingly, Scott Reef quite precisely coincides with Seascape 11 which is characterised by high primary productivity values, warm seafloor temperatures and low slope values (Fig. 3.34). Seascape 11 is also found in numerous areas on the upper slope. However it is absent from surrounding areas of Scott Reef which are defined by moderate (Seascape 7) to low primary productivity values (Seascapes 5 and 9) (Fig. 3.34). This result supports previous findings that Scott Reef is an area of high biological diversity sustained by high primary production.

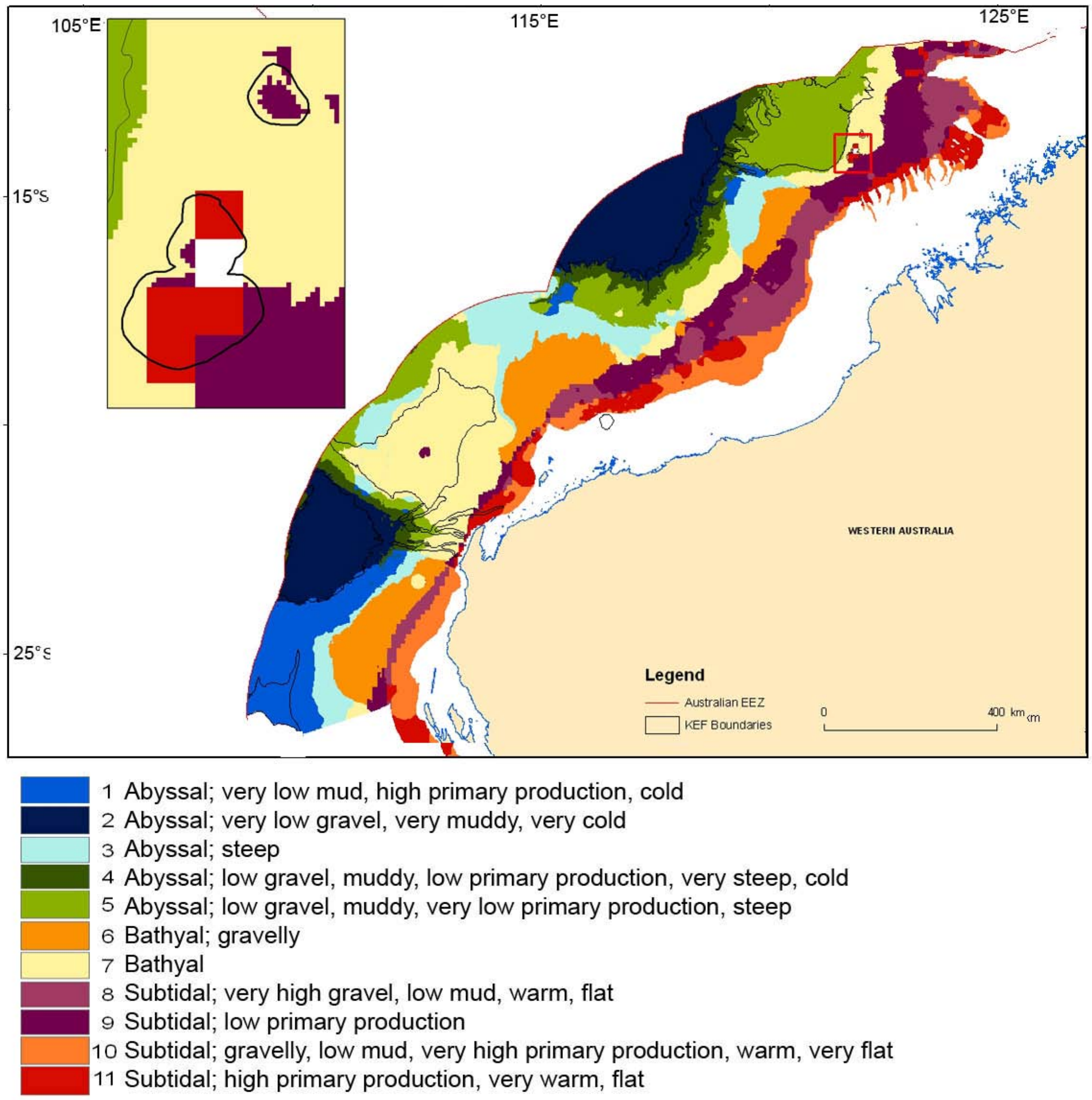

Figure 3.34. Map of seascapes for Scott Reef. The white square represents an area where no data was available for the analysis.

The focal variety analysis suggests that Scott Reef is an area of increased habitat diversity compared to its surroundings. Similar findings have previously been described in other reef studies (Berry, 1986; Heyward *et al.,* 1995) (Fig. 3.35).

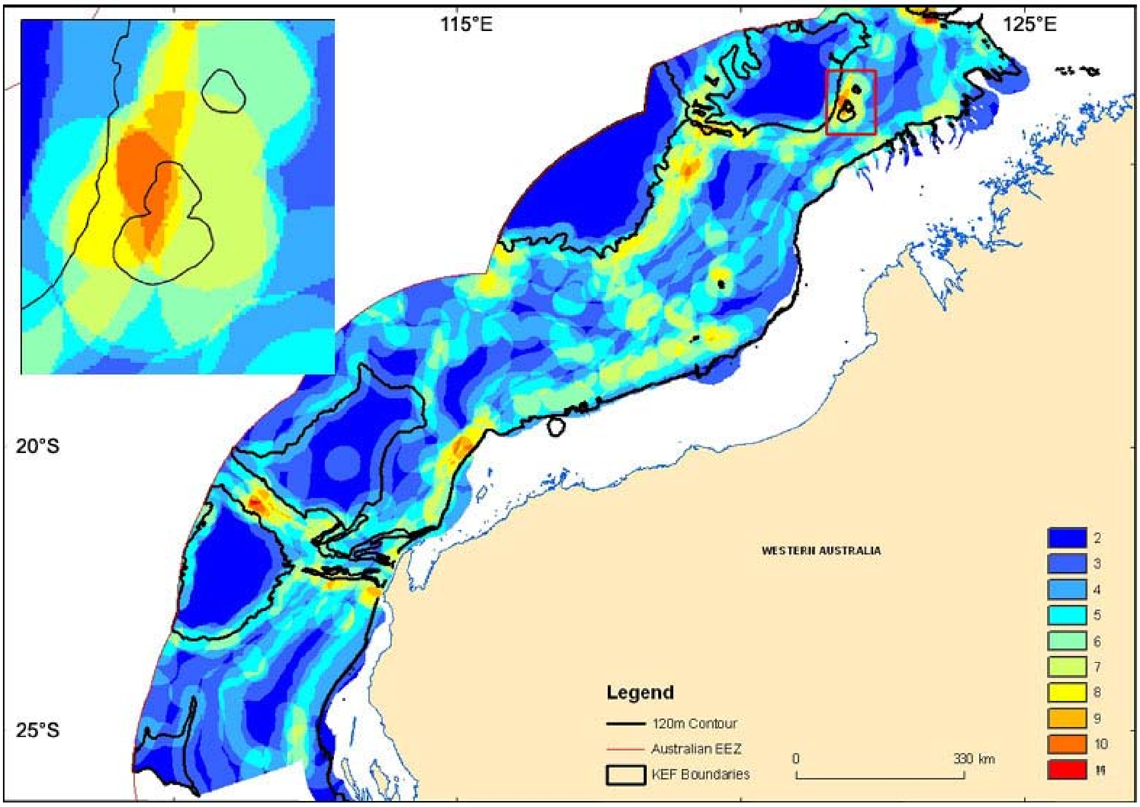

Figure 3.35. Map of vocal variety indices for Scott Reef.

3.8 Integration of biological data into seascapes

3.8.1 Seascapes excluding biological data

A seascapes analysis of the Glomar Shoals region excluding biological data revealed 10 classes (Fig. 3.36), although the Glomar Shoals coincides mainly with a single seascape, Seascape 7 (Fig. 3.36). This seascape has a depth range of 33 to 77 m with a mean of 58 m and is also characterised by the 3rd-lowest gravel content, the highest mud content and the 3rd-highest seafloor temperatures. Interestingly, Seascape 7 extends west and southwest beyond Glomar Shoals, but it does not coincide with any other area we have analysed on the shelf (Fig. 3.36). The North-eastern margin of the Glomar Shoals coincides with Seascape 9 which ranges in depth between 1 and 90 m with a mean of 34 m. This seascape is also characterised by the 3rd-highest mud content, 2nd-highest seafloor temperature and highest slope values. Seascape 9 is also found around some islands of the Dampier Archipelago where the island margins descend into deeper waters (Fig. 3.36). The southeastern shoal margin coincides with Seascape 2, which extends further southwest. Seascape 2 ranges in depth from 50 to 81 m with a mean of 66 m. It is also characterised by the lowest effective disturbance and primary productivity values, the 3rd-highest gravel values and the 2nd-lowest slope values. The southwest margin also coincides with Seascape 1, which ranges in depth from 39 to 77 m with a mean of 56 m. This seascape is characterised by the 2nd-lowest effective disturbance values, the lowest gravel content and seafloor temperatures and the 3rd-lowest slope values. Seascape 1 coincides with a large area on the shelf south of Glomar Shoals (Fig. 3.36). Adjacent to Seascape 7 coinciding with the northern and western margin lies Seascape 3, which is characterised by 2nd-lowest gravel contents, primary productivity vales and seafloor temperatures, as well as 2nd-highest mud contents and 3rd-highest slope values.

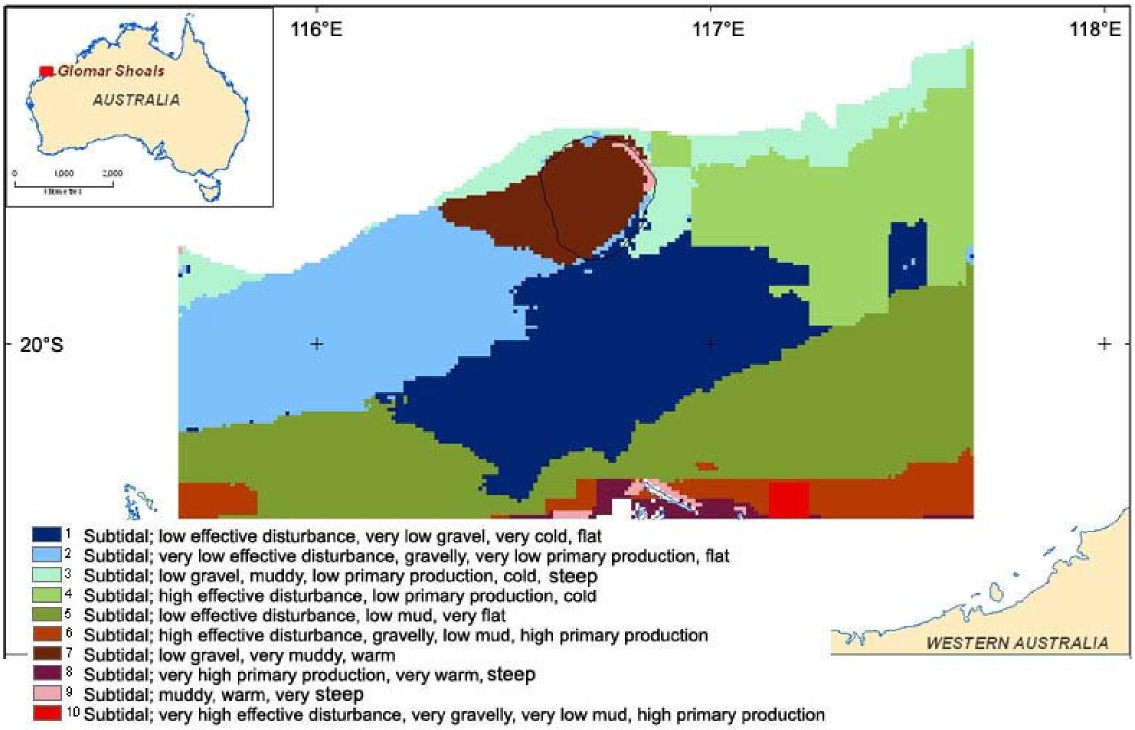

Fig.3.36. Map of the seascapes for Glomar Shoals and surrounds, excluding biological data layer. Glomar Shoals is marked with a black outline.

The resulting focal variety analysis showed that much of Glomar Shoals is an area of high habitat diversity, particularly the eastern margin (Fig. 3.37). The western margin and the centre, however, are areas of low habitat diversity similar to the immediate surroundings (Fig. 3.37).

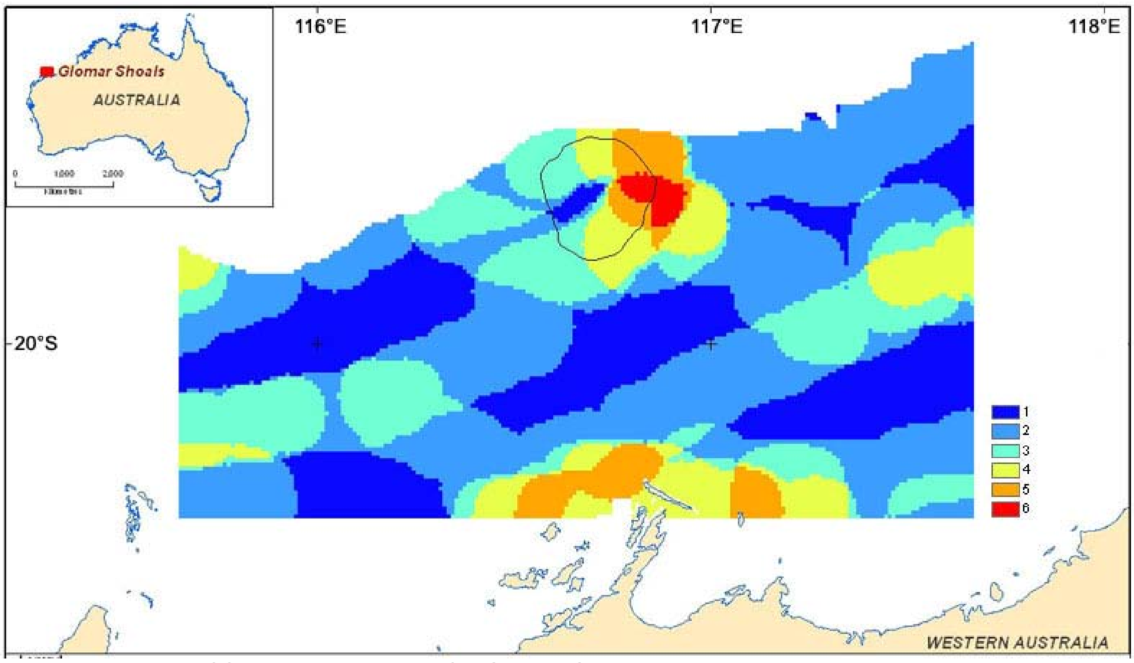

Figure 3.37. Map of focal variety indices for Glomar Shoals and surrounds, excluding the biological data layer.

3.8.2 Seascapes including biological data

A seascapes analysis of the Glomar Shoals region including biological data revealed 11 classes (Fig. 3.38). Interestingly, Glomar Shoals coincides with Seascape 11, which is not found in the adjacent areas (Fig. 3.38). Seascape 11 ranges in depth from 32 to 71 m with a mean of 46 m. It is also characterised by the 2nd-highest diversity index values, the 3rd-highest gravel content and seafloor temperatures. Seascape 11 is also found southwest of Glomar Shoals towards the coast (Fig. 3.38). Adjacent to Seascape 11, covering the shoal margin, is Seascape 10, which has a depth range of 43 to 101 m and a mean depth of 71 m. Seascape 10 is characterised by the highest diversity index values, 3rd-highest slope values and mud content, 2nd-lowest primary production values and 3rd-lowest seafloor temperatures. Seascape 10 coincides with other areas surrounding Glomar Shoals on the shelf (Fig. 3.38). Small areas on the southwestern and western margin of the shoal coincide with Seascape 1, which is characterised by 2nd-lowest effective disturbance values and mud content and the lowest primary productivity values. Seascape 1 has a depth range of 53 to 89m with a mean depth of 66 m. A small area on the southern margin of Glomar Shoals coincides with Seascape 4, which also covers a large area south of Glomar Shoals parallel to the coast (Fig. 3.38). Seascape 4 is characterised by 3rd-highest diversity index values, 3rd-lowest effective disturbance and slope values, the lowest gravel content and the 2nd-lowest seafloor temperatures. The water depth of this class ranges from 42 to 71 m with a mean of 57 m.

Overall seascapes coinciding with Glomar Shoals and its immediate surrounds are characterised by high diversity and low primary productivity (Seascapes 4, 10 and 11) whereas seascapes coinciding with areas closer to the coast are characterised by low diversity and high primary productivity and seafloor temperatures (seascapes 6 – 9) (Fig. 3.38). Seafloor temperatures at Glomar Shoals are high compared to those of the surrounding waters.

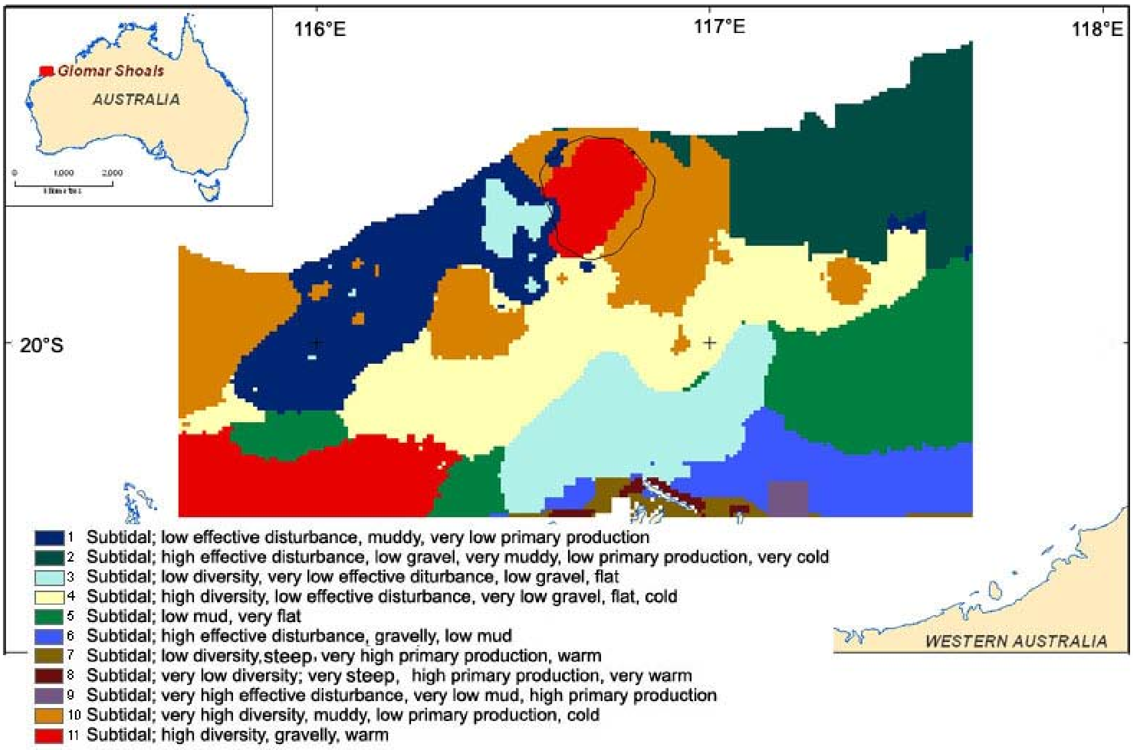

Figure 3.38. Map of the seascapes for Glomar Shoals and surrounds, including biological data layer.

Interestingly, the resulting focal variety analysis showed that the western shoal margin and areas west of Glomar Shoals are high in habitat diversity (Fig. 3.39). This is in direct contrast to the analysis excluding the biological data in which the eastern shoal margin had a higher index. The shoal centre, however, is also rather homogenous, similar to the previous analysis (Fig. 3.39).

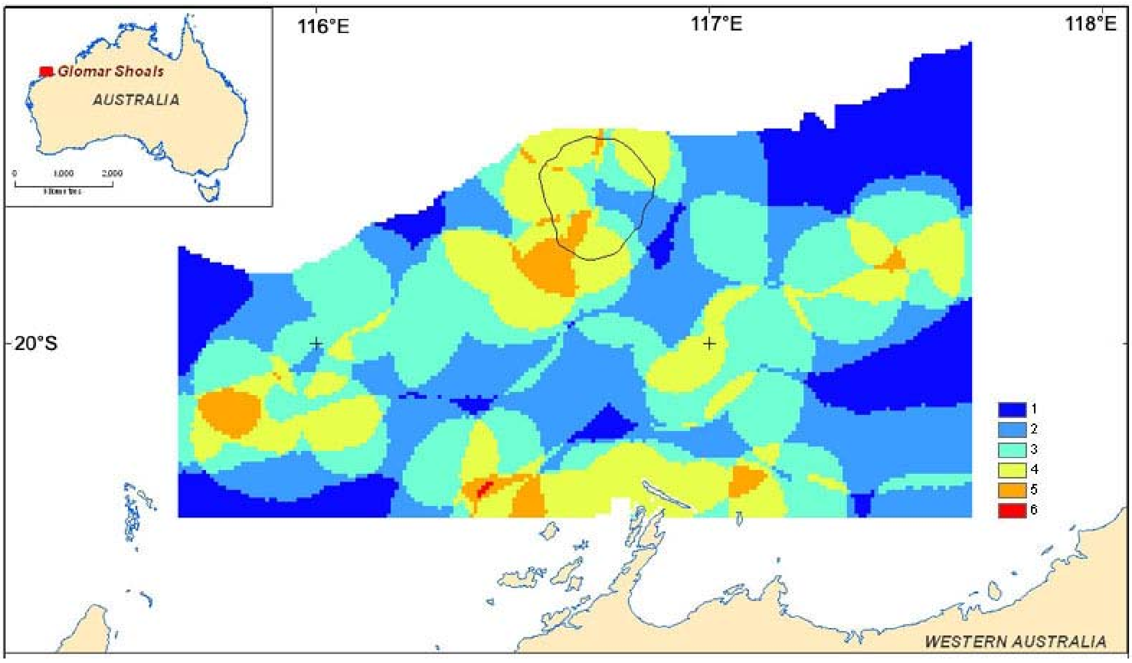

Figure 3.39. Map of focal variety indices for Glomar Shoals and surrounds, including the biological data layer.

3.8.3 Comparison of seascapes with and without biological data

In both analyses, the majority of Glomar Shoals coincides with a single seascape, which is characterised by high seafloor temperatures in both cases (Fig. 3.40). In the analysis that excluded the biological data layer, this seascape extended into the surrounding area west of Glomar Shoals (Fig. 3.40A). In contrast, in the analysis that included the biological data layer, the same area coincided with a second seascape characterised by low diversity indices (Fig. 3.40B). Importantly, the analysis incorporating biological data more closely matches actual geomorphology of the KEF (Figure 3.40B) than the analysis excluding biological data (Fig. 3.40A). This result suggests that the inclusion of biological data into a seascapes analysis, where available, may add another important variable to the analysis and provide a more representative distribution of seascapes.

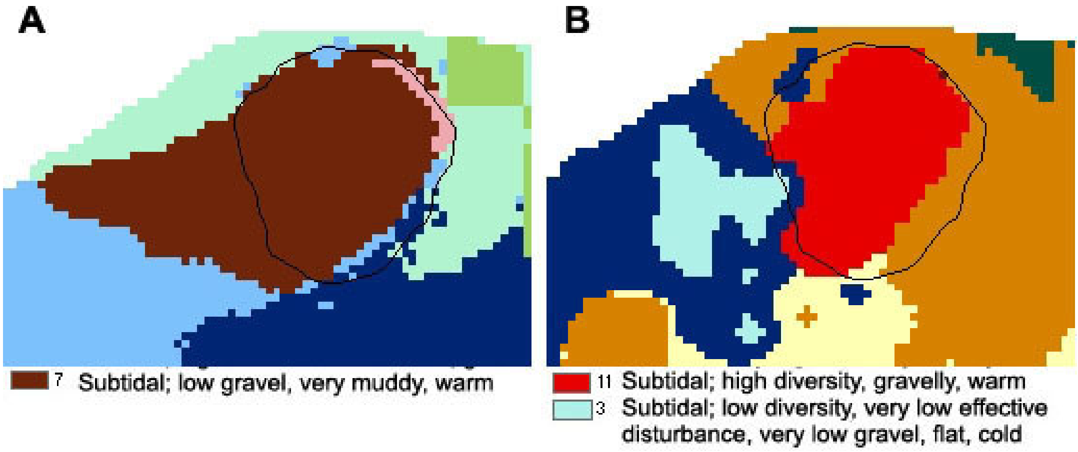

Figure 3.40. Comparison of seascapes coinciding with Glomar Shoals from an analysis (A) excluding biological data and (B) including biological data. The black line outlines Glomar Shoals.

3.9 Statistical analysis of fish assemblage data at Glomar Shoals

3.9.1 Similarity of fish assemblages from Glomar Shoals area

Fish assemblages at Glomar Shoals were not significantly different from those of the surrounding areas, as confirmed by an ANOSIM (R = -0.08; P = 0.79). This is illustrated in the n-MDS ordination which shows that Glomar Shoals samples group well with the samples of the surrounding area with no distinct formation of groups (Fig. 3.41). The negative value of R indicates a higher similarity between the samples of Glomar Shoals and surrounds than between the samples of Glomar Shoals only. The slightly negative value of R is not uncommon in communities where species have a highly clustered spatial distribution as appears to be the case with some of the fish species in the assemblage. Despite fish assemblages at Glomar Shoals being similar to those of the surrounding areas, the overall fish diversity is high at Glomar Shoals compared to the immediate surrounds (Fig. 3.38).

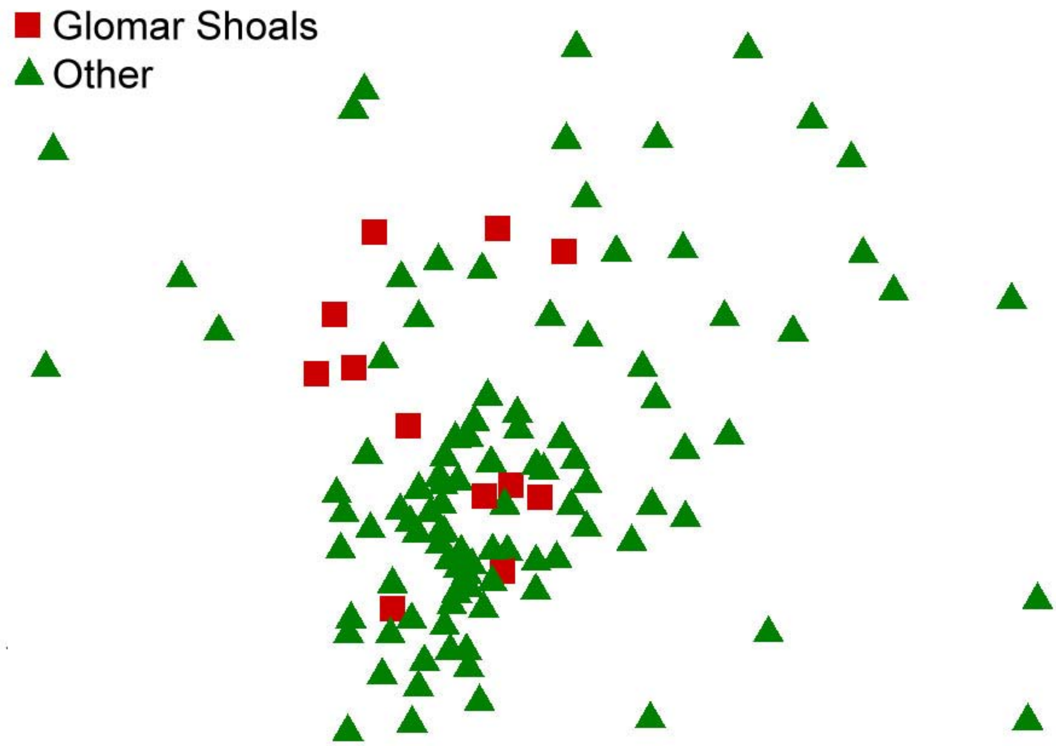

Figure 3.41. n-MDS ordination illustrating the similarity between fish assemblages at Glomar Shoals and surrounding areas. Distance between points indicates similarities between species assemblages, with closer points denoting more similar assemblages. Glomar Shoals samples (red squares) group well with samples taken in the vicinity (green triangles). Stress = 0.22.

15 demersal fish species at Glomar Shoals contributed more than 80% to the similarities observed among sites. The three species contributing the most (>9 % each) were the yellow-spotted triggerfish (*Pseudobalistes fuscus*), the emperor (*Lethrinus* sp.) and the brownstripe red snapper (*Lutjanus vitta*).

3.9.2 Linking fish diversity to environmental variables at Glomar Shoals and surrounding area

We examined the extent to which the physical data are related to the observed biological pattern; here demersal fish assemblages. Each individual environmental variable exhibited a weak correlation against the fish assemblage pattern. The strongest correlation is for mud content (Spearman rank correlation 0.186) while the weakest correlations are for effective disturbance and slope values (0.06 and 0.019 respectively). Slightly stronger correlations are achieved from the combination of environmental variables, with the strongest correlation (0.255) resulting from the combination of mud and gravel contents, effective disturbance values and water depth (Fig. 3.42). However, variables are relatively weak. Hence there is no clear pattern in bubble size apparent (Fig. 3.42).

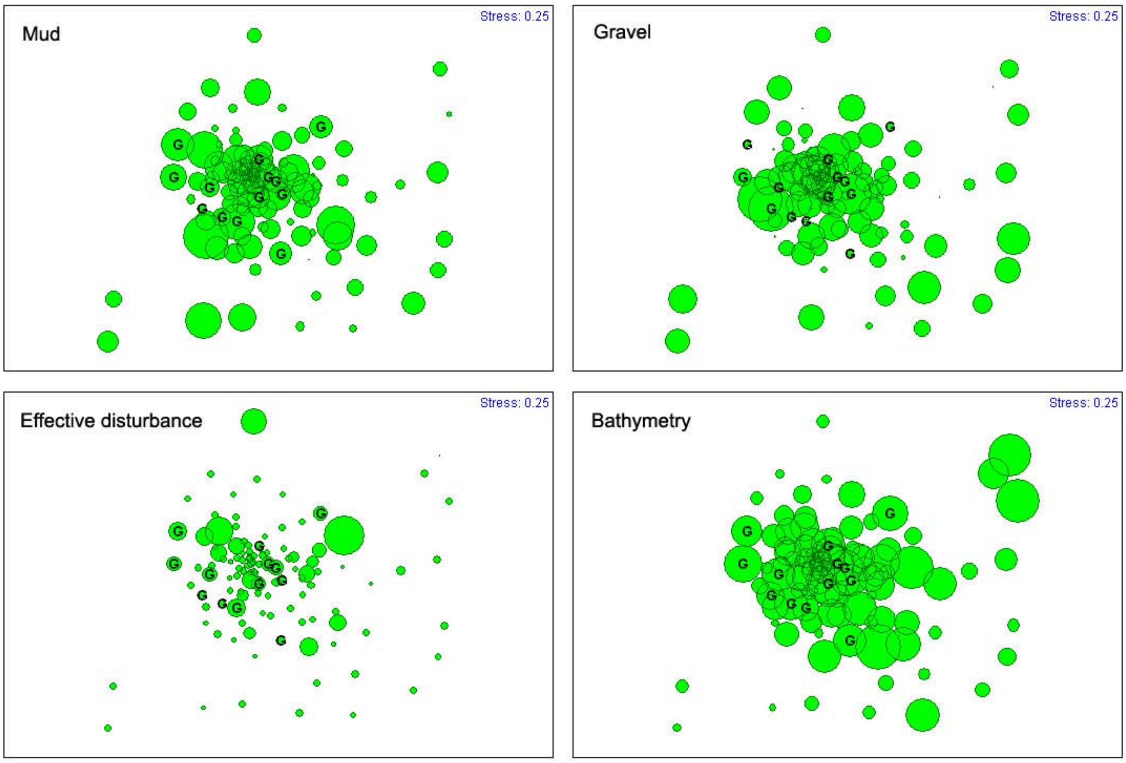

Figure 3.42. n-MDS ordinations with the distribution of sites based on the similarity of fish assemblages. "G" represents a sample from Glomar Shoals. The bubbles represent the four environmental variables identified to produce the best correlation to the distribution of the fish data i.e. mud and gravel content, effective disturbance and water depth. Larger bubbles reflect higher values for the variable shown while small bubbles reflect low values. Weak correlations between environmental variables and fish assemblages are represented by the faint trend of similar-sized bubbles occurring closer together than different-sized bubbles.

3.9.3 Linking environmental variables to fish diversity at Glomar Shoals only

Using the BIO-ENV function we also examined the correlation between fish assemblages and the same environmental factors at Glomar Shoals. Interestingly, it was the slope values that were most strongly correlated to the observed biological pattern (Spearman rank correlation 0.361), and this correlation was stronger than the correlation of mud and gravel content, effective disturbance and water depth combined. In the n-MDS ordination, the sites with similar fish assemblages are positioned closer together and characterised by small to moderate slope values (Fig. 3.43).

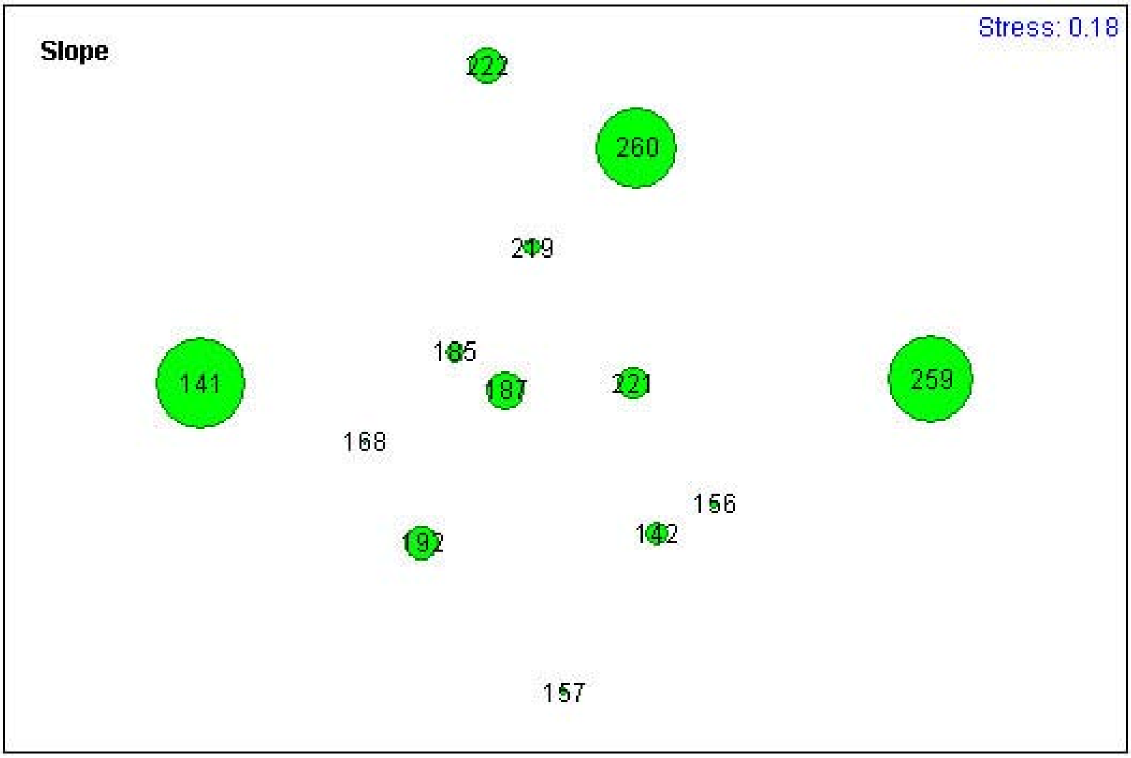

Figure 3.43. n-MDS ordinations with the distribution of sites only from Glomar Shoals based on the similarity of fish assemblages. The bubbles represent slope values for each site. Fish assemblages from small to moderate slopes (smaller bubbles) are closer together than fish assemblages from steep slopes (large bubbles), indicating a relationship between demersal fish assemblages and slope.

4 Discussion

4.1 Representativeness and uniqueness of KEFs

The aims of this study were to identify whether 10 out of 14 KEFs identified by DEWHA represent one or more habitat types and whether these habitats are unique to the region. The assessment was based on the results of a high-resolution seascapes and focal variety analysis conducted for the entire North-west Marine Region. This analysis gives a spatial representation of habitat diversity which together with the associated biological community defines an ecosystem. There are a number of criteria which are applied to marine bioregions to determine potential locations of representative MPAs, including representativeness and uniqueness, and an assessment of these criteria are summarised in Table 4.1 and discussed in more detail below.

Table 4.1. Regional assessment summary for KEFs in the North-west Marine Region.

Geomorphic feature	Representativeness	Uniqueness
Argo Abyssal Plain	YES	NO[1]
Cuvier Abyssal Plain	YES	NO[1]
Exmouth Plateau	YES	NO
Scott Plateau	YES	NO
Bowers & Oates Canyons	YES	NO
Cape Range, Cloates & Mermaid Canyons	YES	NO
Wallaby Saddle	YES	YES[2]
Scott Reef	YES	YES[3]
Holocene coastline	YES	NO
Glomar Shoals	YES	YES[4]

[1] Together, these KEFs represent a unique habitat, as they occur within the same seascape which is found nowhere else in the North-west Marine Region.
[2] Considered unique because the associated seascape is found nowhere else within hundreds of kilometres.
[3] Considered unique because the associated seascape is found nowhere else this far off shelf
[4] Local seascape analysis suggests that Glomar Shoals is unique among surrounding areas, but regional seascape analysis lumps Glomar Shoals into the same habitat type as surrounding areas, likely due to lower resolution at the coarser spatial scale used

4.1.1 The Argo and Cuvier Abyssal Plains

The Argo and Cuvier Abyssal Plain coincided with a single seascape not found anywhere else in the region indicating that, although separately each plain is not unique, taken together, these abyssal plains represent a unique habitat in the region. Both abyssal plains coincide with the same seascape indicating that both abyssal plains represent the same habitat type and by association similar communities. Each individual abyssal plain may therefore not represent a unique ecosystem, and the inclusion of one of the two plains into a system of MPAs may be sufficient for an adequate representation.

The focal variety analysis showed that both abyssal plains are homogenous environments most likely representing one type of ecosystem. The plain margins, however, appear to be more diverse in habitat type as indicated by the occurrence of several other seascapes in these areas. One seascape, in particular, was only found along the abyssal plain and plateau margins where the slope descends steeply into the abyss. This seascape may represent an additional habitat type unique to the area. Thus, inclusion of both abyssal plain and abyssal margin into an MPA may more adequately encompass representativeness and uniqueness than the plain alone.

4.1.2 The Exmouth and Scott Plateaus

The Exmouth and Scott Plateau each coincided mostly with a single seascape indicating that they both represent one single habitat type. Each plateau, however, coincided with a different seascape indicating that habitat types between the two plateaus differed and potentially support different communities. Areas of both plateaus would have to be included into a system of MPAs to ensure a representative protection of both habitat types and associated communities. However, both plateaus coincided with seascapes that were also found in other areas on the northwest margin indicating that these seascapes are not unique to the region and the same habitat types can be found among other geomorphic features in the region.

As observed for the abyssal plains, habitat diversity appeared to be low at both the Exmouth and Scott Plateau whereas the plateau margins showed some degree of habitat diversity. This is confirmed by geological studies that describe the northern margin of the Exmouth Plateau and the western margin of the Scott Plateau as steep and intersected by large canyons and spurs (Exon and Willcox 1980; Exon *et al.,* 1982; Ramsay & Exon 1994; Stagg 1978). These marginal features most likely add to the structural complexity of the environment which may support a more diverse plateau fauna.

4.1.3 The submarine canyons in the North-west Marine Region

The canyon systems in the North-west Marine Region add to the representativeness of ecosystems as they coincided with several habitat types which were not found at the other KEFs. Interestingly, both canyon systems coincided with different seascapes, indicating that they represent different habitat types, both of which would have to be considered for inclusion in a representative system of MPAs. However, our analysis also indicated that the same seascapes were found in close vicinity to the canyons indicating that these habitat types are not 'canyon specific' or unique to the region. Alternatively, this may reflect the resolution of the underlying data compared to the scale of the canyons.

Submarine canyons are known to be areas of high habitat heterogeneity. This was also confirmed in our study which showed high focal variety indices coinciding with the two canyon areas.

4.1.4 The Wallaby Saddle

The Wallaby is a unique geomorphic feature in the North-west Marine Region, and, according to our analysis, it also represents a unique habitat type that neither occurs anywhere else in the southern part of the region, nor with as large an area in the entire North-west Marine Region. The entire Wallaby Saddle and surrounding area may therefore represent a unique ecosystem that would need to be included for a comprehensive coverage of ecosystems in a representative system of MPAs.

Habitat diversity, however, was lowest on the saddle given that the margins coincided with the same seascape as the saddle itself.

4.1.5 Scott Reef

Scott Reef coincided with one seascape which was only found much further onshelf, supporting previous findings that the reef is an ecosystem vastly different from its surroundings. Interestingly, the reef coincided with a seascape which was characterised by high primary productivity in an area that is otherwise defined by low to moderate primary production values. Based on our result and previous studies showing that Scott Reef is an oceanic-reef with unique environmental characteristics, it may even represent an ecosystem unique to the entire bioregion.

The focal variety analysis suggest that Scott Reef is an area of high habitat diversity which confirms previous findings that described discreet reef habitats supporting a range of different communities.

4.1.6 The Holocene coastline

The Holocene coastline was difficult to classify in respect to representativeness and uniqueness. It is a unique geomorphic feature in the North-west Marine Region. Along its entire length, the ancient coastline coincided with seascapes characteristic for the upper shelf of which some did not coincide with any of the other KEFs. The ancient coastline would therefore add additional habitat types to a representative system of MPAs. However, the habitat types would not be unique to the coastline as they are widespread on the upper shelf. The ancient coastline may be separated into a Northern section (north of Broome) characterised by low primary production and a southern section (south of Broome) characterised by high primary production.

Based on the focal variety analysis, habitat diversity is moderate along the Holocene coastline. However, the strandline runs adjacent to areas of high habitat diversity, particularly in the area between Exmouth and Broome where there is an abundance of shoals, banks and terraces.

4.1.7 Glomar Shoals

The initial seascape and focal variety analysis of the entire on-shore North-west Marine Region showed that Glomar Shoals represents the same habitat type as the surrounding areas. In two additional analyses, with and without demersal fish data incorporated, Glomar Shoals coincided with a single seascape that did not occur anywhere else in the surrounding area, indicating that Glomar Shoals represents a habitat type that is not found in the surrounding area. On a regional scale, however, this habitat type may not be unique.

Interestingly, in all three analyses, Glomar Shoals was an area of increased habitat diversity compared to surrounding areas.

4.2 Ecological significance of KEFs

In the following section we briefly discuss whether the KEFs are ecologically significant for the region. The following criteria were evaluated based on important characteristics repeatedly mentioned in the literature (Australian and New Zealand Environmental and Conservation Council, 1998; DEH, 2005; DEWHA, 2008; Heyward *et al.,* 2006; Roff & Taylor, 2000):

- Diversity
- Productivity
- Endemism
- Functional importance
- Vulnerability

4.2.1 Soft-sediment environments – abyssal plains, marginal plateaus & saddles

Since there have been no studies that compare the fauna of marginal plateaus or saddles to that of abyssal plains and other deep-sea features, we will discuss plateaus, saddles and abyssal plains together based on their similarity as deep-sea soft-sediment environments.

Diversity – Deep-sea sediments are among the most species-rich habitats on the planet, and by covering 40% of the Earth's surface, they support a vast number of species, many of which are rare or endemic (Grassle & Maciolek, 1992; Sanders & Hessler, 1969). Based on the anecdotal observations recorded for the abyssal plains, marginal plateaus and the Wallaby Saddle on the northwest margin, no clear conclusions on the species richness of these deep-sea areas can be drawn. However, we can assume that these areas exhibit a similar diversity to other deep-sea soft-sediment environments harbouring a substantial number of species, many of which will have not been described yet (Fromont *et al.,* 2006). Generally, diversity is expected to be lower at abyssal depths (>2,000 m) (*e.g.* the abyssal plains, the Wallaby Saddle and the Scott Plateau) compared to bathyal depths (*e.g.*Exmouth Plateau).

Deep-sea soft-sediment environments show little environmental and habitat variability compared to other deep-sea geomorphic features including canyons, trenches, or seamounts. Environmental variability of deep-sea sediments is mostly reduced to small scale changes in sediment composition and grain size. A variety of biological structures (*e.g.* wood islands, sponge spicules, Sargassum deposits, polychaete mudballs or whale skeletons), however, add some structural complexity to an otherwise relatively homogenous environment (Butler *et al.,* 2001). Consequently, one can expect that the vast majority of animals inhabiting these sediments are small invertebrates, bioturbators and deposit-feeders, living in the top few decimetres of the seafloor. The sediment composition, however, differs between the plateaus and abyssal plains. Sediments on the Exmouth and Scott Plateaus are dominated by calcareous oozes and terrigenous material respectively while abyssal plain sediments are dominated by siliceous clays. This may result in a different species composition of benthic infauna between the two habitats, as macrofaunal species diversity has been shown to be positively correlated to sediment diversity (Etter & Grassle, 1992).

Productivity – No light reaches the deep-sea, and what little food is available sinks from the water column to the bottom. In general, less than 1% of the organic material arrives on the deep-sea floor, resulting in low abundances and small body sizes (Sanders *et al.,* 1965). Whether more food reaches the plateaus compared to the abyssal plains due to their shallower depth is questionable as primary production in the surface waters above both features is low. Localised 'food oases' (e.g., whale carcasses) may be exceptions that temporarily provide an abundance of food for large numbers of animals.

Endemism – With the absence of biogeographic barriers, the notion that the majority of deep-sea species have a cosmopolitan distribution seems logical (Gage & Tyler, 1992; Vinogradova, 1997). Although this assumption is perhaps too simplistic, the distribution of many deep-sea species is extensive, and species composition in deep-sea communities is comparable on a generic level. In the 1950's, Vinogradova (1959) proposed a zoogeographic regionalisation of the world's deep-sea which is still valid today. In this regionalisation, the fauna of the deep-sea, mostly macroinvertebrates, are divided into three zoogeographic regions and six subregions. According to this regionalisation, the deep-sea biota on the Australian northwest margin belongs to Pacific/North Indian deep-sea region and within that region to the North Indian sub-region (Fig. 4.1).

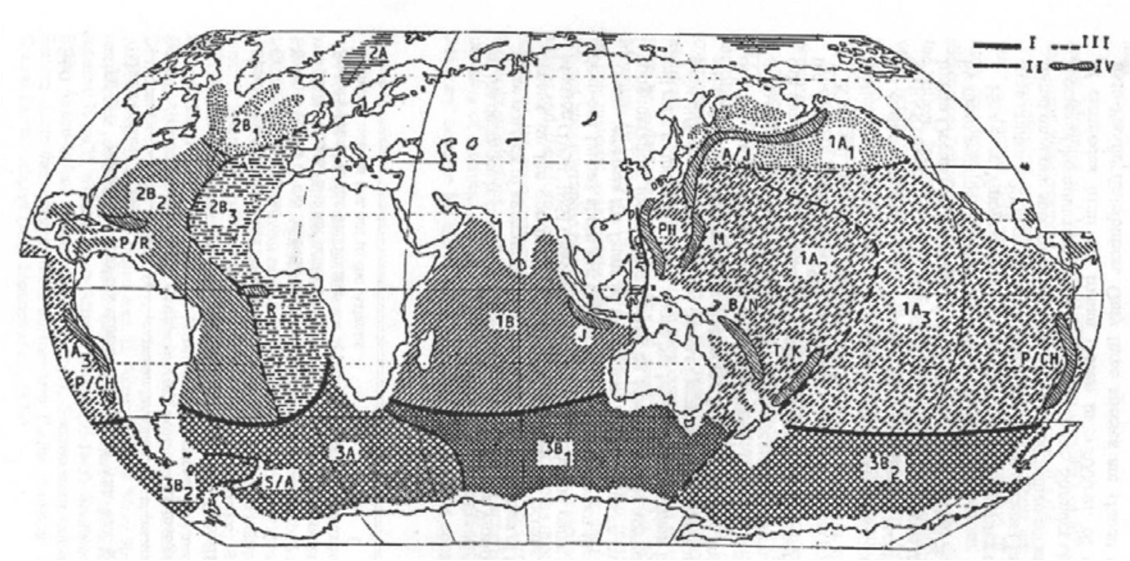

Figure 4.1. Zoogeographic regions of the abyssal and hadal zones of the oceans. Boundaries of the regions (I), subregions (II), abyssal provinces (III) and hadal provinces (IV). Pacific-North-Indian deep-sea region: 1A, Pacific subregion; 1A1, North-Pacific abyssal province; 1A2, West-Pacific abyssal province; 1A3, East-Pacific abyssal province; A/J Aleutian-Japan hadal province; PH, Philippine; M, Mariana; B/N, Bougainville – New Hebrides; T/K Tonga-Kermadec; P/CH, Peru-Chile hadal provinces; 1B, North-Indian subregion; J, Java hadal province. Atlantic deep-sea region: 2A, Arctic subregion; 2B, Atlantic subregion; 2B1, North-Atlantic abyssal province; 2B2 West-Atlantic abyssal province; 2B3, East-Atlantic abyssal province; P/R, Puerto-Rico hadal province; R, province of the Romanche trench. Antarctic deep-sea region: 3A, Antarctic-Atlantic subregion; S/A, South Antilles hadal province; 3B, Antarctic-Indian-Pacific subregion; 3B1, Indian Ocean abyssal province; 3B2, Pacific abyssal province (Vinogradova, 1997).

A recent study of the deep-sea fauna from Pluto Field, an oil production facility 300 km off the Western Australian coast also supports this scheme. Identification of the Pluto Field fauna indicated that the fauna of the upper continental slope, at depths of 350–750 m, has strong affinities to the Indo-Malayan sub-province and is comparable to material from similar depths in eastern Australia (Fromont *et al.,* 2006). The majority of animals collected from Pluto Field had already been recorded from Western Australian waters and were representative of the area and depth. Similarly Williams *et al.* (1996, 2001) found that fish species occurring at mid-slope depths (800-1,500 m) along the Western Australian coast had a wide distribution, some of them even cosmopolitan. However, deep-sea sediment communities often contain many endemic and rare species (Butler *et al.,* 2001), and the deep-water fauna of Western Australia may contain many new and undescribed species (Fromont *et al.,* 2006).

Functional importance – The contribution of the deep-sea sediment fauna to nutrient recycling is minimal compared with shallow water faunas since only 1% of the organic matter produced at the surface reaches the deep-sea floor. However, over long periods deep-sea sediment communities make a contribution to the recycling of nutrients and contaminants. The main functional importance of deep-sea sediments lies in their remoteness, expansiveness and uniqueness as a relatively untouched ecosystem. Currently, there are insufficient data from global studies to reveal the functional differences between abyssal plains, marginal plateaus or saddles.

Vulnerability – The large size and relative remoteness of most deep-sea sediments makes them less vulnerable to human disturbances than shallower or more heterogeneous regions. Species inhabiting these regions may also be less vulnerable to regional extinction simply because they may be more widely distributed than species living in submarine canyons, seamounts and trenches. Not enough is known about deep-sea soft-sediment environments to be certain that the large size of this habitat can negate regional disturbances (Butler *et al.,* 2001). However, it is known that deep-sea organisms are characterised by long lives, slow growth and low rates of recruitment which reduces their capacity to respond to significant disturbances (Grassle, 1977). Currently, there is very little information on the distribution limits of most deep-sea species, and predictions of broad-scale effects of localised disturbances remain speculative.

4.2.2 Submarine Canyons

Diversity – Submarine canyons are areas of high biological diversity (Vetter & Dayton, 1998; Schlacher *et al.,* 2007). They support a rich canyon fauna due to their structural complexity, instability, and hydrodynamics (Vetter & Dayton, 1998; Schlacher *et al.,* 2007). Strong currents funnel sediments and organic matter down the continental slope and supply the benthic community with particulate food. Hence submarine canyons are mostly dominated by sessile filter feeders compared with deep-sea soft-sediment environments which are dominated by deposit-feeders (Kloser *et al.,* 2000; Rowe, 1971; Vetter & Dayton, 1999). Five canyons investigated off southeast Australia harboured a rich sponge fauna comparable to that of seamounts (Schlacher *et al.,* 2007). High densities of other filter feeders such as sea whips and basket stars have been found in other canyons (Brodeur, 2001; Rowe, 1971). Unlike the fauna of other soft-sediment habitats, canyon communities may be well adapted to substratum instability and disturbance (Butler *et al.,* 2001; Okey, 1997).

Productivity – Density and biomass of the benthic infauna in canyons can be higher (Vetter, 1994; Vetter & Dayton, 1998), lower (Maurer *et al.,* 1994) or similar to the adjacent slope (Houston & Haedrich, 1984). An increase in biomass in canyons has been linked to accumulations of large quantities of algae and seagrass (Harrold *et al.,* 1998; Okey, 1997; Vetter, 1994; Vetter & Dayton, 1999) as well as an increased delivery of particulate food due to stronger bottom currents (Gage & Tyler, 1992; Wahlin, 2002). Large numbers of demersal and pelagic fish have been associated with several canyons off southeast Australia, La Jolla submarine canyon system and Pribilof Canyon in the Bering Sea (Brodeur, 2001; Schlacher *et al.,* 2007; Vetter, 1994; Vetter & Dayton, 1999). Hence submarine canyons have been proposed as an important energy supply for fish stocks along some coasts (Vetter, 1994). Whether the canyon fauna is more diverse and abundant than outside the canyon largely depends on the frequency of physical disturbances and the amount of organic matter being deposited in the canyons (Okey, 1997; Vetter & Dayton, 1998, 1999). The response to these events, however, is species specific (Okey, 2003).

Endemism – To our knowledge, there is only one study to date that quantifies the species richness and endemism across several submarine canyons (Schlacher *et al.,* 2007). Schlacher *et al.* (2007) discovered that 79% of 165 sponge species occurred in a single canyon and 126 species (76%) were identified as single site 'spot-endemics'. Although this number may be biased due to the small sample size (n = 14), an increase in sample number may show that some 'spot-endemics' are present at other sites. Interestingly, sponge assemblages were as distinct between different sites within a canyon as they were between canyons. Rowe (1971) discovered designated 'canyon indicator' species which were considerably more abundant within canyons than more cosmopolitan species that also occurred at adjacent non-canyon sites.

Functional importance – Canyons provide conduits for the fast transport of sediments and organic material to the deep ocean which would otherwise be consumed or buried on the shelf (Vetter & Dayton, 1999). Localised upwellings of nutrient-rich deep-sea water have also been recorded around canyons. The accumulation of phytodetritus and organically rich sediments supports high invertebrate and fish abundances (Brodeur 2001; Vetter & Dayton 1998, 1999). Canyons may serve as important nursery grounds for some fish possibly due to their structural complexity and the abundance of prey

(Stefanescu *et al.,* 1994; Vetter & Dayton, 1999). Yoklavich *et al.* (2000) suggested that rocky outcrops along the steep canyon walls may serve as natural refuge from fishing activities for economically important rockfish.

Vulnerability – Assuming that many canyon species have a localised distribution or are endemic to individual canyons, the risk of extinction in canyons is substantially higher than species outside of canyons. Canyon organisms may be better adapted to intermittent disturbances. However, regular fishing activities in canyons have been shown to reduce sponge diversity in canyons off southeast Australia (Schlacher *et al.,* 2007).

4.2.3 Scott reef

Diversity – The fauna of Scott Reef appears to be extraordinary diverse and considerably different from near-shore reef areas. This includes major invertebrate groups such as corals, molluscs, echinoderms as well as fish (Allen & Russell, 1986; Huisman & Morrison, 2007; Marsh, 1986; Veron, 1986; Wells & Slack-Smith, 1986). Coral diversity also appears to be higher at Scott Reef than neighbouring Rowley Shoals and Seringapatam Reef and similar areas on the Great Barrier Reef (Heyward *et al.,* 1995; Veron, 1986). Numerous bird species have been sighted on the reef including migrating species on their way to and from Australia (Berry, 1986).

Productivity – Although we were not able to find any published study measuring the productivity on Scott reef, the area is likely to be more productive than surrounding deeper regions due to organic input from larger animals, including non-aquatic groups like seabirds, lizards and insects (Berry, 1986), as well as corals and coral-associated organisms. Coral mucous is one of the major sources of detritus in lagoon system and greatly contributes to nutrient cycling (Wild *et al.,* 2004). Corals are the most prevalent group recorded at Scott Reef in the OBIS database (Appendix) and thus would be expected to play an important role in the productivity of Scott Reef's ecosystem, particularly compared to the surrounding deepwater areas which are not conducive to coral reef growth.

Endemism – Endemism appears to be rare on Scott Reef. The majority of species found on Scott Reef have a wide-spread distribution across the Indo-Pacific with a strong affinity to the Indonesian fauna (Allen & Russell, 1986; Marsh, 1986; Wells & Slack-Smith, 1986; Veron, 1986). However, most of the sponge species are regionally rare indicating that many sponge species may be endemic (Huisman & Morrison, 2007).

Functional importance – Scott Reef is atypical and may be even unique in that it exhibits environmental properties that are characteristic of both shelf and oceanic atolls. This unique environment results in a rich fauna with a high representation of species that are not found in coastal waters of Western Australia, and Scott Reef is likely to be a 'stepping stone' for fish dispersal between Indonesia and reefs further south including Rowley Shoals (Berry & Marsh, 1986; Huisman & Morrison, 2007). Scott Reef is known to be a nesting ground for green turtles (*Chelonia mydas*) and several bird species. It also serves as a resting site for migrating birds to and from Australia (Berry, 1986).

Vulnerability – Scott Reef, like other coral reefs, has suffered and suffers from the adverse effects of climate change, namely rising sea water temperatures and increasing ocean acidification. In 1998 during a particularly strong *El Niño* event with water temperatures reaching record levels, Scott Reef was the site of mass coral mortality, with the death of 75 – 85% of corals in depths up to 20 m. Recovery at Scott Reef has been comparatively slow due to its geographic isolation. Only coral larvae from remaining living corals on the reef can recolonise the effected areas. However, despite sporadic larval recruitment Scott Reef has been able to recover from this major bleaching event mainly because local effects such as fishing, sedimentation and pollution are minimal. It has also been shown that areas exposed to oceanic water on the outer reef are more resilient to bleaching than protected lagoonal areas. In conclusion, Scott Reef is highly vulnerable particularly to climate change threats; however, its capacity to recoveris high if human impacts are kept to a minimum (Dortch, 2008).

4.2.4 The Holocene coastline

No additional information on the ecological significance of the Holocene coastline could be found other than what has already been stated in the northwest bioregional profile report (DEWHA, 2008). We did not find any additional information on the ecological significance of submerged coastlines from other continental margins. However, according to our seascapes analysis, the ancient coastline may not represent a different habitat type compared to the surrounding areas, indicating that faunal communities may also be similar. Generally, changes in species composition and community structure will change significantly along a longitudinal gradient with a gradual shift from tropical communities in the North to tropical - temperate mixed communities in the south.

4.2.5 Glomar Shoals

No additional information on the ecological significance of Glomar Shoals could be found other than what has already been stated in the northwest bioregional profile report (DEWHA, 2008). Surprisingly, Glomar Shoals was not mentioned in the Northwest Shelf Joint Environmental Management Study (NWSJEMS, 2007). Our analysis indicated that on a regional level Glomar Shoals does not represent a specific habitat type. However, we do know that Glomar Shoals is a high energy environment characterised by increased primary production and coarse gravel, biogenic sediments (McLoughlin & Young, 1985). This most likely results in increased diversity compared to the surrounding areas. Indeed, Glomar Shoals represents a unique habitat type on a local scale as revealed by a fine-scale seascape analysis incorporating both physical and biological data from the KEF and its immediate surrounds.

4.3 Challenges

4.3.1 Limitations of seascape analysis

On a regional level, the seascapes analysis appears to have successfully identified different habitat types for the KEFs. The resolution of 0.01 decimal degrees for the analysis in this study appears to be appropriate for the available seascapes data based on comparison with current biological and physical datasets and knowledge of geomorphology. The seascapes coincided particularly well with some of the large KEFs in the deep-sea such as the abyssal plains and the marginal plateaus which are known to be relatively homogenous environments. Here the coverage of the seascapes data was sufficient to produce a reliable result. As suspected, abyssal plains and marginal plateaus were identified as areas of low habitat diversity. The analysis also indicated that both abyssal plains represent the same habitat type which is not found anywhere else on the northwest margin. In addition, areas of greater habitat diversity, e.g. margins of the abyssal plain and plateaus, could be identified.

Insufficient data coverage may have been the reason why smaller, more diverse KEFs such as the submarine canyons and Glomar Shoals coincided with the same seascapes as the surrounding areas. In these cases, the interpolation of the seascapes data may have resulted in the masking of existing differences between KEFs and surrounding areas. Alternatively, as may have been the case for Glomar Shoals, differences in environmental properties were too subtle to be detected by an analysis on a regional scale. An additional analysis of the Glomar Shoals on a smaller scale, however, revealed the occurrence of a unique seascape for Glomar Shoals. Nonetheless, areas that are too small may result in ecologically meaningless seascape classifications.

This study includes the first seascapes analysis where biological data has been incorporated as an additional spatial layer. The result of the analysis indicated that the addition of the biological data may add some spatial complexity to the classification. The analysis of Glomar Shoals and surrounds, excluding the demersal fish data, showed the presence of one seascape at Glomar Shoals which extended into the surrounding area to the west. This analysis suggests that Glomar Shoals is not unique in the North-west Marine Region. In a second analysis, including the demersal fish data, Glomar Shoals coincided with a seascape characterised by high diversity values while the neighbouring area to the west coincided with another seascape characterised by low diversity values. This second analysis suggests that Glomar Shoals is a unique habitat in the area. However, it is not clear from this trial whether highly mobile animals such as fish are suitable for this kind of analysis.

4.3.2 Paucity of robust biological datasets

One of challenges in determining the ecological importance of the proposed KEFs is the absence of comprehensive biological datasets. As such, the evaluation of the conservation value of these KEFs was based on findings from previous studies on similar habitats in Australia and overseas with reference to the deep-sea literature. Much of the biological data included fish data which may not be the most suitable biodiversity indicator for a deep-sea ecosystem due to their high vertical and horizontal mobility. Although the distribution and abundance of some bathyal fishes has been positively linked to biogenic structures on the seafloor, functional relationships were not reported (Tissot *et al.,* 2006). In contrast, organisms living between the sediment grains may be a better estimate of diversity, as infauna are more directly associated with abiotic factors measured by the physical datasets used here (*e.g*., sediment grain size).

In order to determine biological diversity, species richness needs to be established on two levels: within one feature (alpha diversity) and between features (beta diversity). Ideally biological sampling should be coupled with measurements of biologically meaningful physical data including depth. Biological samples should be sorted to the lowest taxonomic level possible and then grouped into functional groups such as feeding mode, motility, and development mode. A grouping into various functional groups would aid in characterisation of the ecosystem. Further identification to species would be needed to determine rare and endemic species.

4.3.3 Correlation of biological pattern to environmental properties

The statistical analysis of demersal fish assemblages and environmental properties at Glomar Shoals revealed only a very weak correlation. This could be due to several factors. First, fish assemblages may not be ideal for investigating a correlation between a biological pattern and environmental characteristics since they are highly mobile and are therefore most likely not as strongly correlated to physical seafloor factors as benthic invertebrates. Second, fish assemblages may follow a seasonal pattern which would have not be resolved with a one-time sample effort. Finally, ecological factors such as predation, inter- and intra-competition may affect fish assemblages more than the physical variables used in this study. However, numerous other studies have shown a strong correlation between biological patterns and environmental variables supporting the assumption that a suite of biologically meaningful physical variables can be used to describe a habitat type and the associated fauna (Etter & Grassle 1992; Levin *et al.,* 1991; Levin & Gage 1998; Post *et al.,* 2006).

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6 Acknowledgements

We would like to thank the curators and data managers of several Australian museums for providing biological data: Mark McGrouther, Dr Stephen Keable and Ian Loch from the Australian Museum; Dr Merrick Eckins from the Queensland Museum; Gavin Dally from the Northern territory Museum and Dr Gary Poore and Dr Joanne Taylor from the Museum of Victoria. Dr Allan Williams from the CSIRO Division of Fisheries kindly provided fish data. Thanks also to those who provided technical and scientific support. Many thanks to Anna Potter for her help in map-making and general ArcGIS advice, Dr Jin Lin for his statistical advice, Dr Tara Anderson for providing contacts, and Dr Alix Post and Melissa Fellows for reviewing this report.

7 Appendix

Records from the Ocean Biogoegraphic Information Systems database (www.iobis.org) retrieved October 2008 from grids overlapping the KEFs. The ancient strandline at the 125 isobath is not included due to the non-specificity of the grids used in OBIS for such a feature.

Glomar Shoals

280 species were recorded from a 0.5 degree grid (119.5-120E, 16.5-17S):

Species	Common Name	Species	Common Name
Abalistes stellatus	Starry triggerfish	*Lethrinus sp.*	fish
Acanthurus grammoptilus	Finelined surgeonfish	*Lethrinus variegatus*	Slender emperor
Acanthurus nigricans	Whitecheek surgeonfish	*Lophiomus setigerus*	Baudroie bouch&#Ã©; noire
Albula glossodonta	Roundjaw bonefish	*Loxodon macrorhinus*	Sliteye shark
Alectis ciliaris	African pompano	*Lutjanus argentimaculatus*	Mangrove red snapper
Alepes apercna	Smallmouth scad	*Lutjanus erythropterus*	Crimson snapper
Aluterus monoceros	Unicorn leatherjacket	*Lutjanus kasmira*	Common bluestripe snapper
Anacanthus barbatus	Barbeled leatherjacket	*Lutjanus lemniscatus*	Yellowstreaked snapper
Anoplocapros lenticularis	High-backed boxfish	*Lutjanus lutjanus*	Bigeye snapper
Antennarius striatus	Striated frogfish	*Lutjanus malabaricus*	Malabar blood snapper
Anthias sp.	fish	*Lutjanus quinquelineatus*	Five lined snapper
Apistus carinatus	Ocellated waspfish	*Lutjanus sebae*	Emperor red snapper
Apogon albimaculosus	Cream-spotted	*Lutjanus sp.*	fish
Apogon carinatus	Ocellated cardinalfish	*Lutjanus vitta*	Brown stripe snapper
Apogon fleurieu	Cardinalfish	*Mene maculata*	Moonfish
Apogon melanopus	Monster cardinal-fish	*Monocentris japonica*	Dick bride-groom fish
Apogon nigripinnis	Bullseye	*Muraenesox cinereus*	Conger pike
Apogon pallidofasciatus	fish	*Myripristis botche*	Blacktip soldierfish
Apogon quadrifasciatus	Twostripe cardinal	*Naso mcdadei*	Squarenose unicornfish
Apogon semilineatus	Half-lined cardinal	*Nemipterus celebicus*	Celebes threadfin bream
Apogon septemstriatus	Sevenstriped cardinalfish	*Nemipterus furcosus*	Fork-tailed threadfin bream
Apogon sp. 2	fish	*Nemipterus peronii*	Notchedfin threadfin bream
Apogon truncatus	Flagfin cardinalfish	*Nemipterus zysron*	Slender threadfin bream
Argathona rhinoceros	an isopod	*Neomerinthe amplisquamiceps*	Orange scorpionfish
Argyrops spinifer	King soldier bream	*Neopomacentrus nemurus*	Coral demoiselle
Arius thalassinus	Giant seacatfish	*Norfolkia thomasi*	Thomas' triplefin
Arothron reticularis	Reticulated puffer	*Onigocia oligolepis*	Dwarf flathead
Arothron stellatus	Starry toadfish	*Onigocia spinosafish*	name verified
Atelomycterus fasciatus	Banded sand catshark	*Ophidion muraenolepis*	Black-edged cusk-eel
Atule mate	Yellowtail scad	*Orbonymus rameus*	Splitfin Dragonet
Bathygobius cocosensis	Cocos frill-goby	*Ostracion cubicus*	Yellow boxfish
Bathygobius laddi	Brownboy goby	*Ostracion nasus*	Shortnose boxfish
Batrachomoeus occidentalis	Western frogfish	*Parachaetodon ocellatus*	Sixspine butterflyfish
Bleekeria mitsukurii	fish	*Paramonacanthus filicauda*	Threadfin leatherjacket
Bodianus perditio	Golden-spot hogfish	*Parapercis alboguttata*	Whitespot sandsmelt
Cantherhines fronticinctus	Spectacled filefish	*Parapercis nebulosa*	fish
Canthigaster coronata	Crown toby	*Paraplagusia bilineata*	Doublelined tonguesole
Canthigaster rivulata	Brown-lined puffer	*Parapriacanthus ransonneti*	Golden sweeper
Carangoides caeruleopinnatus	fish	*Parastromateus niger*	Black pomfret
Carangoides chrysophrys	Longnose trevally	*Parupeneus chrysopleuron*	Yellow striped goatfish
Carangoides equula	Whitefin trevally	*Parupeneus ciliatus*	Whitesaddle goatfish
Carangoides fulvoguttatus	Yellowspotted trevally	*Parupeneus heptacanthus*	Cinnabar goatfish
Carangoides gymnostethus	Bludger	*Parupeneus indicus*	Indian goatfish
Carangoides hedlandensis	Bumpnose trevally	*Pempheris oualensis*	Bronze sweeper
Carangoides malabaricus	Malabar trevally	*Pempheris schwenkii*	Black-stripe sweeper
Caranx bucculentus	Bluespotted trevally	*Pempheris ypsilychnus*	fish
Caranx sexfasciatus	Bigeye trevally	*Pentapodus nagasakiensis*	Japanese whiptail
Carcharhinus sorrah	Spottail shark	*Pentapodus porosus*	Northwest Australian whiptail

Cephalopholis boenak	Chocolate hind
Chaetodermis penicilligera	fish
Chaetodon lineolatus	Lined butterflyfish
Chaetodontoplus duboulayi	Scribbled angelfish
Chaetodontoplus personifer	Blueface angelfish
Champsodon longipinnis	fish
Chanos chanos	Milkfish
Cheilinus chlorourus	Floral wrasse
Cheilodipterus quinquelineatus	Five-lined cardinalfish
Choerodon cauteroma	Bluespotted tuskfish
Choerodon monostigma	Dark-spot tuskfish
Choerodon sugillatum	Wedge-tailed tuskfish
Chromis fumea	Smokey chromis
Cirrhitichthys aprinus	Spotted hawkfish
Cirripectes filamentosus	Filamentous blenny
Congrogadus spinifer	Spiny eel-blenny
Coradion altivelis	Highfin coralfish
Coradion chrysozonus	Goldengirdled coralfish
Cottapistus cottoides	Marbled stingfish
Crossorhombus azureus	Blue flounder
Cyclichthys orbicularis	Birdbeak burrfish
Dactyloptena macracantha	Spotwing flying gurnard
Dactyloptena orientalis	Oriental flying gurnard
Dactyloptena papilio	Butterfly flying-gurnard
Dactylopus dactylopus	Fingered dragonet
Dannevigia tusca	Australian tusk
Dasyatis kuhlii	Bluespotted stingray
Dasyatis leylandi	Painted maskray
Decapterus macrosoma	Shortfin scad
Decapterus russelli	Indian scad
Dendrochirus brachypterus	Featherfish
Dendrochirus zebra	Zebra turkeyfish
Diagramma labiosum	Painted sweetlips
Diodon holocanthus	Long-spine
Diploprion bifasciatum	Barred soapfish
Dipterygonotus balteatus	Mottled fusilier
Echeneis naucrates	Live sharksucker
Ecsenius bicolor	Bicolor blenny
Engraulis australis	Australian anchovy
Engyprosopon grandisquamum	fish
Engyprosopon maldivensis	Olive wide-eyed
Epinephelus amblycephalus	Banded grouper
Epinephelus areolatus	Areolate grouper
Epinephelus coioides	Orange-spotted grouper
Epinephelus maculatus	Highfin grouper
Epinephelus multinotatus	White blotched grouper
Epinephelus rivulatus	Halfmoon grouper
Epinephelus sexfasciatus	Sixbar grouper
Erosa erosa	Monkeyfish
Eubalichthys caeruleoguttatus	Blue-spotted
Eucrossorhinus dasypogon	Tasselled wobbegong
Eurypegasus draconis	Dragonfish
Feroxodon multistriatus	Manystriped blowfish
Fistularia commersonii	Bluespotted cornetfish
Fistularia petimba	Red cornetfish
Fowleria isostigma	fish
Gadella norops	fish
Glaucosoma buergeri	Deepsea jewfish
Gnathanodon speciosus	Golden trevally
Grammatobothus	Threespot flounder
Gymnocranius elongatus	Forktail large-eye bream
Gymnocranius grandoculis	Blue-lined large-eye
Gymnocranius griseus	Grey large-eye bream
Pentaprion longimanus	Longfin mojarra
Platax batavianus	Humpback batfish
Plectropomus maculatus	Spotted coralgrouper
Plotosus lineatus	fish
Pomacanthus imperator	Emperor angelfish
Pomacanthus sexstriatus	Bluestone kambingan
Priacanthus hamrur	Moontail bullseye
Priacanthus tayenus	Purple-spotted bigeye
Pristipomoides multidens	Gold band jobfish
Pristipomoides typus	Sharptooth jobfish
Pristotis obtusirostris	Gulf damsel
Psenopsis humerosa	fish
Psettina gigantea	Rough-scaled flounder
Psettodes erumei	Indian halibut
Pseudobalistes fuscus	Yellow-spotted triggerfish
Pseudochromis	Spiny dottyback
Pseudochromis reticulatus	fish
Pseudochromis wilsoni	Yellowfin dottyback
Pseudomonacanthus peroni	Pot-bellied leatherjacket
Pseudorhombus diplospilus	Four twin-spot flounder
Pseudorhombus	Ocellated flounder
Pseudorhombus elevatus	Deep flounder
Pseudorhombus jenynsii	Small-toothed flounder
Pseudorhombus megalops	Flatfish
Pseudorhombus spinosus	Spiny flounder
Pterocaesio chrysozona	Goldband fusilier
Pterocaesio digramma	Double-lined fusilier
Pterois russelii	Plaintail turkeyfish
Pterois volitans	Butterfly cod
Rachycentron canadum	Black kingfish
Rainfordia opercularis	Flathead perch
Rhabdamia gracilis	Luminous cardinalfish
Rhina ancylostoma	Bowmouth guitarfish
Rhinobatos sainsburyi	fish
Rhizoprionodon acutus	Milk shark
Rhynchobatus djiddensis	Giant guitarfish
Rhynchostracion	Horn-nose boxfish
Rogadius asper	Olive-tailed flathead
Rogadius patriciae	Black-banded flathead
Samaris cristatus	Cockatoo righteye flounder
Sargocentron rubrum	Redcoat
Saurida argentea	Shortfin saury
Saurida filamentosa	fish
Saurida undosquamis	Brushtooth lizardfish
Scarus ghobban	Blue-barred parrotfish
Scolopsis monogramma	Monogrammed monocle
Scorpaena onaria	fish
Scorpaenopsis neglecta	fish
Selar crumenophthalmus	Bigeye scad
Selaroides leptolepis	Yellowstripe scad
Sepia rhoda	cuttlefish
Sepia smithi	cuttlefish
Seriola dumerili	Greater amberjack
Seriola rivoliana	Almaco jack
Seriolina nigrofasciata	Blackbanded trevally
Siganus fuscescens	Mottled spinefoot
Siganus punctatus	Gold-spotted spinefoot
Sirembo jerdoni	Brown-banded cusk-eel
Solegnathus lettiensis	Gunther's Pipehorse
Sorsogona tuberculata	Tuberculated flathead
Sphyraena forsteri	Bigeye barracuda
Sphyraena obtusata	Obtuse barracuda
Sphyraena putnamae	Sawtooth barracuda

Gymnocranius sp.	fish	*Spratelloides delicatulus*	Delicate round herring
Gymnothorax cribroris	Brown-flecked reef eel	*Stegostoma fasciatum*	Zebra shark
Halichoeres melanochir	Black wrasse	*Suezichthys soelae*	fish
Halophryne diemensis	Banded frogfish	*Sufflamen fraenatum*	fish
Halophryne ocellatus	Ocellated frogfish	*Symphorus nematophorus*	Chinamanfish
Hemigaleus microstoma	Sicklefin weasel shark	*Synodus dermatogenys*	Banded lizardfish
Heniochus diphreutes	False moorish idol	*Synodus hoshinonis*	Blackear lizardfish
Himantura uarnak	Honeycomb stingray	*Synodus indicus*	Indian lizardfish
Hippocampus angustus	Narrow-bellied seahorse	*Synodus jaculum*	Lighthouse lizardfish
Inegocia japonica	Japanese flathead	*Synodus sageneus*	Speartoothed grinner
Iniistius dea	fish	*Taeniura meyeni*	Blotched fantail ray
Iniistius jacksonensis	fish	*Tathicarpus butleri*	Butler's frogfish
Inimicus sinensis	Chinese stinger	*Terapon jarbua*	Jarbua terapon
Labracinus lineatus	Lined dottyback	*Tetrosomus gibbosus*	Humpback turretfish
Lactoria cornuta	Long horned cowfish	*Thenus orientalis*	flathead lobster
Lactoria diaphana	Cow	*Torquigener pallimaculatus*	Orange-spotted toadfish
Lagocephalus inermis	Smooth blaasop	*Trachinocephalus myops*	Bluntnose lizardfish
Lagocephalus lunaris	Blowfish	*Trichiurus lepturus*	Atlantic cutlassfish
Lagocephalus sceleratus	Silver-cheeked toadfish	*Trixiphichthys weberi*	Blacktip tripodfish
Leiognathus elongatus	Longface emperor	*Truncatoflabellum aculeatum*	hard coral
Leiognathus longispinis	fish	*Ulua mentalis*	Longrakered trevally
Leiognathus sp.	fish	*Upeneus japonicus*	Bensasi goatfish
Leptojulis cyanopleura	Shoulder-spot wrasse	*Upeneus sp. 1*	fish
Lethrinus genivittatus	Longspine emperor	*Upeneus tragula*	Freckled goatfish
Lethrinus lentjan	Pink ear emperor	*Uranoscopus cognatus*	Two-spined yellow-tail
Lethrinus microdon	Small tooth emperor	*Xanthichthys lineopunctatus*	Striped triggerfish
Lethrinus nebulosus	Spangled emperor	*Zanclus cornutus*	Moorish idol
Lethrinus olivaceus	Longface emperor	*Zebrias craticulus*	fish
Lethrinus rubrioperculatus	Spotcheek emperor		

Wallaby Saddle

32 species were recorded from a 1-degree grid (109-110E, 26-25S):

Species	Common Name	Species	Common Name
Acanthocybium solandri	Wahoo	Physalia	blue bottle
Alopias vulpinus	Thintail thresher	Platyhelminthes	flatworm
Branchiostoma	lancelet	Porpita	blue button
Carcharhinus longimanus	Oceanic whitetip shark	*Prionace glauca*	Blue shark
Centrolophus niger	Blackfish	*Pseudocarcharias kamoharai*	Crocodile shark
Chaetognatha	arrow worm	*Ruvettus pretiosus*	Oilfish
Coryphaena hippurus	Common dolphinfish	*Siriella thompsonii*	mysid
Enteropneusta	acorn worm	*Sphyrna lewini*	Bronze hammerhead shark
Halobates	water strider	Tanaidacea	crustacean
Isurus oxyrinchus	Atlantic mako	*Tetrapturus audax*	Striped marlin
Janthina	gastropod	*Thunnus alalunga*	Albacore
Lepidocybium flavobrunneum	Escolar	*Thunnus albacares*	Allison's tuna
Leptostraca	crustacean	*Thunnus obesus*	Bigeye tuna
Makaira indica	Black marlin	Tunicata	sea squirt
Nemertea	ribbon worm	Velella	By-the-wind sailor
Nudibranchia	sea slug	*Xiphias gladius*	Broadbill

Cuvier Abyssal Plain

35 species were recorded from a 5-degree grid (105-110E, 25-20S):

Species	Common Name	Species	Common Name
Acanthocybium solandri	Wahoo	Physalia	blue bottle
Branchiostoma	lancelet	Platyhelminthes	flatworm
Carcharhinus brachyurus	Copper shark	Porpita	blue button
Carcharhinus longimanus	Oceanic whitetip shark	*Prionace glauca*	Blue shark
Centrolophus niger	Blackfish	*Pseudocarcharias*	Crocodile shark

Ceratoscopelus warmingii	Lanternfish
Chaetognatha	arrow worm
Coryphaena hippurus	Common dolphinfish
Enteropneusta	acorn worm
Halobates	water strider
Isurus oxyrinchus	Atlantic mako
Janthina	gastropod
Katsuwonus pelamis	Oceanic bonito
Lepidocybium flavobrunneum	Escolar
Leptostraca	crustacean
Makaira indica	Black marlin
Nemertea	ribbon worm
Nudibranchia	sea slug
Ruvettus pretiosus	Oilfish
Siriella thompsonii	mysid
Sphyrna lewini	Bronze hammerhead shark
Tanaidacea	crustacean
Tetrapturus audax	Striped marlin
Thunnus alalunga	Albacore
Thunnus albacares	Allison's tuna
Thunnus maccoyii	Southern bluefin tuna
Thunnus obesus	Bigeye tuna
Tunicata	sea squirt
Velella	By-the-wind sailor
Xiphias gladius	Broadbill

Cape Range Canyons

69 species were recorded from two 1 degree grids (112-113E, 22-21S & 111-112E, 22-21S):

Species	Common Name
Acanthocybium solandri	Wahoo
Astronesthes indicus	fish
Branchiostoma	lancelet
Carcharhinus brachyurus	Copper shark
Carcharhinus longimanus	Oceanic whitetip shark
Carcharhinus obscurus	Dusky shark
Centrolophus niger	Blackfish
Chaetognatha	arrow worm
Coryphaena hippurus	Common dolphinfish
Cyathotrochus pileus	hard coral
Diaphus luetkeni	fish
Diaphus regani	fish
Enteropneusta	acorn worm
Galeocerdo cuvier	Tiger shark
Globigerina bulloides	foraminiferan
Globigerina calida	foraminiferan
Globigerina falconensis	foraminiferan
Globigerina pachyderma	foraminiferan
Globigerina rubescens	foraminiferan
Globigerinella aequilateralis	foraminiferan
Globigerinella calida	foraminiferan
Globigerinita glutinata	foraminiferan
Globigerinoides conglobatus	foraminiferan
Globigerinoides ruber	foraminiferan
Globigerinoides sacculifer	foraminiferan
Globigerinoides tenellus	foraminiferan
Globorotalia crassaformis	foraminiferan
Globorotalia inflata	foraminiferan
Globorotalia menardii	foraminiferan
Globorotalia scitula	foraminiferan
Globorotalia tumida	foraminiferan
Halobates	water strider
Hygophum proximum	Lantern fish
Isurus oxyrinchus	Atlantic mako
Janthina	gastropod
Katsuwonus pelamis	Oceanic bonito
Lamna nasus	Beaumaris shark
Lampanyctus alatus	fish
Lampanyctus nobilis	Noble lampfish
Lepidocybium flavobrunneum	Escolar
Leptostraca	crustacean
Letepsammia formosissima	hard coral
Lobianchia gemellari	fish
Makaira indica	Black marlin
Mola mola	Ocean sunfish
Myctophum asperum	Prickly lanternfish
Nemertea	ribbon worm
Neogloboquadrina dutertrei	foraminiferan
Notoscopelus caudispinosus	Lobisomem
Nudibranchia	sea slug
Orbulina universa	foraminiferan
Physalia	blue bottle
Platyhelminthes	flatworm
Porpita	blue button
Prionace glauca	Blue shark
Pseudocarcharias kamoharai	Crocodile shark
Pulleniatina obliquiloculata	foraminiferan
Sphyrna lewini	Bronze hammerhead shark
Stephanocyathus spiniger	hard coral
Tanaidacea	crustacean
Tetrapturus audax	Striped marlin
Thunnus alalunga	Albacore
Thunnus albacares	Allison's tuna
Thunnus obesus	Bigeye tuna
Triphoturus nigrescens	Highseas lampfish
Tunicata	sea squirt
Velella	By-the-wind sailor
Vinciguerria nimbaria	Frilled lighthouse fish
Xiphias gladius	Broadbill

Exmouth Plateau

85 species were recorded from a 5 degree grid (110-115E, 20-15S):

Species	Common Name	Species	Common Name
Aldrovandia affinis	Gilbert's halosaurid fish	*Globorotalia inflata*	foraminiferan
Aldrovandia phalacra	Hawaiian halosaurid fish	*Globorotalia menardii*	foraminiferan
Anchialina dentata	mysid	*Globorotalia scitula*	foraminiferan
Barbourisia rufa	Velvet whalefish	*Globorotalia tumida*	foraminiferan
Bathypterois guentheri	fish	*Haliichthys taeniophorus*	Ribboned pipefish
Bathytroctes squamosus	fish	Halobates	water strider
Branchiostoma	lancelet	*Hemisiriella parva*	mysid
Candeina nitida	foraminiferan	*Hemisiriella pulchra*	mysid
Centrobranchus andreae	Andre's lanternfish	*Heterophotus ophistoma*	fish
Cetonurichthys subinflatus	fish	*Hexatrygon bickelli*	Sixgill stingray
Chaetognatha	arrow worm	*Hirundichthys oxycephalus*	Bony flyingfish
Chauliodus sloani	Needletooth	*Hirundichthys speculiger*	Mirrorwing flyingfish
Cheilopogon cyanopterus	Margined flyingfish	*Ichnopus pelagicus*	an amphipod
Cheilopogon intermedius	fish	*Janthina*	gastropod
Cheilopogon suttoni	Sutton's flyingfish	*Kali macrura*	fish
Coryphaenoides asprellus	fish	*Lampadena luminosa*	fish
Cypselurus angusticeps	Narrowhead flyingfish	Leptostraca	crustacean
Cypselurus hexazona	fish	Nemertea	ribbon worm
Cypselurus oligolepis	Largescale flyingfish	*Neogloboquadrina dutertrei*	foraminiferan
Cypselurus poecilopterus	Yellow-wing flyingfish	*Neoscopelus macrolepidotus*	Glowingfish
Diaphus holti	Lanternfish	Nudibranchia	sea slug
Dicrolene multifilis	Slender brotula	*Orbulina universa*	name verified
Diretmus argenteus	Silver spinyfin	*Parexocoetus brachypterus*	Sailfin flyingfish
Doxomysis quadrispinosa	mysid	Physalia	blue bottle
Enteropneusta	acorn worm	Platyhelminthes	flatworm
Erosaria poraria	gastropod	*Porpita*	blue button
Eustomias macronema	fish	*Promysis orientalis*	mysid
Exocoetus volitans	Tropical two-wing flyingfish	*Pseudanchialina inermis*	mysid
Globigerina bulloides	foraminiferan	*Pseudanchialina pusilla*	mysid
Globigerina calida	foraminiferan	*Pulleniatina obliquiloculata*	foraminiferan
Globigerina digitata	foraminiferan	*Rondeletia loricata*	Redmouth whalefish
Globigerina falconensis	foraminiferan	*Rouleina guentheri*	fish
Globigerina pachyderma	foraminiferan	*Scombrolabrax heterolepis*	Longfin escolar
Globigerina rubescens	foraminiferan	*Scopelosaurus smithii*	fish
Globigerinella aequilateralis	foraminiferan	*Siriella gracilis*	mysid
Globigerinella calida	foraminiferan	*Siriella thompsonii*	mysid
Globigerinita glutinata	foraminiferan	*Sphaeroidinella dehiscens*	foraminiferan
Globigerinoides conglobatus	foraminiferan	*Sternoptyx obscura*	fish
Globigerinoides ruber	foraminiferan	*Stomias*	fish
Globigerinoides sacculifer	foraminiferan	Tanaidacea	crustacean
Globigerinoides tenellus	foraminiferan	Tunicata	sea squirt
Globoquadrina conglomerata	foraminiferan	Velella	By-the-wind sailor
Globorotalia crassaformis	foraminiferan		

Argo Abyssal Plain

18 species were recorded from a 3 degree grid (116-119S, 16-13S):

Species	Common Name	Species	Common Name
Anchialina typica	mysid	Nudibranchia	sea slug
Branchiostoma	arrow worm	*Oncopagurus monstrosus*	hermit crab
Chaetognatha	lancelet	Physalia	blue bottle
Enteropneusta	acorn worm	Platyhelminthes	flatworm
Halobates	water strider	Porpita	blue button
Hemisiriella pulchraa	mysid	*Sympagurus brevipes*	hermit crab
Janthina	gastropod	Tanaidacea	crustacean
Leptostraca	crustacean	Tunicata	sea squirt

Bowers/Oates Canyons

No species were recorded from a 1 x 2 degree grid (119-120S, 15-13S).

Scott Plateau

16 species were recorded from a combination of 1 and 0.5 degree grids (120-121E, 14-12S and 121-121.5E, 13.5-14.5S):

Species	Common Name	Species	Common Name
Branchiostoma	lancelet	Physalia	blue bottle
Chaetognatha	arrow worm	Platyhelminthes	flatworm
Enteropneusta	acorn worm	Porpita	blue button
Halobates	water strider	Tanaidacea	crustacean
Janthina	gastropod	Tunicata	sea squirt
Leptostraca	crustacean	Velella	By-the-wind sailor
Nemertea	ribbon worm	*Striocadulus sagei*	scaphopod
Nudibranchia	sea slug	Liocranchia reinhardti	squid

Scott Reef

587 species were recorded from a 2 degree grid (121-123E, 15-13S):

Species	Common Name	Species	Common Name
Abralia andamanicaa squid	hard coral	*Herpolitha limax*	hard coral
Abudefduf sexfasciatus	Scissortail sergeant	*Heterocarpus gibbosus*	humpback nylon shrimp
Acanthastrea echinata	hard coral	*Heterocarpus sibogae*	mino nylon shrimp
Acanthurus auranticavus	Orange-socket surgeonfish	*Heterocarpus woodmasoni*	indian nylon shrimp
Acanthurus blochii	Ringtail surgeonfish	*Hydnophora exesa*	hard coral
Acanthurus grammoptilus	Finelined surgeonfish	*Hydnophora pilosa*	hard coral
Acanthurus nigricans	Whitecheek surgeonfish	*Hydnophora rigida*	hard coral
Acanthurus nigricauda	Epaulette surgeonfish	*Jaffaia jaffaensis*	brachiopod
Acanthurus nigroris	Bluelined surgeonfish	*Jasus edwardsii*	decapod
Acanthurus olivaceus	Orangespot surgeonfish	*Jasus verreauxi*	green rock lobster
Acanthurus pyroferus	Chocolate surgeonfish	*Kaupichthys hyoproroides*	False moray
Acanthurus thompsoni	Thompson's surgeonfish	*Labroides dimidiatus*	Cleaner wrasse
Acrhelia horrescens	hard coral	*Labropsis australis*	Southern tubelip
Acropora abrolhosensis	hard coral	*Leptastrea inaequalis*	hard coral
Acropora anthocercis	hard coral	*Leptastrea pruinosa*	hard coral
Acropora austera	hard coral	*Leptastrea purpurea*	hard coral
Acropora brueggemanni	hard coral	*Leptastrea transversa*	hard coral
Acropora cerealis	hard coral	*Leptoria phrygia*	hard coral
Acropora clathrata	hard coral	*Leptoseris explanata*	hard coral
Acropora cytherea	hard coral	*Leptoseris foliosa*	hard coral
Acropora divaricata	hard coral	*Leptoseris hawaiiensis*	hard coral
Acropora donei	hard coral	*Leptoseris incrustans*	hard coral
Acropora elseyi	hard coral	*Leptoseris mycetoseroides*	hard coral
Acropora exquiseta		*Leptoseris papyracea*	hard coral
Acropora florida	hard coral	*Leptoseris scabra*	hard coral
Acropora formosa	hard coral	*Leptoseris striata*	hard coral
Acropora granulosa	hard coral	*Leptoseris yabei*	hard coral
Acropora horrida	hard coral	*Lethrinus amboinensis*	Ambon emperor
Acropora hyacinthus	hard coral	*Lethrinus atkinsoni*	Pacific yellowtail emperor
Acropora latistella	hard coral	*Lethrinus erythropterus*	Longfin emperor
Acropora loisetteae	hard coral	*Lethrinus microdon*	Small tooth emperor
Acropora longicyathus	hard coral	*Lethrinus obsoletus*	Orange-striped emperor
Acropora microphthalma	hard coral	*Lethrinus olivaceus*	Longface emperor
Acropora millepora	hard coral	*Lethrinus ravus*	fish

Acropora nana	hard coral
Acropora nasuta	hard coral
Acropora pulchra	hard coral
Acropora selago	hard coral
Acropora stoddarti	hard coral
Acropora subglabra	hard coral
Acropora subulata	hard coral
Acropora tenuis	hard coral
Acropora valenciennesi	hard coral
Acropora valida	hard coral
Acropora vaughani	hard coral
Acropora willisae	hard coral
Acropora yongei	hard coral
Aethaloperca rogaa	Redmouth grouper
Alopias pelagicus	Pelagic thresher
Aluterus scriptus	Scrawled filefish
Alveopora allingi	hard coral
Alveopora catalai	hard coral
Alveopora spongiosa	hard coral
Alveopora verrilliana	hard coral
Amalda vernedei	gastropod
Amblyglyphidodon	White-belly damsel
Amblygobius decussatus	Orange-striped goby
Amblygobius rainfordi	Old glory
Anacropora puertogalerae	hard coral
Annachlamys macassarensis	bivalve
Anyperodon	Slender grouper
Aphareus furca	Small toothed jobfish
Aphareus rutilans	Rusty jobfish
Apogon coccineus	Ruby cardinalfish
Apogon kallopterus	Iridescent cardinalfish
Apolemichthys trimaculatus	Threespot angelfish
Aprion virescens	Green jobfish
Argyropeza izekiana	gastropod
Aristaeomorpha foliacea	giant gamba prawn
Aristaeopsis edwardsiana	decapod
Aristeus virilis	stout red shrimp
Arothron nigropunctatus	Black spotted blow fish
Arothron stellatus	Starry toadfish
Astreopora explanata	hard coral
Astreopora gracilis	hard coral
Astreopora myriophthalma	hard coral
Asymbolus parvus	Dwarf catshark
Aulostomus chinensis	Chinese trumpetfish
Australomussa rowleyensis	hard coral
Balanophyllia cornu	hard coral
Balistapus undulatus	Orange-lined triggerfish
Balistoides conspicillum	Clown triggerfish
Balistoides viridescens	Titan triggerfish
Bathycongrus odontostomus	fish
Benthosema fibulatum	Spinycheek lanternfish
Bodianus bimaculatus	Twospot hogfish
Caesio cuning	Redbelly yellowtail fusilier
Calotomus carolinus	Carolines parrotfish
Caracanthus unipinna	Pygmy coral croucher
Carangoides ferdau	Blue trevally
Carangoides fulvoguttatus	Yellowspotted trevally
Carangoides orthogrammus	Island trevally
Carangoides plagiotaenia	Barcheek trevally
Caranx ignobilis	Giant trevally
Caranx lugubris	Black jack
Caranx melampygus	Bluefin trevally
Caranx sexfasciatus	Bigeye trevally
Lethrinus rubrioperculatus	Spotcheek emperor
Lethrinus semicinctus	Black blotch emperor
Lethrinus xanthochilus	Yellowlip emperor
Linuparus sordidus	Oriental spear lobster
Liocranchia reinhardti	squid
Lithodes turritus	decapod
Lithophyllon edwardsi	hard coral
Lithophyllon edwardsi	hard coral
Lobophyllia hataii	hard coral
Lobophyllia hemprichii	hard coral
Lutjanus bohar	Two-spot red snapper
Lutjanus decussatus	Checkered snapper
Lutjanus gibbus	Humpback red snapper
Macolor macularis	Midnight snapper
Macolor niger	Black and white snapper
Madrepora oculata	hard coral
Malacanthus brevirostris	Quakerfish
Malacanthus latovittatus	Blue blanquillo
Manta birostris	Atlantic manta
Meiacanthus atrodorsalis	Forktail blenny
Merulina ampliata	hard coral
Merulina scabricula	hard coral
Metanephrops australiensis	northwest lobster
Metanephrops boschmai	bight lobster
Metanephrops neptunus	Neptune lobster
Metanephrops velutinus	velvet lobster
Monotaxis grandoculis	Humpnose big-eye bream
Montastrea curta	unknown
Montastrea magnistellata	unknown
Montastrea valenciennesi	unknown
Montipora aequituberculata	hard coral
Montipora angulata	hard coral
Montipora danae	hard coral
Montipora digitata	hard coral
Montipora efflorescens	hard coral
Montipora floweri	hard coral
Montipora foveolata	hard coral
Montipora grisea	hard coral
Montipora hispida	hard coral
Montipora hoffmeisteri	hard coral
Montipora incrassata	hard coral
Montipora informis	hard coral
Montipora monasteriata	hard coral
Montipora tuberculosa	hard coral
Montipora turgescens	hard coral
Montipora undata	hard coral
Montipora venosa	hard coral
Mulloidichthys flavolineatus	Yellowstripe goatfish
Mycedium elephantotus	hard coral
Myripristis murdjan	Pinecone soldierfish
Naso annulatus	Whitemargin unicornfish
Naso brachycentron	Humpback unicornfish
Naso caesius	Gray unicornfish
Naso hexacanthus	Sleek unicornfish
Naso lituratus	Orangespine unicornfish
Naso lopezi	Elongate unicornfish
Naso minor	Slender unicorn
Naso unicornis	Bluespine unicornfish
Naso vlamingii	Bignose unicornfish
Nebrius ferrugineus	Tawny nurse shark
Neopomacentrus cyanomos	Regal demoiselle
Neoscopelus microchir	fish
Neoscopelus microchir	fish

Carcharhinus	Silvertip shark
Carcharhinus	Grey reef shark
Caryophyllia decamera	hard coral
Caryophyllia grandis	hard coral
Caryophyllia transversalis	hard coral
Caryophyllia unicristata	hard coral
Caulastrea furcata	hard coral
Centropyge bicolor	Bicolor angelfish
Centropyge bispinosus	Coral beauty
Centropyge eibli	Blacktail angelfish
Centropyge nox	Midnight angelfish
Centropyge vrolikii	Angel abu polos
Cephalopholis argus	Argus grouper
Cephalopholis boenak	Chocolate hind
Cephalopholis leopardus	Leopard hind
Cephalopholis sonnerati	Red coral rod
Cephalopholis spiloparaea	Strawberry hind
Cephalopholis urodeta	Darkfin hind
Cetoscarus bicolor	Bicolour parrotfish
Chaetodon assarius	West Australian butterflyfish
Chaetodon auriga	Threadfin butterflyfish
Chaetodon bennetti	Bluelashed butterflyfish
Chaetodon ephippium	Saddle butterflyfish
Chaetodon kleinii	Sunburst butterflyfish
Chaetodon lineolatus	Lined butterflyfish
Chaetodon lunula	Raccoon butterflyfish
Chaetodon lunula	Raccoon butterflyfish
Chaetodon melannotus	Blackback butterflyfish
Chaetodon ornatissimus	Ornate butterflyfish
Chaetodon oxycephalus	Spot-nape butterflyfish
Chaetodon	Spotband butterflyfish
Chaetodon rainfordi	Rainford's butterflyfish
Chaetodon trifascialis	Chevron butterflyfish
Chaetodon ulietensis	Pacific double-saddle
Chaetodon unimaculatus	Teardrop butterflyfish
Chaetodon vagabundus	Vagabond butterflyfish
Chaetodontoplus	Red Sea butterflyfish
Cheilinus fasciatus	Floral wrasse
Cheilinus oxycephalus	Pointed-head wrasse
Cheilinus trilobatus	Tripletail wrasse
Cheilinus undulatus	Humphead wrasse
Chilomycterus reticulatus	Spotfin burrfish
Chlorurus sordidus	Daisy parrotfish
Choerodon jordani	Jordan's tuskfish
Chromis westaustralis	West Australian chromis
Chromis xanthura	Black chromis
Chrysiptera caeruleolineata	Bluefin damselfish
Cirrhilabrus bathyphilus	fish
Cirrhilabrus randalli	fish
Cirrhilabrus walindi	fish
Cirripectes castaneus	Chestnut eyelash-blenny
Cirripectes stigmaticus	Red-streaked blenny
Coeloseris mayeri	hard coral
Coluzea icarus	gastropod
Coradion chrysozonus	Goldengirdled coralfish
Corythoichthys amplexus	Brown-banded pipefish
Coscinaraea columna	hard coral
Creseis virgula	curved needle-pteropod
Crispatotrochus inornatus	hard coral
Cryptopenaeus clevai	decapod
Ctenochaetus striatus	Striated surgeonfish
Cyathotrochus pileus	hard coral
Cycloseris costulata	hard coral

Neoscopelus porosus	fish
Nephropsis acanthura	spinetail lobsterette
Nephropsis serrata	decapod
Nephropsis stewarti	Indian Ocean lobsterette
Nephropsis suhmi	red and white lobsterette
Nettastoma solitarium	fish
Nototodarus hawaiiensis	Hawaiian flying squid
Novaculichthys taeniourus	Rockmover wrasse
Octopus cyanea	Big blue octopus
Odonus niger	Redtoothed triggerfish
Oplophorus trispinosa	decapod
Ostracion rhinorhynchos	Horn-nosed boxfish
Oulophyllia bennettae	hard coral
Oulophyllia crispa	hard coral
Oxycheilinus digramma	fish
Oxycheilinus unifasciatus	Ringtail maori wrasse
Oxypora glabra	hard coral
Oxypora lacera	hard coral
Pachyseris rugosa	hard coral
Pachyseris speciosa	hard coral
Paracirrhites arcatus	Arc-eye hawkfish
Paracirrhites forsteri	Blackside hawkfish
Paraconotrochus zeidleri	hard coral
Paralomis dofleini	decapod
Paramonacanthus japonicus	Cryptic filefish
Parapenaeus lanceolatus	lancer rose shrimp
Parapercis hexophtalma	Speckled sandperch
Parapercis schauinslandii	Flagfin weaver
Parapontocaris levigata	decapod
Parupeneus barberinoides	Bicolor goatfish
Parupeneus barberinus	Dash-and-dot goatfish
Parupeneus cyclostomus	Goldsaddle goatfish
Parupeneus heptacanthus	Cinnabar goatfish
Parupeneus multifasciatus	Banded goatfish
Parupeneus pleurostigma	Sidespot goatfish
Pavona cactus	hard coral
Pavona cactus	hard coral
Pavona clavus	hard coral
Pavona decussata	hard coral
Pavona explanulata	hard coral
Pavona maldivensis	hard coral
Pavona minuta	hard coral
Pavona varians	hard coral
Pavona venosa	hard coral
Pectinia alcicornis	hard coral
Pectinia lactuca	hard coral
Pectinia paeonia	hard coral
Pectinia teres	hard coral
Penaeopsis eduardoi	decapod
Pentapodus emeryii	Double whiptail
Pentapodus nagasakiensis	Japanese whiptail
Physogyra lichtensteini	hard coral
Plagiotremus rhinorhynchos	Bluestriped fangblenny
Platax batavianus	Humpback batfish
Platax pinnatus	Dusky batfish
Platygyra daedalea	hard coral
Platygyra lamellina	hard coral
Platygyra pini	hard coral
Platygyra ryukyuensis	hard coral
Platygyra sinensis	hard coral
Platygyra verweyi	hard coral
Plectroglyphidodon dickii	Blackbar devil
Plectropomus areolatus	Squaretail coralgrouper

Cycloseris vaughani	hard coral
Cyphastrea chalcidicum	hard coral
Cyphastrea microphthalma	hard coral
Cyphastrea serailia	hard coral
Cyphastrea sp. 1	hard coral
Dascyllus aruanus	Banded humbug
Dascyllus reticulatus	Gray humbug
Dascyllus trimaculatus	Threespot dascyllus
Dasyatis kuhlii	Bluespotted stingray
Deltocyathus magnificus	hard coral
Deltocyathus suluensis	hard coral
Dentalium octangulatum	scaphopod
Diala semistriata	gastropod
Diaphus coeruleus	Blue lantern fish
Diaphus watasei	fish
Dinematichthys randalli	Hump-backed dwarf brotula
Diploastrea heliopora	hard coral
Diploprion bifasciatum	Barred soapfish
Diretmichthys parini	Parin's spiny fin
Echeneis naucrates	Live sharksucker
Echinophyllia aspera	hard coral
Echinophyllia aspera	hard coral
Echinophyllia orpheensis	hard coral
Echinopora hirsutissima	hard coral
Echinopora horrida	hard coral
Echinopora lamellosa	hard coral
Echinopora mammiformis	hard coral
Ecsenius alleni	fish
Ecsenius bicolor	Bicolor blenny
Ecsenius schroederi	fish
Elagatis bipinnulata	Rainbow runner
Eledone palari	an octopus
Endopachys bulbosa	hard coral
Enneapterygius flavoccipitis	fish
Enneapterygius tutuilae	High hat triplefin
Epibulus insidiator	Slingjaw wrasse
Epinephelus cyanopodus	Speckled blue grouper
Epinephelus fasciatus	Banded reef cod
Epinephelus fuscoguttatus	Brown-marbled grouper
Epinephelus merra	Honeycomb grouper
Epinephelus polyphekadion	Camouflage grouper
Epinephelus spilotoceps	Foursaddle grouper
Etelis radiosus	Scarlet snapper
Etmopterus evansi	fish
Eugonatonotus chacei	decapod
Euphyllia ancora	hard coral
Euphyllia glabrescens	hard coral
Euthynnus affinis	Black skipjack
Eviota albolineata	Spotted fringefin goby
Favia favus	hard coral
Favia helianthoides	hard coral
Favia laxa	hard coral
Favia lizardensis	hard coral
Favia matthaii	hard coral
Favia maxima	hard coral
Favia mcandrewi	hard coral
Favia pallida	hard coral
Favia rotumana	hard coral
Favia rotundata	hard coral
Favia speciosa	hard coral
Favia stelligera	hard coral
Favites abdita	hard coral
Favites complanata	hard coral

Plectropomus laevis	Blacksaddled coralgrouper
Plectropomus leopardus	Blue-dotted coral-trout
Plectropomus oligacanthus	Highfin coral grouper
Plerogyra sinuosa	hard coral
Plesiastrea versipora	hard coral
Plesionika ensis	gladiator striped shrimp
Plesionika indica	decapod
Plesionika martia	golden shrimp
Plesiopenaeus edwardsianus	scarlet gamba prawn
Pleurosicya coerulea	Blue coral ghost goby
Pocillipora damicornis	hard coral
Pocillopora eydouxi	hard coral
Pocillopora verrucosa	hard coral
Pocillopora woodjonesi	hard coral
Podabacia crustacea	hard coral
Polycheles nanus	decapod
Polycheles typhlops	decapod
Polyphyllia talpina	hard coral
Polyphyllia talpina	hard coral
Pomacanthus imperator	Emperor angelfish
Pomacanthus navarchus	Blue girdled angel
Pomacanthus sexstriatus	Bluestone kambingan
Pomacentrus alexanderae	Alexander's damsel
Pomacentrus amboinensis	Amboina demoiselle
Pomacentrus bankanensis	Speckled damsel
Pomacentrus lepidogenys	Scaly damsel
Pomachromis richardsoni	Richardson's damsel
Porites cylindrica	hard coral
Porites lichen	hard coral
Porites lobata	hard coral
Porites lutea	hard coral
Porites murrayensis	hard coral
Porites nigrescens	hard coral
Porites rus	hard coral
Porites solida	hard coral
Porites sp. 1	hard coral
Porites vaughani	hard coral
Portunus pelagicus	decapod
Propeamussium sibogai	bivalve
Psalidopus huxleyi	decapod
Psammocora contigua	hard coral
Psammocora digitata	hard coral
Psammocora haimeana	hard coral
Psammocora profundacella	hard coral
Psammocora superficialis	hard coral
Pseudanthias lori	Lori's anthias
Pseudobalistes flavimarginatus	Yellowmargin triggerfish
Pseudobalistes fuscus	Yellow-spotted triggerfish
Pseudocheilinus hexataenia	Sixline wrasse
Pseudochromis bitaeniatus	Double-striped dottyback
Pseudochromis cyanotaenia	Blue-barred dottyback
Pseudochromis paccagnellae	Royal dotty back
Pseudogramma polyacanthum	Honeycomb podge
Pseudoplesiops rosae	Large-scaled dottyback
Psychrolutes marcidus	Australian sculpin
Ptereleotris evides	Blackfin dartfish
Pterocaesio digramma	Double-lined fusilier
Pterocaesio marri	Marr's fusilier
Pterocaesio tile	Dark-banded fusilier
Pterocaesio trilineata	Three-stripe fusilier
Puerulus angulatus	banded whip lobster
Puerulus angulatus	banded whip lobster
Pygoplites diacanthus	Royal angelfish

Favites halicora	hard coral
Favites pentagona	hard coral
Favites russelli	hard coral
Flabellum deludens	hard coral
Flabellum hoffmeisteri	hard coral
Flabellum lamellulosum	hard coral
Flabellum magnificum	hard coral
Flabellum politum	hard coral
Forcipiger longirostris	Longnose butterflyfish
Fungia concinna	hard coral
Fungia echinata	hard coral
Fungia fungites	hard coral
Fungia granulosa	hard coral
Fungia horrida	hard coral
Fungia paumotensis	hard coral
Fungia repanda	hard coral
Fungia scruposa	hard coral
Fungia scutaria	hard coral
Fungia simplex	hard coral
Fungiacyathus granulosus	hard coral
Fungiacyathus stephanus	hard coral
Fungiacyathus variegatus	hard coral
Galaxea astreata	hard coral
Galaxea fascicularis	hard coral
Gardineria hawaiiensis	hard coral
Gardineria philippinensis	hard coral
Gardineroseris planulata	hard coral
Genicanthus lamarck	Blackstriped angelfish
Genicanthus melanospilos	Blackspot
Glyphocrangon faxoni	decapod
Glyphocrangon pugnax	decapod
Glyphocrangon regalis	decapod
Gnathanodon speciosus	Golden trevally
Goniastrea aspera	hard coral
Goniastrea edwardsi	hard coral
Goniastrea favulus	hard coral
Goniastrea palauensis	hard coral
Goniastrea pectinata	hard coral
Goniastrea retiformis	hard coral
Goniopora columna	hard coral
Goniopora djiboutiensis	hard coral
Goniopora lobata	hard coral
Goniopora minor	hard coral
Goniopora tenuidens	hard coral
Gracila albomarginata	Masked grouper
Grammatorcynus bilineatus	Double lined mackerel
Grammistes sexlineatus	Goldenstriped soapfish
Gymnapogon urospilotus	B-spot cardinalfish
Gymnocranius elongatus	Forktail large-eye bream
Gymnocranius grandoculis	Blue-lined large-eye bream
Gymnosarda unicolor	Dogtooth tuna
Gymnothorax buroensis	Vagrant moray
Gymnothorax favagineus	Blackspotted moray
Gymnothorax fimbriatus	Darkspotted moray
Gymnothorax	Brown spotted moray
Gymnothorax javanicus	Giant moray
Gymnothorax undulatus	Leopard moray
Gymnothorax zonipectis	Barredfin moray
Hadropenaeus lucasii	trident shrimp
Halichoeres margaritaceus	Pink-belly wrasse
Halichoeres marginatus	Dusky wrasse
Halichoeres prosopeion	Two-tone wrasse
Haliporoides sibogae	jack-knife prawn

Ranina ranina	decapod
Rhombopsammia niphada	hard coral
Rogadius asper	Olive-tailed flathead
Sandalolitha robusta	hard coral
Sargocentron caudimaculatum	Silverspot squirrelfish
Sargocentron spiniferum	Sabre squirrelfish
Scapophyllia cylindrica	hard coral
Scarus altipinnis	Filament finned parrotfish
Scarus flavipectoralis	Rainbow parrotfish
Scarus forsteni	Forsten parrotfish
Scarus niger	Dusky parrotfish
Scarus psittacus	Common parrotfish
Scarus schlegeli	Five-banded parrotfish
Scolopsis bilineata	Two-lined monocle bream
Scolopsis xenochrous	Oblique-barred monocle
Scomberoides lysan	Doublespotted queenfish
Scylla serrata	unknown
Secutor insidiator	Pugnose ponyfish
Sepia planaa cuttlefish	hard coral
Seriatopora hystrix	hard coral
Sicyonia inflexadecapod	hard coral
Siganus argenteus	Streamlined spinefoot
Siganus doliatus	Barred spinefoot
Siganus philippinus	fish
Siganus puellus	Masked spinefoot
Siganus punctatissimus	Peppered spinefoot
Siganus punctatus	Gold-spotted spinefoot
Siganus virgatus	Double-barred spinefoot
Siganus vulpinus	Common foxface
Solenocera melanthodecapod	hard coral
Sphyraena barracuda	Commerson's sea pike
Spirula spirula	Ram's horn squid
Squilloides leptosquilla	unknown
Stegostoma fasciatum	Zebra shark
Stephanocyathus explanans	hard coral
Sthenoteuthis oualaniensis	Purpleback flying squid
Strobopagurus sibogae	unknown
Styliferina goniochil	agastropod
Stylocoeniella armata	hard coral
Stylocoeniella guentheri	hard coral
Stylodactylus licinus	decapod
Stylodactylus multidentatus	decapod
Stylophora pistillata	hard coral
Sufflamen bursa	Boomerang triggerfish
Sufflamen fraenatum	fish
Sympagurus brevipes	decapod
Symphorichthys spilurus	Sailfin snapper
Symphyllia agaricia	hard coral
Symphyllia recta	hard coral
Symphyllia valenciennesii	hard coral
Taeniura meyeni	Blotched fantail ray
Thalassoma amblycephalum	Bluntheaded wrasse
Thalassoma jansenii	Jansen's wrasse
Thalassoma quinquevittatum	Fivestripe wrasse
Triaenodon obesus	Whitetip reef shark
Trimma okinawae	Okinawa rubble goby
Trimmatom nanus	fish
Truncatoflabellum	hard coral
Trypaea australiensis	decapod
Turbinaria frondens	hard coral
Turbinaria peltata	hard coral
Turbinaria reniformis	hard coral
Turbinaria stellulata	hard coral

Heliofungia actiniformis	hard coral
Hemipristis elongata	fish
Hemitaurichthys polylepis	Pyramid butterflyfish
Heniochus acuminatus	Pennant coralfish
Heniochus chrysostomus	Threeband pennantfish
Heniochus diphreutes	False moorish idol
Heniochus singularius	Singular bannerfish
Heniochus varius	Horned bannerfish
Ucla xenogrammus	Largemouth triplefin
Upeneus tragula	Freckled goatfish
Variola albimarginata	White-edged lyretail
Variola louti	Moontail seabass
Xanthichthys caeruleolineatus	Bluelined triggerfish
Zanclus cornutus	Moorish idol
Zebrasoma scopas	Twotone tang