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2009/09
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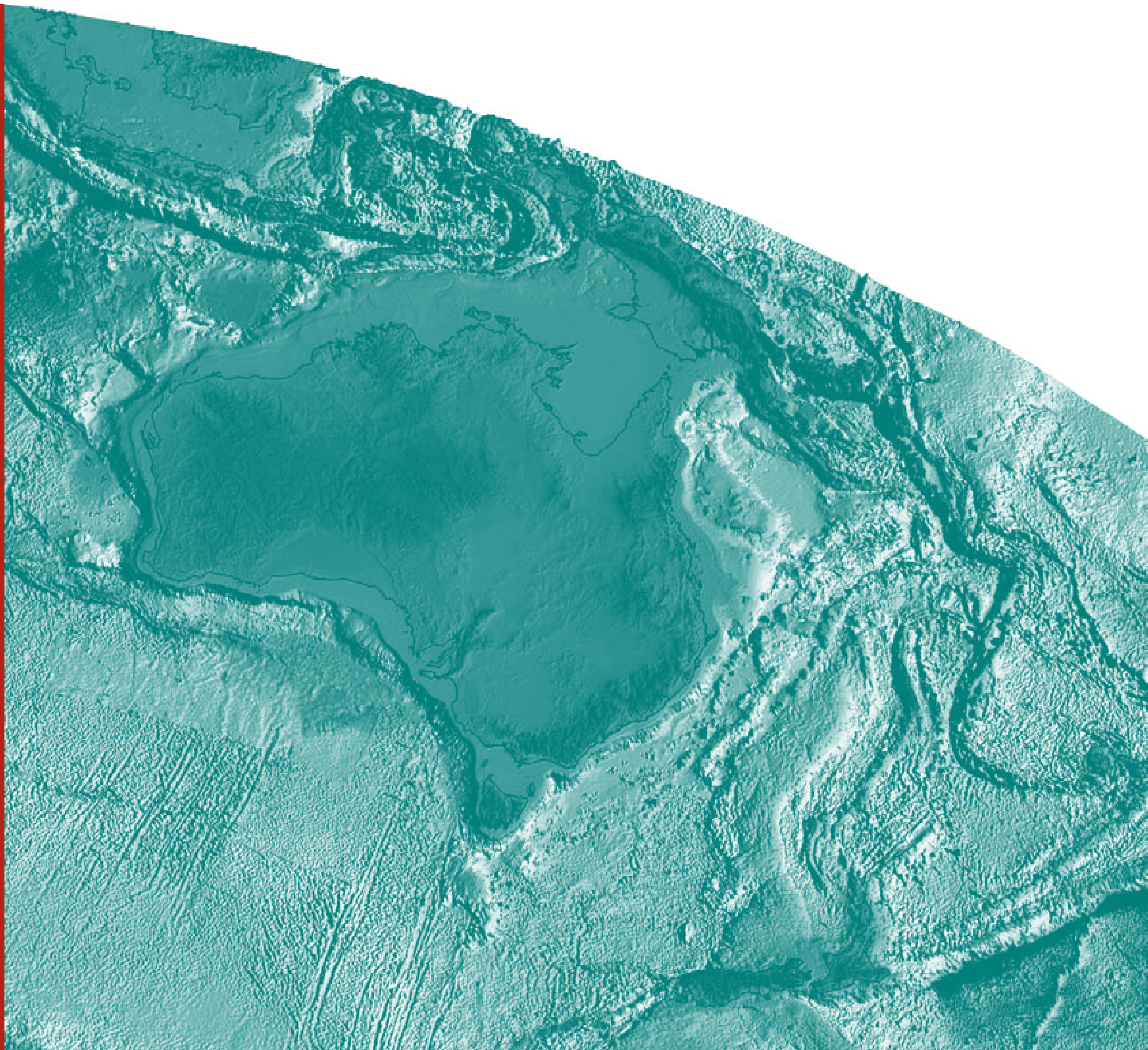

Ceduna Sub-basin: Environmental Summary

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by

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Department of Resources, Energy and Tourism
Minister for Resources and Energy: The Hon. Martin Ferguson, AM MP
Secretary: Mr John Pierce

Geoscience Australia
Chief Executive Officer: Dr Neil Williams PSM

ISSN 1448-2177
ISBN 798- 921498-54-1 Hardcopy
ISBN 798- 921498-53-4 CD-ROM
ISBN 798- 921498-52-7 Web

GeoCat # 65838

Bibliographic reference*:* Hughes, M.G., Nichol, S., Przeslawski, R., Totterdell, J., Heap, A.D., Fellows, M. and Daniell, J., 2009. Ceduna Sub-basin: Environmental Summary. Geoscience Australia Record 2009/09. 96pp.

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Executive Summary

This report is one of a series of environmental summaries of frontier basins that are scheduled for acreage release during the timeframe of the 'Energy Security Initiative' (2007-2011). The aim of these reports is to synthesise the available environmental information to adequately equip the exploration industry to anticipate as many as possible of the environment-related issues that may impact on exploration and potential future production activities.

This report summarises environmental information relating to the Ceduna Sub-basin, which is located to the south of the Great Australian Bight and includes 126,300 km^2 of seafloor. It is bounded by the Madura Shelf to the north, Eyre Sub-basin to the west and Recherche Sub-basin to the south. These sub-basins, together with the Bremer and Denmark Sub-basins (located further to the west), form the Jurassic–Cretaceous Bight Basin, which underlies the continental shelf and slope as well as extending over 300 km onshore from the coast. The Bight Basin is overlain unconformably by the dominantly cool-water carbonates of the Cainozoic Eucla Basin.

In addition to >33,000 line km of deep seismic data and core data from 10 wells in the Ceduna and Eyre Sub-basin region, Geoscience Australia is also the custodian for >9,000 line km of multibeam data and >8,000 line km of shallow sub-bottom profiler data. Metadata for these geophysical data sets and controlled access is available through the Petroleum Information Management System (PIMS) at http://www.ga.gov.au/oracle/npd/.

The single and multibeam bathymetry data have been gridded at a 0.0025° resolution to facilitate interpretation of the geomorphic features of the region. The geomorphology of the Ceduna Sub-basin is characterised by a range of erosional features that vary in scale according to the slope of the sea floor. Steeper areas such as the shelf escarpment and eastern sector of the lower slope have developed deeply incised valleys and canyons up to 1 km in relief. In contrast, low gradient surfaces such as the Ceduna Terrace and the central to western sector of the slope are dissected by troughs and discontinuous scarps that give local relief of only tens of metres. There is evidence for mass movement in the form of large slump blocks and debris fans at the foot of escarpments below the shelf break. Several volcanic cones provide positive relief to the terrain, but their effect is highly localised.

Geoscience Australia currently holds analytical data for 120 surface sediment samples from the Ceduna Sub-basin and adjacent Eyre Sub-basin. This information is discussed in this report and tabulated in the appendix. An additional 74 samples were collected on a recent survey and are currently being processed. The analytical results from these recent samples will eventually be available through the Marine Sediments Data Base (MARS), which can be accessed at http://www.ga.gov.au/oracle/mars/. The presently available information shows that the surface sediments of the Ceduna Sub-basin form part of the large, cool-water carbonate province of the Great Australian Bight. Production of carbonate sediment mostly occurs on the shelf, with the outer shelf and upper slope characterised by texturally varied bryozoan-rich sediment facies. Within the deeper waters of the Ceduna Sub-basin, including the terrace and canyons, sediments are carbonate-rich sandy mud and muddy sand, with localised concentrations of gravel.

The coastal and shelf waters in the Great Australian Bight region display an anti-cyclonic circulation pattern in summer and a generally easterly-directed flow pattern in winter. The Flinders Current, which is the only part of the system directly affecting the Ceduna Sub-basin, generally flows to the west. Summer up-welling is regionally important and likely to have a strong influence on the biota. Wave energy over the Ceduna Sub-basin is persistently high by world standards, but tides are largely inconsequential. Given the large water depths over the Ceduna Sub-basin, the dominant seabed disturbance mechanism is most likely to be slope failure and related mass-wasting and turbidity currents. Oceanic connectivity within the GAB is extensive and there is a seasonal link to tropical waters through the Leeuwin Current system.

It is difficult to identify biodiversity patterns specific to the Ceduna Sub-basin, because not enough is known about the species that occur in the region. Based on broad-scale patterns and some detailed knowledge of the geologic and oceanographic characteristics of the area, the following local patterns seem likely. The Ceduna Sub-basin is home to a broad range of fauna, including fish and sessile, mobile, epibenthic and infaunal invertebrates. At present, species richness, abundance, and endemism for most groups is unknown. The Ceduna Sub-basin may act as a nursery for some coastal species, including the commercially important southern calamari and rock lobster. The lower continental slope of the Ceduna Sub-basin is cut by canyons, particularly in the eastern sector of the basin, which may contain a high number of endemic species, most of which have yet to be discovered. Much of the Ceduna Sub-basin sediments are dominated by fine material, so species and communities associated with mud are expected to dominate benthic habitats. Notwithstanding the limited knowledge of the region's biology, the region supports a fishery worth $200 million annually, which includes the northern Rock Lobster and southern Bluefin Tuna fisheries. The region also contains both migratory paths and seasonal habitats for 16 species of cetacean including the Southern Right whale.

Given the limited biodiversity information available, the use of seascapes and focal variety analysis offer the opportunity to combine the geological/geophysical, geomorphological, sedimentological and oceanographic information described in this report to highlight regions where the seabed (and by inference biological habitats) are most diverse. This approach has previously been used by the Department of Environment, Water, Heritage and the Arts to guide the design of marine protected areas. In the Ceduna Sub-basin region, rugose and dissected regions of the mid- to lower-slope show up as regions of greatest seabed habitat heterogeneity. Areas of high seabed habitat heterogeneity have previously been prioritised and targeted as places for the establishment of marine protected areas. Targets for possible marine protected areas also include those that are unique (or relatively uncommon) and/or spatially restricted. In the Ceduna Sub-basin region (including the Eyre Sub-basin) these regions coincide with seascapes 1, 2 and 4, which are described and mapped in this report.

Much of the environmental information described here is also included in a Geographic Information System (GIS) for the Ceduna Sub-basin, which accompanies this report.

1. Introduction

1.1 AIM AND SCOPE

In August 2006 the Federal Government funded the Energy Security Initiative covering the period 2007-2011. As part of this initiative, Geoscience Australia is compiling environmental summaries of frontier basins scheduled for acreage release in a given financial year. The specific aim of the 'environmental summary for frontier basin' series of reports is to synthesise the available environmental information to adequately equip the exploration industry to anticipate as many as possible of the environment-related issues that may impact on exploration and potential future production activities. The information reported will include locations of gazetted marine parks, fisheries activities, shipping lanes, existing infrastructure, and maritime boundaries where applicable.

Geological and geophysical information relevant to environmental management includes geomorphology, sediments, and oceanography and is being used by the Department of Environment, Water Heritage and the Arts (DEWHA) to design the National Representative System of Marine Protected Areas (NRSMPA). Biological information contained in the reports will include what is known about principal pelagic and benthic species, migratory paths, and any known threatened, endangered or protected species (TEP) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). It is not the purpose of these environmental summary reports to assess the environmental impact of petroleum exploration and production activities, nor is it to specify the environment-related impediments to the petroleum industry. The purpose is simply to make available to industry a summary of the environmental knowledge pertaining to an area of acreage release so that they are sufficiently informed to make their own assessment.

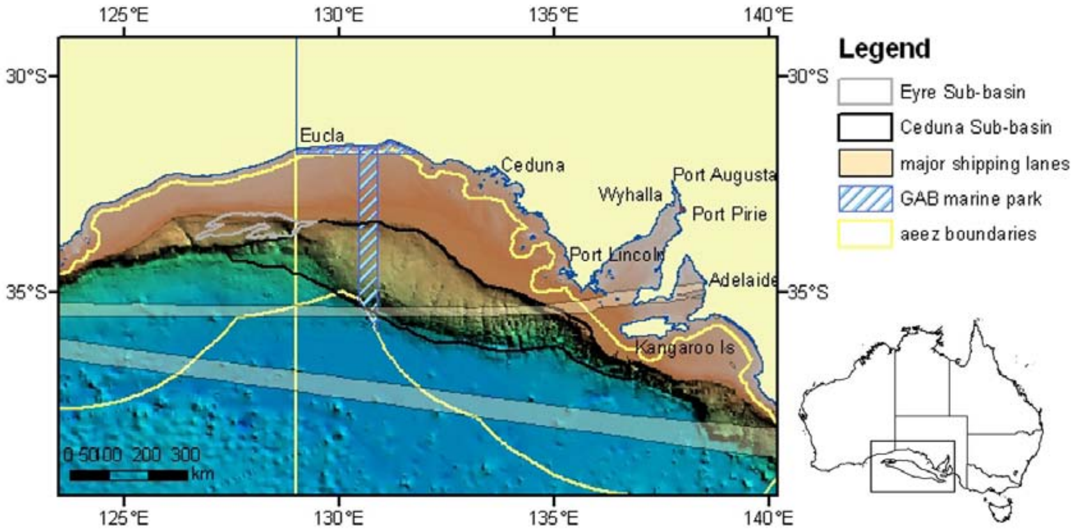


***Figure 1.1**: Location map showing the Ceduna Sub-basin, maritime boundaries, marine parks and major shipping lanes and ports.*

1.2 REGIONAL OVERVIEW

This report summarises environmental information relating to the Ceduna Sub-basin, which is located to the south of the Great Australian Bight and bounded by the 127.3°E and 137.3°E meridians and the 33.3°S and 37.1°S parallels (Fig. 1.1). It includes 126,300 km^2 of seafloor with depths ranging from 150 to 5,500 m. The surface geomorphological expression of the Ceduna Sub-basin is a marine terrace extending south from the shelf edge, with the western slope heavily dissected by canyons. It is situated in the temperate climatic zone characterised by persistent westerly winds. The sub-basin is bounded to the south by the Southern Ocean that has an unlimited fetch for generating waves, and it is bounded to the north by the world's longest zonal shelf that results in complex oceanographic circulation including up-welling and associated primary productivity. Bisecting the western half of the Ceduna Sub-basin in a north-south direction is the Great Australian Bight Marine Park, and bisecting the basin in the east-west direction is a major shipping lane serving Port Adelaide (Fig. 1.1) Seabed dump sites located in the region are shown in Figure 1.2. The South Australian fishery, which includes the waters over the Ceduna Sub-basin, is worth close to $200 million annually and includes the northern Rock Lobster and southern Bluefin Tuna fisheries. The region contains both migratory paths and seasonal habitats for 16 species of cetacean including the Southern right whale. The Great Australian Bight also supports a high number of invertebrate species, including many that are endemic.

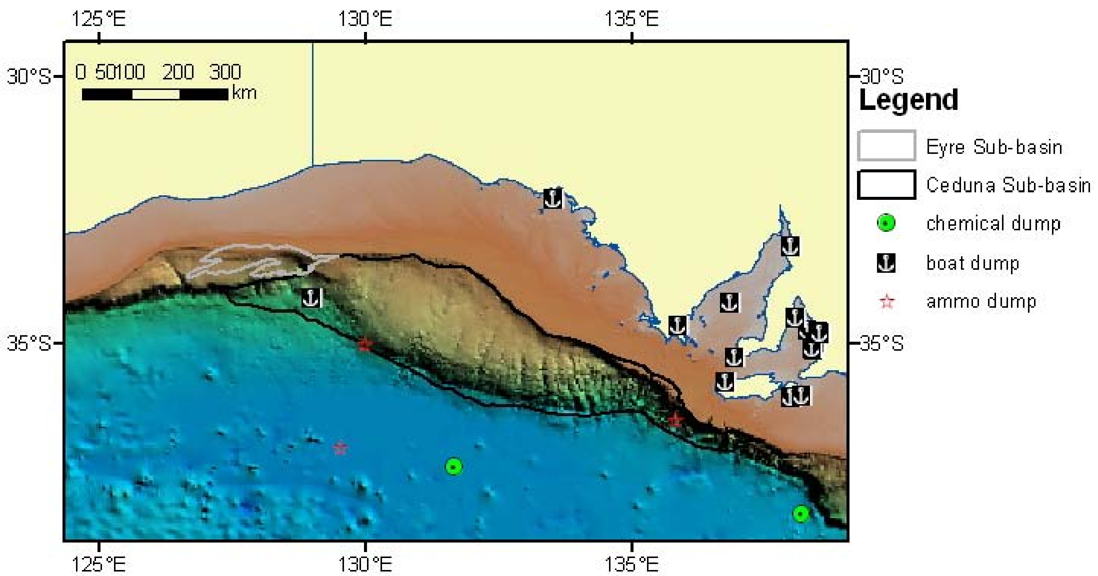


__Figure 1.2__: Location map showing the Ceduna Sub-basin and nearby seabed dump-sites. The information shown is from the Australian Marine Spatial Information System and represents the best information available at the time of publication.

1.3 APPROACH AND CHAPTER OUTLINE

The environmental information for the Ceduna Sub-basin has been compiled and presented in a manner consistent with the Geographic Information System (GIS) provided with this report. The GIS includes the results of an analysis to obtain representative seascapes. Seascapes are the principal environmental output produced by Geoscience Australia in recent years to assist DEWHA with the design and implementation of a National Representative System of Marine Protected Areas for Australia (Section 1.1). The following section summarises the geological history of the Ceduna Sub-basin and provides a tectonic and depositional context for the geophysical data and geomorphology of the sub-basin, which are discussed in Sections 3 and 4, respectively. The surface sediment properties are described in Section 5. These sections provide all of the information necessary to characterise benthic habitats. Section 6 discusses the oceanographic processes operating in the sub-basin, which influence both the benthic and pelagic ecology described in Section 7. Section 8 synthesises the information contained in the first 7 sections into a seascape map of the Ceduna Sub-basin.

2. Geological History

2.1 REGIONAL GEOLOGICAL SETTING

The Jurassic–Cretaceous Bight Basin is a large, mainly offshore basin situated along the western and central parts of the continental margin of southern Australia. The basin also includes Cretaceous sedimentary rocks that extend over 300 km onshore from the coast. The Bight Basin extends from the Leeuwin Fracture Zone in the west, to just south of Kangaroo Island in the east, where it adjoins the Otway Basin (Fig. 2.1). The basin underlies the continental shelf and slope, including two bathymetric terraces (Eyre Terrace and Ceduna Terrace), in water depths ranging from less than 200 to over 4000 m. The main depocentres (including the Ceduna Sub-basin) occur in the eastern part of the Bight Basin. To the east of these depocentres, a thin Bight Basin succession overlies Proterozoic basement of the Gawler Craton and deformed Early Palaeozoic rocks of the Kanmantoo Trough. To the north, basement includes a variety of Proterozoic and older terranes. Basement trends have had a profound influence on the structural development of the Bight Basin, controlling the location and orientation of early basin-forming structures (Stagg et al., 1990; Totterdell et al., 2000; Teasdale et al., 2001; Totterdell & Bradshaw, 2004). The Bight Basin is overlain unconformably by the dominantly cool-water carbonates of the Cainozoic Eucla Basin. To the south, the uppermost sequences of the Bight Basin onlap highly extended continental crust and rocks of the continent-ocean transition on the abyssal plain between Australia and Antarctica (Sayers et al., 2001).

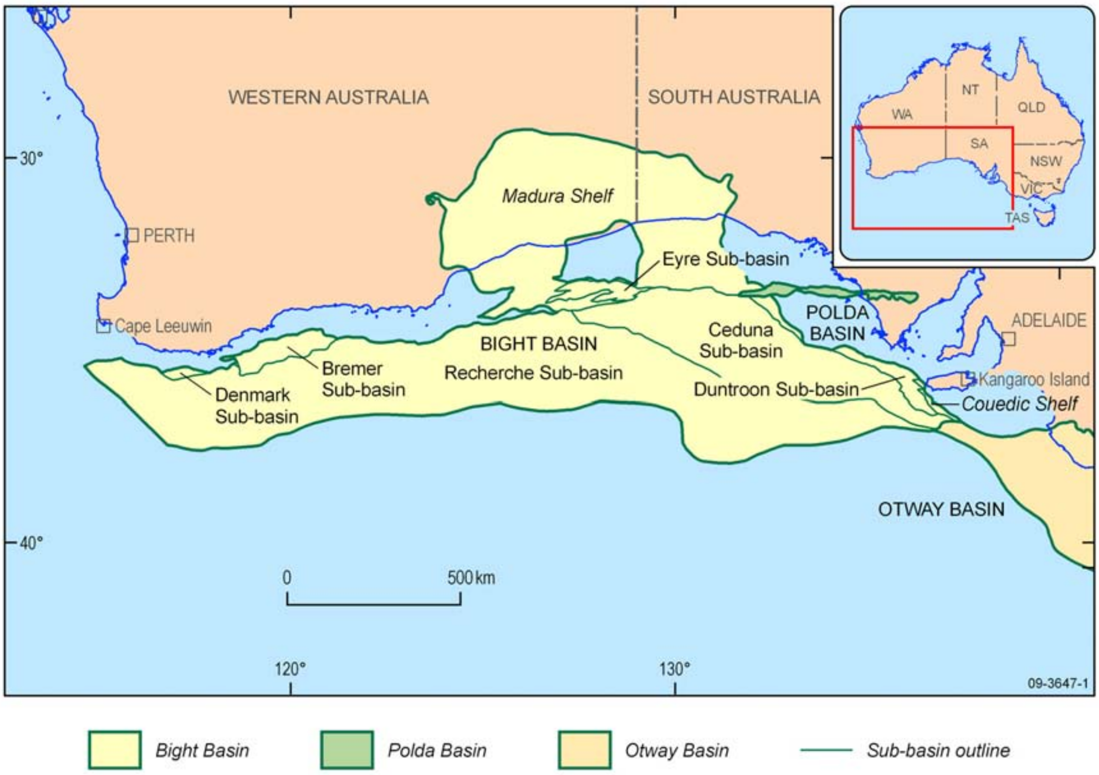


Figure 2.1: *Location map showing the Bight Basin along the southern Australian margin, together with its component sub-basins.*

2.2 STRUCTURAL ELEMENTS

The Bight Basin is one of a series of Mesozoic to Cainozoic depocentres that developed along Australia's southern margin during a period of extension and passive margin evolution that commenced in the Middle–Late Jurassic (Fraser & Tilbury, 1979; Bein & Taylor, 1981; Willcox & Stagg, 1990; Stagg et al., 1990; Hill, 1995; Totterdell et al., 2000; Norvick & Smith, 2001; Totterdell & Bradshaw, 2004). The basin contains five main depocentres—the Ceduna, Duntroon, Eyre, Bremer and Recherche sub-basins (Fig. 2.1 and 2.2). Thin platform cover areas are present along the northern and eastern margins (Madura and Couedic Shelves). The largest and thickest depocentre, the Ceduna Sub-basin, contains a sedimentary section approximately 15 km thick. The deepwater Recherche Sub-basin adjoins the Ceduna Sub-basin and extends west along the southern margin as far as the Leeuwin Fracture Zone. Perched half-graben systems of the Denmark, Bremer and Eyre sub-basins lie to the north of the Recherche Sub-basin. The Duntroon Sub-basin adjoins the Ceduna Sub-basin to the east, and consists of a series of oblique extensional depocentres.

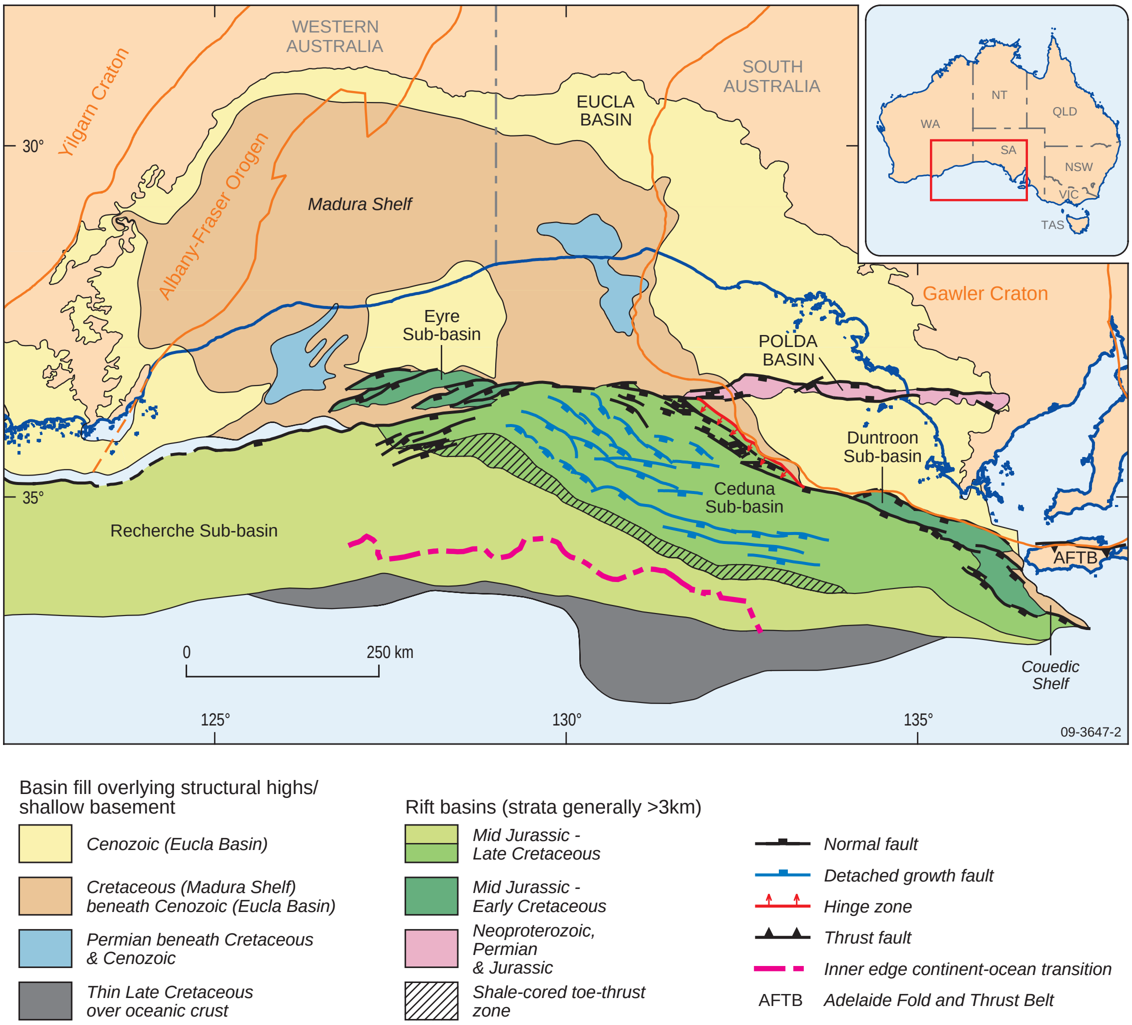


Figure 2.2: *Map of the structural elements of the eastern Bight Basin (Bradshaw et al. 2003).*

2.3 TECTONIC EVOLUTION

The Bight Basin formed within a tectonic framework dominated by the break-up of eastern Gondwana. The basin evolved through repeated episodes of extension and thermal subsidence leading up to, and following, the commencement of sea-floor spreading between Australia and Antarctica (Totterdell & Bradshaw, 2004).

The basin was initiated during a period of Middle–Late Jurassic to Early Cretaceous upper crustal extension. At this time a convergent margin existed on the eastern margin of the continent. Incipient rifts were developing between Australia and Antarctic, India and Antarctica, and India and western Australia, the extensional systems forming a triple junction (Norvick & Smith, 2001; Fig. 2.3a). Rifting along this system eventually resulted in sea-floor spreading between India and Australia/Antarctica, but the rift along the southern margin failed at that time. In the Bight Basin, a NW–SE to NNW–SSE extension direction, superimposed on east–west and northwest–southeast-oriented basement structures, resulted in oblique to strongly oblique extension and the formation of en echelon half graben in the Eyre, inner Recherche, eastern Ceduna and Duntroon Sub-basins (Fig. 2.2 and 2.4). The areal extent of the early extensional structures beneath the thick Ceduna Sub-basin cannot be determined due to the thickness and nature of the sedimentary section. The anomalously thick nature of the sub-basin may indicate, however, that Jurassic–Early Cretaceous rifts are present at depth. The Early Cretaceous was characterised by post-rift thermal subsidence in the Bight Basin. By the mid-Cretaceous, open ocean lay to the west and a seaway extended along the margin to the eastern Bight area (Fig. 2.3b).

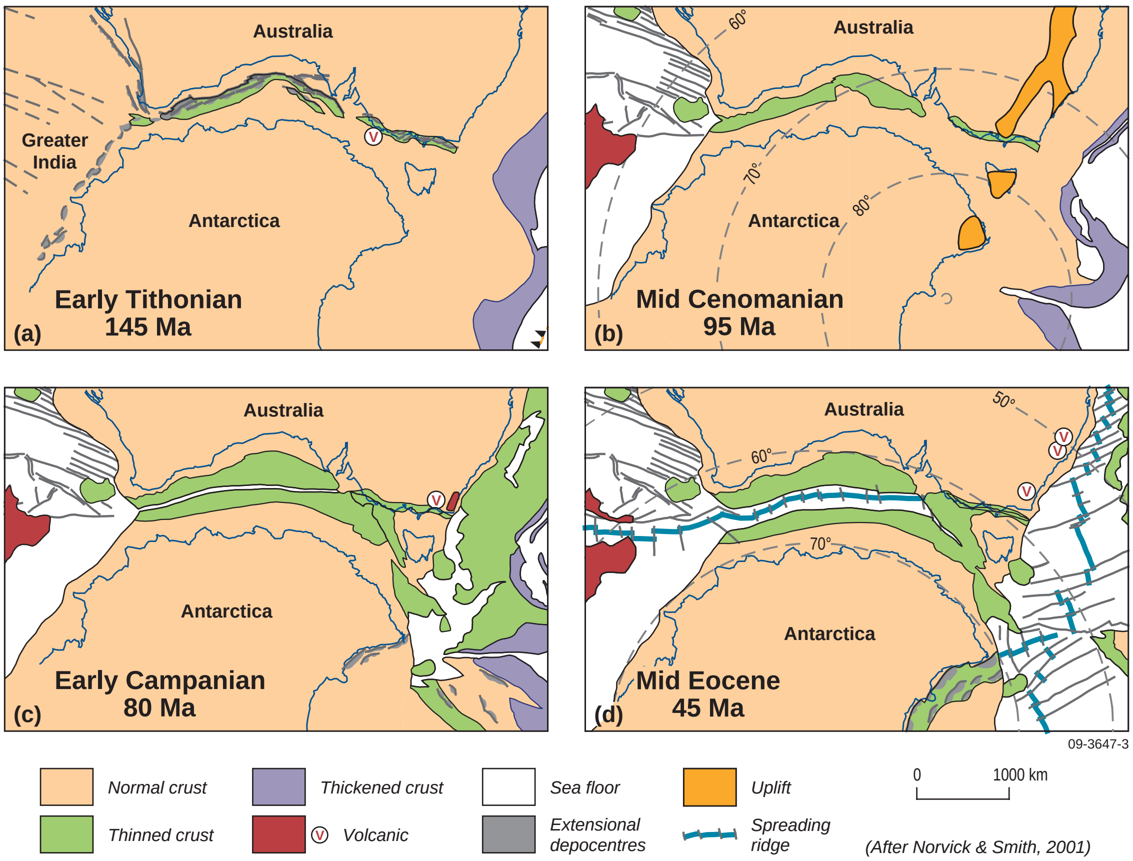


***Figure 2.3**: Plate tectonic reconstructions for the southern Australia–Antarctica conjugate margin (Norvick & Smith, 2001).*

Post-rift thermal subsidence was followed by a phase of accelerated subsidence, which commenced in the Late Albian and continued until continental break-up in the Late Santonian–Early Campanian. During this phase of enhanced subsidence, the dominant structural feature was a system of gravity-driven, detached extensional and contractional structures, which developed in the Cenomanian as a result of deltaic progradation (Fig. 2.5 and 2.6). Several authors (Veevers et al., 1991; Raza et al., 1995; Totterdell et al., 2000; Krassay & Totterdell, 2003) have speculated that the deltas of the Ceduna Sub-basin were fed by sediments derived from the eastern Australian highlands about 1500 km to the east-northeast. Fission track studies indicate that the eastern Australian highlands were affected by a regional-scale cooling event in the mid-Late Cretaceous (100-80 Ma; Late Albian-Campanian) caused by kilometre-scale uplift and denudation. At around 90-100 Ma, subduction ceased along the eastern Australian margin, resulting in dynamic rebound of the cratonic platform (Waschbusch et al., 1999). This rebound is likely to have resulted in the development of a regional drainage gradient to the west. It is possible that much of the sediment eroded from this area was transported west and south-westwards towards the Bight depocentre (Totterdell et al., 2000; Totterdell & Bradshaw, 2004).

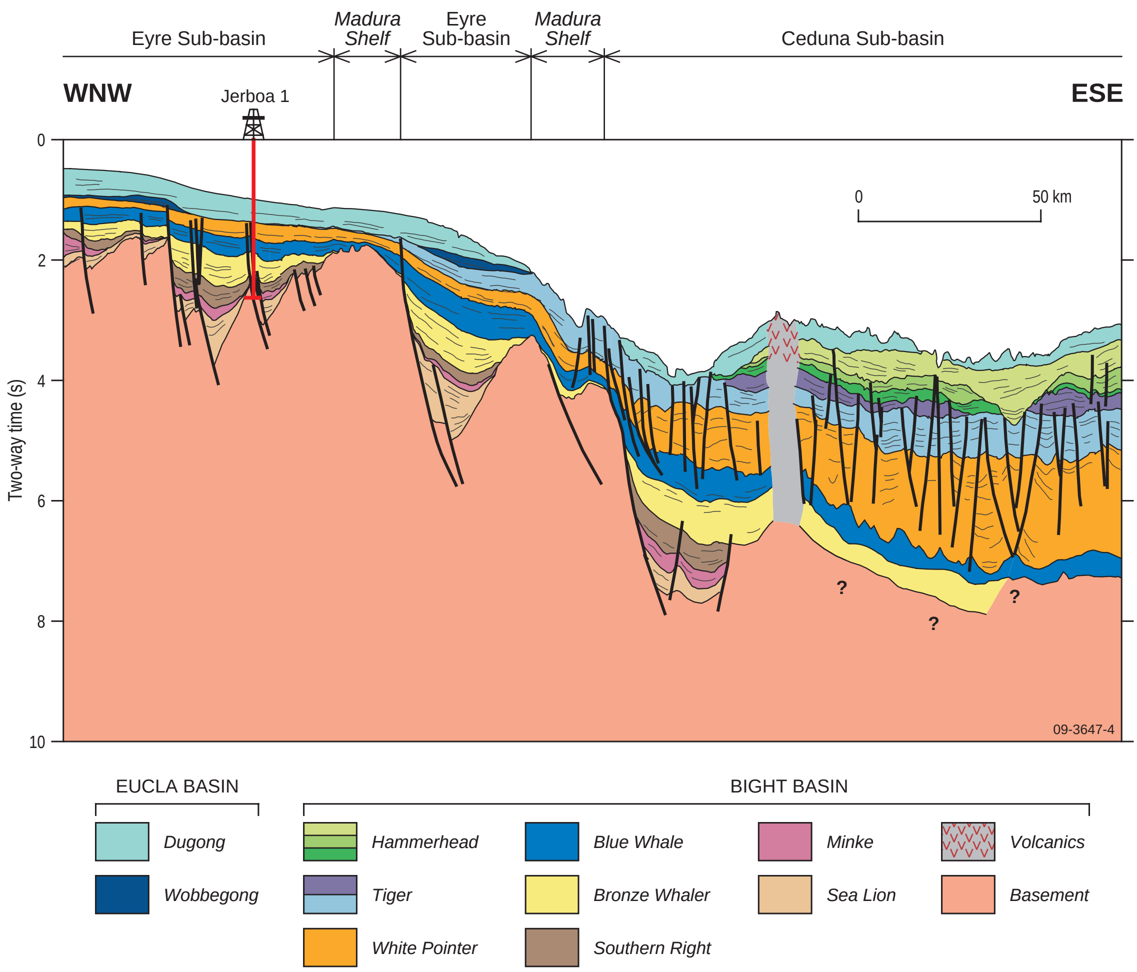


Figure 2.4: *Geoseismic cross-section from the Eyre Sub-basin across the outer part of the northwestern Ceduna Sub-basin (Totterdell & Bradshaw, 2004).*

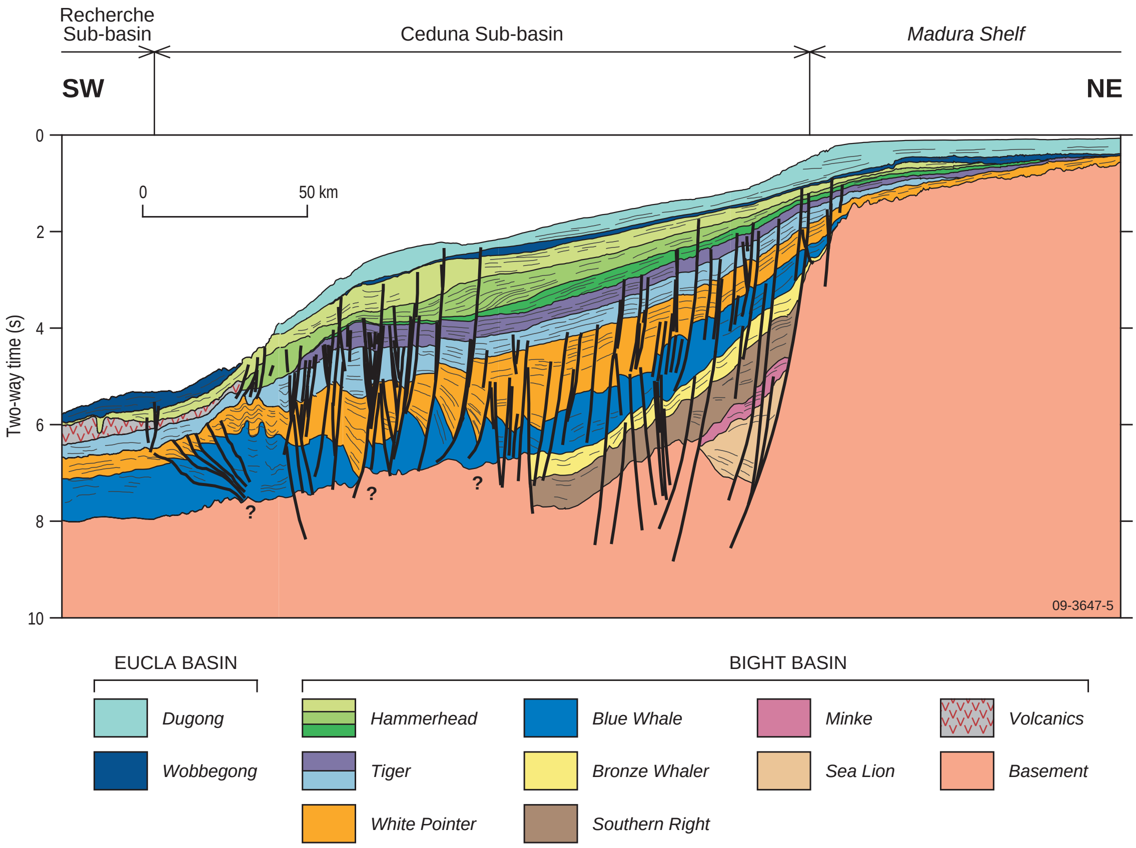


***Figure 2.5**: Geoseismic cross-section across the northern Ceduna Sub-basin (Totterdell & Bradshaw, 2004).*

Evidence for upper crustal extension during this period of accelerated subsidence preceding break-up is limited to localised Turonian–Santonian extensional faulting; including the reactivation and propagation of Cenomanian growth faults (Fig. 2.5 and 2.6). The upper crustal extension that is observed is not consistent with the amount of accommodation created, so it is suggested that the accelerated subsidence rate may have been caused by depth-dependent stretching processes (i.e. where stretching of the lower crust and upper mantle is greater than that of the upper crust).

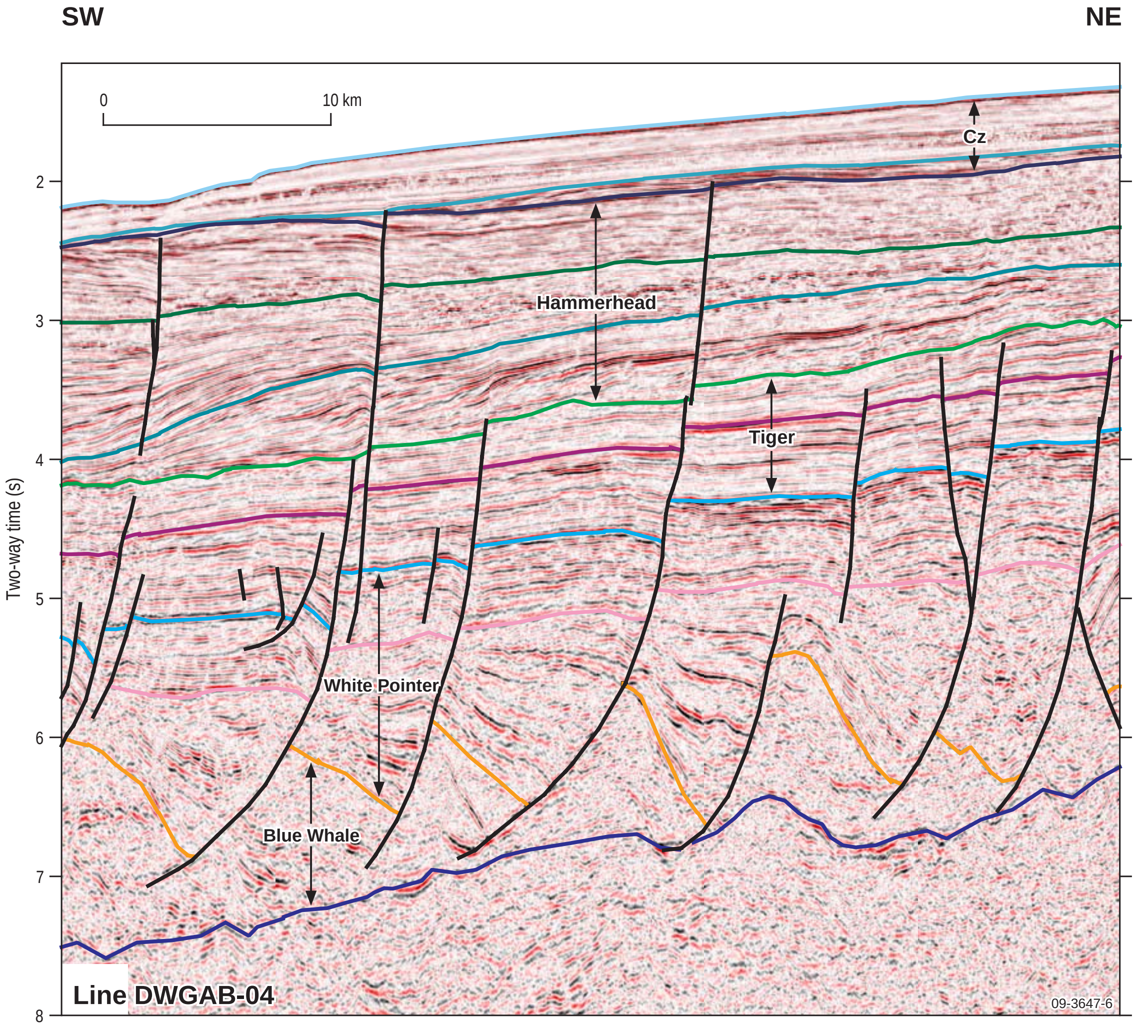


Figure 2.6*: Seismic line showing typical structural architecture, northern Ceduna Sub-basin (Totterdell & Krassay, 2003a).*

The commencement of sea-floor spreading in the latest Santonian was followed by a further period of thermal subsidence and establishment of a passive margin. Ultra- to very slow spreading between Antarctica and Australia commenced around 83 Ma (Sayers et al., 2001; Fig. 2.3c) and continued for almost 20 million years. Because of the slow spreading, the seaway along the southern margin would have remained narrow. In the Middle Eocene (around 45 Ma) (Tikku & Cande, 1999), there was a dramatic increase in the rate of spreading, and continental separation began in earnest (Fig. 2.3d). This resulted in subsidence of the margin, which is reflected in the strongly onlapping nature of the sequence boundary at the base of the Dugong Supersequence.

2.4 TECTONOSTRATIGRAPHY

A tectonostratigraphic framework for the eastern part of the Bight Basin was compiled by Totterdell et al. (2000) and Totterdell and Bradshaw (2004), based on the sequence stratigraphic and structural interpretation of an extensive grid of seismic data, tied, where possible, to 9 petroleum exploration wells in the offshore Bight Basin (Fig. 2.7 and 2.8); data from the 2003 Gnarlyknots-1A well was not available for those studies, however the drilling results are consistent with the sequence stratigraphic framework. Stratigraphic control in the Madura Shelf and northern Ceduna Sub-basin is provided by the Apollo-1 and Potoroo-1 wells, which intersect thin mid-Late Cretaceous successions at the edge of the sub-basin, and Gnarlyknots-1A, which was drilled farther basinward (Fig. 2.7). In the Eyre Sub-basin, Jerboa-1 penetrated the latest Jurassic-Early Cretaceous section. Further south, in the southern Ceduna and Duntroon Sub-basins, Platypus-1, Greenly-1, Duntroon-1, Borda-1, Echidna-1 and Vivonne-1 provide information on the Early-Late Cretaceous succession.

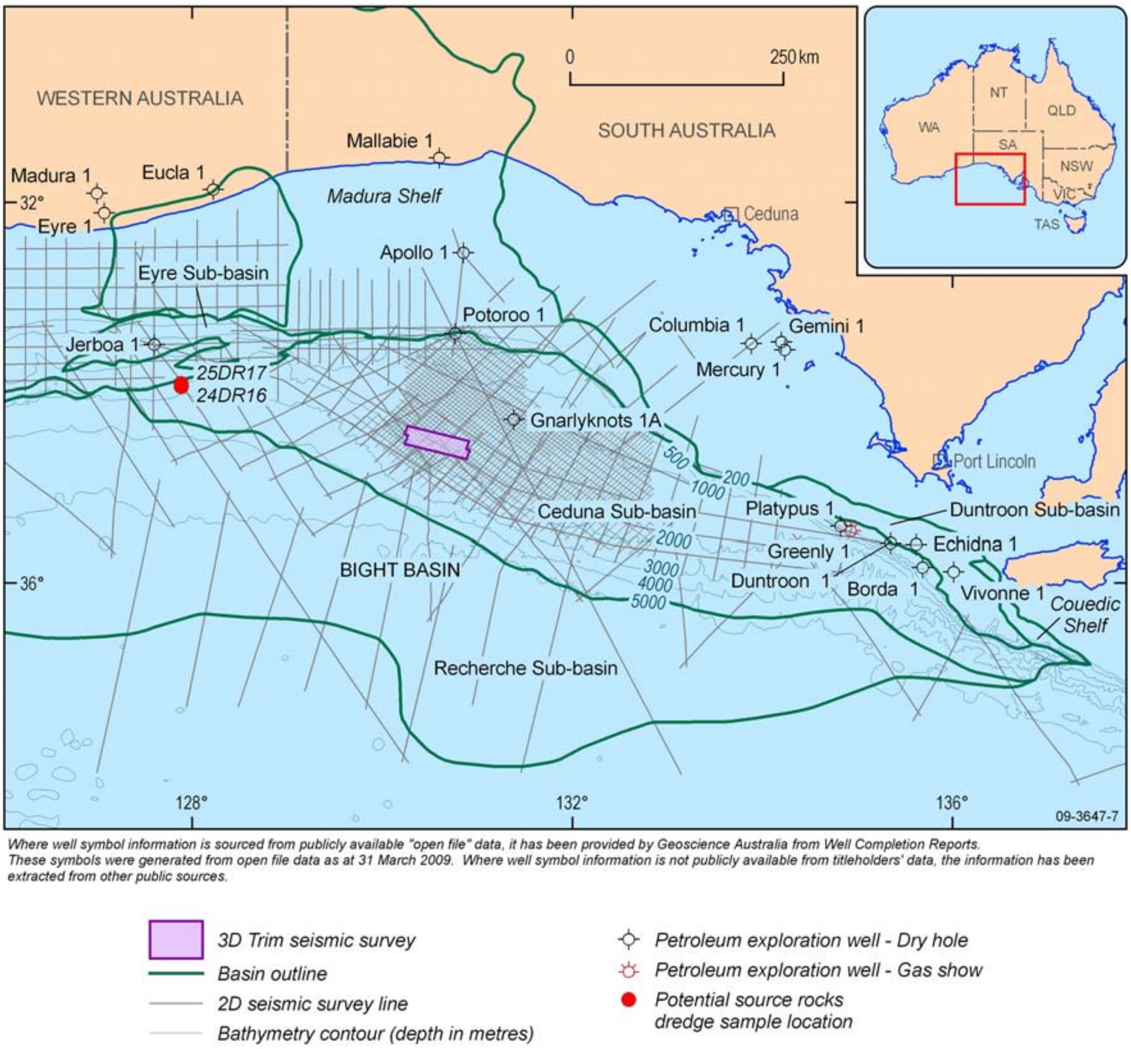


Figure 2.7*: Map showing location of seismic lines and wells in the eastern Bight Basin.*

The tectonostratigraphic development of the Bight Basin can be described in terms of four basin phases (Fig. 2.8; Totterdell et al., 2000). Basin Phase 1 (BP1) records the initiation of sedimentation during the Middle-Late Jurassic to earliest Cretaceous phase of NW–SE to NNW–SSE intracontinental extension. This resulted in the formation of a series of oblique extensional and transtensional half grabens in the Bremer, Eyre and Duntroon sub-basins, and along the northern and eastern margins of the Ceduna Sub-basin (Fig. 2.2, 2.4, and 2.5). The syn-rift Sea Lion and Minke supersequences comprise fluvial–lacustrine sandstone, siltstone, mudstone successions.

The extensional phase was followed by a period of slow thermal subsidence that lasted throughout most of the Early Cretaceous (Basin Phase 2; Fig. 2.8). This phase is represented by the Berriasian Southern Right Supersequence and the Valanginian to mid-Albian Bronze Whaler Supersequence.

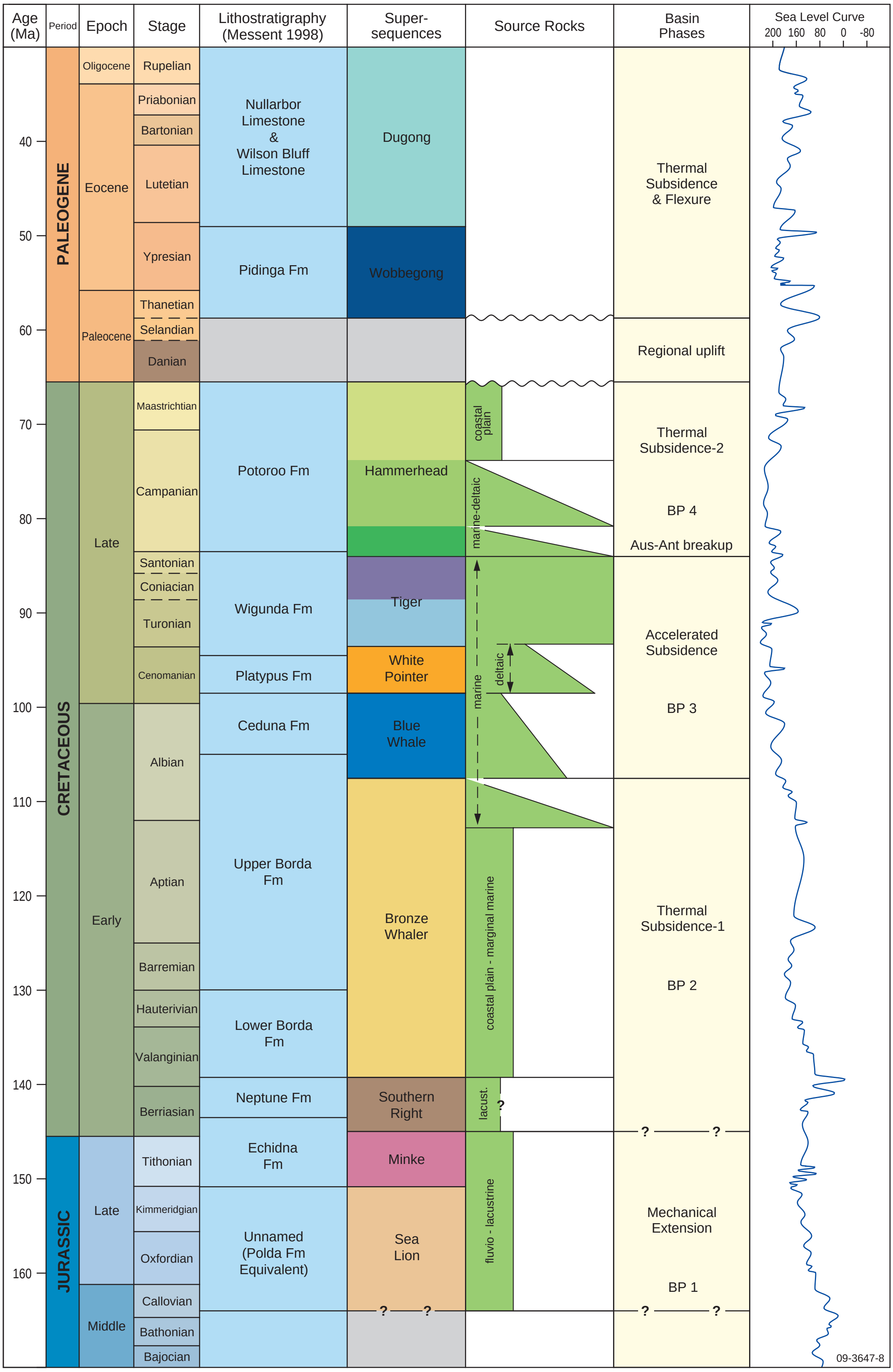


***Figure 2.8**: Schematic stratigraphy of the Bight Basin (after Totterdell & Krassay, 2003b).*

Deposition during this time was largely non-marine, although some marine influence is evident late in this phase. In the Eyre Sub-basin, the Southern Right Supersequence is thin and characterised by lowstand fluvial sandstones; the presence of coal is interpreted on the basis of seismic reflection character. In the Duntroon Sub-basin the Southern Right Supersequence largely comprises a thick aggradational mudstone succession. The overlying Bronze Whaler Supersequence generally consists of an aggradational succession of fluvial and lacustrine sediments. In the Eyre Sub-basin, the extent of deposition of BP2 is generally constrained by the half-graben bounding faults, but the succession does not thicken appreciably into the faults, indicating that little or no actual upper crustal extension occurred at this time. Overall, the succession has an onlapping, sag-fill geometry, which indicates that accommodation was created largely by thermal subsidence and compaction, with deposition concentrated over the earlier half graben.

An abrupt increase in subsidence rate in the mid-Albian signalled the start of the third basin phase (BP3; Fig. 2.8). This period of accelerated subsidence, which continued until the commencement of sea-floor spreading between Australia and Antarctica in the Late Santonian, coincided with a period of rising global sea level (Fig. 2.8). This combination of factors resulted in the creation of accommodation at a high rate, and the first major marine flooding event in the basin and the widespread deposition of marine silts and shales of the Albian–Cenomanian Blue Whale Supersequence. The present-day distribution of the supersequence indicates that the seaway at that time extended along the southern margin from the open sea in the west towards the Otway Basin in the east. Progradation of deltaic sediments into this seaway (White Pointer Supersequence) commenced in the Cenomanian, following uplift and erosion along the eastern margin of the continent. Deposition was rapid, resulting in the development of overpressure in the underlying marine shales, and a short-lived period of shale mobilisation and growth faulting throughout the northern half of the Ceduna Sub-basin (Fig. 2.6). Interpretation of seismic facies suggests that a broad band of coaly sediments is present within the White Pointer Supersequence in the inner part of the Ceduna Sub-basin. The Cenomanian deltaic sediments are overlain by the marginal marine, deltaic and open marine sediments of the Turonian–Santonian Tiger Supersequence. In wells, the supersequence is dominated by mudstones and a few thick sandstone units. On seismic data, the supersequence has a largely flat-lying aggradational character.

Continental break-up in the Late Santonian was followed by a period of thermal subsidence and the establishment of the southern Australian passive margin (BP4; Fig. 2.8). It was during this phase that the second large progradational delta developed, represented by the Latest Santonian–Maastrichtian Hammerhead Supersequence (Fig. 2.5 and 2.6). In contrast with the earlier deltaic system, this sand-rich delta is characterised by strongly prograding stratal geometries and shows no evidence of widespread shale tectonics. A dramatic reduction in sediment supply at the end of the Cretaceous saw the abandonment of deltaic deposition. There is some seismic evidence of regional uplift at this time. The Hammerhead Supersequence, and much of the underlying Tiger Supersequence, are absent across the Eyre Sub-basin. In addition, there is an angular unconformity between the Bight and Eucla Basin successions on the Madura Shelf, where Cretaceous units are progressively eroded across the shelf (Fig. 2.5). From the Late Palaeocene to present, the largely cool-water carbonates of the Eucla Basin accumulated on a sediment-starved passive margin. A short phase of magmatism in the Middle Eocene, coinciding with the onset of rapid spreading, affected the central Ceduna Sub-basin. This magmatic phase was characterised by both extrusive volcanism (volcanoes, flows, volcanic build-ups) and the intrusion of sills, dykes and deeper igneous bodies (Schofield & Totterdell, in prep.).

3. Geophysics

3.1 INTRODUCTION AND DATA SOURCES

This section summarises the availability and coverage of acoustic datasets to assist with environmental and geological assessment. The key data types described are bathymetry, acoustic reflectivity, and sub-bottom profiler data. The purpose of this section is simply to provide an overview of the data available within the Ceduna Sub-basin. A description of the geomorphology and stratigraphy interpreted from these data sets is contained in Sections 2 and 4.

3.2 BATHYMETRY

Bathymetric information is collected using several techniques (Table 3.1). Geoscience Australia's (GA) bathymetry data holdings consist of ship-track (single-beam) bathymetry, multibeam sonar bathymetry, digitised soundings from hydrographic charts, laser airborne depth sounder (LADS) data, predicted bathymetry from satellite altimetry, and other geophysical measurements. Geoscience Australia combines and interpolates these datasets to provide bathymetric grids for marine zone management, research and acreage release areas at a nominal resolution of 0.0025 degrees (~250m) (Fig. 3.1).

Table 3.1*: Methods of bathymetric data acquisition.*

Technique	Examples	Depth Range	Advantages	Limitations
Leadline	Leadline	0-50 m	Very inexpensive; can be used to collect small seabed samples	Inaccurate due to wind and currents; pre echo-sounder technology
Airborne/ Satellite Remote Sensing	Landsat TM, IKONOS	0-25 m, clear water only (50 m max.)	Very large areas can be assessed	Limited optical penetration due to attenuation; many features cannot be optically distinguished
Airborne bathymetry	LIDAR – LADS, SHOALS	0-50 m, clear water only	Very rapid, high accuracy coverage; can identify micro-scale geomorphic features	Expense of aircraft operation, turbid waters, bad weather
Single-beam acoustics	High to low frequency echo-sounders (~200-3.5 kHz)	Up to full ocean depth	Depth range; can provide subsurface information	Requires multiple, closely spaced lines
Multibeam sonar	Simrad EM300 RV Southern Surveyor	1-1000's m	Large swath coverage; bathymetry and backscatter	Large expense and data volumes
Satellite altimetry	ETOPO2	Up to full ocean depth	Global	Low spatial resolution and inaccurate in places

Much of the historical bathymetric data comprises single-beam or ship track bathymetry. In these systems a transducer produces an acoustic signal (typically 3.5–200 kHz) that propagates through the water column directly below the ship. The two-way travel time can be converted to depth if the velocity of sound in water is accurately known. Many of the bathymetric soundings held by GA were acquired using single beam technology and recorded on Australian Hydrographic Survey (AHS) fairsheets, and Admiralty Charts (metadata for AHS fairsheets and charts may be found at http://www.hydro.gov.au/asdd/source/).

The density of ship-track survey lines is highly variable, and in some areas data points can be tens of kilometres apart. By contrast, areas with swath bathymetry coverage have a high density of soundings (density is dependant primarily on depth). Fairsheet (mainly single-beam) data is available for most areas of the continental shelf at relatively low data density.

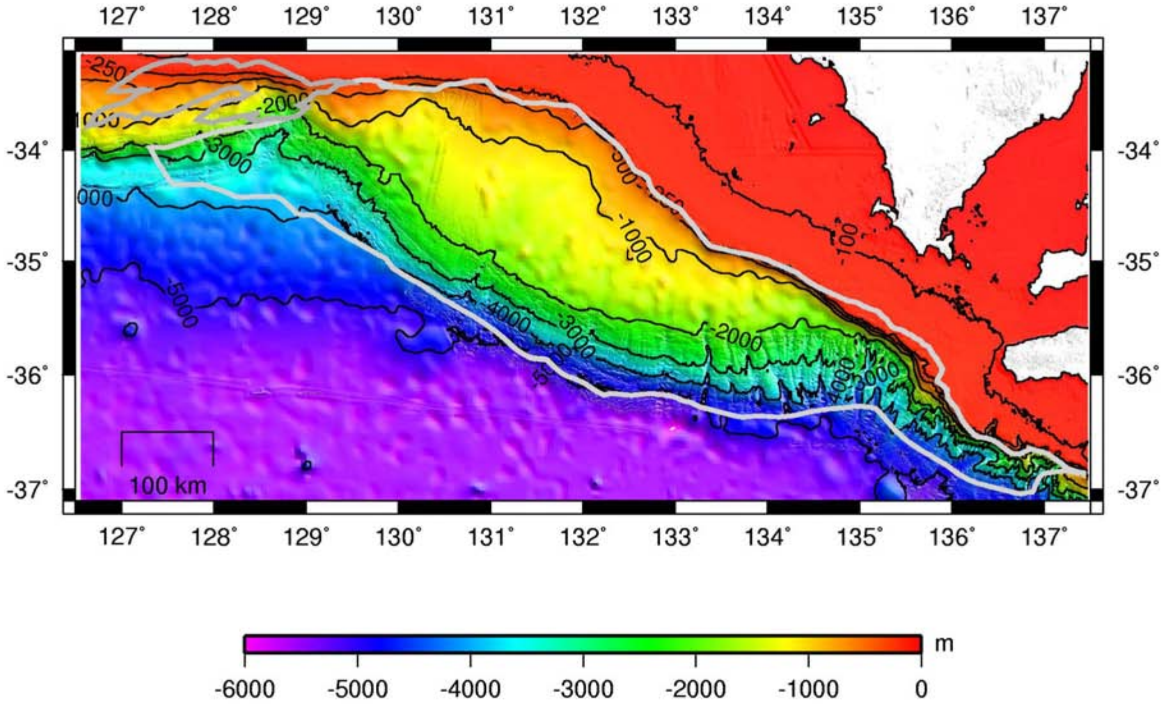


Figure 3.1*: Bathymetry compilation for the Ceduna (pale grey) and Eyre (grey) sub-basins.*

Multibeam sonar mapping systems record a swath comprising up to 200 beams that allow large areas of the seabed to be mapped with high accuracy (Hughes Clarke et al., 1996). The acoustic beams form a swath that fans out up to several times the water depth. Adjustments and post-processing are made for sound velocity, ship motion (heave, roll, pitch) and tidal variation providing a highly accurate bathymetric model of the seabed. Various multibeam sonar systems exist and can be used in as little as a few metres water depth, to full ocean depth with corresponding differences in horizontal and vertical resolution.

Multibeam sonar systems provide the highest resolution bathymetry information within the Ceduna Sub-basin and are a key tool for understanding the geomorphology and habitats of the seabed (Sections 4 and 7). The Ceduna Sub-basin has an extensive coverage of deep water multibeam bathymetry (Figs. 3.2–3.4.). Twelve surveys in total pass through the region (Table 3.2) with three particular surveys targeting the geomorphology, surficial geology, and stratigraphy of the region (Hill et al., 2000; 2004; and Totterdell et al., in prep). Five surveys are transit data sets acquired opportunistically as a research vessel passes through Australian waters. The bulk of the multibeam surveys have targeted the southern margin of the basin in depths greater than 2000 m.

The un-interpolated bathymetry grid presented in Figure 3.3 is shown at a resolution of ~250 m and shows the actual coverage of multibeam bathymetry in the Ceduna Sub-basin region. The data densities shown in Figure 3.4 indicate it is reasonable to grid the multibeam datasets at a much higher resolution than ~250 m. The SS01_2007 survey targeted numerous areas in water depths greater than 1000 m. Datasets from this survey typically have a resolution better than 50 m. A description of the geomorphology of the Ceduna Sub-basin, based largely on multibeam bathymetry, is contained in Section 4.

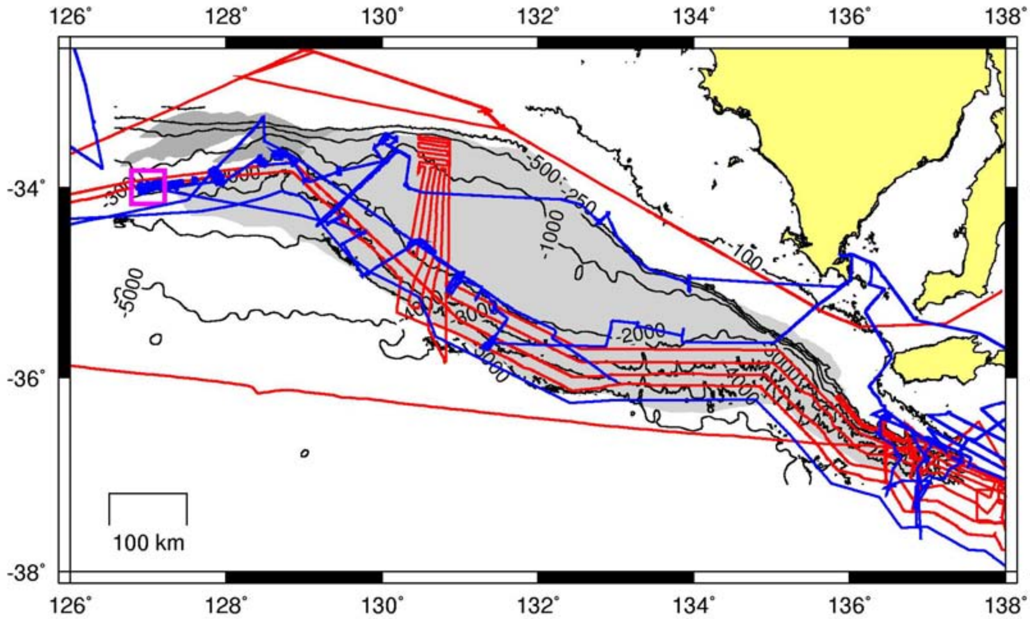


Figure 3.2: *All survey tracks shown have multibeam sonar data available. Tracks that are blue also have backscatter or sidescan data available. The Eyre sub-basin is shown in grey and the Ceduna sub-basin in pale grey. The pink box denotes the approximate outline of Figure 3.6.*

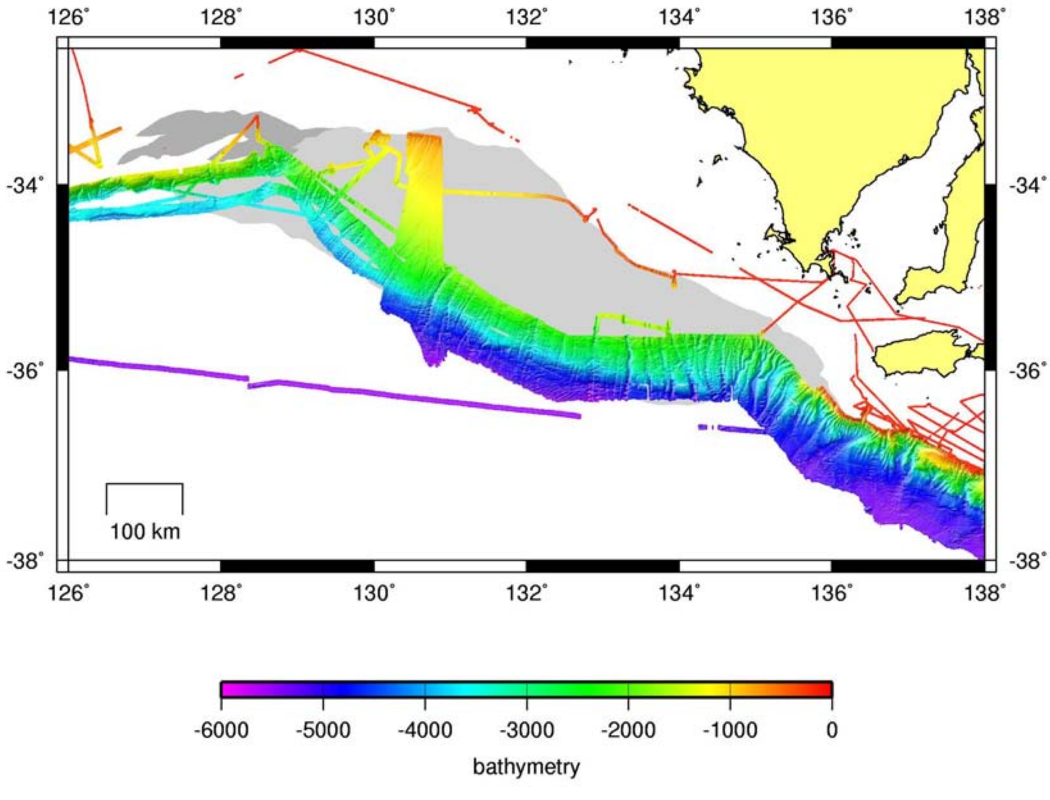


Figure 3.3: *Coverage of multibeam sonar bathymetry within the Ceduna Sub-basin and adjacent areas. The Eyre sub-basin is shown in grey and the Ceduna sub-basin in pale grey.*

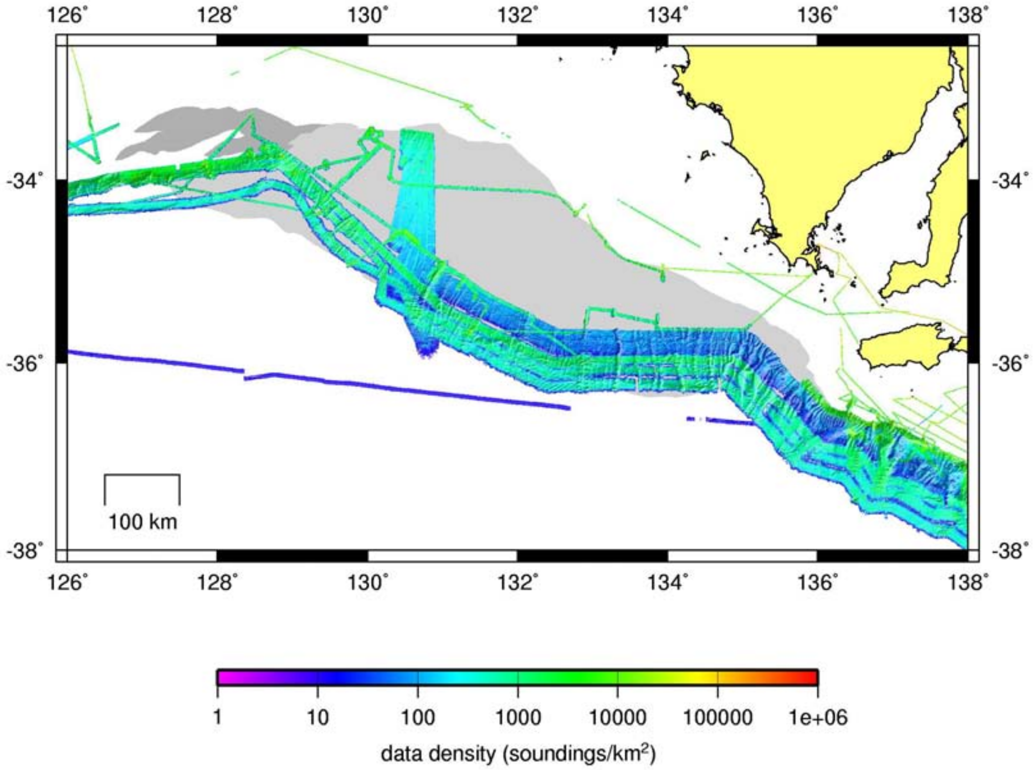


Figure 3.4*: Multibeam sonar data density grid for the Ceduna Sub-basin and adjacent areas. The Eyre sub-basin is shown in grey and the Ceduna sub-basin in pale grey.*

Table 3.2: *Marine surveys within the Ceduna/Eyre sub-basins. MB indicates multibeam bathymetry was acquired, BS indicates acoustic backscatter was acquired, SS indicates that sidescan was acquired and SBP indicates that sub bottom profiler data was acquired. Most Geoscience Australia surveys have post cruise reports that document data acquisition and preliminary data interpretation. Surveys without reports were run by organisations other than Geoscience Australia.*

GA survey no.	Survey name	Ship	MB	BS	SS	SBP	Report
0157	Adedav	N/O L'Atalante	Y	N	N	N	No
0222	Austrea1	N/O Marion Dufresne	Y	N	N	N	Hill et al., 2000
0224	Bioview	FR/V Southern Surveyor	Y	Y	Y	N	No
0245	Auscan2	N/O Marion Dufresne	Y	N	N	N	Hill et al. 2004
2350	Adelaide	HMAS Cook	Y	N	N	N	Hughes Clarke 1990
2396	vt82	N/O Marion Dufresne	Y	N	N	N	No
2397	Palaeomurray	FR/V Southern Surveyor	Y	Y	Y	Y	No
2400	Leeuwin_current	FR/V Southern Surveyor	Y	Y	Y	N	No
2423	SS01_2007	FR/V Southern Surveyor	Y	Y	Y	N	No
2424	SS01_2007	FR/V Southern Surveyor	Y	Y	Y	Y	Totterdell et al (in prep)
2425	SS02_2007	FR/V Southern Surveyor	Y	Y	Y	Y	No
2433	SS03_2007	FR/V Southern Surveyor	Y	Y	Y	Y	No

3.3 ACOUSTIC REFLECTIVITY (SIDESCAN AND BACKSCATTER)

Multibeam sonar systems acquire both bathymetry and acoustic reflectivity. The latter carries important information about the physical properties of the seabed such as roughness, hardness and homogeneity (Beaudoin et al., 2002). Reflectivity datasets can assist in seafloor characterisation (habitats/substrate types) and hence are an important and complimentary dataset to bathymetry (Fig. 3.5).

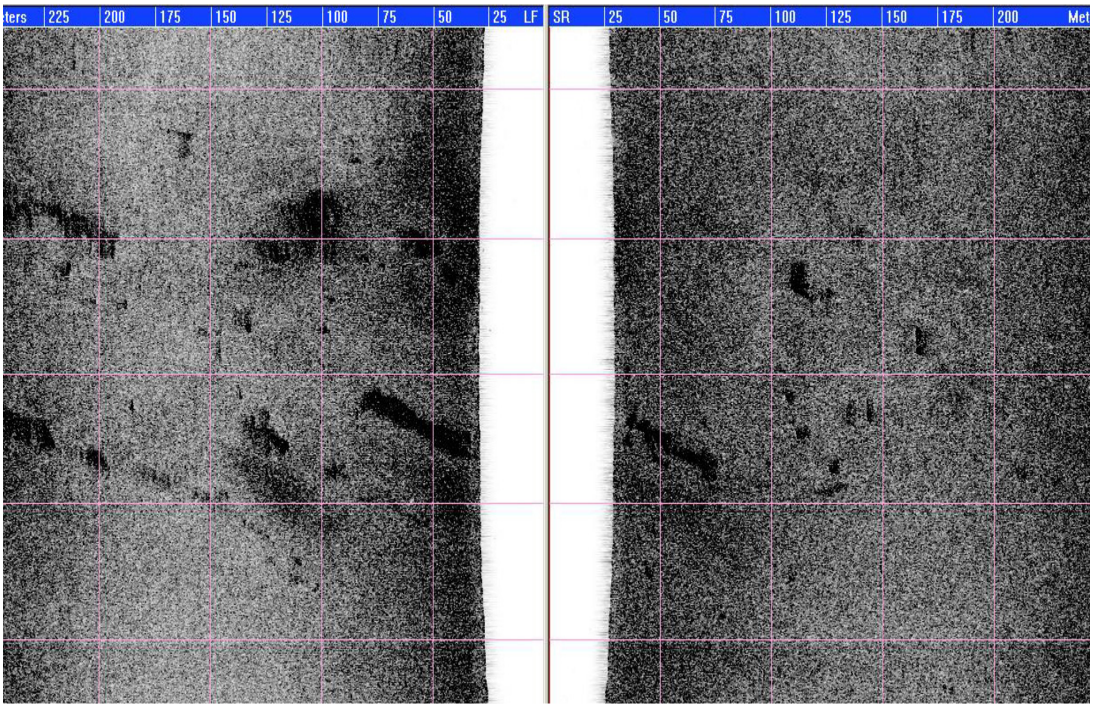


Figure 3.5*: Example of sidescan sonar data from the Ceduna sub-basin. Dark patches indicate regions of strong backscatter possibly related to bedrock outcrop.*

The acoustic backscatter registered by sidescan sonars is normally logged as two time series of intensity values, one each for the port and starboard side, recorded at the reception transducer (Tyce, 1986). In contrast, multibeam sonars register the acoustic backscatter in three different forms:

1. the average backscatter strength for each beam;
2. a time series of backscatter strength around the detection point of each received beam; and
3. two time series of backscatter strength (port and starboard) for each received ping, which will generate data very similar to a sidescan (Beaudoin, 2002).

Multibeam sonars, like the Simrad EM300 on the RV Southern Surveyor, acquire both the average beam strengths (i.e. type 1), and 'pseudo-sidescan' (i.e. type 3). Since the resolution achieved by the multibeam sonar sidescan is of a comparable resolution to stand alone sidescan systems they are considered equivalent for this review.

Sound attenuates (decays) through the water column and through interactions with the seabed. As a result, several biases are introduced into backscatter and sidescan datasets during acquisition. These biases need to be corrected before these data can be used for seabed characterisation and habitat analysis (Fonseca & Calder, 2005; Fonseca & Mayer, in prep). The distortions are generated by:

- Variable Transmit power
- Variable Receiver gains
- Variable Pulse widths
- Changing areas of seabed insonification
- Attenuation in the water column
- Seafloor slope

- Sediment angular response
- Spherical spreading
- Beam patterns
- Speckle noise
- Applied time varying gain (or TVG) or Lambertian corrections
- Slant range
- Positioning

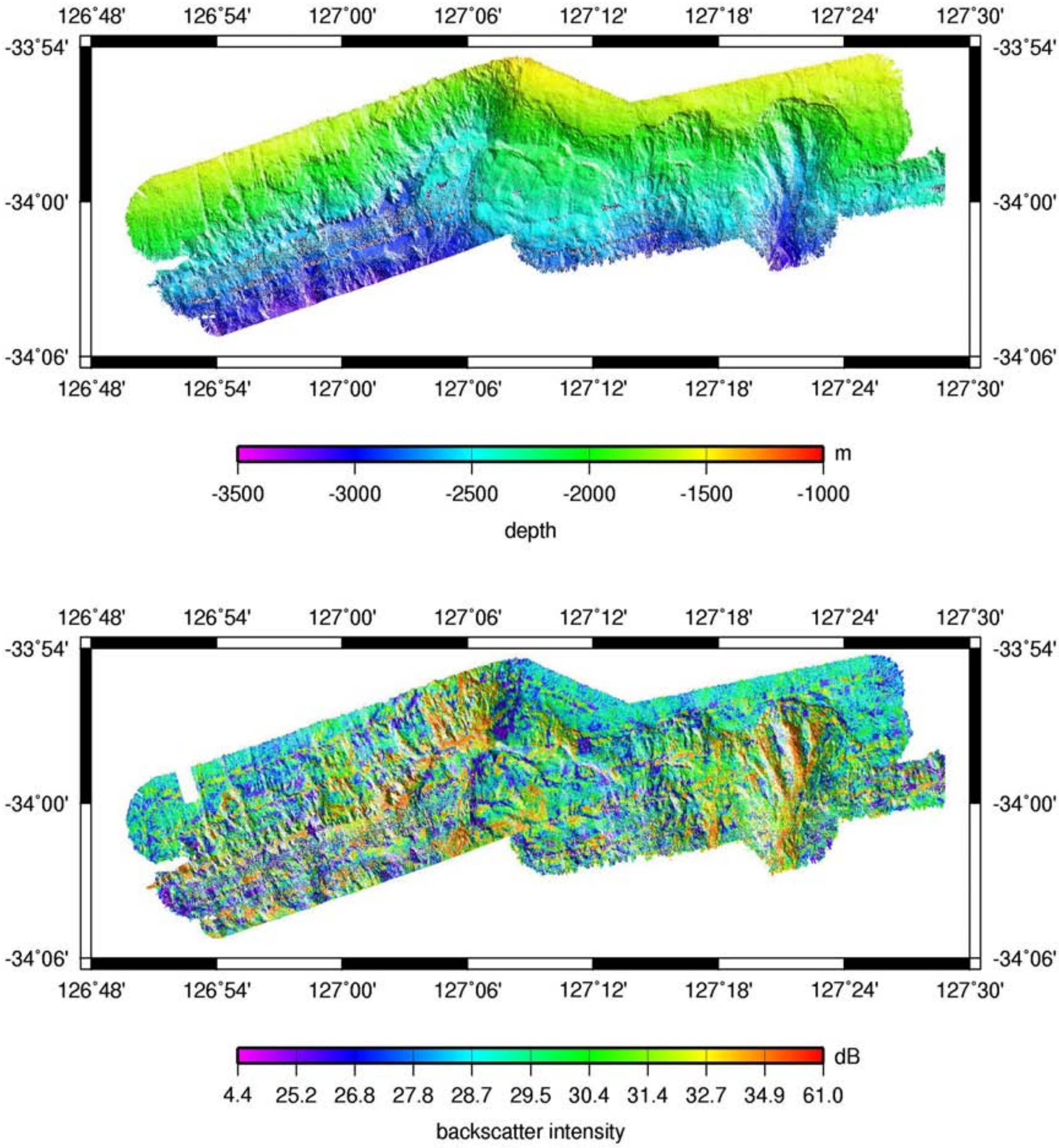


***Figure 3.6**: Multibeam bathymetry and associated backscatter for a region of canyons in the Ceduna Sub-basin. See Figure 3.2 for survey location.*

Within the Ceduna Sub-basin there are eight marine surveys that have both sidescan and backscatter data recorded with multibeam sonar bathymetry (Fig. 3.1). At present this data is not combined into interpolated grids due to the associated distortions in the data and lower coverage of data compared to bathymetry (when data types other than multibeam are taken into consideration).

Rudimentary processing of some data from the Ceduna Sub-basin indicated that this is a potentially valuable dataset for seabed characterisation (Fig. 3.6). Extensive regions of high backscatter (yellow and orange) are associated with the floors of canyons and low backscatter (purple and dark blue) areas indicate regions of probable sediment accumulation.

3.4 SUB-BOTTOM PROFILER

Sub-bottom profiling (SBP) systems are used to identify and characterize layers of sediment or rock under the seafloor. The technique used is similar to a simple echo-sounder. A transducer emits a sound pulse vertically downwards towards the seafloor, and a receiver records the return of the pulse once it has been reflected off the seafloor. Parts of the sound pulse will penetrate the seafloor and be reflected off the different sub-bottom layers. The data that is obtained using this system provides information on these sub-floor sediment layers.

Sub-bottom profile data are generally delivered in the SEGY binary format (.sgy) with one file per seismic line. Parums (2007) provides a summary of the SBP data holdings at GA, including general information about the surveys, maps showing the SBP lines, location of data holdings, and media used. Four surveys within the Ceduna Sub-basin have associated sub-bottom profiler data (Table 3.1; Fig. 3.7).

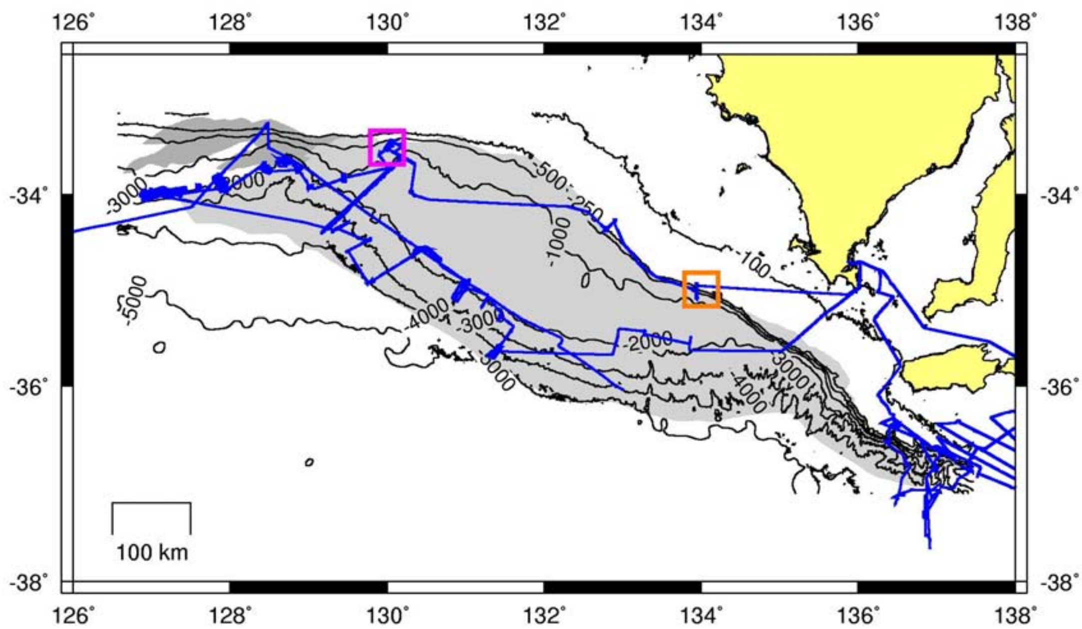


***Figure 3.7**: Coverage of sub-bottom profiler datasets held by Geoscience Australia. The Eyre sub-basin is shown in grey and the Ceduna sub-basin in pale grey. The pink and orange squares indicate the approximate locations of Figures 3.8 and 3.9 respectively.*

Sub-bottom profiler data within the Ceduna Sub-basin have been used to identify surficial and sub-seabed features related to possible hydrocarbon seepages (Totterdell et al., in prep.). Depressions observed in multibeam bathymetry (Fig. 3.8) have been measured at about 150 m in diameter and 5 m in depth, and are thought to be a result of fluid escape (either active features or palaeo-features).

Associated with these depressions (or pockmarks) are enhanced reflectors, possibly resulting from variations in seabed composition in these areas. Elsewhere SBP datasets have been effective at mapping out thicknesses of Holocene sediments and provide a tool for interpreting older bedrock/sediments in the shallow sub surface. In the Ceduna Sub-basin features observed in surficial (bathymetry) and shallow subsurface (SBP) datasets are often reflected in seismic datasets as they are a result of large-scale faulting, mass wasting, and possibly fluid escape (Totterdell et al. in prep.).

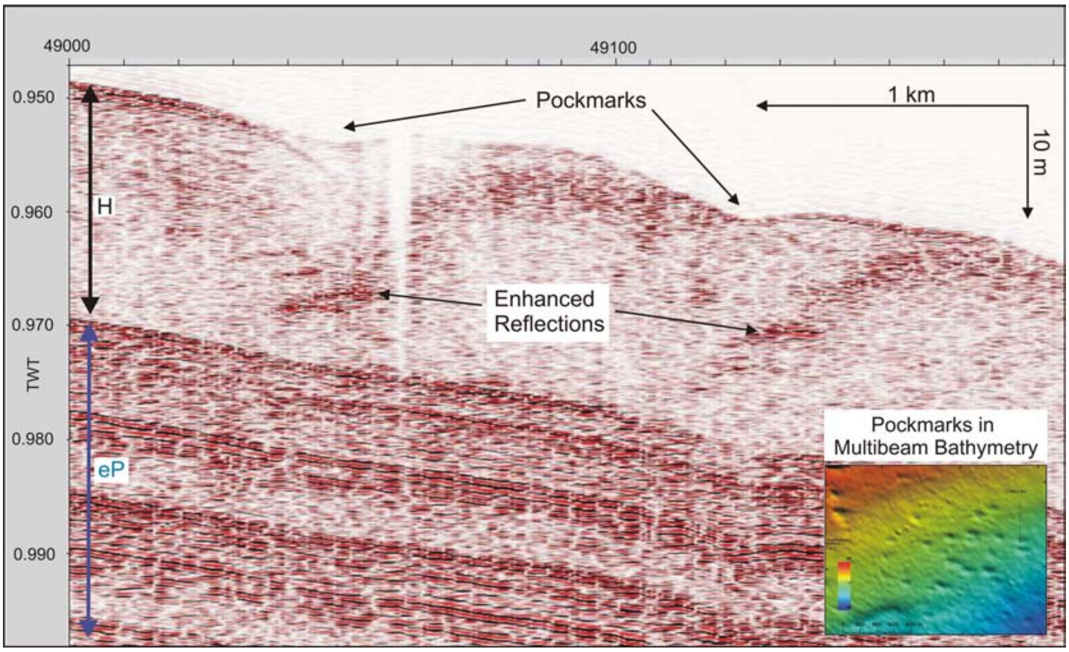


***Figure 3.8**: Interpreted stratigraphy from the sub-bottom profile in region of pockmarks. eP = early Pleistocene unit; H = late Pleistocene/Holocene unit.*

3.5 SUMMARY

Multibeam bathymetry data covers approximately half of the Ceduna Sub-basin region with the bulk of the data concentrated in deeper portions of the basin. Coverage of acoustic reflectivity and sub-bottom profiler data is more limited (Table 3.3) and restricted to detailed geological surveys such as Totterdell et al. (in prep). All datasets are publicly available through Geoscience Australia for further inspection and processing by external clients.

***Table 3.3:** Summary of marine geophysical datasets available in the Ceduna/Eyre Sub-basin region. No coverage area is supplied for sub-bottom profiler as only profile information is acquired*

Data types	Coverage Area (km^2)	Survey data (kilometres)
Bathymetry	2.1 x 10^6	22700
Acoustic Reflectivity	1.0 x 10^6	9200
Sub-bottom profiler	-	8500

4. Geomorphology

4.1 INTRODUCTION AND DATA SOURCES

Previous studies of the marine geomorphology along the continental margin of southern Australia have concentrated on the continental shelf and upper slope. The first systematic description of the general physiography of the seafloor within the Great Australian Bight (GAB) was made by Connolly and Von der Borch (1967), following the pioneering work of Sprigg (1952; 1963) who mapped the submarine canyons to the south of Adelaide. With regard to the area of seafloor within the Ceduna Sub-basin, Connolly and Von der Borch (1967) described the Ceduna Terrace (referred to as Ceduna Plateau) as an "area of gently sloping sea floor" having a "generally smooth but sometimes rough surface with relief of up to 80 fathoms". They interpreted the Ceduna Terrace as a relict depositional surface that has experienced subsequent erosion. Subsequent bathymetric surveys in the GAB have partially mapped the area of seafloor bounded by the Ceduna Sub-basin, including:

- the AUSTREA-1 survey on the *L'Atalante* in 1999-2000 (Hill et al., 2001);
- the AUSCAN expedition (Hill & De Decker, 2004) and the AUSFAIR GAB transit on the *Marion Dufresne* in 2003 and 2006, respectively;
- the 2006 Palaeo Murrays survey on *Southern Surveyor* (De Deckker, 2006); and
- Geoscience Australia survey SS2007/01 in 2007 on *Southern Surveyor* (Mitchell et al., 2008) (Fig. 3.2).

None of these surveys mapped extensive areas of seafloor, and were limited to collecting multibeam sonar data and samples along single track lines and within relatively small areas of interest (e.g. canyons and scarps). A synthesis of research in the GAB is available in Richardson et al. (2005) and information on the broader geomorphic context of the southwest planning region is presented by Potter et al. (2006).

For this report, the description and interpretation of bathymetry within the Ceduna Sub-basin is based on the new Geoscience Australia 250 m resolution grid for the Australian margin, supplemented with an overlay of higher resolution multibeam sonar mapping collected on Geoscience Australia survey SS2007/01. A combination of the available bathymetric and sediment information (Section 5) has been used here to provide the most detailed description and interpretation of seafloor geomorphology and sediment facies for this area to date.

4.2 GENERAL CHARACTERISTICS

The Ceduna Sub-basin forms a major geomorphic province that fringes the broad continental shelf of the GAB. The Sub-basin covers an area of 126,300 km^2 and is oriented northwest to southeast with a northern boundary that follows the trend of the shelf break at ~150 m to 200 m water depth, and a southern boundary that approaches the edge of the abyssal plain (Fig. 4.1). The Sub-basin therefore extends across the upper and lower continental slope, with the former occupied by the Ceduna Terrace, a seaward sloping surface that is 700 km in length and has a maximum width of approximately 170 km. The lower slope continues beyond the outer boundary of the Ceduna Sub-basin where it forms the Recherche Lower Slope that adjoins the abyssal plain (Harris et al. 2005). In plan view, the sub-basin tapers toward the northwest and southeast, where respective widths reduce to less than 70 km and 80 km. To the west, the Ceduna Terrace adjoins the Eyre Terrace and to the east it borders a steep and narrow reach of the continental slope that is deeply incised by several canyons.

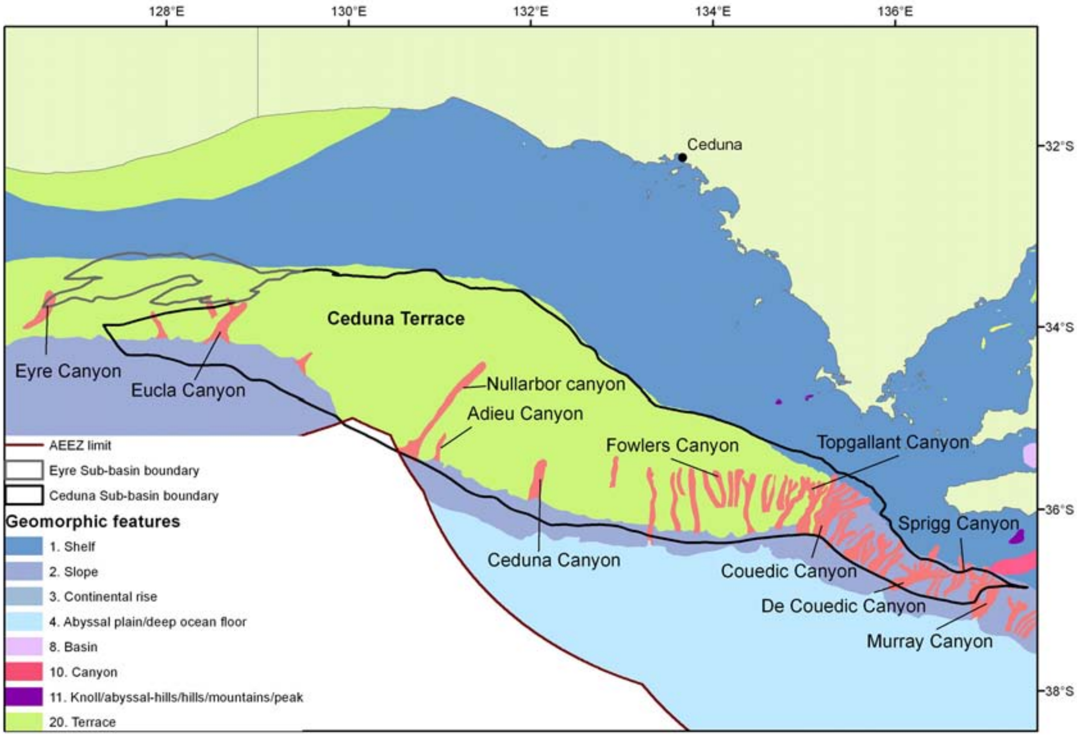


Figure 4.1: *Map showing major geomorphic features of the Ceduna Sub-basin and surrounding area. Adapted from Harris et al. (2005) to show Sub-basin boundaries and canyon names.*

The profile of the seafloor from the continental shelf to the upper slope along the northern boundary of the Ceduna Sub-basin grades from a convex slope in the northwest to a steep escarpment in the southeast (Fig. 4.2). Maximum relief of the escarpment is ~1000 m in the southeast, whereas the gentler slope has 200 m of relief. The landward edge of the Ceduna Terrace sits at the foot of the escarpment in about 500 m water depth. To seaward, water depths across the terrace increase to about 2000 m with an average slope of 0.6^o. The Ceduna Terrace therefore comprises the upper, low gradient part of the continental slope. The lower and steeper part of the slope extends to about 4500 m water depth, with gradients of 2^o to 3.7^o. Beyond this extends the abyssal plain where water depths exceed 5500 m.

4.2.1 Upper Slope and Ceduna Terrace

The Ceduna Terrace comprises two morphological zones (Fig. 4.2). The first zone encompasses a 0.5^o to 4^o slope that extends from the base of the shelf scarp to the 1000 m depth contour. This slope is about 30 km wide within the central part of the terrace and narrows to less than 6 km toward the east. The second zone is a gently undulating surface with a gradient less than 0.5^o that extends to the 2000 m depth contour. The surface of this broader zone of the Ceduna Terrace is generally low relief, with isolated hills that rise less than 200 m above the seafloor. The detailed form and distribution of these hills remains unclear, due to the relatively low resolution of the bathymetric grid for most of the Ceduna Terrace.

High resolution multibeam bathymetry data collected during the 2007 *Southern Surveyor* survey record some of the detailed characteristics of the seafloor for localised areas of the shelf scarp and Ceduna Terrace. In particular, these images reveal a highly irregular and dissected submarine terrain.

Thus, the central part of the escarpment that separates the continental shelf from the terrace is characterised by an abrupt, semi-continuous cliff at the shelf break with debris fans at its base, plus steep gullies and valleys with up to 100 m relief that extend onto the inner edge of the terrace (Fig. 4.3). Sidescan sonar images of the shelf break include dark areas that are interpreted as limestone outcrop, suggesting the cliff and gullies also comprise limestone (Mitchell et al., 2008).

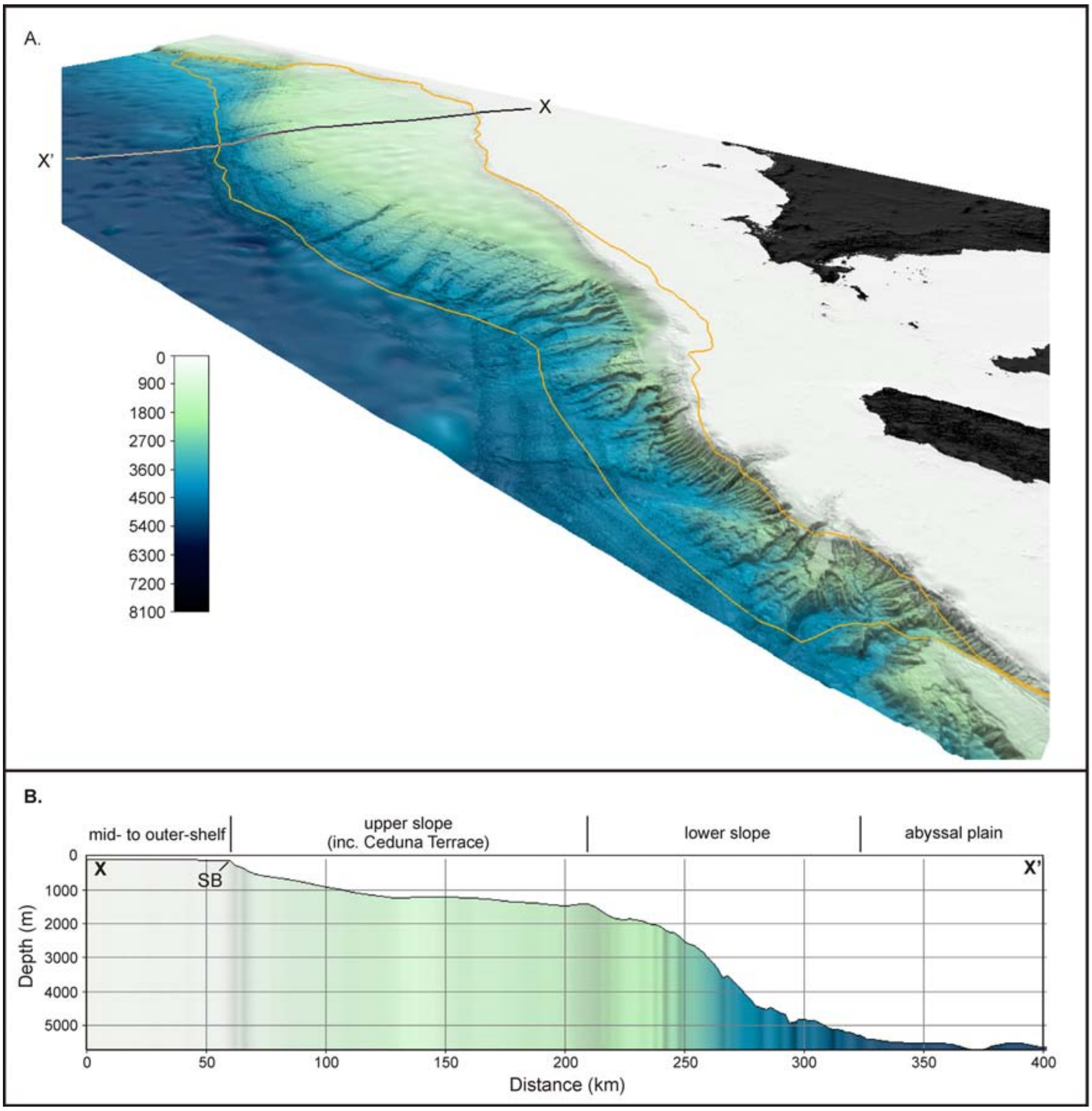


Figure 4.2: A. *Perspective view of the seafloor of the eastern Great Australian Bight, looking to the northwest (vertical exaggeration x3). Colour scale shows water depths in metres. The line X–X' delimits the bathymetric profile in B and the orange line marks the boundary to the Ceduna Sub-basin.* ***B.*** *Representative bathymetric profile across the Ceduna Sub-basin from the shelf to abyssal plain. SB = shelf break.*

The inner part of the Ceduna Terrace is also an irregular surface for a 100 km^2 area between 1090 and 1640 m water depth (Fig. 4.4). This area is characterised by a dissected seafloor of narrow, curvilinear troughs and irregular scarps with a local relief of up to 180 m. Similarly, an area covering

~145 km^2 at the northern margin of the terrace (centred on 33.49°S, 130.03°E) shows that it is stepped, with at least three sub-terraces separated by scarps that have 30–70 m relief (Fig. 4.5). The orientation of the scarps is irregular, ranging from cross-slope to down-slope, with underlying fault control interpreted from sub-bottom and regional seismic profiles (Mitchell et al., 2008). Local topography across the sub-terraces is also irregular, and is characterised by small depressions, pockmarks, mounds and discontinuous ridges with overall relief of less than 20 m.

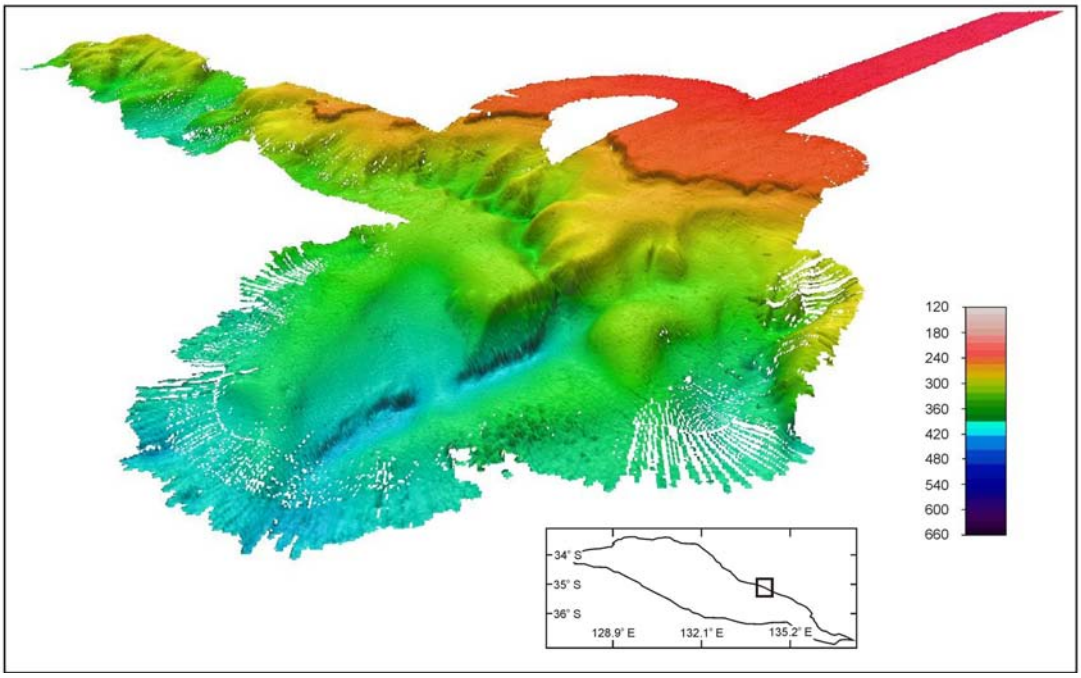


Figure 4.3: *Perspective view of escarpment at the outer edge of the continental shelf in the central area of the Ceduna Sub-basin, showing gullies feeding into a 100 m deep valley that extends onto the inner part of the Ceduna Terrace (vertical exaggeration x3). Colour scale shows water depths in metres. Inset map shows location within the Ceduna Sub-basin.*

The largest mapped area of the Ceduna Terrace is a strip between 130.4°E and 130.85°E extending to the outer slope. Mapped during the AUSTREA-1 survey on the *L'Atalante* in 1999, these data provide medium resolution bathymetry that reveals several troughs extending up to 50 km across the inner part of the terrace on a general NE to SW trend (Fig. 4.6). These troughs are up to 20 m in relief and 10 km wide, with headwalls that are up to 70 m high. It is likely that this trough morphology is characteristic of the entire Ceduna Terrace. This inference is supported by high resolution multibeam data collected in 2007 (SS2007/01) along the outer edge of the terrace showing numerous troughs and discontinuous scarps. In addition, this data shows that the Ceduna Terrace is crossed by the upper reaches of several canyons in the eastern half of the terrace. The largest of these is the Ceduna Canyon, which has incised up to 400 m into the terrace and has a 100 m high headwall in 1800 m water depth (Fig. 4.7). The high resolution swath data also shows two volcanic cones in 1800 m water depth, the largest being 140 m high (Fig. 4.8).

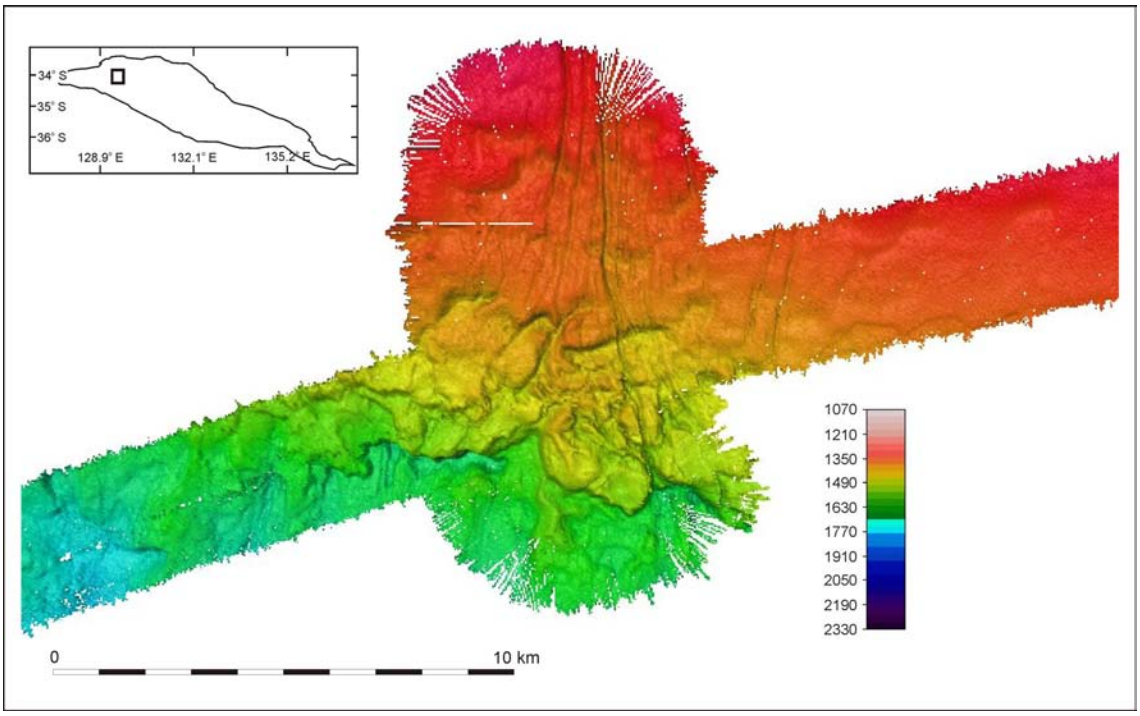


Figure 4.4: *Plan view bathymetric image of the outer Ceduna Terrace centred on 33.82° S 129.45° E, showing narrow troughs and irregular scarps with up to 20 m and 180 m relief, respectively. Water depth increases to the south from 1090 m to 1640 m. Colour scale shows water depths in metres. Inset map shows location within the Ceduna Sub-basin.*

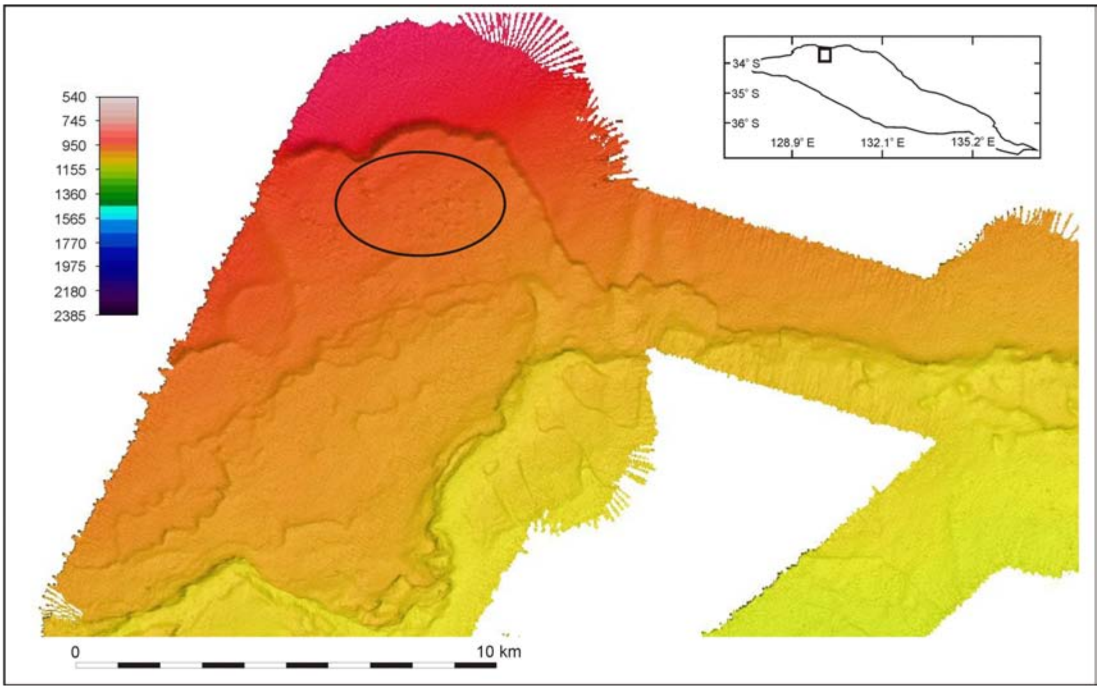


Figure 4.5: *Plan view bathymetric image of the inner Ceduna Terrace showing stepped terrace morphology, irregular scarps and a pockmark field (circled). The scarp in the lower part of the image is ~70 m in relief and fault-controlled. Colour scale shows water depths in metres. Inset map shows location within the Ceduna Sub-basin.*

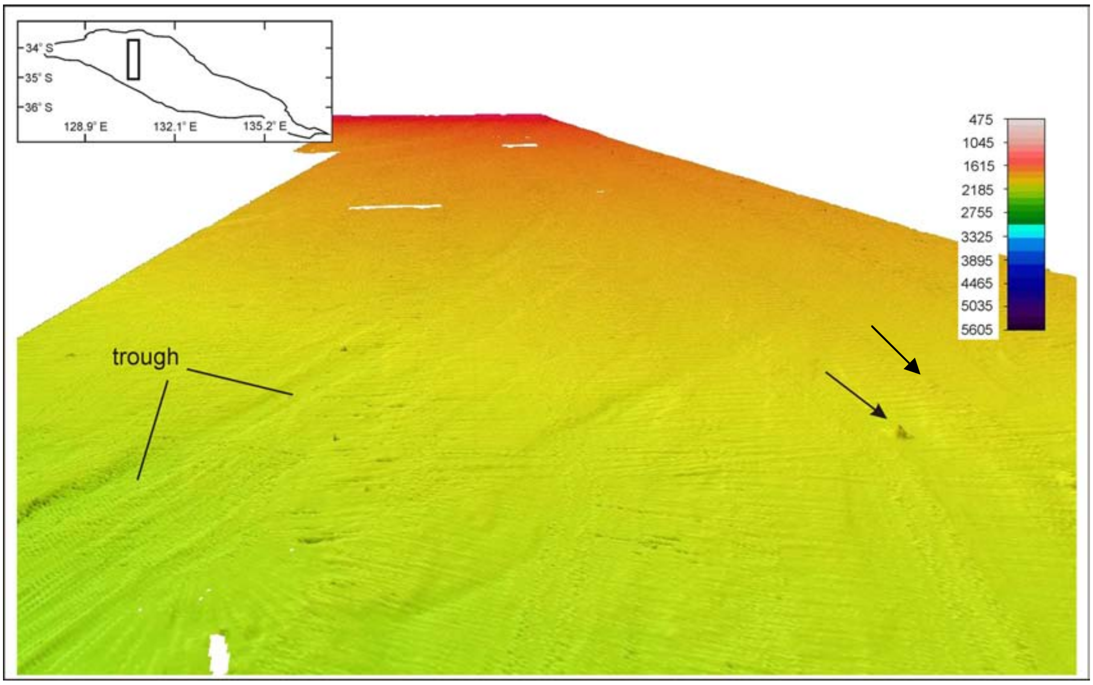


Figure 4.6: *Perspective view of the Ceduna Terrace looking to the north, showing long shallow troughs oriented NE to SW and a small volcanic cone (arrow) approximately 100 m high (vertical exaggeration x3). This area was mapped in 1999 during the AUSTREA-1 survey. Colour scale shows water depths in metres. Inset map shows location within the Ceduna Sub-basin.*

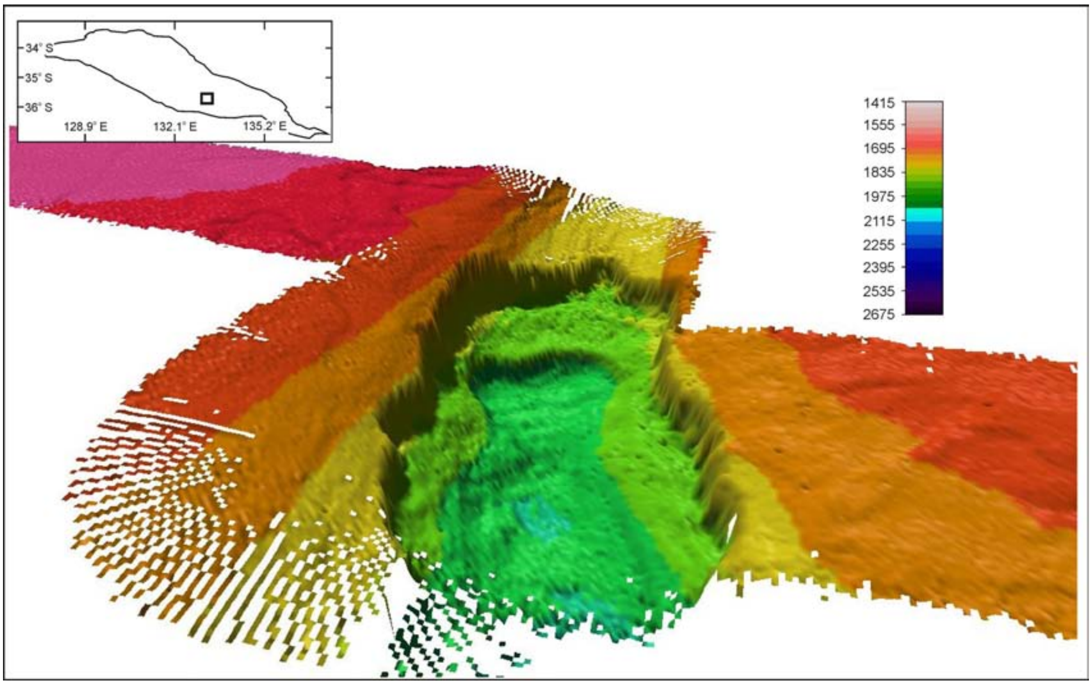


Figure 4.7: *Perspective view of the Ceduna Canyon extension from the lower continental slope onto the Ceduna Terrace within the eastern sector of the Ceduna Sub-basin (vertical exaggeration x3). Maximum relief in the canyon is ~400 m. Colour scale shows water depths in metres. Inset map shows location within the Ceduna Sub-basin.*

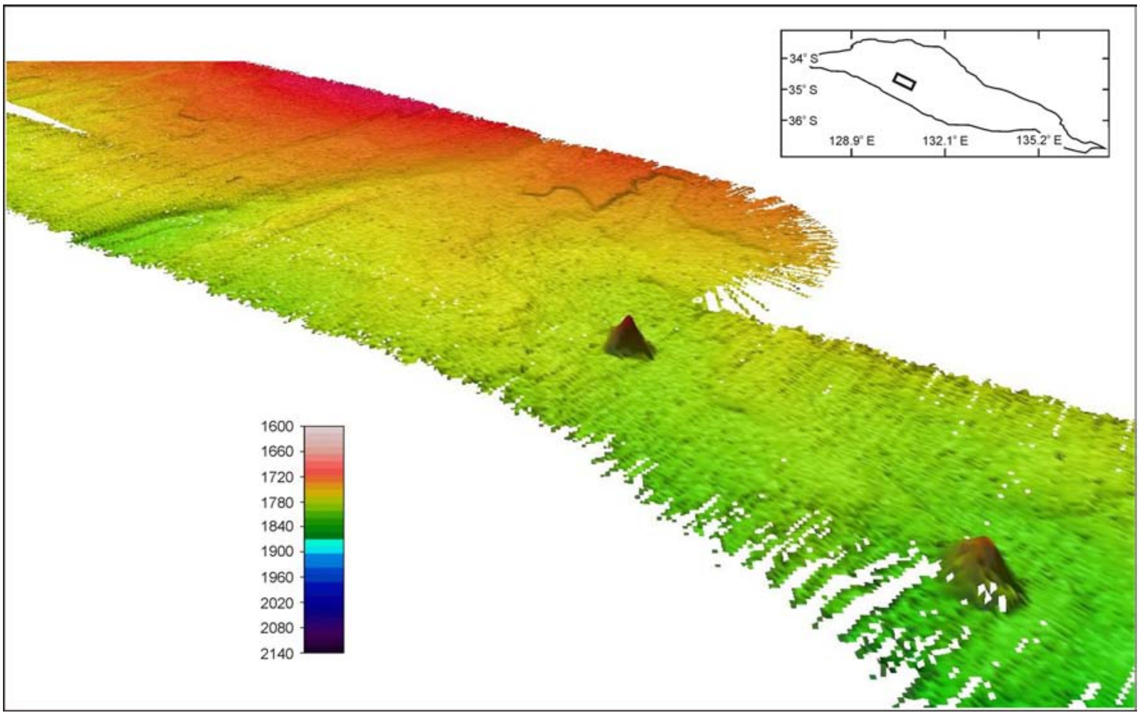


Figure 4.8: *Perspective view looking to the northwest across the outer edge of the Ceduna Terrace showing low discontinuous scarps and two volcanic cones on a gentle slope (vertical exaggeration x3). The cone in the centre is 140 m high and located at 34.7279 °S, 130.6743 °E. Colour scale shows water depths in metres. Inset map shows location within the Ceduna Sub-basin.*

4.2.2 Lower Slope

The profile of the lower continental slope varies along the length of the Ceduna Sub-basin. Where the slope extends from the edge of the Ceduna Terrace, the profile is convex and relatively broad, with a maximum width of 60 km and an average gradient of ~2^{o} (Fig. 4.9). In contrast, along the eastern end of the basin (east of ~135^{o}E) the slope is characterised by a steep, concave profile that is ~25 km wide with a gradient of 10–15^{o}. The western sector of the lower slope (west of 128.9^{o}E) adjoins the Eyre Terrace and includes the Eucla Canyon. This feature strikes to the SW and has an irregular valley floor that broadens across the lower slope to a maximum width of 40 km and relief of ~500 m. The rugose character of the Eucla Canyon is enhanced by a volcanic cone that rises 500 m above the canyon floor at 2600 m water depth and is surrounded by several smaller peaks that may also be volcanic in origin (Fig. 4.10; see also Section 2.4 for discussion of vulcanism). Further west, the lower slope appears to have a concave-to-convex down slope profile; however, relatively low resolution bathymetry data in this area precludes a detailed description.

4.2.3 Canyons and Trenches

Canyons and trenches are the primary morphological features on the lower continental slope in the Ceduna Sub-basin. Multibeam sonar data covers the entire lower slope of the sub-basin, with the exception of the far western end (an area of 2400 km^2). Within the well mapped area of the lower slope, 15 canyons of varying size are recognised, plus at least five shallow canyons. A shallow canyon is here defined as having relatively low gradient slopes on its sidewalls (<15%) and a shallow valley (100–300 m relief). Of the 15 main canyons, 10 are named systems with the largest being the Murray, Nullarbor and Ceduna Canyons (Fig. 4.1). Most of these canyons have headwalls on the Ceduna Terrace, with the exception of those in the eastern end of the Sub-basin that are incised into the outer continental shelf. This area of the slope is also characterised by intensive gullying of slopes that form steep canyon walls.

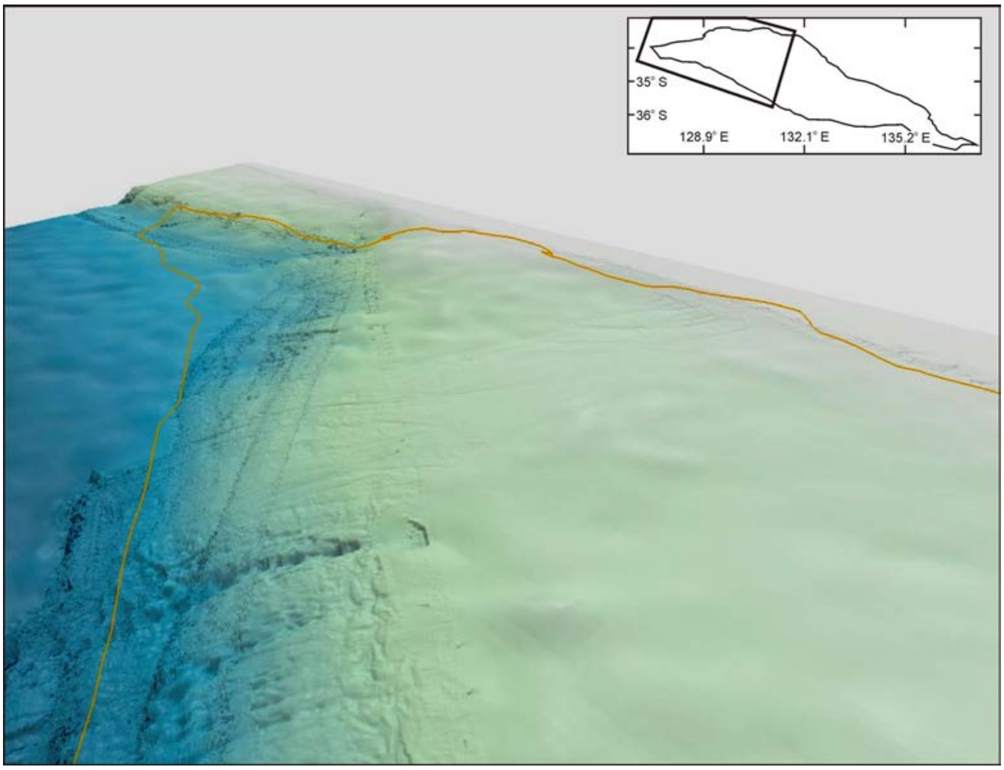


***Figure 4.9:** Perspective view of the lower continental slope in the western sector of the Ceduna Sub-basin looking west (vertical exaggeration x3). In this area the slope is convex and broad with relatively short, shallow trenches. The Nullarbor Canyon is in the foreground. The orange line marks the boundary of the Ceduna Sub-basin. Inset map shows location within the Ceduna Sub-basin.*

The upper part of the Nullarbor Canyon was mapped in high resolution as part of the 2007 Geoscience Australia survey (SS2007/01) and provides a good example of canyon morphology (Fig. 4.11). The canyon has a headwall that forms a 250 m near-vertical scarp that extends along the slope for at least 10 km. Below the headwall, the canyon floor maintains a width of six to eight kilometres that is straight and characterised by a series of deep holes that are progressively deeper down slope, reaching a maximum depth of 500 m below the surrounding slope. Locally, the canyon floor is irregular with ridges and troughs aligned down-slope, giving relief of 20–30 m. The lower half of the Nullarbor Canyon was not mapped by the 2007 survey; however, bathymetric data from earlier surveys suggests that this irregular morphology continues to at least 4500 m water depth.

In the other main canyons, valley morphology appears similar to the Nullarbor Canyon. Thus, each canyon follows a straight path down the slope with uniform widths of 5–10 km and depths of up to 1000 m. The exception to this occurs in the eastern end of the sub-basin where canyons have formed tributary systems on the upper slope that coalesce on the lower slope becoming up to 15 km wide (Fig. 4.12).

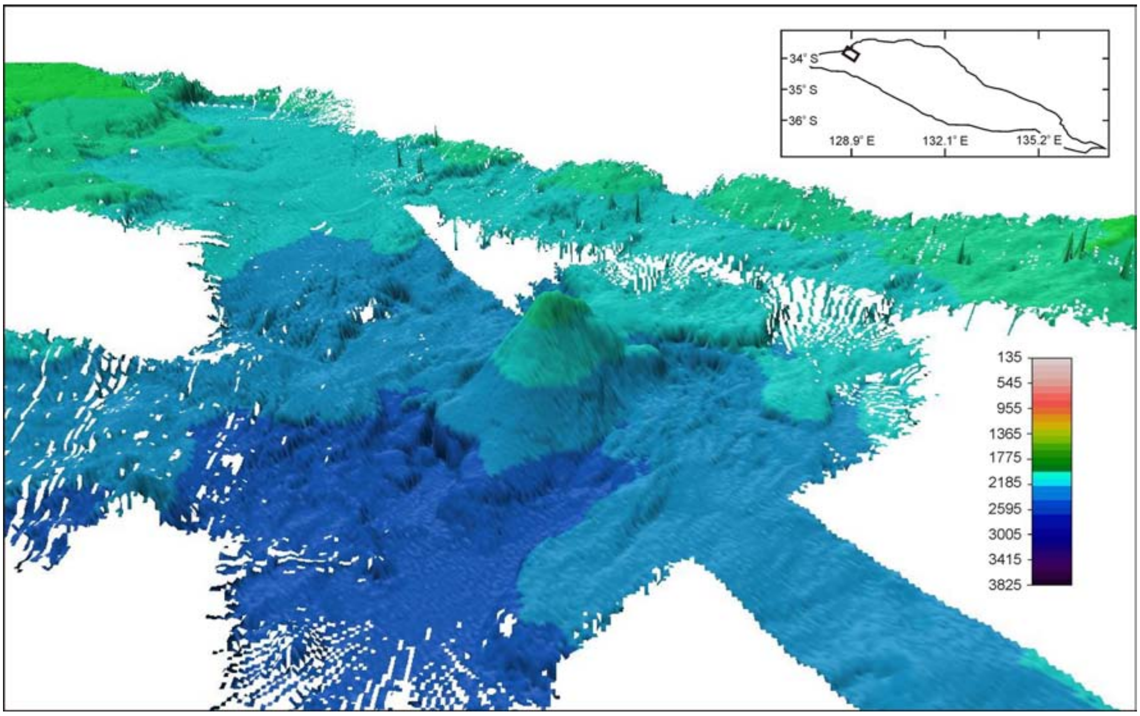


Figure 4.10: *Perspective view of the volcanic cone on the floor of the Eucla Canyon, looking north (vertical exaggeration x3). Colour scale shows water depths in metres. Inset map shows location within the Ceduna Sub-basin.*

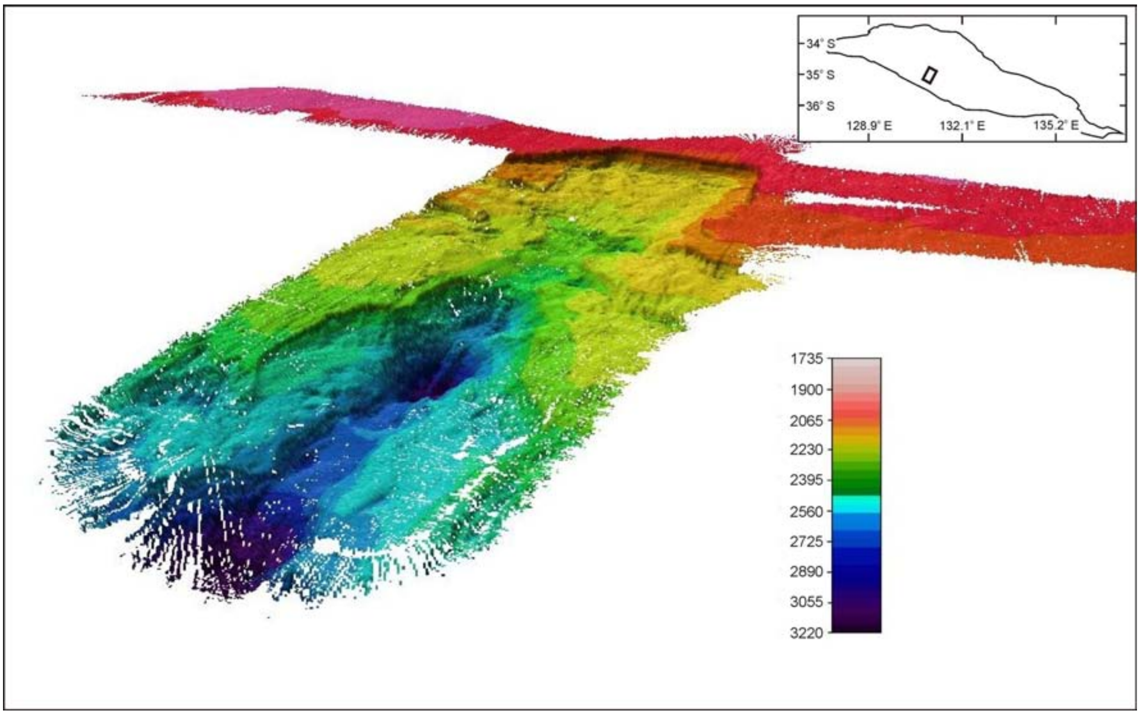


Figure 4.11: *Perspective view of the Nullarbor Canyon incised into the lower continental slope of the Ceduna Sub-basin (34.91^{o}S, 130.99^{o}E) (vertical exaggeration x3). Note the deep holes along the canyon axis. Colour scale shows water depths in metres. Inset map shows location within the Ceduna Sub-basin.*

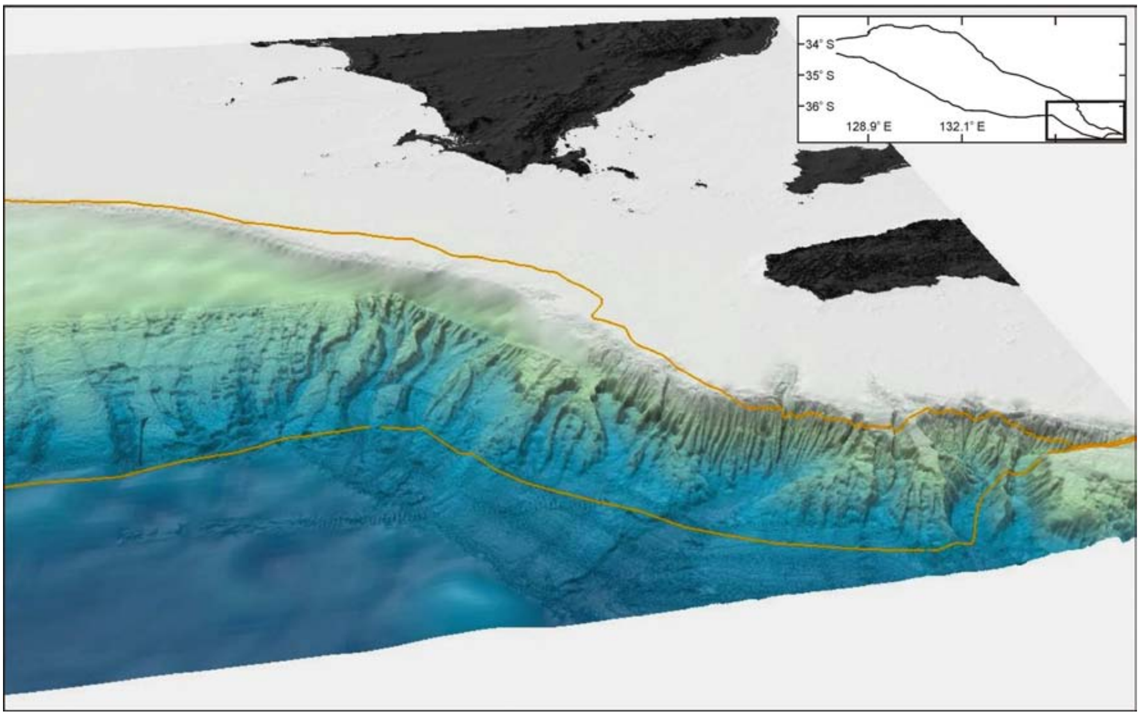


Figure 4.12*: Perspective view of multibeam bathymetry of the lower continental slope in the eastern sector of the Ceduna Sub-basin, which shows canyons incised into the mid-shelf and highly dissected interfluves (vertical exaggeration x3). The orange line represents the boundary of the Ceduna Sub-basin. Inset map shows location within the Ceduna Sub-basin.*

Erosion across the lower slope in the central to western parts of the Ceduna Sub-basin is less intensive than for the eastern portion. With the exception of the area around the Eucla Canyon, this area is characterised by straight trenches cutting across the lower slope and terminating above the continental rise. These trenches are typically less than 200 m in relief and up to 30 km long with headwalls on the lower slope (Fig. 4.9). Some of the trenches extend onto the Ceduna Terrace, but based on available data, these appear few in number. This is in contrast to the more localised downcutting that characterises slope erosion in the eastern sector where the slope is strongly dissected and much steeper (> 20^{o}). The eastward transition to a steeper continental slope (centred on 35.75^{o}S, 132.27^{o}E) incorporates a 300 m high scarp that extends 35 km along the slope in about 3100 m water depth. This appears to be the only evidence for large-scale erosional retreat of the slope in this area. All other evidence indicates localised canyon and trench downcutting are the primary erosion processes in the Ceduna Sub-basin.

High resolution bathymetric data collected across a canyon in the far western part of the Ceduna Sub-basin during the 2007 Geoscience Australia survey (SS2007/01) shows an example of terrace morphology along the canyon floor and on adjacent slopes (Fig. 4.13). Terrace scarps are up to 100 m high and oriented across the slope, suggesting trench widening via lateral erosion and slumping of slopes. Also in the western area, the slope has a 100 m high scarp that extends about 50 km along the depth interval of 1650–1700 m. A large slump block approximately 10 km in length sits below the scarp, providing further evidence of localised mass movement. Two canyon heads rise to this scarp and fall away to at least 3000 m water depth (Fig. 4.14).

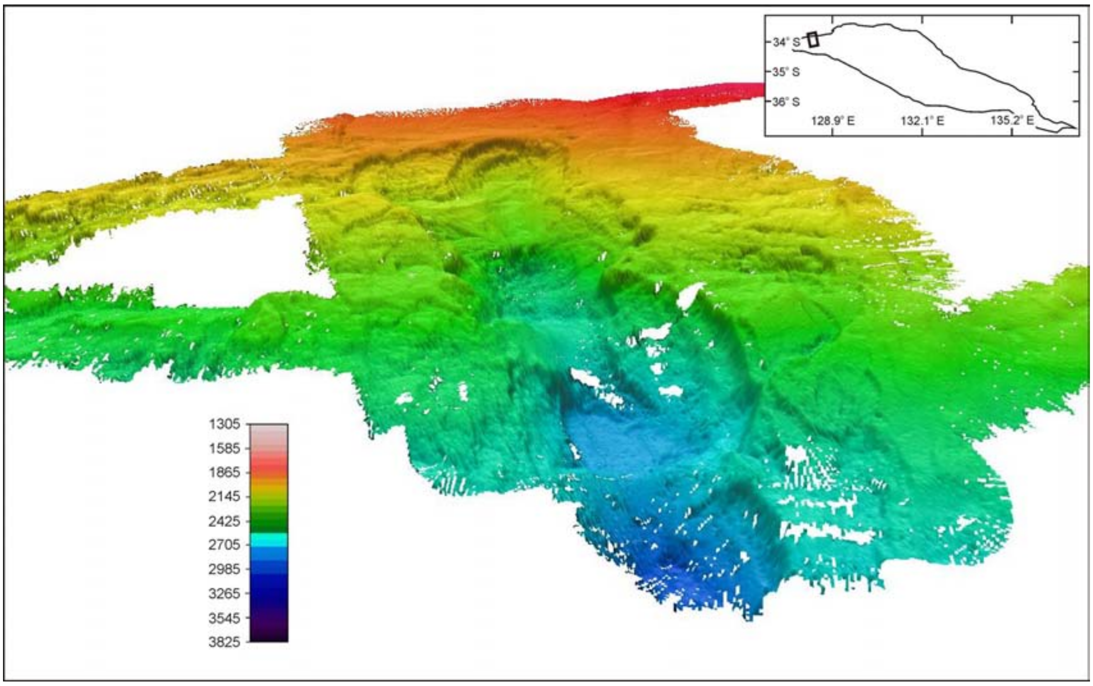


Figure 4.13: *Perspective view of a 400-500 m deep canyon incised into the lower continental slope in the western sector of the Ceduna Sub-basin (33.8°S, 127.84°E) (vertical exaggeration x3). Note the terrace morphology along the trench floor and on adjacent slopes. Water depth ranges from 1650 m at the headwall to 3200 m in the lower right. Colour scale shows water depths in metres. Inset map shows location within the Ceduna Sub-basin.*

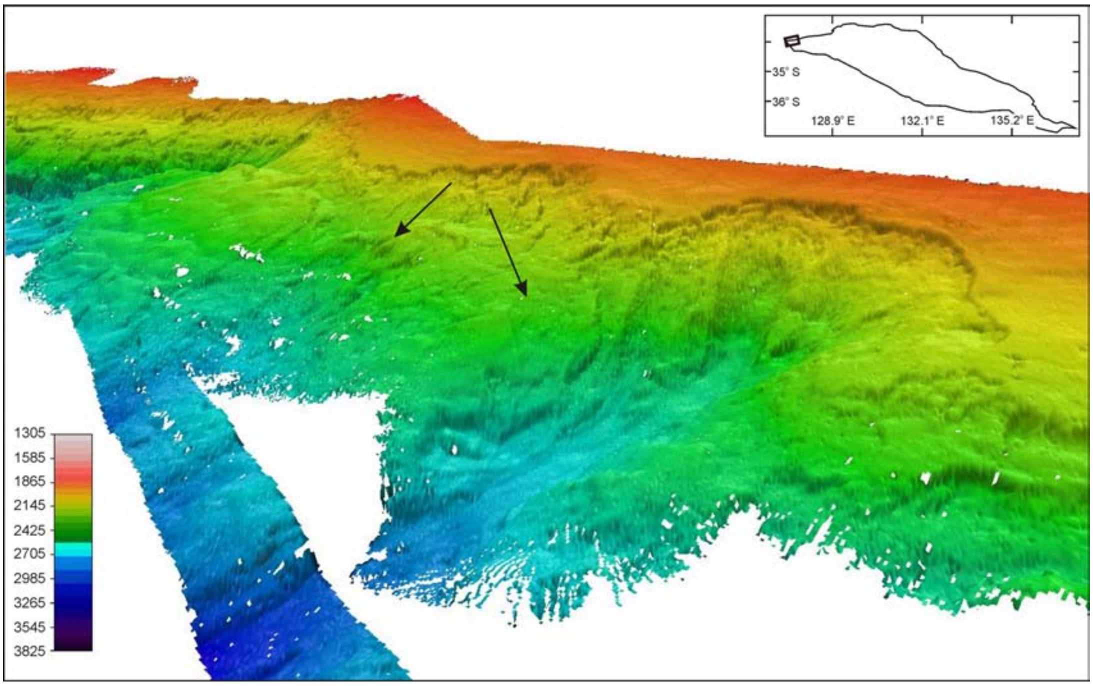


Figure 4.14: *Perspective view of a 10 km long slump block (arrow) and scarp cut into the lower slope of the western Ceduna Sub-basin (vertical exaggeration x3). Colour scale shows water depths in metres. Inset box shows location within the Ceduna Sub-basin.*

4.3 SUMMARY

The geomorphology of the Ceduna Sub-basin is characterised by a range of erosional features that vary in scale according to the slope of the sea floor. Steeper areas such as the shelf escarpment and eastern sector of the lower slope have developed deeply incised valleys and canyons up to 1 km in relief. In contrast, low gradient surfaces such as the Ceduna Terrace and the central to western sector of the slope are dissected by troughs and discontinuous scarps that give local relief of tens of metres. Evidence for mass movement is also found in the form of large slump blocks and debris fans at the foot of escarpments below the shelf break. Several volcanic cones provide positive relief to the terrain, but their effect is highly localised. Overall, the geomorphology of the Ceduna Sub-basin reflects a long history of submarine erosion that has produced a highly irregular, locally unstable terrain.

5. Sediments

5.1 INTRODUCTION AND DATA SOURCES

The initial description of surface sediments along the southern continental margin of Australia by Connolly and Von der Borche (1967) was regional in scale and did not include material from the Ceduna Sub-basin. Similarly, Wass et al. (1970), who recognised the continuity of calcareous sand deposits and presence of extensive bryozoan colonies along the southern continental shelf, did not extend their study to the deeper waters of the Ceduna Sub-basin. The Ceduna Terrace and adjacent slope were first systematically sampled in 1986 as part of an investigation of the upper continental slope and submarine canyons of the GAB (BMR Survey 66, Davies et al., 1989). Textural properties of sediment samples collected on this survey are included in this report.

More recently, James et al. (2001) and Rivers et al. (2007) have added detail regarding bathymetric zonation of carbonate sediments and ocean circulation across the continental shelf and upper slope of southern Australia. A key finding of this work being that the Ceduna sector of the outer shelf has persisted throughout the Quaternary as a major zone of carbonate production (a “sediment factory”) under the influence of seasonal up-welling that promotes growth of bryozoan colonies on the outer shelf and upper slope. These environmental conditions are also recognised by James et al. (2004) as integral to the formation of prograding clinoforms on the upper continental slope within the Eyre Sub-basin, which adjoins the western edge of Ceduna Sub-basin.

Information presented here on the texture and composition of seafloor sediments of the Ceduna Sub-basin is derived from 82 sample entries in the MARS database held by Geoscience Australia (Appendix A). These samples also form part of the regional interpolation of seabed sediment types of the southwest planning region, available separately in Potter et al. (2006).

5.2 GENERAL CHARACTERISTICS

Surface sediments across the Ceduna Sub-basin are part of the widespread cool-water carbonate province that characterises the Great Australian Bight (Wass et al., 1970; James et al., 2001). A total of 12 sediment facies are mapped by James et al. (2001) for the GAB, with five of these (Facies B, SB, BB, CC & M; Table 5.1) distributed across the outer shelf and upper slope and therefore partly within the Ceduna Sub-basin. Modern production of carbonate sediments occurs chiefly on the outer shelf where seasonal up-welling provides a nutrient supply from cool, deep oceanic waters (James et al., 2001). Epibenthic bryozoan and sponge communities are the dominant sediment generating organisms in this area and are associated with the bryozoan sand and gravel (Facies B), the branching bryozoan sand (Facies BB), the spiculitic branching bryozoan mud (Facies SB) and the coral-*Celleporaria* (Facies CC) sediment facies of James et al. (2001). In deeper water, including the Ceduna Terrace and canyons on the slope, pelagic calcareous ooze forms the spiculitic mud facies (Facies M) as a thin (decimetre thick) surface deposit. Locally, subtle variations in sediment texture exist in association with topography of the Ceduna Sub-basin. Thus, the low gradient surface of the Ceduna Terrace is covered by massive to bioturbated beds of nannofossil foram ooze that appear undisturbed (Rollet et al., 2001). In contrast, the scarps and canyons of the slope to terrace are characterised by a thin veneer of nannofossil foram ooze variably overlying mudstone and debris flow deposits.

Grain size information for the 82 sediment samples held in the MARS database for the Ceduna Sub-basin is summarised into mud, sand and gravel content (Fig. 5.1). The great majority of samples are classified as sandy mud, with minor gravel content. Average content for each fraction is 59% for mud (range: 0.04–97.3%), 37% for sand (range: 2.7–98.4%) and 3.5% for gravel (range: 0–88.5%). Five samples yielded gravel content greater than 25% (one of which was 88.5%). Carbonate analysis of separate size fractions from 74 samples show that all are carbonate-rich, with average content of 82.4% (range: 1.3–92%) for mud, 87.3% (3–98%) for sand and 84.2% (0–100%) for the gravel fraction. Four gravel-dominated samples yielded no carbonate material. Bulk sample analysis on all samples yielded an average carbonate content of 83.5% (range: 1.5–100%).

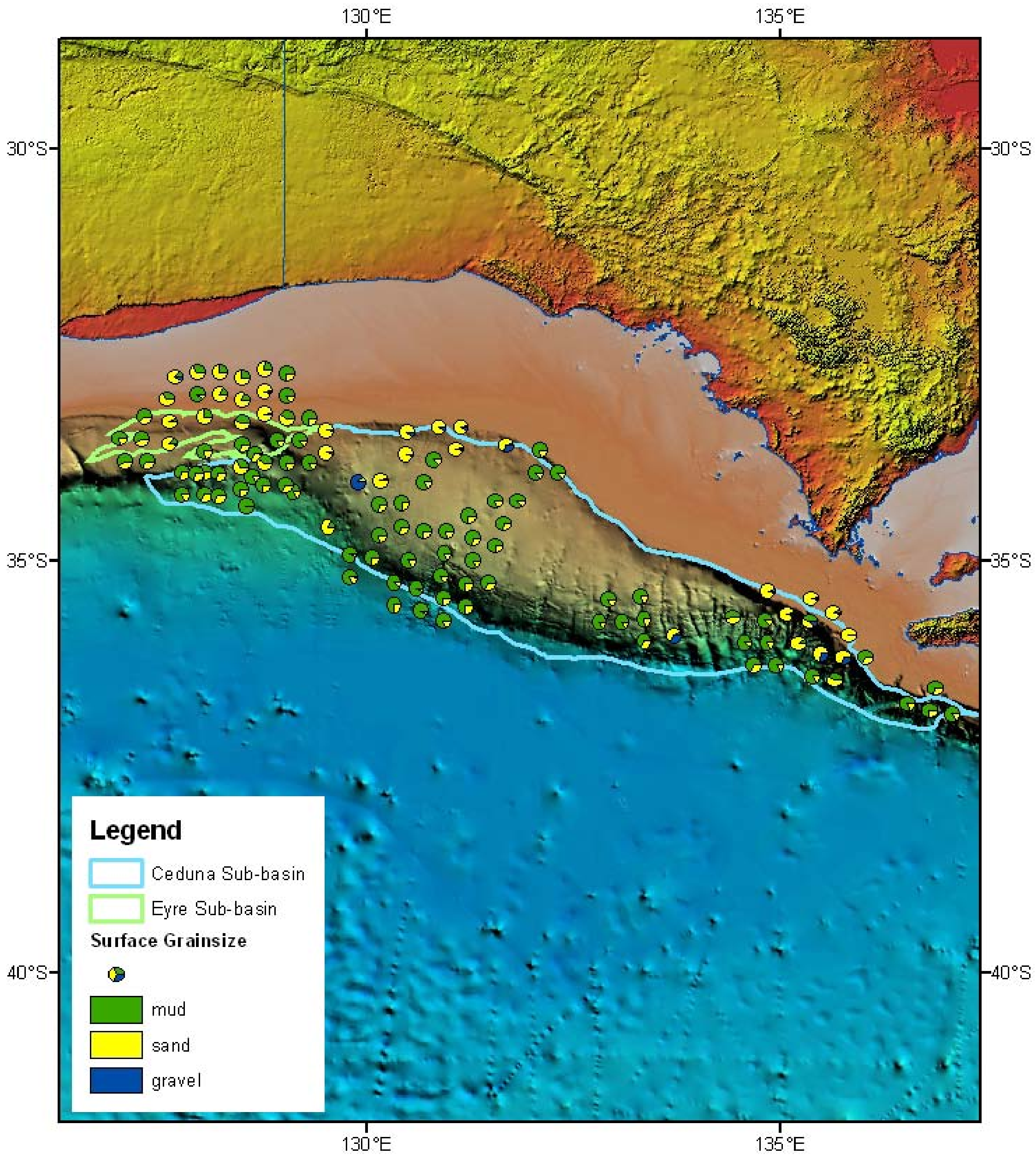


Figure 5.1: *Map showing approximate mud, sand and gravel content in surface sediments within the Ceduna Sub-basin and adjacent Eyre Sub-basin.*

Table 5.1: *List of sediment facies for the Great Australian Bight. Detailed facies descriptions are provided in James et al. (2001). Facies codes are also referred to in Section 7.2.*

Sediment Facies	Code	Location	Depth (m)
Rhodolith Gravel	R	Inner Shelf & Mid Shelf (western GAB)	35-50
Quartzose Skeletal Sand & Gravel	Q	Inner Shelf & Mid Shelf	30 - 65
Mollusc-Intraclast Sand	MI	Inner Shelf & Mid Shelf	30 - 65
Intraclast Sand	I	Mid Shelf	65 - 100
Intraclast Mollusc Sand & Gravel	IM	Mid Shelf	50 - 100
Bryozoan Intraclast Sand	BI	Outer Shelf	55 – 125
Intraclast Bryozoan Sand	IB	Outer Shelf	80 - 125
Bryozoan Sand & Gravel	B	Outer Shelf & Upper Slope	60 - 210
Spiculitic, Branching Bryozoan Mud	SB	Outer Shelf & Upper Slope	80 - 200
Branching Bryzoan Sand	BB	Outer Shelf & Upper Slope	90 - 330
Coral-*Celleporaria* Gravel	CC	Upper Slope	210 - 360
Spiculitic Mud	M	Upper Slope	210 – 500+

5.3 SPATIAL DISTRIBUTION

An analysis of sediment texture and carbonate content for the major geomorphic environments of the Ceduna Sub-basin reveals subtle spatial patterns. Figures 5.2 and 5.3 show plots of mud and sand content for samples collected on two transects across the Ceduna Terrace and the lower continental slope. All samples are mud-dominated in the range of 70–90%, with a weak trend towards slightly lower mud content toward the deeper waters of the lower slope.

Variations in sediment texture across the major geomorphic environments of the Ceduna Sub-basin are summarised in Table 5.2 and plotted by sample in Figures 5.4 and 5.5. The sediments on the shelf scarp that forms the northern boundary of the sub-basin have the highest sand (64±34%) and carbonate (94±4%) content, reflecting proximity to the bryozoan and sponge source on the outer shelf. Of note, scarp samples in water depths less than about 500 m tend to have sand content greater than 80%. Sand content reduces to less than 40% in samples from the deeper waters of the scarp, between 500 m and 1000 m (Fig. 5.5). For the remainder of the Ceduna Sub-basin, summary statistics suggest relative homogeneity of sediment texture across the upper slope (Ceduna Terrace), lower slope and canyon floor environments, with mean values for mud and sand content falling within a narrow range; 70–73% for mud and 25–29% for sand (Table 5.2). However, scatter plots of individual samples reveal considerable variability within the dataset (Fig. 5.4 and 5.5).

Sediments across the upper slope occupied by the Ceduna Terrace are the most uniform of all geomorphic environments of the Sub-basin. Sandy mud predominates, with sand content among 13 samples in the range of 14% to 44%, excluding one outlier sample that comprises 96% sand. In contrast, sand content for 28 samples from the lower slope ranges from 3% to 74%, with mud comprising the remainder of the deposit in all but two samples from water depths of 1800 m and 2780 m; for which carbonate gravel comprises 26% and 33% of each sample, respectively. Overall, gravel deposits appear to be localised and unrelated to water depth in their occurrence.

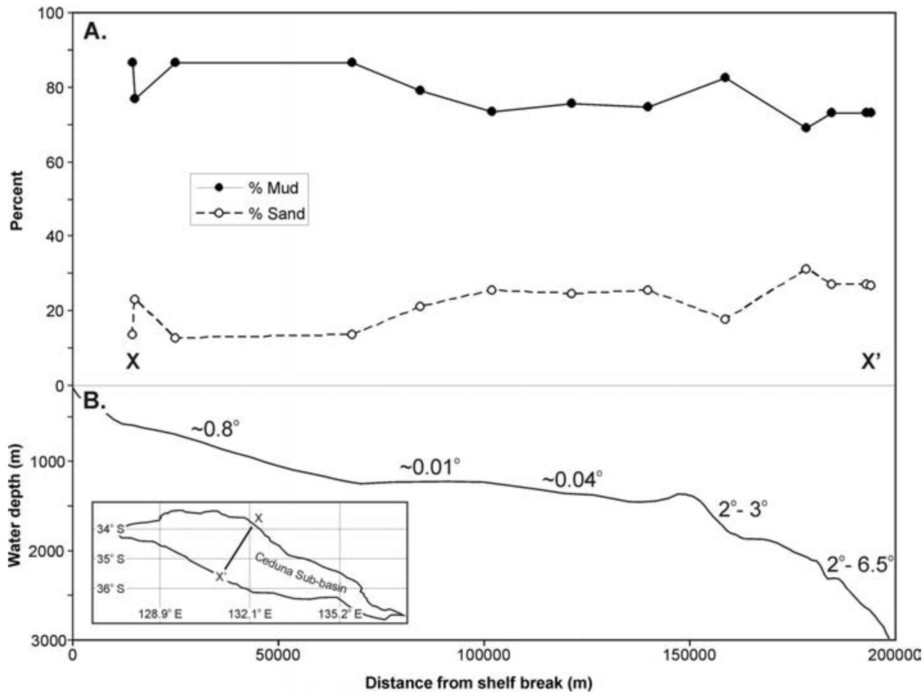


Figure 5.2: ***A.*** *Plot of mud and sand content in surface sediments with distance across the Ceduna Terrace and lower slope; transect 1.* ***B.*** *Bathymetric profile of the sample transect with average slope gradients indicated. Inset map shows the transect location.*

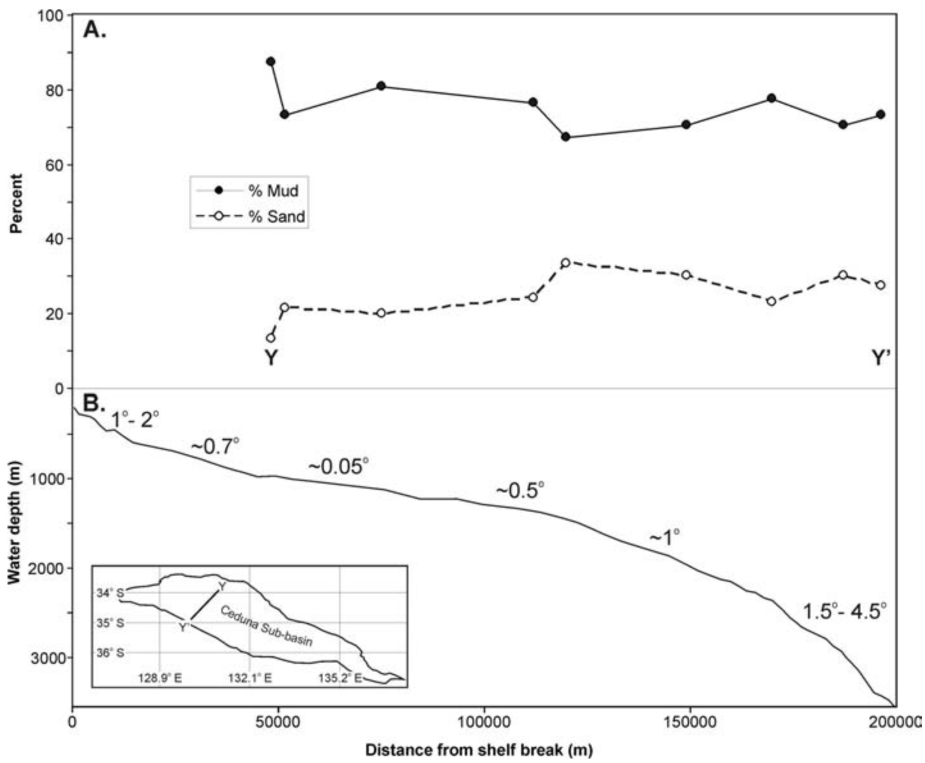


Figure 5.3: ***A.*** *Plot of mud and sand content in surface sediments with distance across the Ceduna Terrace and lower slope; transect 2.* ***B.*** *Bathymetric profile of the sample transect with average slope gradients indicated. Inset map shows the transect location.*

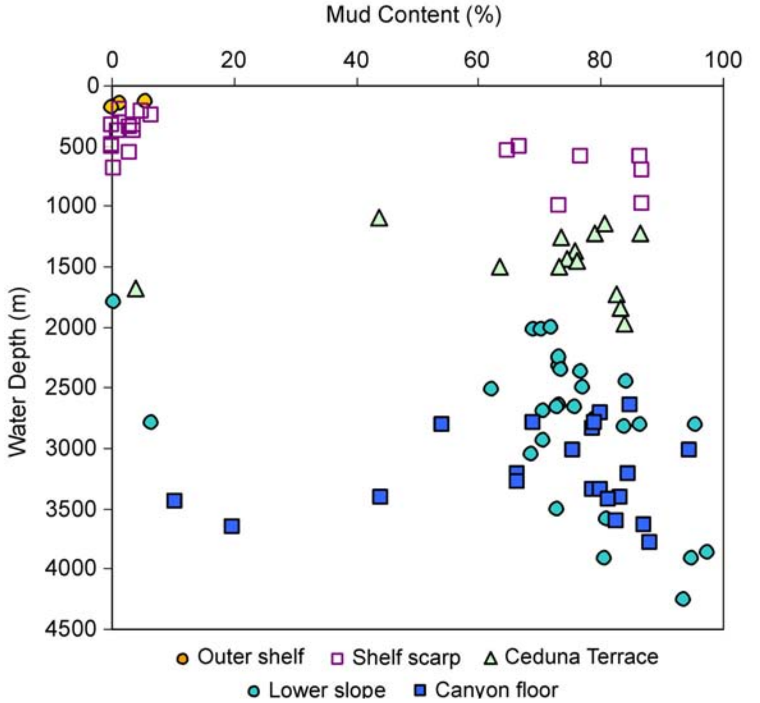


Figure 5.4: *Scatter plot of mud content versus water depth for 82 surface sediment samples from the shelf scarp, upper slope (Ceduna Terrace), lower slope and canyon floor environments of the Ceduna Sub-basin. Three samples from the edge of the outer shelf are included for comparison.*

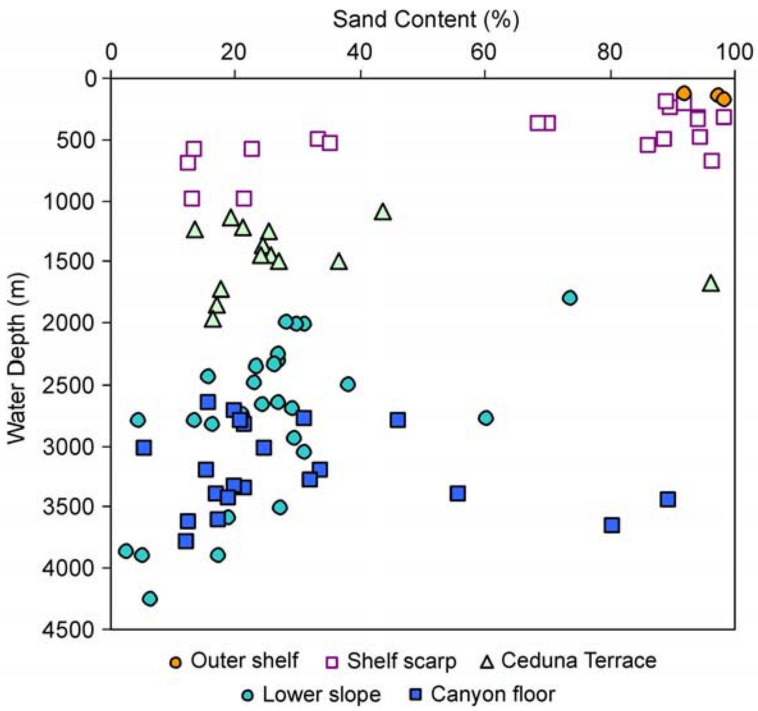


Figure 5.5: *Scatter plot of sand content versus water depth for 82 surface sediment samples from the shelf scarp, upper slope (Ceduna Terrace), lower slope and canyon floor environments in the Ceduna Sub-basin. Three samples from the edge of the outer shelf are included for comparison.*

Table 5.2: *Summary statistics for mud, sand and carbonate content in surface samples from the four major geomorphic environments of the Ceduna Sub-basin (σ = standard deviation; n = number of samples with the value in brackets the number for CaCO3 data; CT = Ceduna Terrace).*

	Mud (%)		**Sand (%)**		**CaCO3 (%)**		
	Mean	**σ**	**Mean**	**σ**	**Mean**	**σ**	**n**
Shelf scarp	30	38	64	34	94	4	19 (17)
Upper slope (CT)	70	22	29	29	86	7	14 (12)
Lower slope	73	22	25	15	83	16	28 (21)
Canyon floor	71	22	29	22	75	21	21 (18)

Surface sediments from canyons are mostly sandy mud, with sand content in 18 of the 21 samples ranging from 6% to 46% (Fig. 5.5). Gravel is either absent from canyon sediments, or comprises less than 2%. Three outlier samples are muddy sand, with up to 89% sand content. These sandy samples represent the deepest waters (3400–3700 m) of Whidbey Canyon and two unnamed canyons. However, other canyons are characterised by mud-dominated sediments at comparable water depths, so there is no clear bathymetric trend in sediment texture within canyons. Nor is it possible to discern trends in sediments along individual canyons due to the small sample number per canyon; the greatest sample size being five from the Nullarbor Canyon.

Carbonate content is uniformly high across all depositional environments of the Ceduna Sub-basin (Fig. 5.6). For the 68 samples for which carbonate data is available, all but six samples comprise in excess of 75% carbonate. Samples with lower carbonate content, in the range of 13% to 65%, are associated with deeper waters of the lower slope and three canyons (Whidbey, Eucla and an unnamed canyon). However, as previously noted for sediment texture, there is no clear relationship between water depth and carbonate content. Samples with low carbonate content presumably represent localised anomalies from the generally carbonate-rich character of surface sediments throughout the Ceduna Sub-basin.

5.4 SUMMARY

Surface sediments of the Ceduna Sub-basin form part of the large cool-water carbonate province of the Great Australian Bight. Production of carbonate sediment mostly occurs on the shelf, with the outer shelf and upper slope characterised by four, texturally varied bryozoan-rich sediment facies. Within the deeper waters of the Ceduna Sub-basin, including the terrace and canyons, sediments are carbonate-rich sandy mud and muddy sand, with localised concentrations of gravel. Overall, there are no strong spatial trends in sediment texture within the Ceduna Sub-basin, although there is a subtle increase in mud content with water depth.

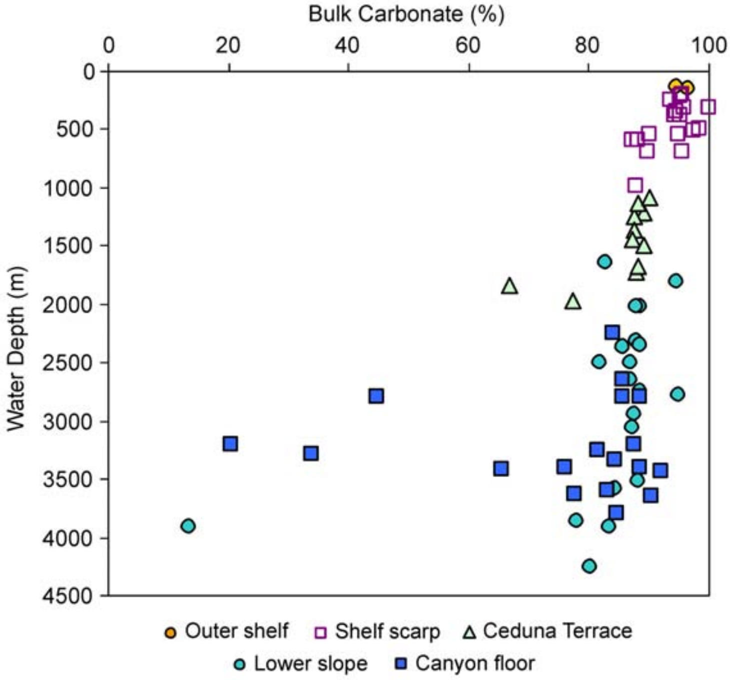


Figure 5.6: *Scatter plot of carbonate content versus water depth for 68 surface sediment samples from the shelf scarp, upper slope (Ceduna Terrace), lower slope and canyon floor environments in the Ceduna Sub-basin. Two samples from the edge of the outer shelf are included for comparison.*

6. Physical Oceanography

6.1 INTRODUCTION AND DATA SOURCES

The Great Australian Bight (GAB) consists of a complex and inter-related circulation system that is driven by local winds, heating and evaporation of shelf waters, as well as remote forcing from the Western Australian shelf and the Southern Ocean (Middleton and Bye, 2007; Ridgeway and Condie, 2004). Middleton and Bye (2007) provide an exhaustive review and describe the current knowledge of the region's physical oceanography as limited to a first-order understanding and description of the summer and winter circulation and only a few observational studies. Tidal measurements are limited to coastal waters and long-term wind wave measurements to one site only (Middleton and Bye, 2007; Hemer, 2008). Information for this review of the physical oceanography of the Ceduna Sub-basin and broader Great Australian Bight has been drawn from key journal references, the CSIRO Atlas of Regional Seas (CARS), the National Marine Bioregionalisation of Australia GIS (Department of Environment and Heritage, 2005), and the Bureau of Meteorology.

6.2 CLIMATIC DESCRIPTION

The following sub-sections present both the annual mean and monthly means representative of seasonal values for sea surface temperature (SST) and seafloor temperature and sea surface and seafloor salinity. Primary productivity (PP) in surface waters and the mixed layer depth (MLD) are also presented. The information is a subset of the National Marine Bioregionalisation GIS, which was drawn from the CARS data base.

6.2.1 Temperature

On a global scale ocean temperature varies with latitude and largely reflects the intensity of solar radiation incident on the surface of the oceans. The ocean temperature influences the range of species present in a region. It also influences oceanic circulation through its effect on density and pressure gradients. Localised spatial and temporal variation in oceanic temperature often indicates the incursion of ocean currents from outside the region and the mixing of different water masses.

The SST over the Ceduna Sub-basin is characteristic of temperate ocean waters with the annual mean SST grading from 17°C at the western end of the sub-basin to 16°C at the eastern end (Fig. 6.1). Typical values for SST over the sub-basin in January, April, July and October are 18.5°C, 18.4°C, 15.5°C and 15.2°C, respectively (Fig. 6.2 to 6.5). While SST is relatively uniform across the sub-basin, there is a thermal gradient across the shelf and into the gulfs throughout the year. The annual mean seafloor temperature is 4.2°C at bottom depths of 1000 m in the sub-basin and decreases down to 2.3°C at bottom depths of 2000 m (Fig. 6.6).

On a synoptic time-scale, the heating of shelf waters in the late spring and summer months creates regions of warm water adjacent to the coast, which can become cut-off from the coast to create relatively short-lived warm pools associated with strong SST fronts. Short-lived pools of cool surface water and associated fronts also occur during the summer months in the eastern Great Australian Bight (and over the Ceduna Sub-basin) and are probably linked to up-welling events (Herzfeld, 1997; Section 6.3.5). Fronts also develop at the mouth of Spencer Gulf along the edge of cold up-welled plumes (Middleton and Bye, 2007; Section 6.3.5).

6.2.2 Salinity

On a global scale ocean-surface salinity largely reflects the balance between evaporation and precipitation. The ocean salinity influences circulation through its effect on density and pressure gradients. Together salinity and temperature determine density and distinguish water masses.

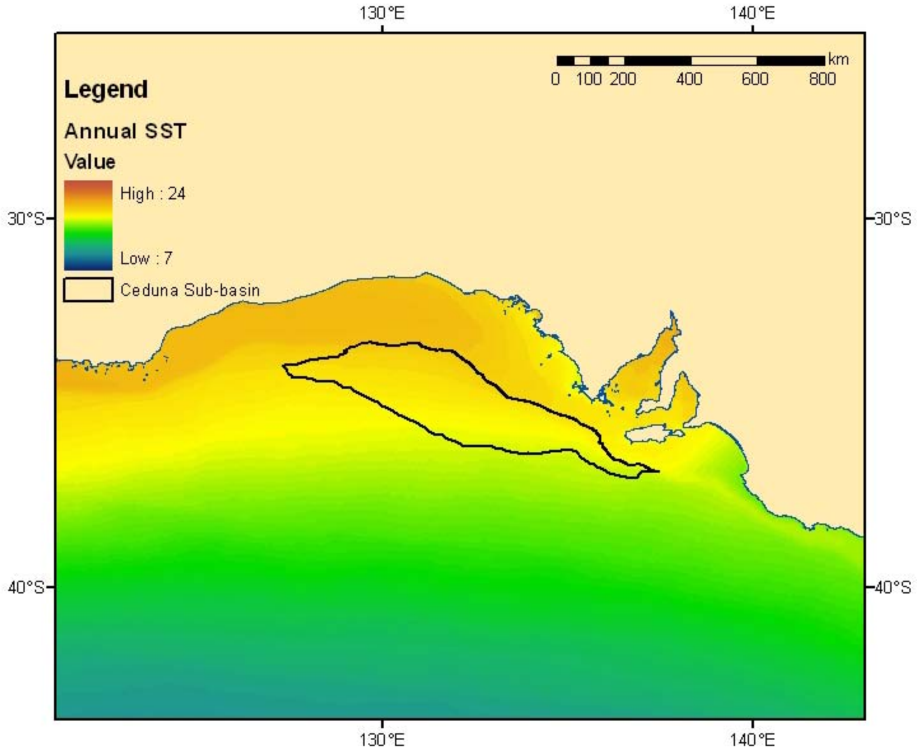


Figure 6.1*: Annual mean SST over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

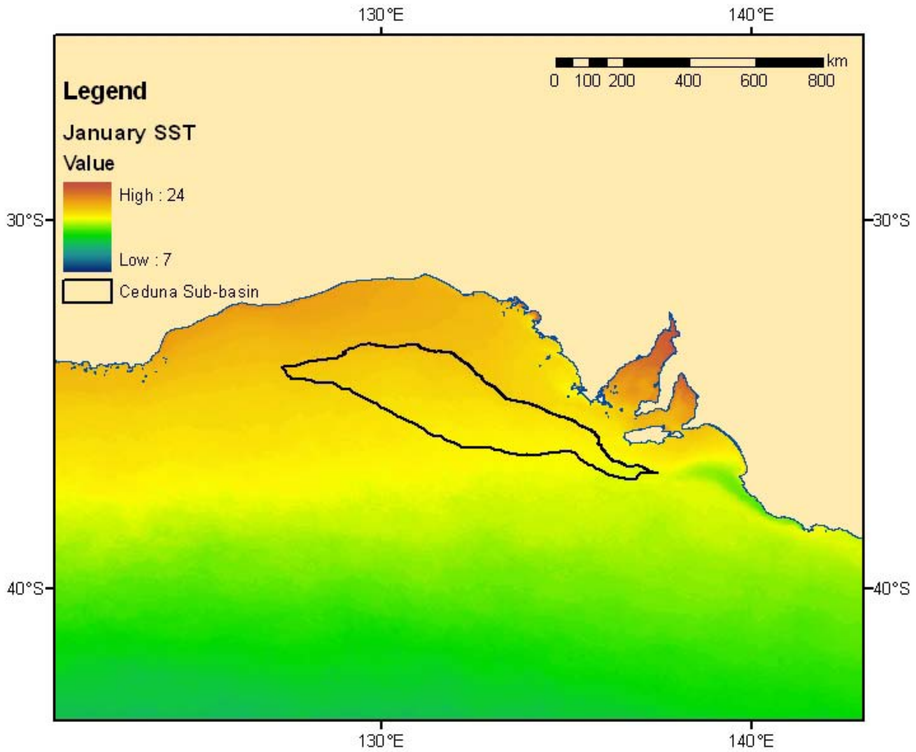


Figure 6.2*: Mean January SST over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

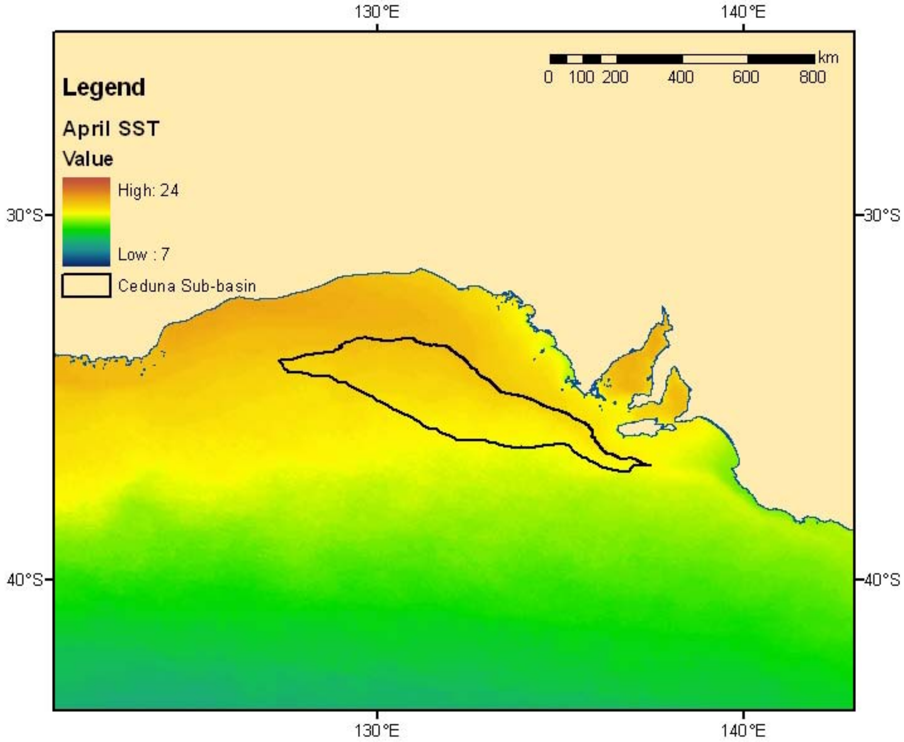


Figure 6.3*: Mean April SST over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

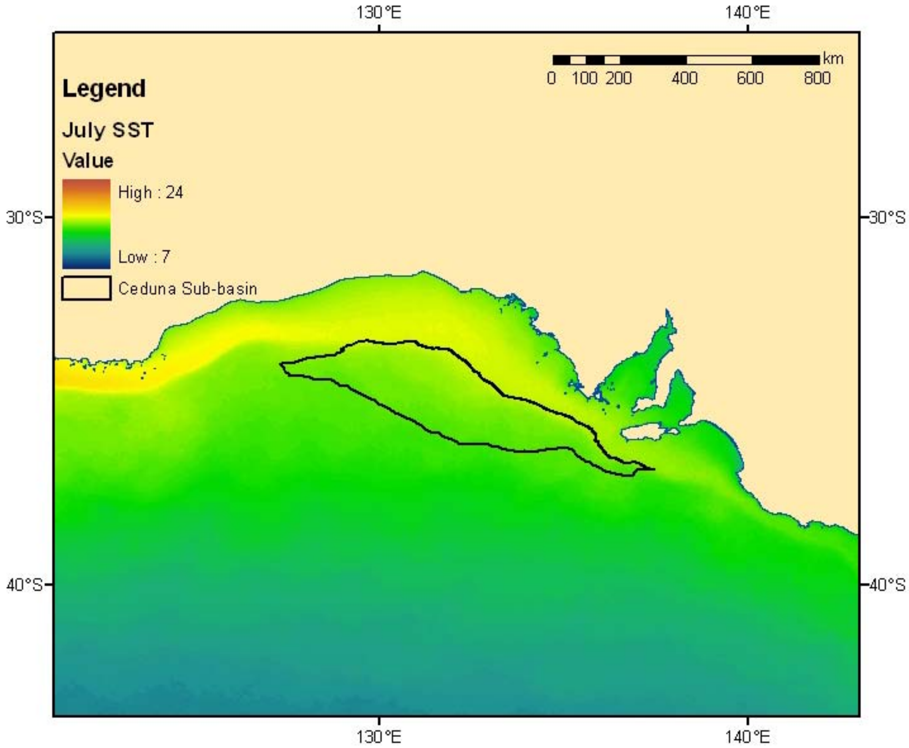


Figure 6.4*: Mean July SST over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

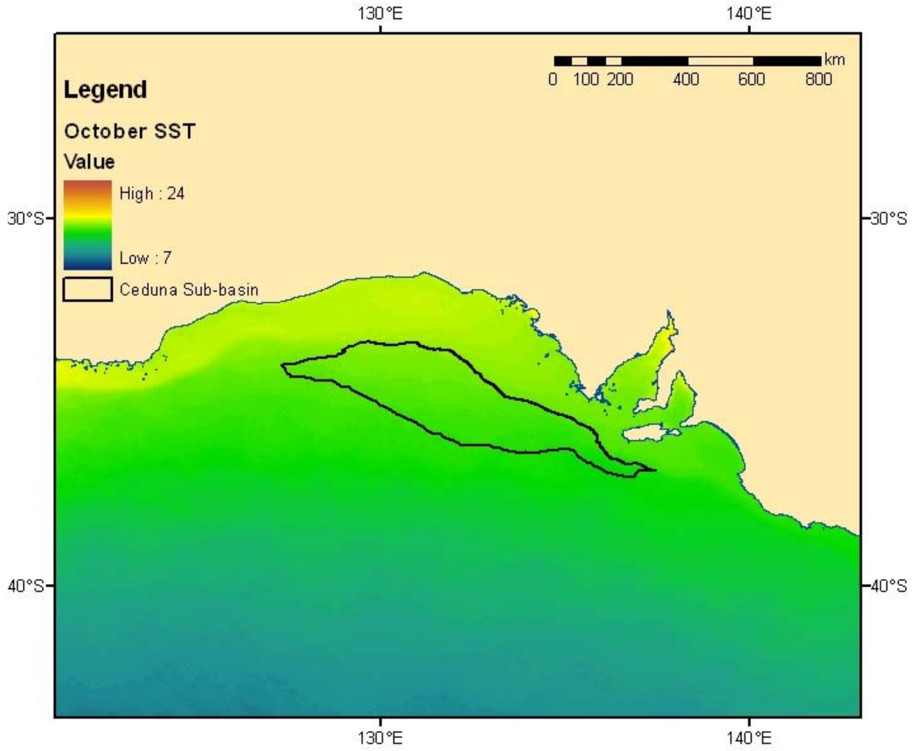


Figure 6.5: *Mean October SST over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

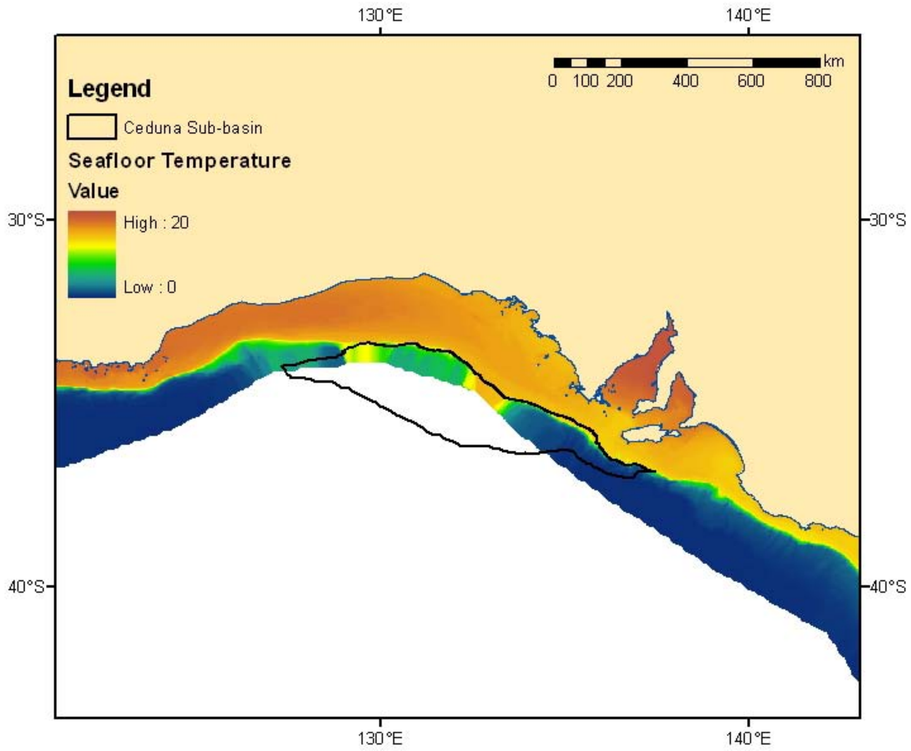


Figure 6.6: *Annual mean seafloor temperature over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

Localised spatial and temporal variation in salinity often indicates the incursion of ocean currents from outside the region and the mixing of different water masses.

The annual mean surface salinity is 35.6 μM at the northern extreme of the Ceduna Sub-basin and grades to 35.4 μM at the southern extreme (Fig. 6.7). There is a strong cross-shelf gradient with surface salinity in the shallow coastal waters and particularly the gulfs reaching values of 37.5 μM. due to high evaporation, which is important for coastal circulation and down-welling of waters across the sub-basin (Section 6.3.5). The annual mean seafloor salinity is 34.4 μM at bottom depths of 1000 m in the sub-basin increasing to 34.7 μM at bottom depths of 2000 m (Fig. 6.8).

Surface salinity has been used as the primary means for distinguishing between principal water masses in the Great Australian Bight. The Leeuwin Current, originating in Indonesia and flowing more than 5500 km down the west coast of Australia and rounding Cape Leeuwin, advects warm, low salinity water into the Great Australian Bight along the shelf-break (Ridgeway and Condie, 2004; McCreary et al., 1986; Section 6.3.2). Leeuwin Current water enters the Great Australian Bight around May, reaches its furthest eastern limit of approximately 130°E in July and remains in the western Great Australian Bight until October (Rochford, 1986; Fig. 6.4 and 6.7). A second mass of warm water exists in the central Great Australian Bight most of the year and is recognised by its high salinity (>36 PSU; Fig. 6.7). A third major water mass that is cooler and is identified by its low salinity extends across the southern region of the Great Australian Bight and is attributed to a west wind drift cold water mass (Herzfeld, 1997; Fig. 6.1 and 6.7).

6.2.3 Primary Productivity

Photosynthetic primary productivity is the amount of carbon fixed by organisms (marine plants and algae) through the synthesis of organic matter using energy derived from solar radiation. Put simply, it is a food source derived from carbon dioxide, water and sunlight that supports the rest of the marine ecosystem (Thurman and Trujillo, 2004). The amount of photosynthetic primary production in a region reflects both the amount of solar radiation (light energy) and the supply of mineral nutrients (i.e. nitrate, phosphorus, iron and silica) (Thurman and Trujillo, 2004).

In temperate waters such as those in the Great Australian Bight nutrient availability is the most important limiting factor to primary production. As a consequence the annual mean primary productivity is highest in coastal waters close to the principal source of mineral nutrients, and it decreases exponentially once off the continental shelf. The annual mean primary productivity is relatively uniform across the Ceduna Sub-basin with an indicative value of 200 mg m^{-2} d^{-1}. This is an order of magnitude smaller than adjacent coastal waters (Fig. 6.9). There is considerable seasonal variation in primary productivity with the least production occurring during summer and autumn with indicative values of ca. 110 mg m^{-2} d^{-1} (Fig. 6.10 and 6.11) and greatest during winter and spring with values up to ca. 250 mg m^{-2} d^{-1} (Fig. 6.12 and 6.13).

Considerable spatial and temporal variability in primary productivity occurs at synoptic time scales and is related to up- and down-welling (Section 6.3.5).

6.2.4 Mixed Layer Depth

The surface mixed layer of the ocean has a constant salinity, temperature and density. It represents the thickness of the water column that is regularly mixed and therefore exposed to the atmosphere. The mixed layer depth is determined by the turbulence in the upper water column and is therefore influenced by the strength of atmospheric winds and their effect on waves and surface currents. If the mixed layer extends much deeper than the photic zone (ca. 100 m) this can limit primary productivity. The annual mean mixed layer depth over the Ceduna Sub-basin is ca. 50 m, which is well inside the photic zone (Fig. 6.14).

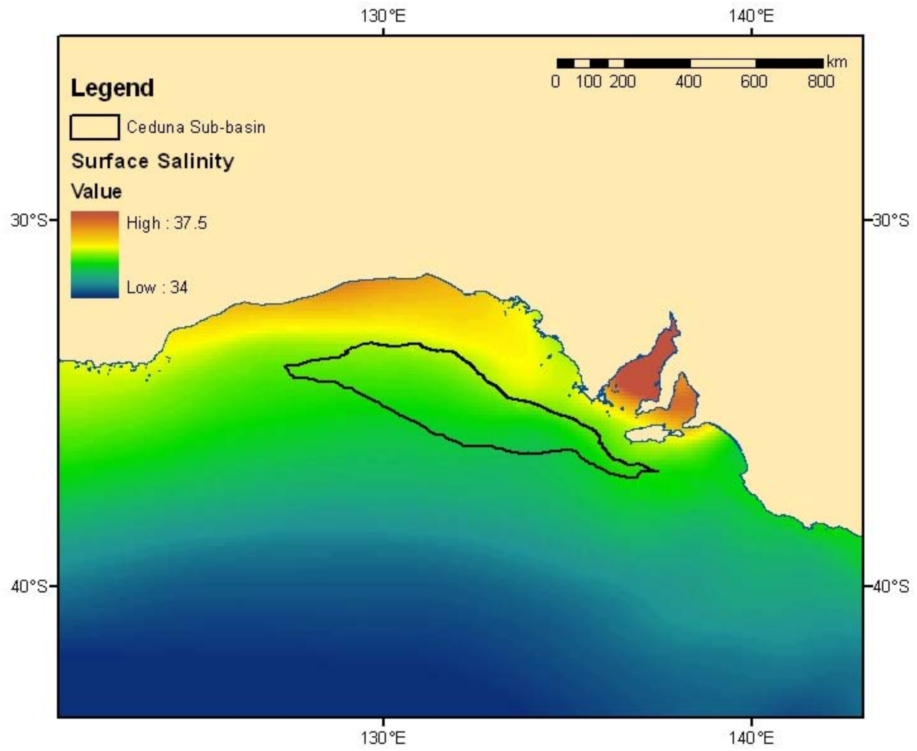


Figure 6.7*: Annual mean surface salinity over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

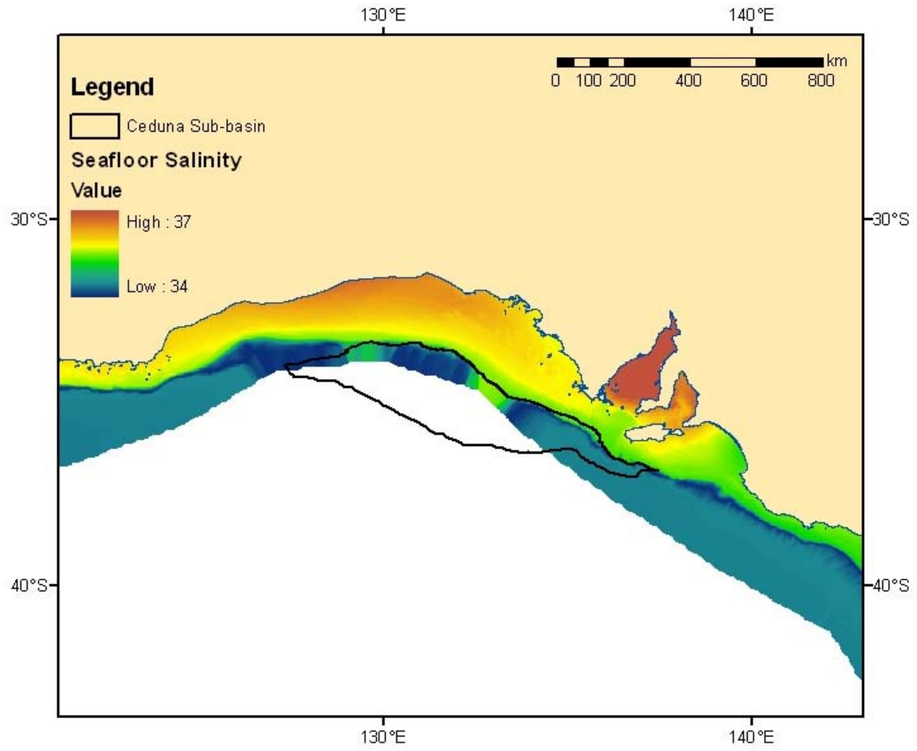


Figure 6.8*: Annual mean seafloor salinity over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

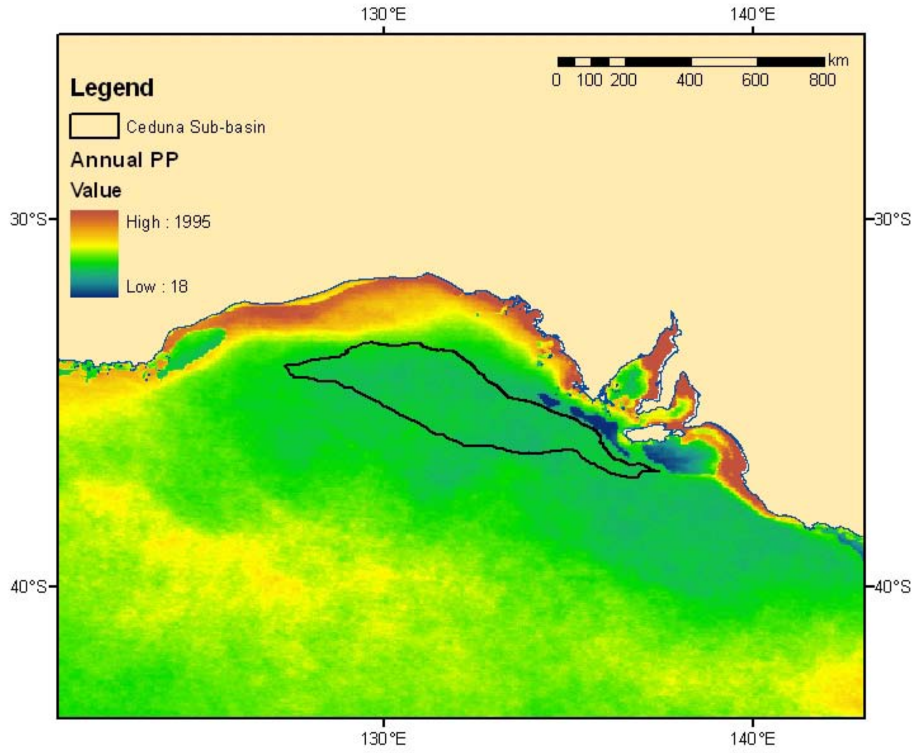


Figure 6.9: *Annual mean primary productivity (PP) over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

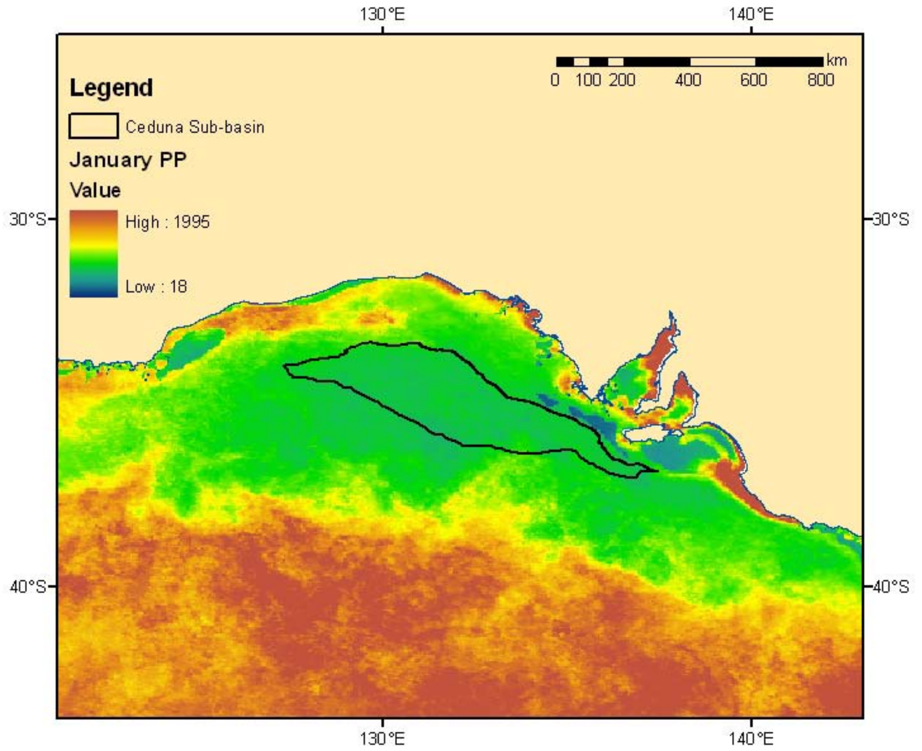


Figure 6.10: *Mean January primary productivity (PP) over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

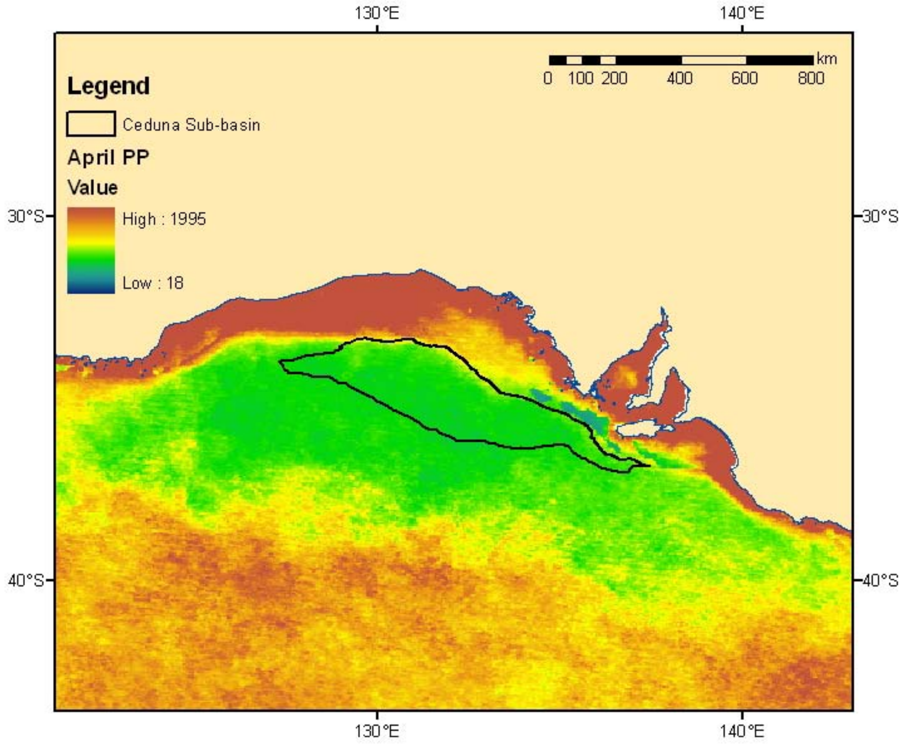


***Figure 6.11**: Mean April primary productivity (PP) over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

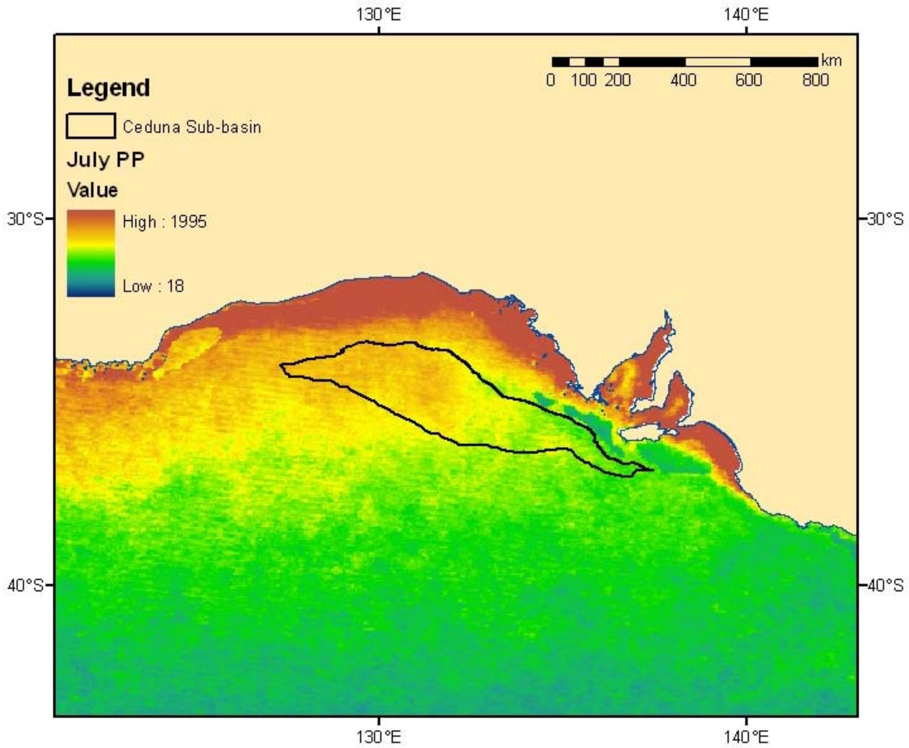


***Figure 6.12**: Mean July primary productivity (PP) over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

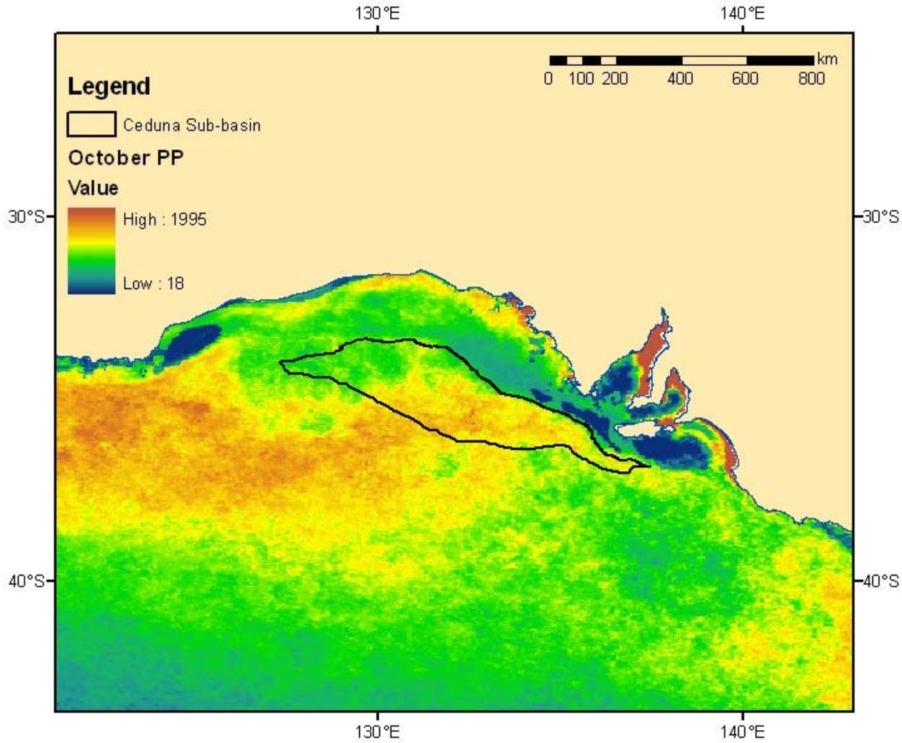


Figure 6.13: *Mean October primary productivity (PP) over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

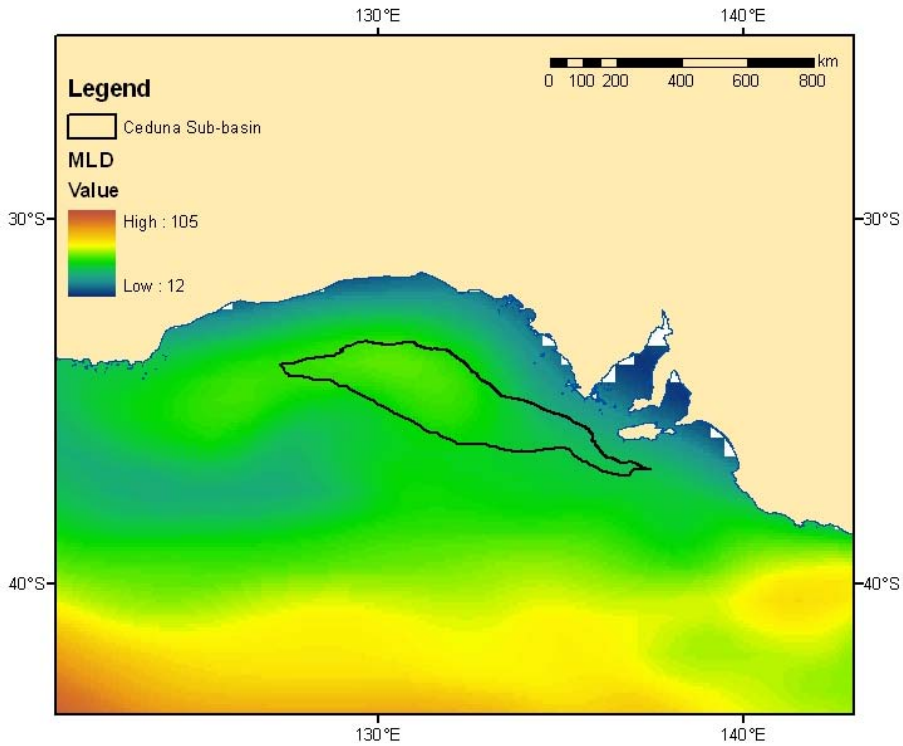


Figure 6.14: *Annual mean mixed layer depth (MLD) over the Ceduna Sub-basin obtained from the National Marine Bioregionalisation GIS (Department of Environment and Heritage, 2005).*

6.3 OCEANIC CIRCULATION

6.3.1 Overview

The general picture of summer and winter circulation in the Great Australian Bight, including the Ceduna Sub-basin, is shown in Figures 6.15 and 6.16, respectively. During summer the average winds blow in an anticyclonic direction around the Great Australian Bight and the resulting mean surface ocean circulation is an anticyclonic gyre that results in part from a southward topographic Sverdrup transport, raised sea level and a westward Coastal Current, and the eastward South Australia current (Middleton and Bye, 2007; Fig. 6.15). Mean current speeds in this summer circulation are weak; about 10 cm s^{-1}. Also during summer, widespread down-welling occurs along the shelf break and up-welling occurs off Kangaroo Island and the Bonney Coast (Middleton and Bye, 2007; Fig. 6.15). During winter a combination of winds and thermohaline forcing and the Leeuwin Current act to reverse the Coastal Current to eastward flowing, parallel with the South Australia Current (Fig. 6.16). Mean current speeds in this generally easterly winter circulation are larger; about 30 cm s^{-1}. The only westward current during winter is the generally weak Flinders Current (Middleton and Bye, 2007; Fig. 6.16). Down-welling is widespread in winter and driven by dense water formation in the gulfs and coastal waters of the Great Australian Bight (Middleton and Bye. 2007). Super-imposed on this climatically-averaged picture are short-lived circulation patterns associated with the passage of atmospheric pressure systems with a frequency 3-12 days that force coastal trapped waves with associated current speeds of up to 30 cm s^{-1} (Middleton and Bye, 2007).

6.3.2 The Leeuwin and inshore Coastal Currents

In the west the Leeuwin Current enters the Great Australian Bight with speeds of up to 90 cm s^{-1} during winter. The easterly-directed average wind stress during winter results in an Ekman flux that raises sea level near the coast. The geostrophic motion arising from this sea level anomaly combines with the Leeuwin Current entering from the west to result in an easterly flowing Coastal Current across the entire southern margin during winter (Middleton and Bye, 2007; Fig. 6.16). The speed of the Coastal Current is reduced from that achieved by its predecessor, the Leeuwin Current, and is 15–30 cm s^{-1} on average (Cirano and Middleton, 2004; Middleton and Bye, 2007).

The Leeuwin Current is generally absent from the Great Australian Bight during summer and the Coastal Current reverses to flow westward; consistent with the average summer wind stress (Church et al., 1989; Middleton and Platov, 2003; Ridgeway and Condie, 2004; Fig. 6.15). The summer hydrographic situation also contributes to the Coastal Current. The warming of central shelf waters during summer (Fig. 6.2) results in their reduced density and a positive sea surface elevation anomaly, whereas closer to the coast the increased salinity (Fig. 6.7) due to enhanced evaporation results in increased density and a negative anomaly; the resulting geostrophic motion contributes to the westerly flowing Coastal Current (Middleton and Platov, 2003; Middleton and Bye, 2007).

6.3.3 The South Australia Current

During summer the eastward flowing South Australia Current is companion to the westward flowing Coastal Current and represents the outboard arm of the anticyclonic gyre (Fig. 6.15; Section 6.3.1). The summer hydrographic situation in the Great Australian Bight also contributes to the South Australia Current; with a negative sea surface elevation anomaly due to cooler temperatures outboard of the positive anomaly that exists over the central shelf (Section 6.3.2; Fig. 6.2). The easterly-directed average wind stress during winter means that the South Australia current flows persistently eastward year-round, with average speeds in winter of up to 30 cm s^{-1} (Cirano and Middleton, 2004; Middleton and Bye, 2007). This current impacts the extreme northern boundary of the Ceduna Sub-basin.

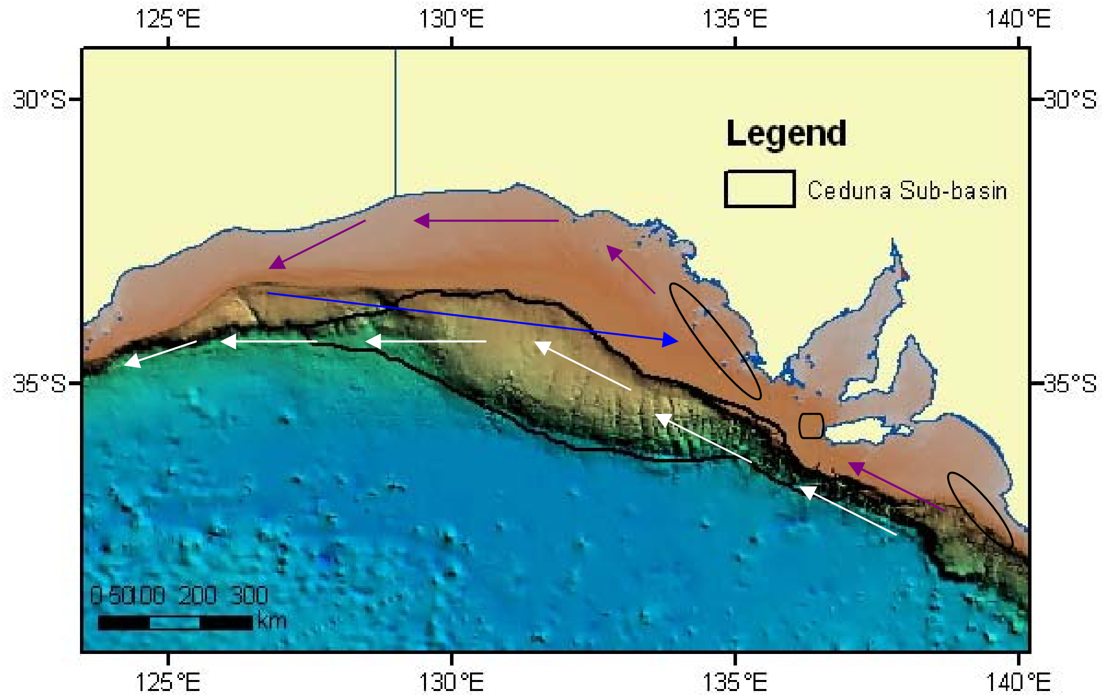


Figure 6.15*: Schematic of the mean summer circulation in the GAB and over the Ceduna Sub-basin. Established (and possible) up-welling is also shown as red (green) (Blue, South Australia Current; Violet, Coastal Current; White, Flinders Current). After Middleton and Bye (2007).*

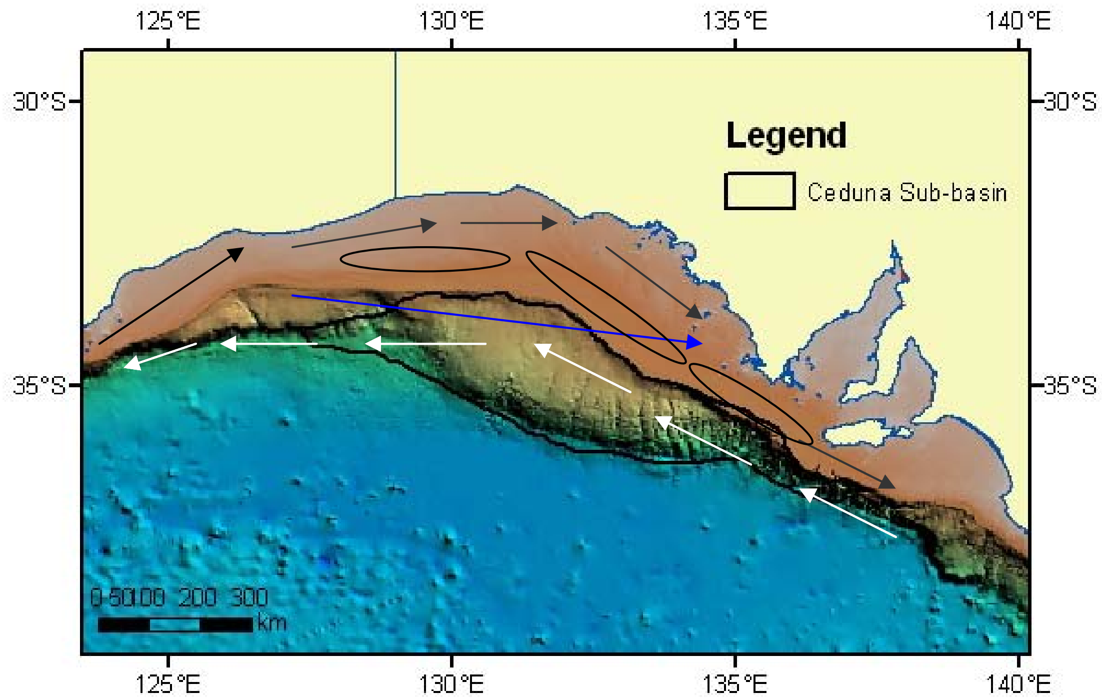


Figure 6.16*: Schematic of the mean winter circulation in the GAB and over the Ceduna Sub-basin. Down-welling is also shown as blue (Blue, South Australia Current; Grey, Coastal Current; Black, Leeuwin Current; White, Flinders Current). After Middleton and Bye (2007).*

6.3.4 The Flinders Current

The Flinders Current is the only current in the region that persistently flows across the Ceduna Sub-basin. Observations of the Flinders Current are limited to perhaps half a dozen studies of variable and generally limited coverage and most only offer indirect evidence of the current (see Middleton and Cirano, 2002 for a review). The Flinders Current is best described as a northern boundary current arising from an equatorward Sverdrup transport driven by the positive wind stress curl over the ocean south of Australia, which is deflected to the west upon encountering the Australian continent due to frictional dissipation of vorticity and mass conservation arguments (Hufford et al., 1997; Middleton and Cirano, 2002).

The OCCAM model results show the Flinders Current running westward along the 4000 m isobath, which lies along the southern margin of the Ceduna Sub-basin. At a section across the sub-basin the modelled transport is 9.7 Sv to the north and 10.6 Sv to the west in summer and in winter the values are 4.1 Sv to the north and 4.8 Sv to the west (Middleton and Cirano, 2002). Limited field measurements reported by Callahan (1972), Schodolk and Tomczak (1997) and Hufford et al. (1992) support the OCCAM model predictions. Inferred current velocities from CTD measurements at longitude 118°E in winter show a westward flow with a speed of about 20 cm s^{-1} at depths of 400-600 m, and reducing to near zero at a depth of 1000 m (Cresswell and Peterson, 1993; Fig. 6.17). At this location in the western Great Australian Bight the Flinders Current develops into the Leeuwin Undercurrent (Middleton and Bye, 2007).

6.3.5 Up- and down-welling

Up-welling in the GAB region generally occurs during summer (Fig. 6.15), and can arise due to anti-cyclonic high pressure systems that commonly sit in the bight for periods of 3-10 days producing up-welling favourable wind stresses that are a factor 2–4 times larger than the summer-average stresses (Middleton and Bye, 2007). This mechanism typically leads to up-welling of shelf waters from depths of 150–250 m, particularly off Kangaroo Island and the Bonney Coast where a ‘cool-pool’ of dense, nutrient-rich water develops (Petrusevics, 1993; Middleton and Bye, 2007). Note that this up-welled water is not evident in the seasonal SST data off Kangaroo Island (Fig. 6.2), because the events are relatively short-lived, but there is some evidence in the summer-averaged primary productivity data (see the small area adjacent to the western tip of Kangaroo Island and a more extensive area off the Bonney Coast in Fig. 6.10). Cool, nutrient-rich waters suggestive of up-welling also occur in coastal waters of the eastern GAB and along the western coast of the Eyre Peninsula (Fig. 6.15; Middleton and Platov, 2003; Middleton and Cirano, 2002; Baird, 2003). Despite numerical model results to the contrary (Middleton and Cirano, 2002), there is little direct evidence for widespread shelf-break up-welling west of Kangaroo Island. Rather, available data suggest that the ‘cool-pool’ off Kangaroo Island generally appears constrained until subsequent up-welling events and coastal currents advect water from this ‘cool-pool’ to the adjacent coastal regions of the eastern GAB and as far west as the Eyre Peninsula (McClatchie et al., 2006).

In short, shallow up-welling is clearly evident off the Bonney Coast and western tip of Kangaroo Island, but the extent to which occasional coastal cool water masses off the Eyre Peninsula represent local up-welling or advection from the east remains to be established. There is further uncertainty relating to the mechanism for up-welling in the region, since it has been noted that strong up-welling events are not always connected to winds that produce an offshore-directed surface Ekman flux (e.g. Herzfeld and Tomczak, 1999). Herzfeld and Tomczak (1999) demonstrated that the topography of the GAB region results in an intensification of the eastern side of the anticyclonic gyre that characterises the summer circulation (Fig. 6.15), which would favour up-welling off Kangaroo Island and the Bonney Coast over any potential up-welling further to the west. To further complicate the picture Kämpf (2006) described an up-welling process independent of winds and the related surface Ekman flux. During summer the South Australian Current episodically reverses direction towards the northwest with speeds of 10–15 cm s^{-1}, which opposes the direction of Kelvin wave propagation and results in up-welling of deep water (>300 m) via the submarine canyons that cut the shelf edge (Fig. 4.1 and 4.2; Kämpf, 2006; 2007).

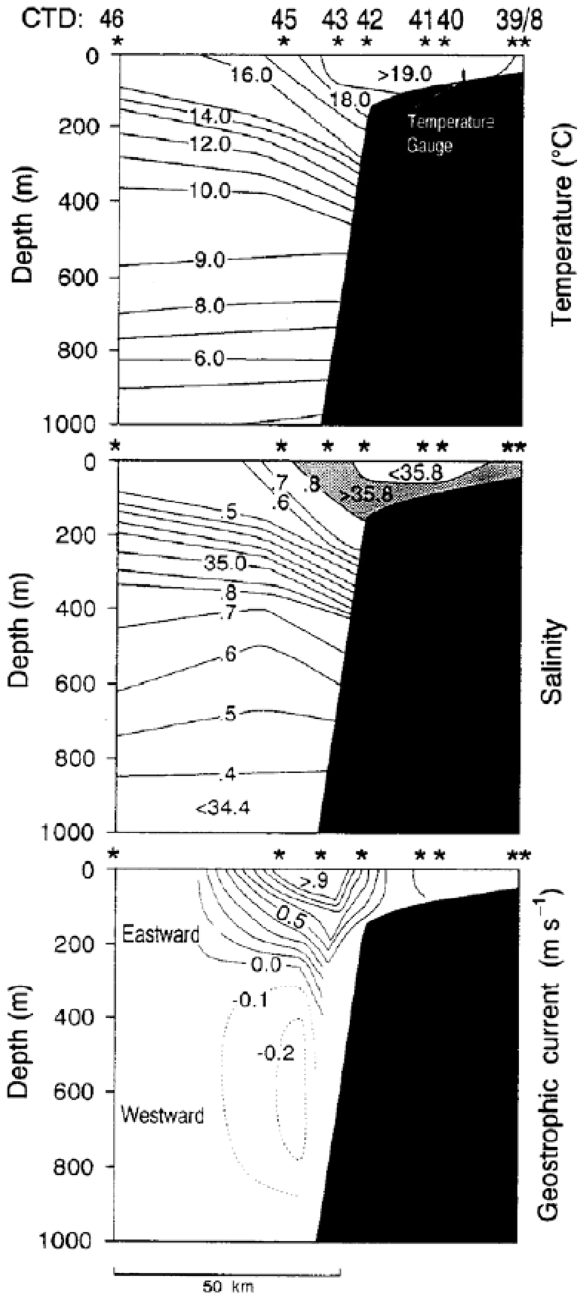


Figure 6.17*: Cross-shelf CTD sections (top panel, temperature; mid panel, salinity) and the inferred geostrophic motion (bottom panel). Measurements were obtained near 118°E during June 1987 (After Cresswell and Peterson, 1993).*

Winter time winds and cooling of surface water (Fig. 6.4) lead to widespread coastal down-welling in the GAB region to depths of 200 m (Fig. 6.16; Hammat, 1995; Middleton and Bye, 2007). This may be further enhanced in the eastern GAB by dense, saline waters exiting the gulfs (Fig. 6.7; Godfrey et al., 1986; Lennon et al., 1987).

6.3.6 Coastal-trapped waves

During winter, low pressure systems and associated fronts pass over the Great Australian Bight with a frequency of 3–12 days. These atmospheric systems move from west to east at a speed of about 10 m s^{-1}, which is comparable to the predicted phase speed of coastal-trapped waves suggesting possible resonant forcing of the waves (Noye et al., 1999; Middleton and Bye, 2007). Root-mean-square current speeds on the shelf within the coastal-trapped-wave frequency band during winter are typically 20–30 cm s^{-1}, but sometimes reach 50–90 cm s^{-1} (Middleton and Bye, 2007). While storms cross the region in summer also, they tend to track up to 5° of latitude further south (Hurrell et al., 1998), probably reducing the potential for resonantly forcing a coastal-trapped wave mode. Nevertheless, such waves have been observed during summer, and have been linked to up-welling off the Bonney Coast (Section 6.3.5). Root-mean-square current speeds on the shelf within the coastal-trapped-wave frequency band during summer are 20–50 cm s^{-1} (Middleton and Bye, 2007).

6.4 TIDES

Tide behaviour in the coastal waters and gulfs in the north of the Great Australian Bight is complex; responding to both the shelf and coastal configuration (see Hutchinson, 1988; Bowers and Lennon, 1990). Further seaward in the deeper waters over the Ceduna Sub-basin, however, the tide behaves as a simple Kelvin wave that propagates from west to east across the Great Australian Bight without any significant shelf resonance (Irish and Snodgrass, 1972; Middleton and Bye, 2007). Tidal currents on the shelf are generally <10 cm s^{-1} (Hahn, 1986; Middleton and Bye, 2007). Tidal currents over the Ceduna Sub-basin are also likely to be small. Studies of any potential internal tides in the region are lacking (Middleton and Bye, 2007).

6.5 WIND WAVES

The maximum water depth to which waves influence the seabed is equal to half the wavelength and significant influence on the seabed is limited to depths less than one-quarter of the wavelength. The wavelength L can be estimated using $L = \frac{gT^2}{2\pi}$ where g is gravitational acceleration and T is wave period (e.g. Wright, 1995). Even for the longest period swell waves, ca. 15 s, the wavelength would be 350 m, and thus the maximum depth to which the seabed would be even marginally influenced by waves is 175 m. Water depths across the Ceduna Sub-basin are typically >>200 m (Section 4.2), thus the seabed in the region will not be influenced by waves. Nevertheless, waves will have an impact on shipping, platforms and any sea-surface operations associated with potential exploration and production in the area.

Hemer et al. (2008) presented a detailed assessment of the available wave data for the entire southern margin of Australia. The data included (a) waverider buoy data from four buoys located at Cape Sorell, Cape de Couedic, Cape Naturaliste and Rottnest Island (Table 6.1); and (b) ten years (1997-2006) of numerical model output from the WAVEWATCH III wave hindcast model (Tolman et al., 2002) at the nearest grid point to the waverider buoys. The former provided significant wave height H_s and peak wave period T_p whereas the latter also provided wave direction information. The nearest buoy and model grid point to the Ceduna Sub-basin analysed by Hemer et al. is Cape de Couedic located some 150 km to the east of the Ceduna Sub-basin off the western tip of Kangaroo Island in 80 m water depth. Nine years of numerical model output from the WAM wave model (Hasselman et al., 1988) was also available from the Bureau of Meteorology, and the record from the grid point approximately central to the Ceduna Sub-basin has also been analysed for this report Table 6.1.

***Table 6.1**: List of locations on the southern margin of Australia for which wave information is available and periods for which analysis have been undertaken both in this report and Hemer et al. (2008).*

Location	Longitude	Latitude	Water depth (m)	Analysis period
Cape Sorrell	145° 1′ E	42° 9′ S	100	11/07/1985 to 31/12/2006 [1,2]
Cape de Couedic	136° 37′ E	36° 4′ S	80	01/11/2000 to 31/12/2006 [1]
Cape Naturaliste	114° 47′ E	33° 22′ S	50	07/11/1998 to 31/12/2006 [1]
Rottnest Island	115° 24′ E	32° 7′ S	50	25/07/1991 to 31/12/2006 [1]
Central Ceduna	131° 30′ E	34° 30′ S	1400	28/02/1997 to 28/02/2006

1. Waverider buoy continues to be operational
2. Interrupted record (6 year gap)

Wind waves that impact on the Ceduna Sub-basin region are predominantly generated by the latitudinal westerlies that blow persistently throughout the year in a belt roughly between latitudes 40°S and 60°S. The fetch is effectively infinite, resulting in long-period swell. Locally-generated storm seas also impact the region, however, and arise from the eastward passage of extra-tropical low pressure systems and associated fronts (Middleton and Bye, 2007; Hemer et al., 2008). There is a seasonal shift of the northern-most margin of the storm belt from approximately 45°S during the summer months, northwards to approximately 35°S during the winter months, which leads to a seasonal variability of the wave climate (Hurrell et al., 1998). This is manifest as an increase in both significant wave height and peak wave period during winter recorded at the Cape de Couedic waverider buoy (Hemer et al., 2008). Wave spectra recorded from the Great Australian Bight are typically uni-modal (Provis and Steedman, 1985). During high energy conditions, particularly in winter, the extra-tropical low pressure systems and associated fronts track directly over the region so that a bi-modal spectrum does not have the fetch available to develop (Middleton and Bye, 2007; Young and Gorman, 1995).

The minimum and maximum monthly mean H_s measured by the Cape de Couedic waverider buoy occur in summer and winter and are 2.2 m and 3.1 m, respectively and the corresponding T_p are 11.8 s and 13.6 s (Table 6.1; Hemer et al., 2008). Nine years of hindcast wave data for the central Ceduna Sub-basin are shown in Figure 6.18 (see also Table 6.1), and a similar seasonal pattern is evident. Monthly modal H_s range from 1.9 m in summer to 2.6 m in winter. The distribution of wave heights is highly skewed, with H_s commonly reaching 4 m in winter and occasionally up to 10 m (Fig. 6.18). Note that the wave periods shown in Fig. 6.18 are significantly less than those presented by Hemer et al. (2008), because they are mean wave periods (T_m) and not peak wave periods T_p. The largest and longest period waves are from the southwest and propagate to the northeast, consistent with the atmospheric systems in the Southern Ocean propagating eastward with a period of 6-8 days (Fig. 6.18; Simmonds and Keay, 2000; Hemer et al., 2008).

6.6 OCEANIC CONNECTIVITY

The interconnectedness of locations in the ocean has relevance to the geographic range of species and to endemism, developmental life-cycles for particular species, food supply etc. Oceanographic processes such as current circulation, tides, and waves can all connect one location with another. The most distant connection to the Great Australian Bight is probably Indonesian waters via the Leeuwin Current (Ridgeway and Condie, 2004). A picture of the interconnectedness of waters within the Great Australian Bight can be obtained by comparing the advection distances of water masses over relevant time scales to biota. Middleton and Bye (2007) provide the following observations and indicative values in relation to water mass advection:

- The winter time Coastal Current may advect water 1300–2700 km to the east over a 3 month period.
- The Flinders Current may advect water 800 km to the west over a 3 month period.

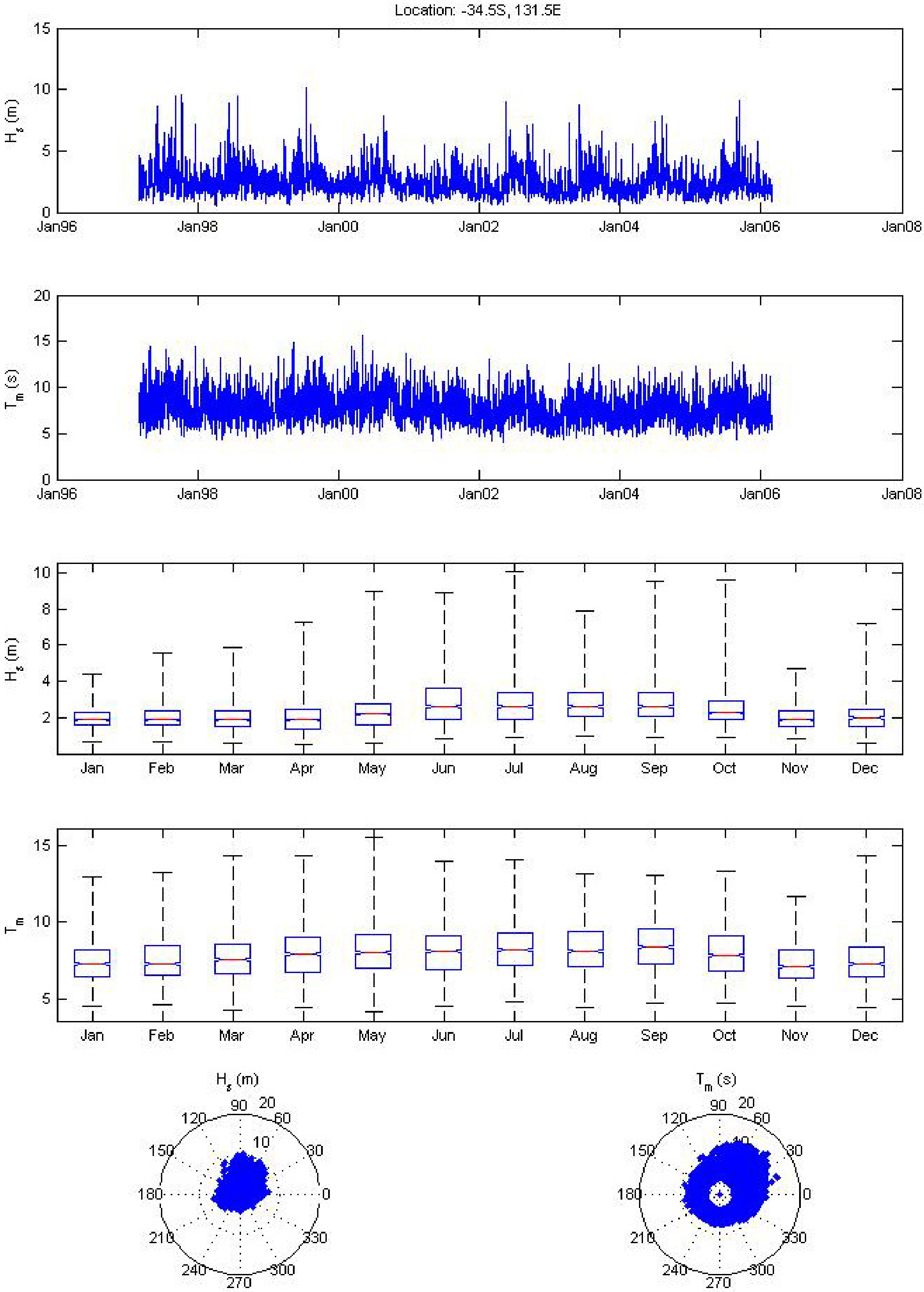


***Figure 6.18**: Nine years of hindcast wind-wave data from the WAM wave model for the centre of the Ceduna Sub-basin. Top two panels are time series of significant wave height and mean wave period, the next two panels are monthly statistics. The red line is the monthly median, the upper and lower extents of the blue box are the 75th and 25th percentiles (i.e. the monthly inter-quartile range) and the dashed lines show the full range of monthly observations. Polar plots of the magnitude and direction of significant wave height and mean wave period are also shown (note the Cartesian coordinate system and that azimuths are the direction waves are propagating to).*

- Coastal-trapped waves may advect water 30 km back and forth over a period of 10 days.
- Coastal down-welling during winter may provide a means for connecting shelf water to the westward flowing Flinders Current.
- Stokes drift associated with the persistent northeasterly-directed wind waves and swell may be an important mechanism for onshore transport of surface waters.

A detailed analysis of connectivity with due consideration to specific biota is beyond the scope of this report. Suffice to say that the waters over the Ceduna Sub-basin have a direct connectivity with the shelf waters of the Great Australian Bight, and indirect connectivity with its coastal and gulf waters, as well as further afield via the Leeuwin Current.

6.7 SEABED DISTURBANCE

In this report seabed disturbance refers to the potential for bed sediment to be mobilised or significant changes in bed elevation to occur through bedform migration. Processes that potentially cause seabed disturbance include bed shear from waves, tides and oceanic currents, as well as mass-movement due to slope failure and associated gravity currents.

As already noted, water depths over the Ceduna Sub-basin are too large for any significant impact of wind waves on the seabed and tidal currents are weak (Sections 6.4 and 6.5). There have been no studies of internal tides in the region (Middleton and Bye, 2007), thus their influence is unknown. Only the Flinders Current directly impacts the Ceduna Sub-basin (Section 6.3.4; Fig. 6.15 and 6.16). Inferred velocities of the Flinders Current along a transect at longitude 118°E show that it flows westward with a speed of about 20 cm s^{-1} at depths of 400-600 m, but the current is reduced to near zero at a depth of 1000 m (Cresswell and Peterson, 1993; Fig. 6.17). Measured or inferred current velocities over the Ceduna Sub-basin are unavailable, but based on the data available to the west the current's impact on the seabed is expected to be minimal.

Slope failure and subsequent down-slope mass movement and/or gravity currents are expected to be effective agents of seabed disturbance in the Ceduna Sub-basin. Evidence of these processes has already been discussed in Section 4.2 and examples are shown in Figure 4.13. The escarpments, canyons and trenches that figure prominently on the upper and lower shelf slope within the sub-basin in water depths of 200–1000 m and 2000–4500 m, especially at the eastern end of the sub-basin, are particularly relevant (Fig. 3.1, 4.1 and 4.12). The age of major seabed failures in the sub-basin are unknown, but the shelf slope has been classified as erosional (Section 4.3), thus it is expected that mass movement and related seabed disturbance are continuing at the present time.

6.8 SUMMARY

Coastal and shelf waters in the Great Australian Bight region display an anti-cyclonic circulation pattern in summer and a generally easterly-directed flow pattern in winter. These oceanic currents are driven both by wind and thermohaline forcing related to the generally arid climate and large seasonal temperature difference. The Flinders Current, which is the only part of the system directly affecting the Ceduna Sub-basin, generally flows to the west. Summer up-welling is regionally important and likely to have a strong influence on the biota. Wave energy over the Ceduna Sub-basin is persistently high by world standards, but tides are largely inconsequential. Given the large water depths over the Ceduna Sub-basin, the dominant seabed disturbance mechanism is most likely to be slope failure and related mass-wasting and turbidity currents. Oceanic connectivity within the GAB is extensive and there is a seasonal link to tropical waters through the Leeuwin Current system.

7. Ecology

7.1 INTRODUCTION AND DATA SOURCES

This section summarises the available information on the ecology of the Ceduna Sub-basin, including patterns of biodiversity and biogeography. The first half of the chapter focuses on current human use of the region: marine protected areas and commercial fisheries. The second half of the chapter concentrates on biological knowledge of the area, beginning with global biological patterns, then narrowing to the regional level of the Great Australian Bight, and finally focusing on specific ecological facts known about the Ceduna sub-basin through surveys and biogeographical databases.

7.2 CURRENT USE OF THE CEDUNA SUB-BASIN

Parts of the Ceduna Sub-basin are currently used for both conservation and commercial purposes. Although activities associated with these purposes may potentially interact with each other, animal migrations and fisheries are often seasonal, and temporal variation may therefore keep potentially conflicting activities separate (Table 7.1).

Table 7.1*: Temporal variation in potentially vulnerable environmental and commercial activities in the Ceduna sub-basin and nearby waters*

Event	Potential vulnerabilities	J	F	M	A	M	J	J	A	S	O	N	D
Southern right whale migration	interruption of reproductive behaviour, direct harm through equipment and vessel interactions, disruption of migration routes						■	■	■	■	■		
Rock lobster fishery	entanglement with lobster pots etc.	■	■	■	■	■						■	■
Giant crab fishery	entanglement with crab traps etc.	■	■	■	■	■						■	■
Humpback whale migration	interruption of reproductive behaviour, direct harm through equipment and vessel interactions, disruption of migration routes						■	■		■	■		

1. Edyvane (1998); 2. Linnane et al. (2007); 3. Currie et al. (2006)

7.2.1 Benthic Protection Zone

The Benthic Protection Zone (BPZ) is a 20 nautical mile-wide, 200 nautical mile-long north-south strip between 130° 28′E and 130° 51′E that runs across the continental shelf and slope to the limit of Australia’s Exclusive Economic Zone. The deeper half of the BPZ includes part of the Ceduna Sub-basin (Fig. 7.1). The northernmost edge of the BPZ overlaps with the Marine Mammal Protection Zone (MMPZ), which runs in an east-west band perpendicular to the BPZ (Fig. 7.1).

The BPZ was formed in 1998 as part of the Great Australian Bight Marine Park (GABMP) to conserve ecosystems that are characteristic of the region (Great Australian Bight Marine Park, 2005). Whereas other parts of the GABMP are designed to protect sea mammals, the main purpose of the BPZ is to conserve a transect of benthic (i.e. seafloor) habitats and the biological communities associated with them. The BPZ includes six of the 12 known sediment facies to occur in the Great Australian Bight (Facies Q, MI, I, IB, BB, M; see Table 5.1 for code definitions) and thus represents a range of benthic habitats characteristic of the region (James et al., 2001; McLeay et al., 2003). Benthic communities vary significantly among facies, although the causal relationships are unknown (Ward et al., 2006). Due to the lack of terrigenous sediment input in the GAB, it may be that biota cause sediment differences, rather than the more usual converse case. Indeed biogenic carbonate makes up a considerable fraction of the sediments in the Ceduna Sub-basin (Section 5.2).

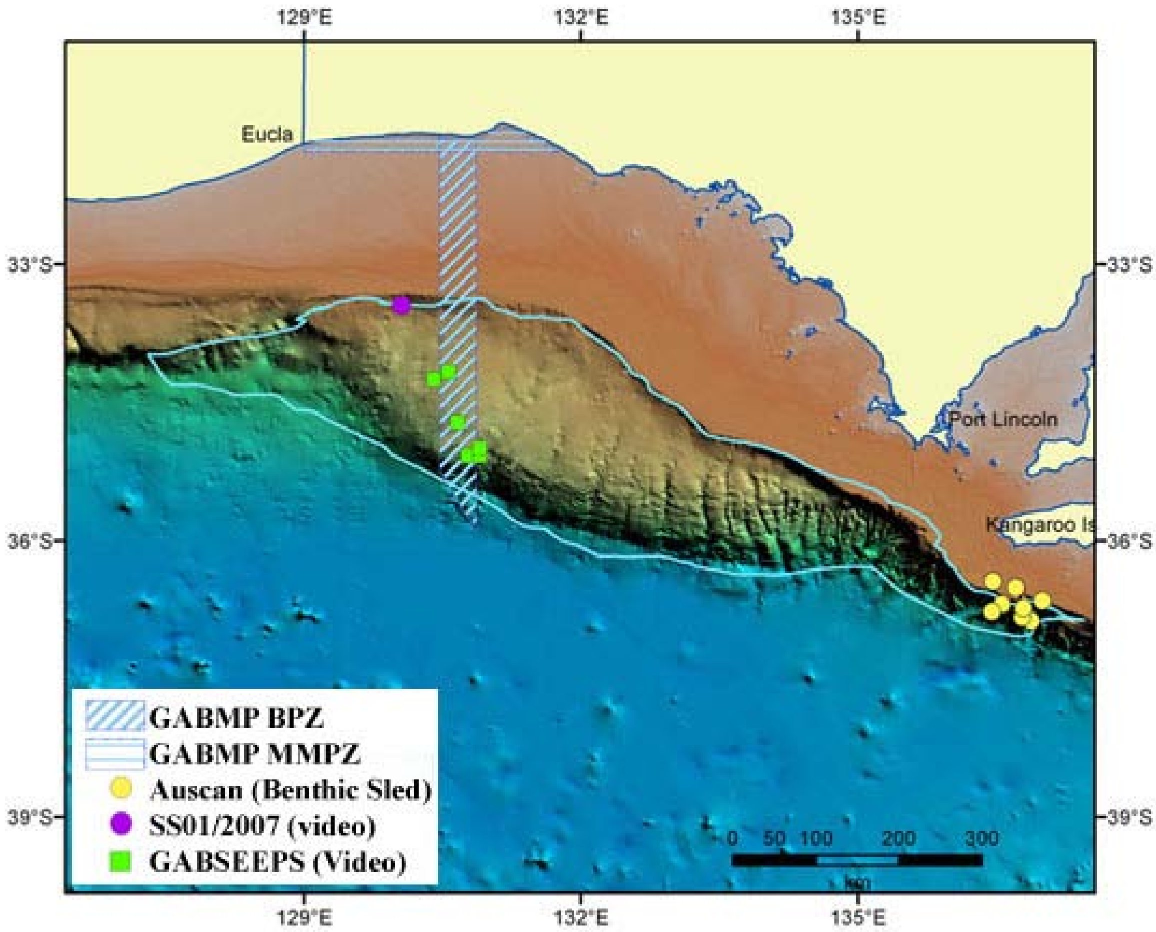


Figure 7.1: *Map of the biologically relevant aspects of the Ceduna Sub-basin, including GAPMP zoning (Section 7.2.1) and sites of biological sampling or video (Section 7.3). The Benthic Protection Zone is the north-south band of the GAB Marine Park, while the Marine Mammal Protection Zone is the east-west band.*

7.2.2 Legislation & Restrictions

The BPZ is managed by the Commonwealth under the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC*). Accordingly, the Commonwealth Great Australian Bight Management Plan 2005–2012 restricts certain recreational and commercial activities, with offending parties subject to fines and prosecution. Mining and petroleum operations are completely prohibited in the MMPZ of the GABMP (Fig. 7.1), but they may be conducted in the rest of the BPZ with approval from the Governor General after a detailed process (Fig. 7.2). All fishing activity and vessel access is prohibited in the MMPZ during whale and sea lion breeding season (1 May–31

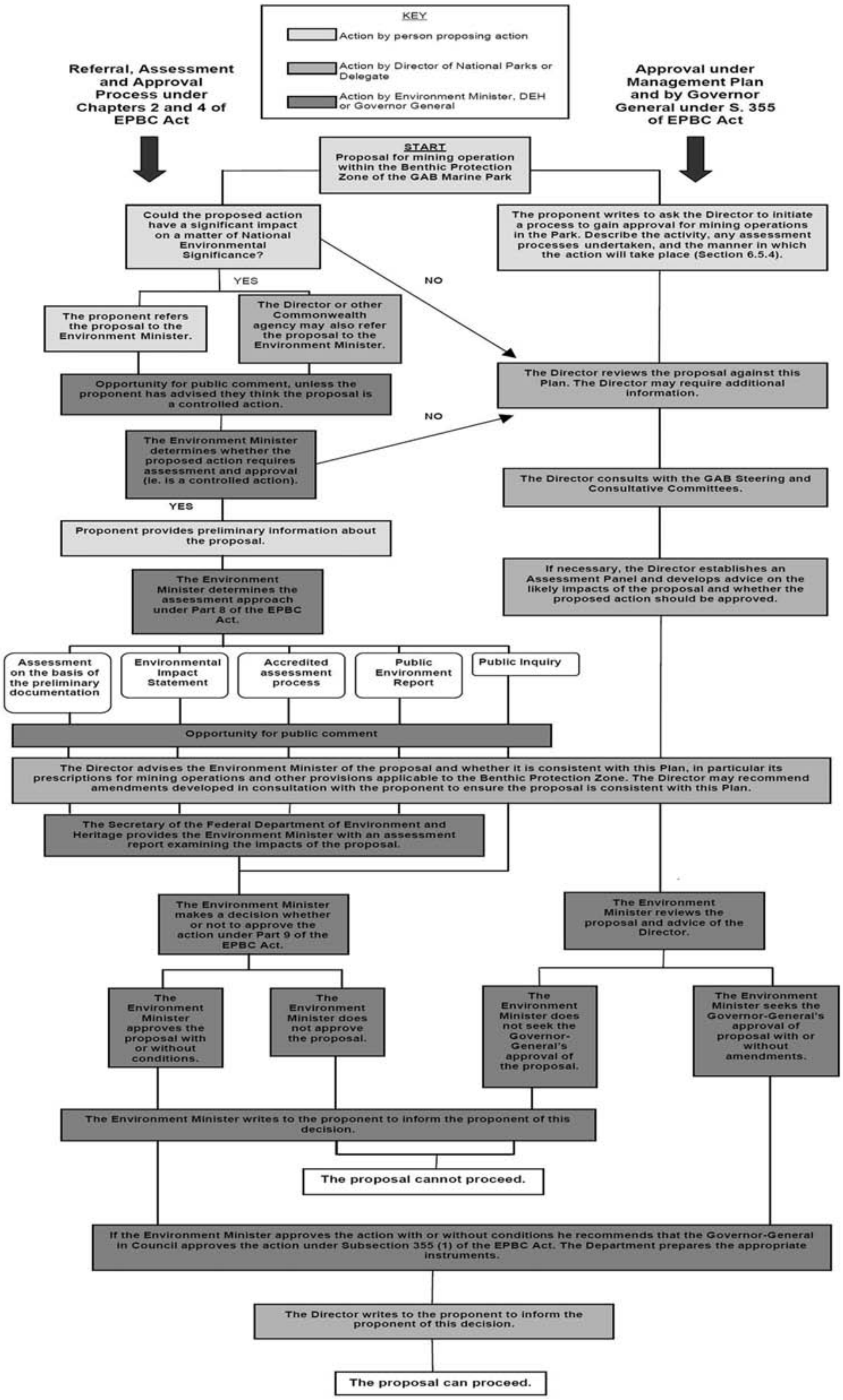


Figure 7.2: *Process for permission of mining/petroleum activity in the BPZ under the EPBC. Flowchart is modified from the Great Australian Bight Management Plan Part B. More information about the approval process for activities in areas of environmental significance can be found at* www.environment.gov.au/epbc/assessmentsapprovals

October). The rest of the BPZ allows recreational and commercial fishing, although permits are required for the latter.

7.2.3 State Fisheries

In 2005/2006 the South Australian wild fisheries were valued at $193.5 million with six major marine fisheries under state jurisdiction: Sardine, Western Zone Abalone, West Coast Prawn, Northern Zone Rock Lobster, Giant & Blue Swimmer Crab, and Marine Scalefish (Knight et al., 2007). Of these, the Sardine, Blue Swimmer Crab, Western Zone Abalone and West Coast Prawn fisheries operate only in intertidal and coastal regions, and these species spend all or most of their life cycles in shallow waters. Thus, these fisheries are highly unlikely to directly interact with any part of the Ceduna Sub-basin, although they may provide a seasonal food source to offshore migratory species. Rock Lobster, Giant Crab, and Marine Scalefish fisheries operate in parts of the Ceduna Sub-basin; however, only a limited number of these animals are caught in this region, with most fishing effort concentrated on the continental shelf.

7.2.3.1 Northern Zone Rock Lobster

Southern Rock Lobsters (*Jasus edwardsii*) represent the most valuable wild fishery in South Australia, valued at $81.1 million in 2005/2006 (Knight et al., 2007). The fishery is divided into two management zones: the Southern Zone which includes state waters east of the Murray River mouth, and the Northern Zone which includes all other state waters including the northern landward edge of the Ceduna Sub-basin (Fig. 7.3). Despite its larger geographical area the Northern Zone Rock Lobster Fishery (NZRLF) accounts for only 19% of the value of the entire rock lobster fishery, due to the prevalence of patchy granite reefs in this region, which provide less habitat for rock lobsters than the more continuous and interconnected limestone reefs of the southern zone (Linnane et al., 2007). The majority of NZRLF activity is conducted in only ten of the 42 Marine Fishing Areas (MFAs), only one of which is in the Ceduna Sub-basin, MFA 48 (Fig. 7.3). In 2005, 14% of the total NZRLF catch was fished from MFA 48, but most of this is likely to be concentrated in shallower shelf waters towards Kangaroo Island, outside the boundary of the Ceduna Sub-basin (Fig. 7.3). The NZRLF operates seasonally, from November to May. During this time, commercial vessels lower steel-framed pots covered with wire mesh to the seafloor and retrieve them the following day. Pots are deployed in large batches (usually 50-100) attached to a longline.

The Southern Rock Lobster occurs around mainland Australia, mainly in depths 1-200 m (Fig. 7.4a). Lobsters mate between April and July, and the females brood their eggs over winter for 3–4 months. Larvae hatch in early spring and spend 1–2 years freely swimming in offshore waters (Fig. 7.4b) before they metamorphose and settle on reefs (Linnane et al., 2007).

7.2.3.2 Giant Crab

The Giant (King) Crab (*Pseudocarcinus gigas)* fishery was valued at $221,000 in 2005/2006, including both by-catch of the NZRLF and targeted efforts (Knight et al., 2007). The Giant Crab fishery is managed according to the regionalisation of the NZRLF, divided into two zones and 42 MFAs (Fig. 7.3). Catch rates are higher in deeper offshore locations and reflect habitat preferences of crabs for the shelf edge (Currie et al., 2006). Like the NZRLF, the Giant Crab fishery operates November–May, with multiple baited steel-framed pots set on the seafloor overnight.

Giant crabs are endemic to Australia and occur in soft mud habitats at depths of 20–600 m (Fig. 7.4c), with the highest densities at the edge of the continental shelf (approximately 200 m). Giant crabs are highly mobile, with journeys of up to 400 km recorded. The planktonic larval phase of giant crabs lasts 3–4 months prior to settlement (Currie et al., 2006). The crabs are long-lived and slow growing, making them potentially vulnerable to overfishing and environmental impacts.

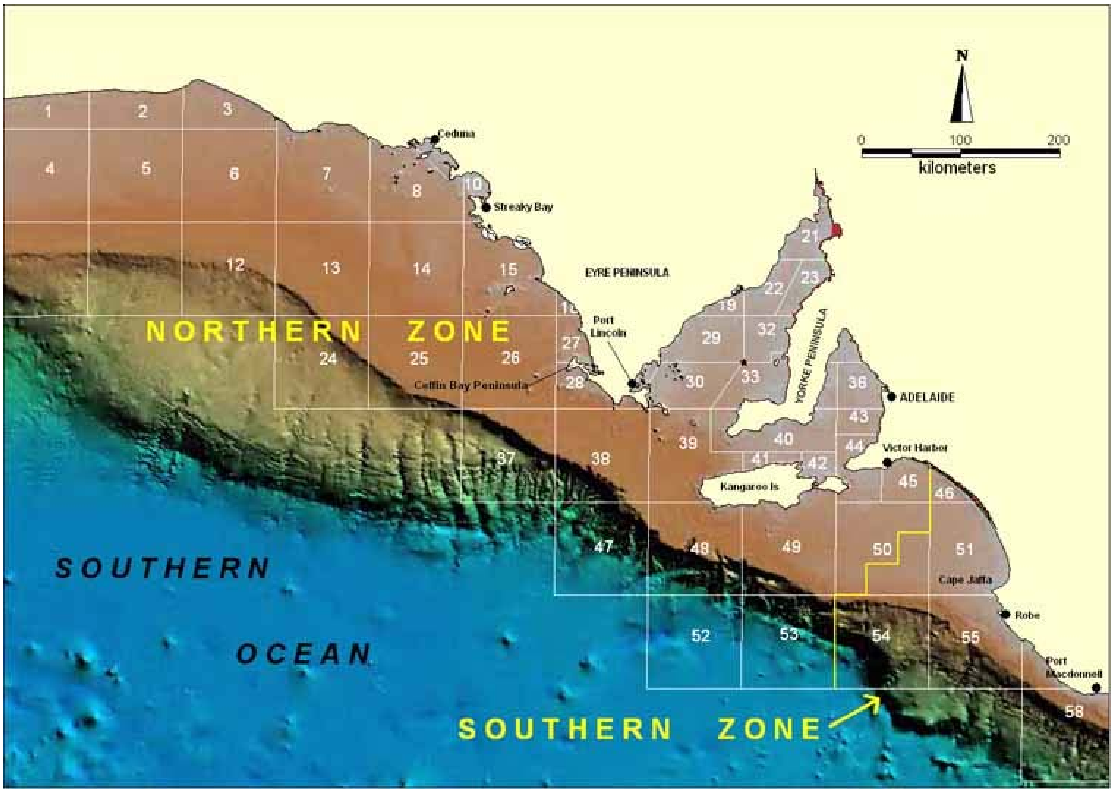


Figure 7.3: *Management areas for the South Australian Rock Lobster and Giant Crab fisheries, including the two management zones. Only areas 12, 24, 37, 47, and 48 in the Northern Zone overlap with the Ceduna Sub-basin (modified from Linnane et al., 2007).*

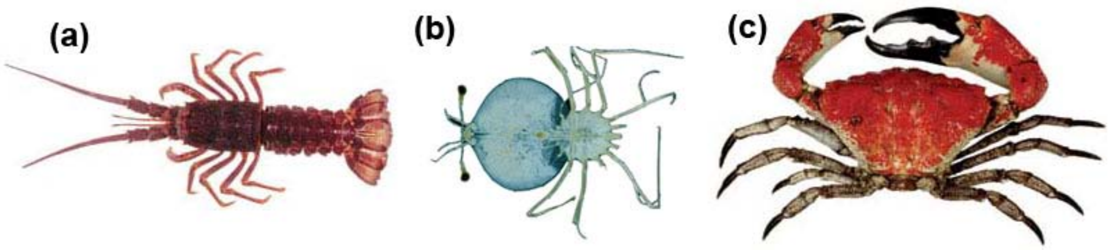


Figure 7.4: Commercially-important crustaceans associated with the Ceduna Sub-basin: (a) Southern rock lobster *(Jasus edwardsii)* occurs on the continental shelf, (b) Rock lobster larvae occurs offshore and in deeper waters, and (c) Giant crab *(Pseudocarcinus gigas)* occurs in deeper muddy habitats. Images (a) and (c) modified from *www.fish.gov.au*, and image (b) modified from CSIRO; images are not to scale.

7.2.3.3 Marine Scalefish

The Marine Scalefish industry was valued at $17.1 million in 2005/2006, with the highest values originating from King George whiting ($3.9 million), snapper ($3.3 million), garfish ($2.1 million), and calamari ($2.1 million), all of which are harvested primarily in shallow waters outside the Ceduna Sub-basin.

The Marine Scalefish Fishery includes most marine species of fish, molluscs, crustaceans, annelids and sharks, but excludes rock lobster, prawns, abalone, blue crabs and freshwater fish species, all of which are managed separately. This is a multi-method and multi-species fishery; fishing effort shifts temporally and spatially between species, depending on their relative abundance and value. Most species in this fishery are caught in coastal waters, but several species are caught in deeper waters such as those of the Ceduna Sub-basin: Bronze or Dusky Whalers (*Carcharhinus obscurus*), Ocean Jacket (*Nelusetta ayraudi*), Snapper (*Chyrsophys auratus*) and Yellow-tail kingfish (*Seriola lalandi*) (Fig. 7.5). Other species may use deeper waters as juvenile nurseries (e.g. Southern Calamari), migration routes (e.g. snapper), or vectors for larval dispersal. See Appendix B for a full list of fish records from the Ceduna Sub-basin, including commercially important species from both State and Commonwealth fisheries.

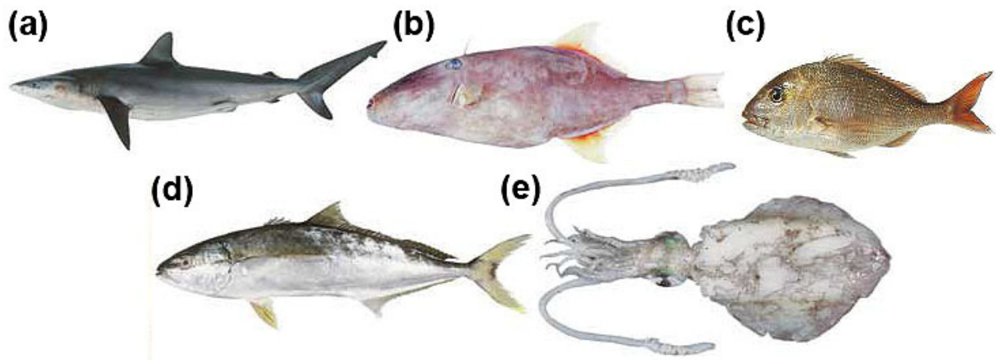


***Figure 7.5:** Targeted species of the Marine Scalefish industry associated with the Ceduna Sub-basin: (a) Dusky whaler* (Carcharhinus obscurus), *(b) Ocean jacket* (Nelusetta ayraudi), *(c) Snapper* (Chrysophys auratus), *(d) Yellowtail kingfish* (Seriola lalandi), *and (e) Southern calamari* (Sepioteuthis australis). *Images modified from www.fish.gov.au and not to scale.*

7.2.4 Commonwealth Fisheries

Five major Commonwealth-managed fisheries operate in the Great Australian Bight: Southern and Eastern Scalefish and Shark, Southern Bluefin Tuna, Skipjack Tuna, Western Tuna and Billfish, and Small Pelagic.

7.2.4.1 Southern and Eastern Scalefish and Shark

The Southern and Eastern Scalefish and Shark fishery encompasses several sectors, two of which are prevalent in the GAB: the Great Australian Bight Trawl and the Gillnet and Hook Fishery. The Great Australian Bight Trawl had a national value of $15.5 million in 2005/2006 (ABARE, 2007). It is a multi-species fishery that uses trawl gear to regularly target demersal fish. The fishery operates in two zones: 1) inshore on the continental shelf where deepwater flathead (*Platycephalus conatus*) and Bight redfish (*Centroberyx gerrardi*) are the main species taken; and 2) offshore on the continental slope where oreo dories (Oreosomatidae) and orange roughy (*Hoplostethus atlanticus*) are targeted seasonally (Fig. 7.6). All of these species have been found in or near the Ceduna Sub-basin (Appendix B). Sponges, jellyfishes, squid, sharks and rays, and a range of crustacea are also captured by these fisheries as bycatch. In July 2007, the Australian Fisheries Management Authority closed almost all trawling in the Southern and Eastern Scalefish and Shark fishery in depths below 700 m.

The Gillnet and Hook Fishery had a national value of $21.5 million in 2005/2006 (ABARE, 2007) and encompasses a variety of fishing methods depending on the species targeted. Shark hooks and gillnets primarily target gummy sharks (*Mustelus antarcticus*); scalefish hooks target blue eye trevalla (*Hyperoglyphe antarctica*) and ling (*Genypterus blacodes*); and fish traps target ling (Fig. 7.7). All of these species have been found in or near the Ceduna Sub-basin (Appendix B).

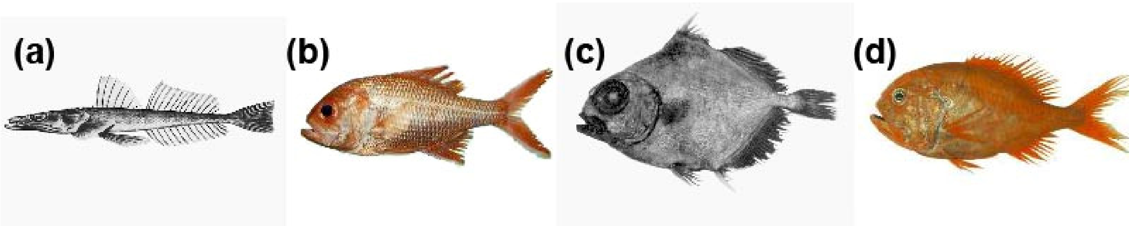


***Figure 7.6:** Targeted species for the Great Australian Bight Trawl found in or near the Ceduna Sub-basin: (a) Deepwater flathead* (Platycephalus conatus)*, (b) Bight redfish* (Centroberyx gerrardi)*, (c) Spiky oreo* (Neocyttus rhomboidalis)*, and (d) orange roughy* (Hoplostethus atlanticus)*. Images modified from www.fishbase.org and not to scale.*

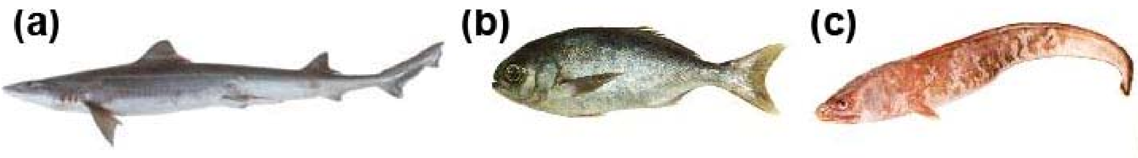


***Figure 7.7:** Targeted species for the Gillnet and Hook Fishery found in or near the Ceduna Sub-basin: (a) gummy sharks* (Mustelus antarcticus)*, (b) blue eye trevalla* (Hyperoglyphe antarctica)*, and (c) ling* (Genypterus blacodes)*. Images modified from www.fishbase.org and not to scale.*

7.2.4.2 Southern Bluefin Tuna

Southern Bluefin Tuna (*Thunnus maccoyii*) is an extremely valuable single-species fishery, with a national value of $37.5 million in 2005/2006 (ABARE, 2007) (Fig. 7.8a). The majority of fish landed in this fishery are captured in oceanic purse seines off the GAB and the southeastern coast of Australia. After capture, live tuna are often transported to Port Lincoln in southeastern Australia and grown in fish-pens to increase their value on the Japanese market.

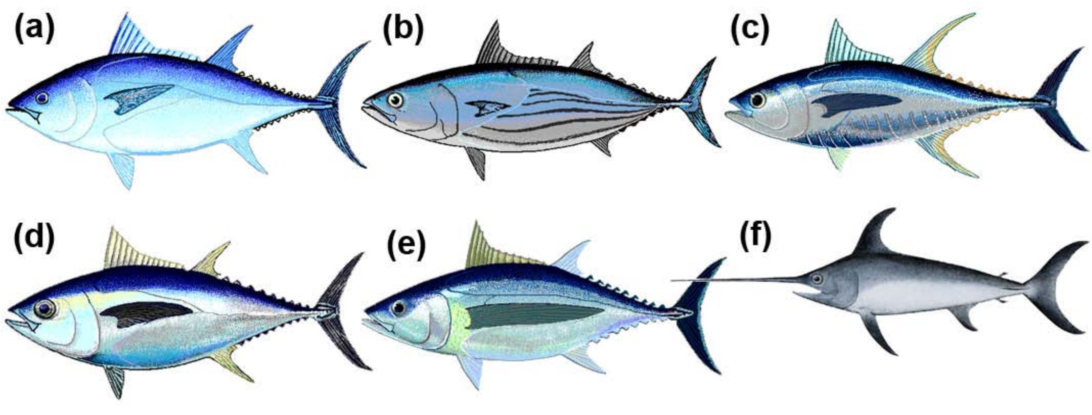


***Figure 7.8:** Targeted species for the Southern Bluefin, Skipjack, and Western Tuna and Billfish fisheries found in or near the Ceduna Sub-basin: (a) Southern bluefin tuna (*Thunnus maccoyii*), (b) Skipjack tuna* (Katsuwonus pelamis)*, (c) Yellowfin tuna* (T. albacares)*, (d) Bigeye tuna* (T. obesus)*, (e) Albacore tuna* (T. alalunga)*, and (f) Swordfish* (Xiphias gladius)*. Images modified from www.fishbase.org and not to scale.*

T. maccoyii is a highly migratory species with a broad southern distribution that includes the Great Australian Bight. This species has also been captured in pelagic waters over the Ceduna Sub-basin (Appendix B) and is prevalent in the GAB during summer due to an increase in prey associated with up-welling (Willis and Hobday, 2007). The species usually stays within 20 m of the surface and schools at bathymetric features where pilchards, squid, crustaceans or other prey are likely to be (Willis and Hobday, 2007).

7.2.4.3 Skipjack Tuna

The Skipjack tuna (*Katsuwonus pelamis*) fishery was valued at $1.4 million in 2003/04 (DEH 2005). Almost 98% of all fish landed are skipjack (Fig. 7.8b), with other species (e.g. bigeye and yellowfin tuna, frigate mackerel, sharks, mahi mahi, rays and marlins) captured rarely as by-catch. Oceanic purse seines are used to catch over 95% of total landings for this fishery, although mid-water longlines and hand lines are also used. Like southern bluefin tuna, skipjack are captured off the south-eastern to western coasts of Australia, and are then transported back to Port Lincoln.

7.2.4.4 Western Tuna and Billfish

The Western Tuna and Billfish Fishery were worth $2.7 million in 2005/2006 (ABARE, 2007). A variety of tuna and billfish are captured using sub-surface longlines and oceanic purse seines. The fishery has a very broad geographic extent that extends westward from the Cape York Peninsula to the South Australian/Victorian border. Species targeted by this fishery include the yellowfin tuna (*Thunnus albacares*), bigeye tuna (*T. obesus*), albacore tuna (*T. alalunga*), and Broadbill swordfish (*Xiphias gladius*), all of which have been found in the Ceduna Sub-basin (Fig. 7.8c-f) (Appendix B).

7.2.4.5 Small Pelagic

The Small Pelagic Fishery is a relatively small, low-value temperate fishery that extends beyond 3 nm south of latitude 28°S in Queensland around to 31°S in Western Australia. The fishery is separated into four fishing zones, with the GAB falling within zone B. A variety of small pelagic fish are captured for bait and fish meal using oceanic purse seines and mid-water trawls, including redbait (*Emmelichthys nitidus*), jack mackerel (*Trachurus symmetricus, T. declivis, T. novaezelandiae*), and blue mackerel (*Scomber australasicus*). The latter three species have been found in the Ceduna Sub-basin (Fig. 7.9) (Appendix B). Although this is a small industry, small pelagic fishes are a critical component of mid-trophic food webs, and are therefore fundamental to the functioning of pelagic ecosystems.

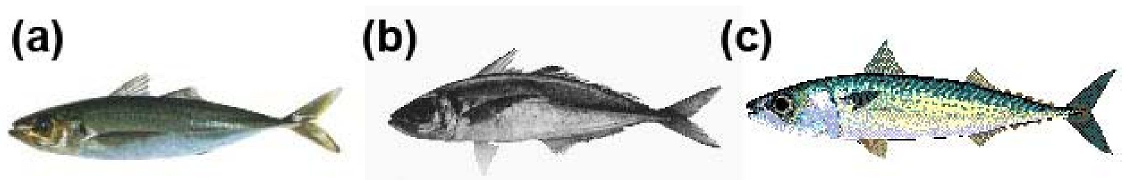


Figure 7.9: *Targeted species for the Small Pelagic Fishery found in or near the Ceduna Sub-basin: (a) Greenback jack mackerel* (Trachurus declivis)*, (b) Yellowtail jack mackerel* (T. novaezelandiae)*, and (c) Blue Mackerel* (Scomber australasicus)*. Images modified from www.fishbase.org and not to scale.*

7.3 BIOTA OF THE CEDUNA SUB-BASIN

The Ceduna Sub-basin is home to a variety of animals, including both commercially and ecologically important species. Most of our knowledge about ranges, life histories, and environmental impacts stems from species important to industry (e.g. fish) or conservation (e.g. cetaceans). In contrast to vertebrates, the ranges of most marine invertebrates in southern Australia are relatively unknown, with the exception of commercially important species, invasive pests, and certain taxa surveyed from the BPZ such as sponges (Sorokin et al., in press). Although there are records of marine invertebrate ranges in southern Australia, knowledge of invertebrate occurrences and ranges in the GAB is extremely limited, and information about biota in the Ceduna Sub-basin is almost non-existent. Much of the biological information pertaining to the Ceduna Sub-basin must therefore be extrapolated from known large-scale patterns, as well as regional data from the Great Australian Bight.

7.3.1 General: Relationships to Physical Variables

Abiotic variables are often used as surrogates to predict biodiversity and species abundance, particularly in deep waters and other areas that are difficult or costly to biologically sample. Recent developments in swath mapping, sediment characterisation, and oceanographic modelling have greatly facilitated the collection of physical data to be used as potential surrogates. Slope, depth, sediment grain size, substrate type, and sediment mobility have all been linked to benthic species or communities (Post et al., 2006 and references therein). Unfortunately, very little data exists for the utility of surrogates in the deep sea, and most of our knowledge of the relationships between abiotic and biotic variables comes from the continental shelf (Richardson et al., 2005) Nevertheless, the integration of multiple abiotic factors has already been used to identify seascapes, regions of shared abiotic characteristics that may represent regional biodiversity (Whiteway et al., 2007; Section 8).

Some global and other large-scale patterns of marine biodiversity are probably due to one or more geological or oceanographic factors:

- *Latitudinal gradients.* Diversity of some offshore and deep-sea benthos, including bivalves, gastropods, and isopods, show clear latitudinal gradients in the northern hemisphere and high levels of variation across regions in the southern hemisphere (Gray, 2001; Rex et al., 1993). The cause of latitudinal gradients and the difference between hemispheres remain unknown.
- *Intermediate depth & distance.* Across the continental shelf, species richness may be highest at intermediate depths and distances offshore (Cleary et al., 2005). There is not enough data from the deep sea to draw comparable relationships between the shelf and deep sea (Gray, 2001).
- *Canyon biodiversity.* Biodiversity is often higher inside submarine canyons than outside, probably due to detritus transport driven by slope and oceanographic conditions (Vetter and Dayton, 1998; 1999). Submarine canyons are also more likely to contain endemic fauna than nearby non-canyons at similar depths (Vetter and Dayton, 1998; 1999), due to geographic barriers to recruitment and evolutionary isolation.
- *Deep sea biodiversity.* Surveys over the past two decades have revealed that the deep sea has a high level of biodiversity, possibly related to patchiness of organic input coupled with low productivity, lack of barriers to dispersal, and the regular occurrence of intermediate disturbances, which balance species competition and extinction (Grassle and Morse-Porteous, 1987; Kukert and Smith, 1992).

7.3.2 Regional: Great Australian Bight

The Great Australian Bight is part of the Southern Province as defined by the draft National Benthic Marine Bioregionalisation for Australia. Bioregionalisations were based on structure of demersal fish communities, as well as large-scale geomorphology. Provinces such as the Southern Province represent areas of regional endemism (Heap et al., 2005).

7.3.2.1 Cetaceans

The southern right whale (*Eubalanea australis*) is the most common baleen whale in the GAB and is listed as 'endangered' under the *EPBC* (Fig. 7.10). Due to the migratory nature of this species, it is difficult to estimate population sizes, but there are perhaps 60,000 right whales in the southern hemisphere, with the transient Australian population estimated to be around 1500 individuals. During the austral winter, whales migrate from their feeding grounds in the Southern Ocean to breeding grounds along the southern Australian coast (Fig. 7.10), one of only two habitats in the world in which this species will reproduce (Edyvane, 1998). Although their exact migratory routes are unknown, a large proportion of whales heading to Australian breeding areas probably pass through the Ceduna Sub-basin. Once in coastal waters, most animals aggregate near the Head of Bight within a narrow band no more than 1 km from the coast. They are protected year-round in South Australia's Whale Sanctuary and are protected during breeding season in the GABMP Marine Mammal Protection Zone, which excludes all vessels from the area between 1 May and 31 October.

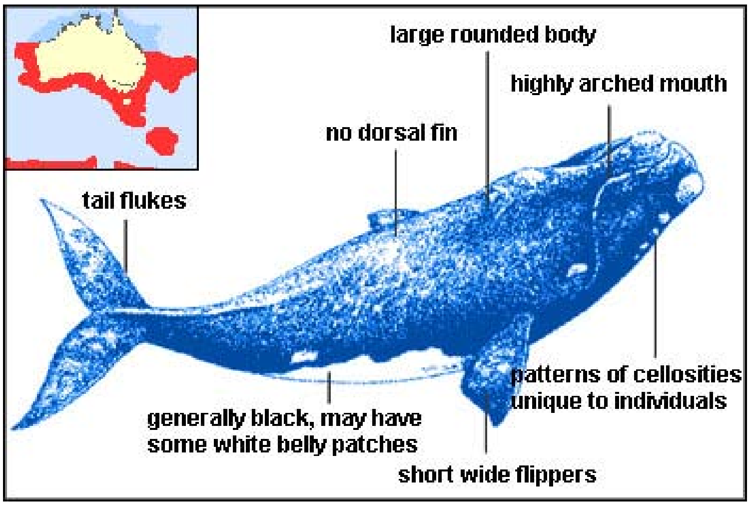


Figure 7.10: *Identifying features of the southern right whale (*Eubalanea australis*) and the range of the Australian population. Image modified from www.whales.sa.gov.au.*

The southern right whale is vulnerable to extinction due to a combination of factors. This species has a low birth rate, averaging one calf every three years (Edyvane, 1998). Low genetic diversity associated with low abundances also makes this species vulnerable to collapse. In addition, the habitat requirements for breeding and calving bring the whale in close proximity to human activity where vessel collisions, noise, and pollutants may all negatively impact fitness. Finally, southern right whales swim slowly, often near the surface; and this behaviour increases their risk of vessel collisions and harassment. For more information, refer to the Commonwealth's Southern Right Whale Recovery Plan 2005-2010.

At least 16 other species of cetacean have been recorded in the GAB, including migratory species such as sperm, blue, minke and humpback whales and residential species such as killer whales and toothed whales (i.e. dolphins) (Edyvane, 1998). Under the *EPBC Act*, all cetaceans are protected in Australian waters, and it is an offence to kill, injure, take, trade, keep, move, harass, chase, herd, tag, mark or brand any cetacean. Severe financial and legal penalties apply. Anyone undertaking an activity that may impact on a cetacean must be granted an official permit from the Minister, and permits are not issued for killing or taking an animal for live display. The National Cetacean Action Plan lists relevant threats to cetaceans in Australian waters; including immediate threats via shipping strikes, disturbance, harassment, and degradation of habitat; and long-term threats via contamination of marine environments by chemical pollutants.

7.3.2.2 Other Vertebrates

The GAB is home to many other species of ecological and commercial importance. Several fisheries operate in the region (Sections 7.2.3 and 7.2.4), and the commercially important southern bluefin tuna (*Thunnus maccoyii*), Australian salmon (*Arripis truttaceus*), and Australian herring (*Arripis georgianus*) are influenced by the Leeuwin current and associated up-welling events (Sections 6.3.2 and 6.3.5).

The Australian sea lion (*Neophoca cinerea*) is listed as 'near threatened' under the *EPBC Act.* It is endemic to southern Australia, and the cliffs along the GAB coast provide a significant habitat to breeding colonies (McLeay et al., 2003). The Australian sea lion inhabits coastal waters and does not venture off the shelf.

Several other species that are known or predicted to occur in the GAB are considered to be of conservation significance. Of these 91 species, 69% are sea mammals or seabirds which occur or aggregate near the coast, and the rest are fish. There are no invertebrates on the list (see Appendix C in *Great Australian Bight Marine Park Management Plan 2005-2012*).

7.3.2.3 Invertebrates

The Great Australian Bight supports one of the world's most diverse soft-sediment ecosystems (Ward et al., 2006), with exceptionally rich assemblages of ascidians, nudibranchs, and bryozoans (Edyvane, 1998). Pelagic sampling from the BPZ shelf has revealed diverse communities of zooplankton, including salps, chaetognaths, copepods, crustacean and fish larvae, pteropods, euphausids, amphipods, and polychaetes (Hobday, 2001). The GAB has an extraordinary level of endemism; 85% of fish, 95% of molluscs, and 90% of echinoderms are estimated to be endemic to southern Australia (Poore, 1995), compared to under 15% endemism for each of these groups in the tropical regions of Australia (Poore, 1995). Similarly, the GAB has one of the world's highest species richness of macroalgae, with over 1200 species (McLeay et al., 2003) and 75% of red algae species endemic to southern Australia (Womersley, 1990).

The high levels of species richness and endemism in the GAB may be explained several ways. The Leeuwin current allows for incursions of tropical species to the region (Section 6.3.2), and over time, certain of these species may have established isolated populations and evolved independently of their tropical source populations. In addition, the continental shelf is unusually wide in the GAB, providing a relatively large area in which many shallow water species can exist. Finally, the relative isolation of the GAB due to geographic barriers allows species to evolve in a defined region, with minimal emigration to other parts of Australia.

Compared to fish and sea mammals, there is little known about marine invertebrates in the GAB, other than the broad trends mentioned above. One of the main hindrances in determining the diversity of invertebrates is the severe lack of knowledge about geographic distributions, basic biology, and even the existence of many invertebrate species. In a survey of sponges in the BPZ, only 25% (27 out of 109) of taxa were able to be identified to species level, and of these, 48% (13 out of 27) were new records for the GAB (Sorokin et al., in press). It therefore seems likely that many invertebrate species in the GAB have not even been recorded yet.

7.3.2.4 Summary of GAB Biodiversity Patterns

Much of the regional information about biodiversity in the Great Australian Bight is derived from the continental shelf, and very little is known about biodiversity along the lower continental slope and in deeper waters of the GAB. Nevertheless, some patterns of biodiversity in the GAB have been observed, although their applicability to deeper waters or other taxonomic groups remains uncertain:

- *Overall biodiversity.* The GAB supports a high number of invertebrate species, including endemic species, particularly among ascidians, bryozoans, and sponges.
- *Demersal fish.* Offshore community patterns of demersal fish may be less complex than inshore provinces (Last et al., 2006). In deep water, demersal fish may exhibit strong bathymetric zoning (Last et al., 2006).
- *Feeding mode.* Suspension feeders were the most common feeding group collected on the continental shelf of GABMP BPZ, representing 86% of species found. This is unusually high and may reflect lack of terrigenous sediment input, which limits the food available to deposit feeders (Ward et al., 2006).
- *Distribution of sessile fauna.* As groups, sponges, ascidians, and bryozoans are broadly distributed on the continental shelf of the GAB, but individual species may have much more limited distributions. For example, Ward et al. (2005) found that these groups occurred at approximately 90% of the benthic sites sampled; but Sorokin et al. (in press) found that most demosponge species collected in this area were only recorded at less than 7% of the sites.
- *Substrate and sessile fauna.* The outer shelf and upper slope are often dominated by abundant bryozoan and sponge communities, which occur more frequently on hard substrate than soft. Among hard substrata, Tertiary or Pleistocene limestone not covered in sediment has the most bryozoans, sponges and other sessile invertebrates. Rippled sandy bottoms have almost no epibenthos (Richardson et al., 2005).
- *Biodiversity, depth, and grain size.* On the continental shelf, species richness and biomass decline with increasing depth and proportion of mud in the sediments, except for crabs and shrimp which increase with mud content (Ward et al., 2006). Smaller sessile species may be more prevalent in deeper waters with higher proportions of mud, as they may be able to better use fine sediments (Sorokin et al., in press).

7.3.3 Local: Ceduna Sub-basin

Biological information from the Ceduna Sub-basin is extremely limited and confined to records from two databases (OBIS, Museum of Victoria) and three surveys (GABSEEPS, AUSCAN,SS01/2007; Fig. 7.1). Specific results from these surveys are presented below, with a general synopsis of biological patterns in the sub-basin at the end of the section.

7.3.3.1 Databases

The Ocean Biogeographic Information System (OBIS) is an initiative of the Census of Marine Life whereby organisations and individuals contribute records of locations of marine species; this information is then freely available over the web at www.iobis.org. OBIS allows the user to search for all species recorded in a specified latitude/longitude quadrat. The Ceduna Sub-basin was searched using 1° quadrats, and records from a total of 185 species were returned, most of which were fish (84%). Most fish species were commercially important, either targeted directly or caught as bycatch (Appendix B). Invertebrate groups were poorly represented, including only molluscs (9%), cnidarians (5%), arthropods (2%) and an echinoderm (<1%). The full species list is compiled in Appendix B, along with the particular quadrats in which each species was found. This table in no way comprehensively represents the fauna of the Ceduna Sub-basin, because it is heavily biased towards commercially-important species, as evident by the large number of fishery species.

Furthermore, ranges for species cannot be determined due to the many sampling methods and levels of effort used to compile these records. For example, it seems highly unlikely that Quadrat A actually contains more species than Quadrat B, which had none (Appendix B). Rather, it is more likely that Quadrat A was sampled more frequently, possibly due to its inclusion of the shelf, which is usually sampled more frequently than deeper waters.

Museum of Victoria records of the Ceduna Sub-basin list 22 invertebrates species, almost equally divided among arthropods (32%), echinoderms (36%), and molluscs (32%). Only two species were collected from more than one location (*Parapagurus bouvieri* and *Histioteuthis miranda*). The full species list is compiled in Appendix C, along with the latitude and longitude at which the species was collected.

7.3.3.2 GABSEEPS

The GABSEEPS survey (Geoscience Australia marine survey 231) was conducted in February 2001 to identify warm seeps in the Great Australian Bight and assess them for minerals. A secondary objective was to maximise the amount of data collected through piggy back projects that would add to national petroleum prospectivity and biodiversity databases. As part of this project, a bottom-towed video camera was deployed, grab and box core samples were collected, and near-surface zooplankton was sampled.

Sampling included sites in and around the Nullarbor Canyon and the Benthic Protection Zone, with video from six sites, plankton tows from 13 sites, and dredges from 15 sites. Dredge performance was extremely poor, and very few samples were returned, including only a handful of corals, some ophiuroids, unidentified meiofauna, a crab, and a dory. Both daytime and nocturnal plankton tows were undertaken, but no results were recorded, with the exception of small and large salps noted at one of the holes in the Nullarbor Canyon. Video was a success at most sites, with the exception of two sites where the video was unfocused. Bioturbated sediment and scattered fauna were observed at depths of 1280–1425 m, indicative of soft-sediment communities (two northernmost points on Fig. 7.1). In contrast, abundant fauna including corals and fish were recorded from lava outcrops and bulbous manganese crusts at an approximate depth of 1600 m (middle point on Fig. 7.1, immediately south of the two points previously mentioned). The orientation of gorgonians at this site suggested a southeasterly or northeasterly bottom current. There were no biological notes from the final site.

No known effort has been made since the GABSEEPS survey to identify zooplankton or benthic fauna from samples or video, and all known results from this survey are confined to brief ship logs and notes
(www.marine.csiro.au/nationalfacility/franklin/plans/2001/fr01_01p.html).

7.3.3.3 AUSCAN

The AUSCAN (AUStralian CANyons) survey was conducted in Feb–March 2003 to investigate Australia's southern margin through multibeam swath-mapping, geophysical profiling, oceanographic measurements, and geological and biological sampling. Only a minor component of the survey involved biological sampling, and this was done by deploying plankton nets and benthic sleds in and around Sprigg and Du Couedic Canyons on the far eastern side of the Ceduna Sub-basin (Fig. 7.1). Vertical plankton tows with a mesh size of 300 µm were undertaken at 10 sites at depths of 130–200 m, and horizontal tows with a mesh size of 150 µm were done at 3 sites at depths of 20–30 m. Benthic sleds were deployed at eight sites for various durations (Fig. 7.1), and samples were identified only at a broad taxonomic level.

Samples retrieved from plankton tows suggest that the eastern part of the Ceduna Basin contains a diversity of zooplankton. Approximately 80% of the total biomass was represented by scyphozoans, ctenophores, copepods, isopods, and decapods. The tows also contained forams, radiolarians, acantharians, and pteropods, as well as coelenterate, fish, and crustacean larvae. The foraminiferal assemblages were similar across all sites and were dominated by *Globigerinoides ruber*, a direct reflection of the season in which samples were collected (Appendix 9 in Hill and De Deckker, 2004).

In contrast, benthic sleds did not recover a large number of specimens, with the most number of specimens (159) and species (47) collected on the continental shelf at a depth of 161 m (Fig. 7.11) (Appendix 10 in Hill and De Deckker, 2004). Specimens included mostly macro-invertebrates from a range of groups; including cnidarians, crustaceans, sponges, echinoderms, polychaetes, and molluscs. A few ascidian, salp, bryozoan and fish specimens were also recovered. Samples were lodged at the South Australian Museum, but there have been no efforts to further identify specimens to a finer taxonomic level (T. Laperousaz, SA Museum Marine Invertebrates Collection Manager, pers. comm.).

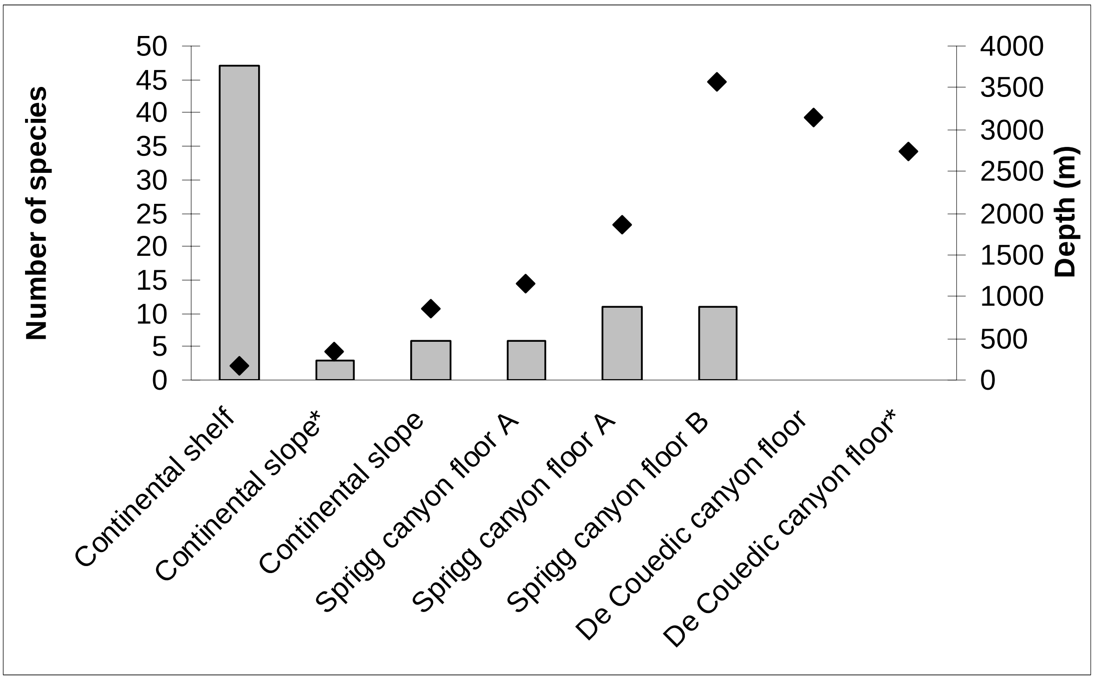


***Figure 7.11**: Number of species returned from sled deployments at measured depths from the AUSCAN survey in 2003. No specimens were collected in the De Couedic canyon sites. Asterisks mark the 250 kg sled; all other sites were sampled with a 1-tonne sled. Deployment times varied across sites.*

As stated in the AUSCAN report, 'the quantity of benthos recovered in the canyons… was disappointing', with two sites returning no macrofauna, and the other sites returning a lower number of specimens and species than expected. These results may reflect a lack of macrofauna in this region, but this seems highly unlikely in light of the range of depths sampled and the known diversity of macrofauna in the GAB, particularly canyons (Section 7.2.2). Furthermore, benthic sleds returned some gorgonians and bryozoans, and these groups are often associated with other sessile and sedentary invertebrates to which they provide food and habitat. The rich diversity of zooplankton collected from the tows would also logically be associated with a similarly rich benthos, due to benthic-pelagic coupling and presence of pelagic larvae from benthic fauna. It seems likely that the sled was inadequate for the task, possibly due to unsuitable terrain for sled sampling, as the two sites that returned no samples were located inside canyons (Fig. 7.11).

Excluding the potential problems with the benthic sled, several other issues prohibited standardisation and proper analyses: Two different sizes of benthic sled were used, a 1-tonne sled and a much smaller 200 kg sled. Sleds were deployed for varying times, and the duration of deployment at two sites was not recorded. Finally, the depth varied across all sites between 161 and 3570 m, with no replication of any sites at similar depths. The combination of these problems with extremely low sample numbers means that the benthic data is of very little practical use, other than to possibly identify new species or distribution of known species; but even this cannot be attempted until fine-scale taxonomic identification is complete.

7.3.3.4 SS01/2007

The SS01/2007 seeps survey was conducted in Feb–March 2007 to investigate the potential for petroleum resources though dredging basement rocks and mapping potential seeps. As part of this project, a video camera was deployed in the northwestern part of the Ceduna Sub-basin to explore pockmarks noted on the seafloor, providing 28 minutes of footage of the epibenthos along a 1.3 km transect (714-740 m depth, 21.3°C) (Fig. 7.1).

Sediment was sandy mud, mostly hummocky due to mounds formed via bioturbation, possibly by shrimp or gobies (Fig. 7.12). Particles of various sizes were prevalent in the water, many clearly zooplankton due to obvious movement independent of any current. Video was low-quality with no size reference, but some fauna could be identified to a broad taxonomic level. Based on a conservative estimate using only obvious morphological differences, at least eighteen fish and invertebrate species were detected on the seafloor and in the water immediately above it, excluding small zooplankton (Table 7.2; Fig. 7.13). Most species were recorded only once, with several exceptions. An isolated sessile invertebrate (Unknown D) was found relatively frequently; due to the quality of the footage it was impossible to determine if this was a sponge, ascidian, or some other animal (Fig. 7.13e). A long-legged pinkish invertebrate drifted past the camera on several occasions (Fig. 7.13a). Based on the unequal sizes of the legs and the robust body, this is unlikely to be a pycnogonid (D. Staples, pers. comm.) and is much more likely to be the larval phyllosoma stage of a crustacean.

***Table 7.2**: Conservative estimate of species recorded from SS01/2007 video. Numbers indicate individuals found per species.*

Anemone	Fish sp. A	Fish sp. B	Fish sp. C	*Helicolenus* sp. [1]	Unkn B [2]	Unkn C [3]	Unkn E [4]	Unkn G [3]	Unkn H [3]	Unkn shrimp [5]	Unkn A [6]	Unkn F [4]	Unkn I [7]	*Mora moro* [8]	Elongated fish	Phyllosoma	Unkn D [9]
1	1	1	1	1	1	1	1	1	1	2	2	2	2	3	5	8	15

[1] Based on tentative identification from Hiroyuki Motomura, Australian Museum. May also be *Trachyscorpia* sp.
[2] Thin cylindrical appearance; possibly a tubeworm
[3] Sessile benthic invertebrate
[4] Possibly a worm
[5] Bright red and very quick
[6] Spines or tentacles visible; possibly an anemone or urchin

[7] At least three appendages protruding from sediment
[8] Based on tentative identification from Mark McGrouther, Australian Museum
[9] Sessile benthic invertebrate with two symmetrical lobes or appendages protruding from sediment with nodule or lobe in centre

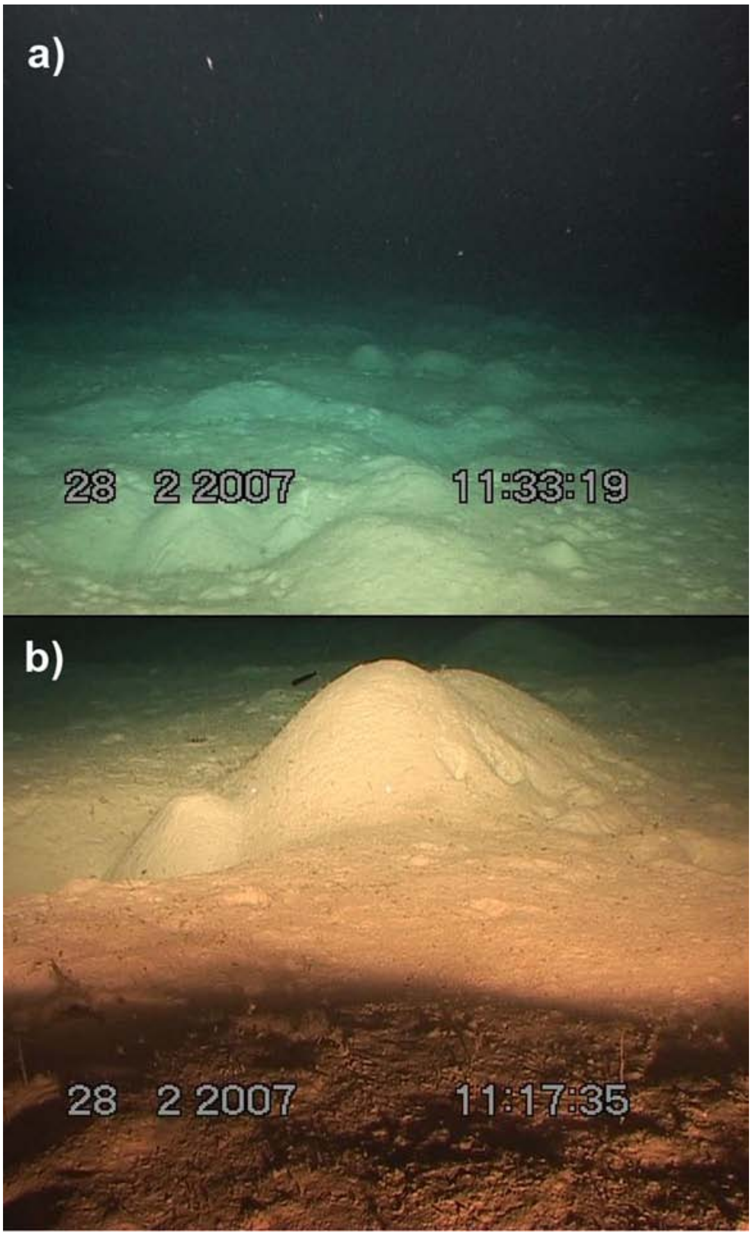


Figure 7.12: *Image captures from the SS01/2007 video in the northwestern Ceduna Sub-basin, showing seafloor characters including: a) typical hummocky terrain (depth 733 m), and b) mounds formed via biological activity with sandy mud in the foreground (depth 716 m).*

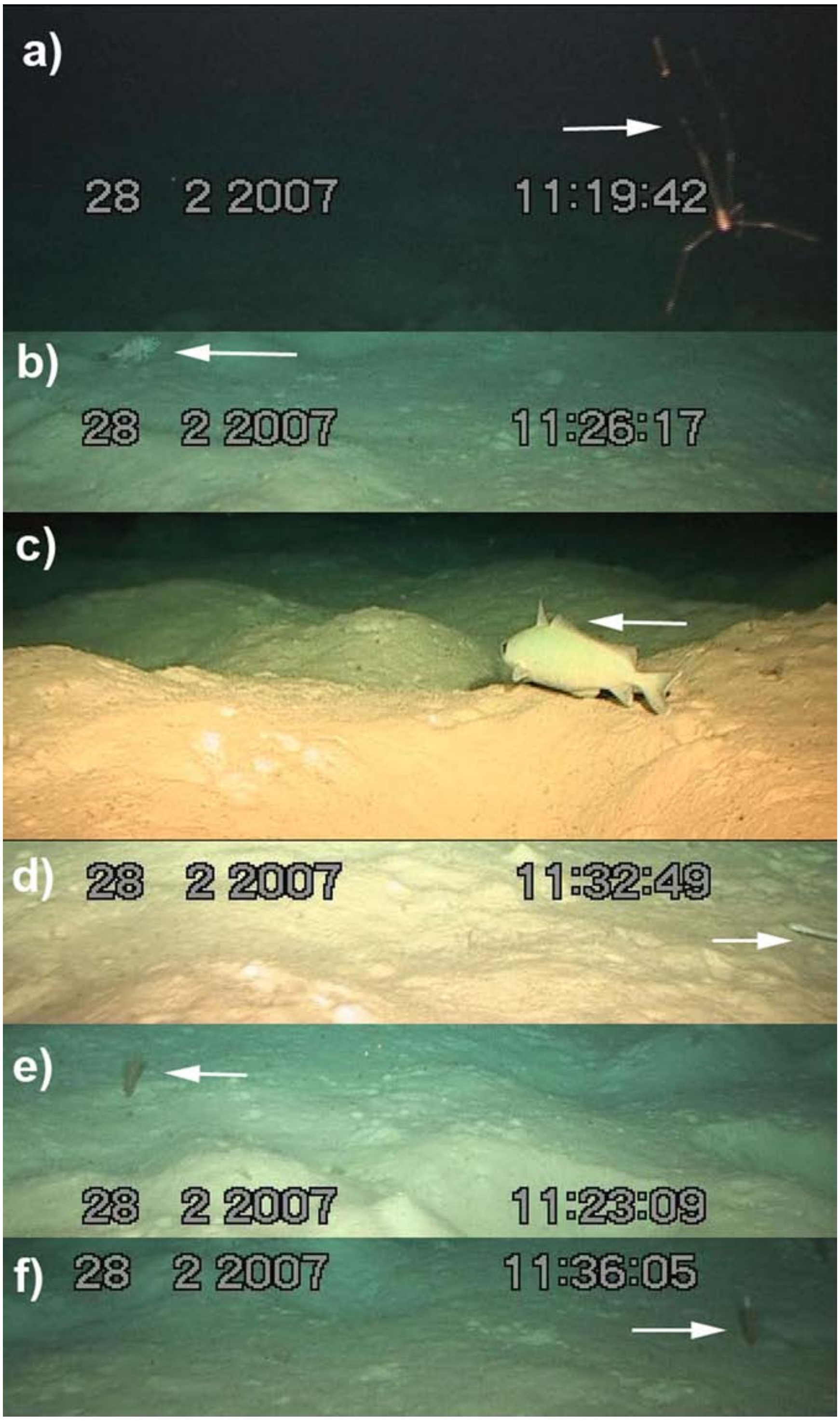


Figure 7.13: *Image captures from the SS01/2007 video at 714-740 m in the northwestern Ceduna Sub-basin, with organisms marked by arrows: a) unknown pelagic organism, possibly crustacean phyllosoma (depth 718 m); b) Helicolenus* sp. *(724 m); c) Mora moro (715 m); d) elongated fish (732 m); e) sessile invertebrate (Unknown D) found relatively frequently (721 m); f) sessile invertebrate (Unknown F) (737 m). The width of each photo represents the entire width of video, but due to vertical movement of the camera and lack of spatial reference points, the size of these organisms cannot be compared.*

7.3.3.5 Summary of Ceduna Sub-basin Biodiversity Patterns

It is difficult to identify biodiversity patterns specific to the Ceduna Sub-basin, because not enough is known about the species which occur in this region. Nevertheless, based on more broad-scale patterns (Sections 7.3.1 and 7.3.2.4) and some detailed knowledge of geologic and oceanographic characteristics of the area, several local patterns seem likely.

- *Diversity of fauna.* The Ceduna Sub-basin is home to a broad range of fauna, including fish and sessile, mobile, epibenthic and infaunal invertebrates, as confirmed by the few samples and video collected from the region. Unfortunately, species richness, abundance, and endemism for most groups remain unknown due to lack of fine-scale taxonomic identification on the few samples that exist.
- *Nursery.* The Ceduna Sub-basin may act as a nursery for some coastal species, including the commercially important southern calamari and rock lobster, as indicated by OBIS records of some coastal species in the deeper waters of the Ceduna Sub-basin. Larvae and juveniles of these and other species may use the relatively large expanse of continental slope to develop and grow before migrating to inshore waters.
- *Canyons.* The lower continental slope of the Ceduna Sub-basin is cut by canyons, particularly in the eastern sector of the basin, which may contain a high number of endemic species, most of which have yet to be discovered (Section 7.3.3.3).
- *Mud-dominated communities.* Much of the Ceduna Sub-basin sediments are dominated by fine sediments (Fig. 5.1) so species and communities associated with mud are expected to dominate benthic habitats here. This may result in a larger number of smaller sessile species than those on the continental shelf, at least among sponges (Sorokin et al., in press).

8. Seascapes

8.1 INTRODUCTION AND DATA SOURCES

A significant challenge facing marine scientists is the development of a robust and defensible way to represent potential seabed habitats and ecosystems based on easily mapped and spatially-abundant biophysical properties. Geoscience Australia has undertaken a classification of biophysical datasets to create seabed habitat maps or ‘seascapes’ for Australia’s marine region (see Harris et al., 2007 for background). The procedure for creating seascapes is inspired by the shelf classification applied in eastern Canada by Roff & Talyor (2000) and Roff et al. (2003). It represents one evidence-based method that can be applied to ecologically-meaningful biophysical data in the marine environment to spatially represent habitats and ecosystems (Fig. 8.1). Each seascape corresponds to a region of seabed that contains similar biophysical properties and by association similar seabed habitats and communities. Maximum seabed biodiversity is assumed to coincide with maximum seabed habitat heterogeneity, which is likely to occur in regions of maximum seascape diversity. The shelf classification of Roff & Taylor (2000) has been adapted by Geoscience Australia for a new analysis of national data to derive seascapes for Australia’s marine region (Whiteway et al., 2007).

The assumption that biophysical properties can be used as surrogates to represent marine biodiversity is central to the seascapes approach. While linkages between the biophysical environment and biota seem intuitive, understanding how the biota relates to biophysical properties is only half the story. It is equally important to identify which biophysical properties are important. Biophysical variables that are most suited to deriving seascapes are those that are easily quantified, have a wide distribution, and a known and measurable association with the biota (Post, 2008; Bax & Williams, 2001). Given the availability and distribution of common datasets for Australia’s marine region, separate seascapes were derived for the shelf (on-shelf) and slope, rise and abyssal plain/deep ocean floor (off-shelf) environments (Table 8.1). All data were interpolated from point data and gridded at 0.05° (~5 km) resolution to provide 100% coverage of the sea floor.

Table 8.1: *Datasets used in the derivation of seascapes.*

Dataset	Units
On-shelf	
Water depth	(m)
Sea Floor Temperature	(°C)
% Gravel	(weight %)
% Mud	(weight %)
Primary Production	(mg C m^{-2} day^{-1})
Slope (rugosity)	(°)
Effective disturbance	(dimensionless)
Off-shelf	
Water depth	(m)
Sea Floor Temperature	(°C)
% Gravel	(weight %)
% Mud	(weight %)
Primary Production	(mg C m^{-2} day^{-1})
Slope (rugosity)	(°)

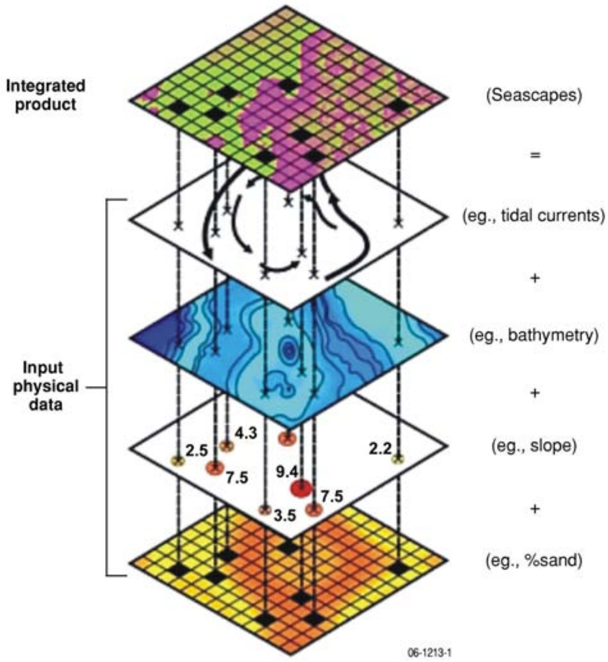


Figure 8.1*: Schematic diagram showing derivation of seascapes from multiple spatial layers of biophysical data. The seascapes represent the integrated product of the individual datasets (From Whiteway et al., 2007).*

Hierarchical classification schemes have the intrinsic predictive power of describing the relationships between physical habitats and their associated biological communities. Roff and Taylor (2000) suggest that a hierarchical classification scheme is essential for the selection of representative or distinctive habitats. This has prompted the development of a number of different classification schemes and recognition that marine regions can be divided into the following broad hierarchical units (for example):

- Provinces
  - Biomes
    - Geomorphic Features
      - Biotopes

Other equally valid terms may be used in place of these, and there is any number of possible different divisions in the hierarchy. However, the above hierarchical scheme can be used to guide the derivation of the seascapes for Australia's marine region.

8.2 CLASSIFICATION METHODOLOGY

Below is a summary of the classification methodology used by Geoscience Australia for deriving the seascapes for the Australian margin, including the Ceduna Sub-basin. A full description of the methodology can be found in Whiteway et al. (2007).

8.2.1 Unsupervised Classification

The seascapes were classified using the Iterative Self Organising Classification (ISOclass) methodology in the software package ERMapper. This methodology is an unsupervised crisp classification, meaning that the classification is run without any user input to help define the classes and each data point can only belong to one class. There are several solutions to finding the final classification and selecting the optimal number of classes and location of the best class boundaries is essential. Statistically, there will be an optimal number of classes, or seascapes, into which the data can be divided that will minimise the uncertainty. In making the final decision, the distribution and make-up of the possible classes (seascapes) were compared with the broad-scale knowledge of the geology and ecology of the marine region.

8.2.2 Seascape Names

The seascapes are named with reference to the hierarchical scheme outlined in Section 8.1. At the scale of provinces and biomes, water depth is the most important variable. A plot of the mean and standard deviation values of water depth allow each of the seascapes to be ranked in order of increasing water depth (Figs. 8.2 & 8.3). At the scale of geomorphic features, correlation of the seascapes with the geomorphic features map of Australia's margin (Heap & Harris, 2008) provides an independent check on seascape character and spatial extent. After depth, the seascapes are named using geomorphic features that comprise >25% of the area of each of the seascapes, except for on-shelf seascapes 2 and 8, where the feature with the highest percent area covered is used (Table 8.2). Finally the seascapes can be ranked using the mean values of the remaining physical properties. Where a seascape is ranked in the top or lowest three of the mean values for any of the physical properties then that property is included as a descriptor for the seascape (Table 8.3).

8.3 SEASCAPES FOR THE AUSTRALIAN MARGIN

A total of 13 and 9 ecologically-meaningful seascape classes were derived for the on-shelf and off-shelf regions of the Australian margin, respectively (Figs. 8.4 & 8.5; Table 8.3). The seascapes are most strongly delineated by variations in seabed sedimentology, slope (rugosity), and temperature. No on-shelf seascapes occur in the Ceduna Sub-basin region (including the Eyre Sub-basin).

Complete descriptions for the national distribution of each of the 13 seascapes derived for the shelf are contained in Heap et al. (in press). Several trends in their occurrence and distribution can be discerned at a continental scale. Firstly, the on-shelf seascapes divide into two broad latitudinal groups (Fig. 8.6). The southern group (seascapes 1-7, which mostly cover the Ceduna Sub-basin region) is characterised by generally sandy, cooler environments relative to the northern group (seascapes 9-13) which is characterised by muddier, warmer environments and shallower water. Interestingly, seascapes dominated by gravel occur only on the southern margin. Additionally, the overall distribution of on-shelf seascapes appears to be more diverse and variable for the northern group, with significant heterogeneity over many parts of the shelf, particularly the central and northern Great Barrier Reef shelf and the outer Arafura and Sahul Shelves. Conversely, the distribution of on-shelf seascapes in the southern group is more uniform with each of the seascapes covering a relatively large area. Further work is required to determine if this difference in variability is a true reflection of the seascape distribution or merely a function of data density; more sediment samples are available for the northern margins.

On-shelf environments of the low-gradient and muddy shallow shelf basins of the Gulf of Carpentaria, Joseph Bonaparte Gulf, Gulf of Carpentaria and Bass Strait are represented by seascapes 13 and 5, respectively. On-shelf seascape 8 occurs predominantly on the west and east shelf regions and may represent a transitional environment between temperate and sub-tropical and tropical environments. On-shelf seascape 11 occurs along the coast, principally in the north, and is characterised by very high primary production (Fig. 8.4). This appears to be an anomaly, as this zone is a region of elevated turbidity caused by river runoff, strong tidal and wave currents. This seascape, although correctly identified as a different region, is more likely to be a zone of high turbidity and relatively low primary productivity due to reduced light penetration to the bed.

Off the shelf, the distribution of seascapes lacks a distinct latitudinal pattern seen in the on-shelf seascapes and is more related to seafloor temperature as a function of depth (Fig. 8.5). The seascapes are associated with a general decrease in grain size with depth and distance offshore. For the mid- to lower-slope, abyssal plain and deep ocean floor environments on the southern and western margins, seascapes are principally defined by slope (rugosity) and primary production. For other areas, seascape distribution is more complex, with bathymetry and slope (rugosity) emerging as key descriptors.

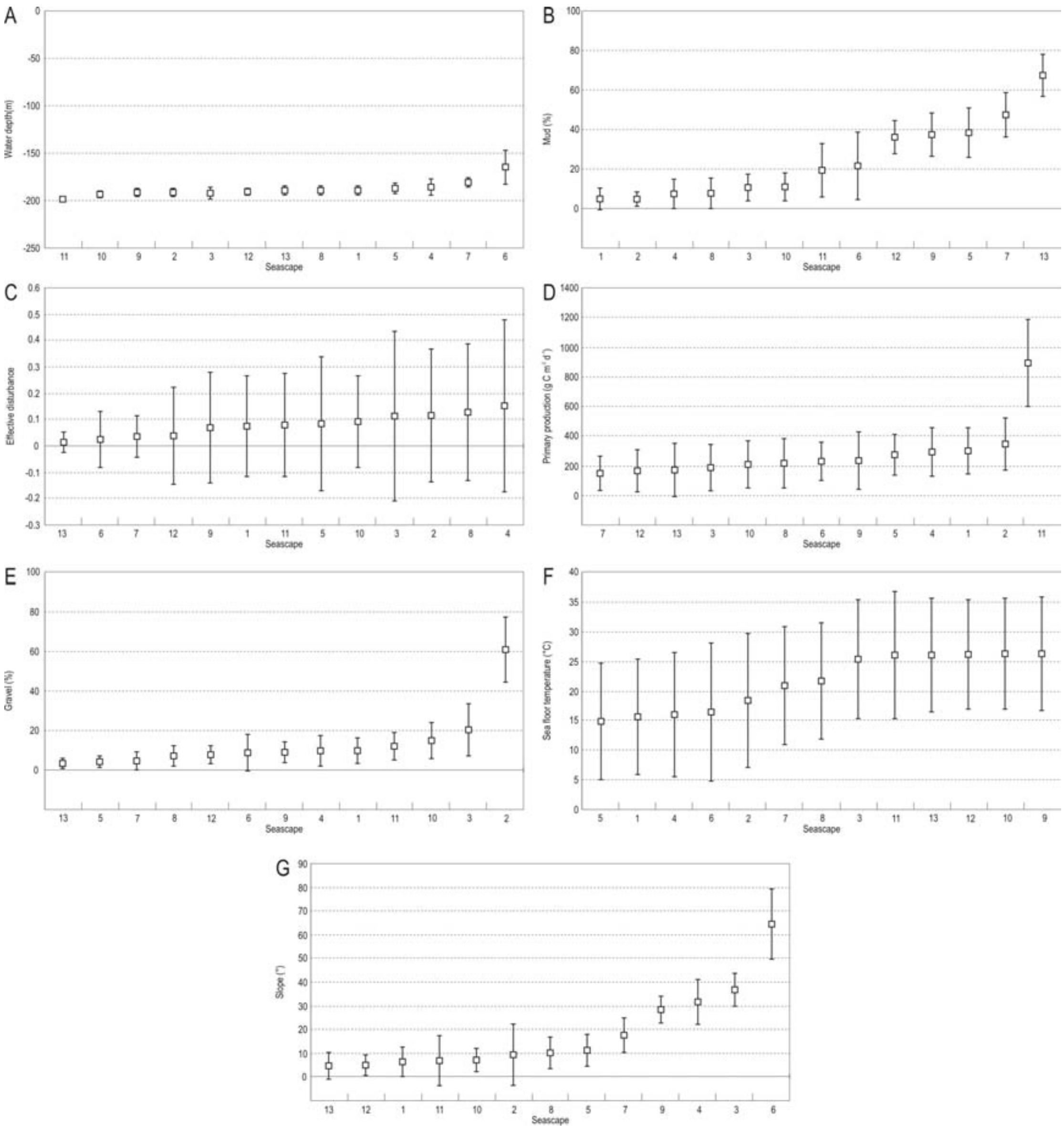


Figure 8.2: *Graphs of seascape versus: (A) water depth; (B) mud content; (C) effective disturbance; (D) primary production; (E) gravel content; (F) sea floor temperature; and (G) slope for the on-shelf seascapes of the Australian margin. Physical properties with the three highest and lowest mean values are used as distinguishing properties in naming each of the seascapes. Plots show means and limits of one standard deviation.*

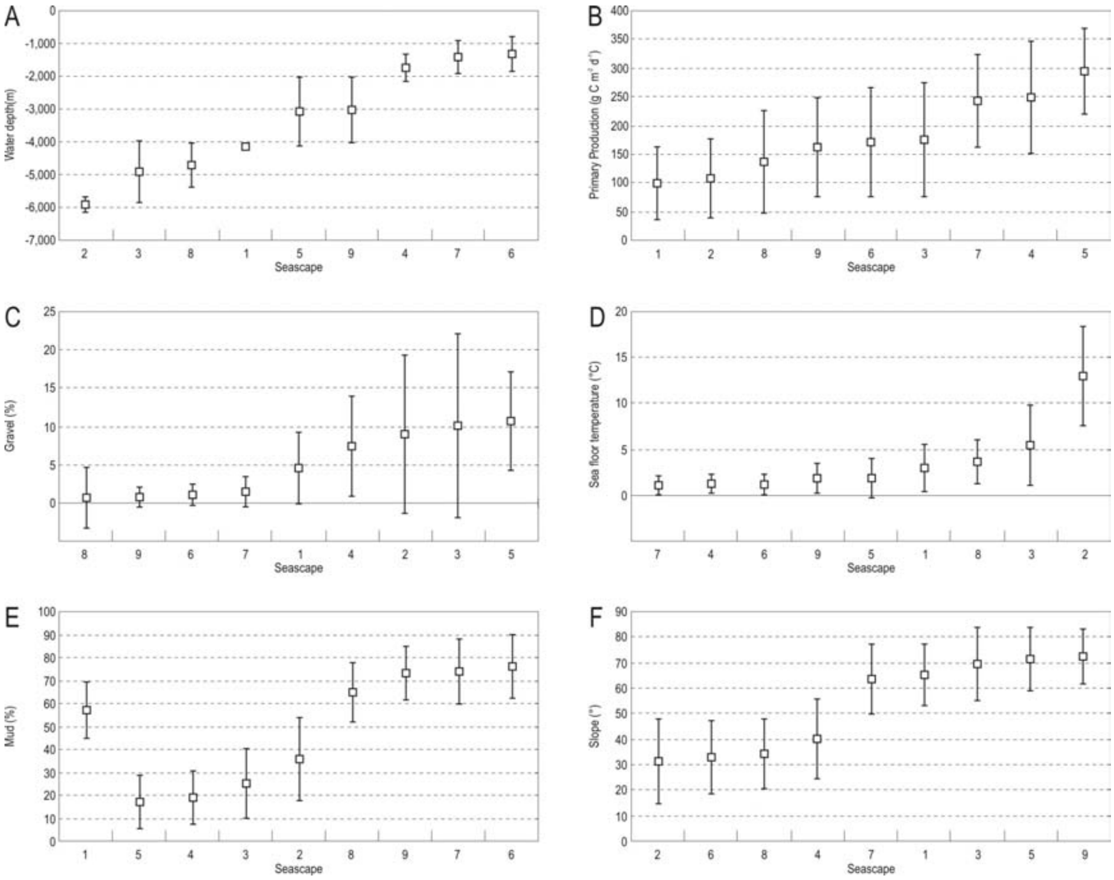


Figure 8.3: *Graphs of seascape versus: (A) water depth; (B) primary production; (C) gravel content; (D) sea floor temperature; (E) mud content; and (F) slope for the off-shelf seascapes of the Australian margin. Physical properties with the three highest and lowest mean values are used as distinguishing properties in naming each of the seascapes. Plots show means and limits of one standard deviation.*

Nationally, off-shelf seascape 6 coincides with the vast, mostly sedimented, relatively flat abyssal plain environments around the margin. Where these deep-ocean environments have relief, including on the southern margin associated with margin spreading and in the vicinity of submarine canyons at the base of the slope, they are dominated by seascape 7. On the southeast margin, off-shelf seascapes 4 and 5 replace seascapes 6 and 7 as being the dominant types in the deep ocean. This may be a true change in seascape type, and the boundary south of Tasmania coincides with an ecological boundary based on demersal fish data (DEH, 2005). However, we note that relatively few sediment data were available for the deep southeast region, and it could be that the change in dominant seascape is a reflection of the paucity of sediment data in this region.

The following section draws on the continental-scale analysis of the seascapes presented in Heap et al. (in press) and emphasizes descriptions of the distribution and nature of those seascapes that are characteristic of the Ceduna Sub-basin region.

Table 8.2: *Percentage of geomorphic feature (from Heap & Harris, 2008) comprising the total area each of: a) on-shelf and b) off-shelf seascapes for the Australian margin. Highlighted cells identify the geomorphic features used to characterise each seascape.*

a) On-shelf seascapes

	Seascape												
Feature	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Abyssal plain/deep ocean floor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apron/fan	0.00	2.04	1.55	1.22	15.71	2.53	65.31	10.34	1.29	0.00	0.00	0.00	0.00
Bank/shoals	3.31	0.16	16.98	0.73	0.04	0.31	0.65	1.59	26.50	15.27	0.70	20.56	13.20
Basin	2.82	0.08	0.92	0.07	4.01	0.14	1.16	0.00	1.61	9.91	0.84	44.02	34.40
Canyon	0.00	0.08	1.99	0.59	3.23	7.68	57.04	10.92	2.79	0.29	0.00	1.93	13.46
Continental rise	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deep/hole/valley	19.04	0.29	9.95	3.64	5.62	1.35	11.21	11.34	8.44	13.87	1.12	9.60	4.55
Escarpment	20.46	0.00	0.00	35.70	25.69	18.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Knoll/abyssal-hills/hills/mountains/peak	73.09	0.00	0.00	19.13	4.80	2.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pinnacle	1.18	0.00	13.61	5.02	0.29	3.08	12.72	3.84	19.04	5.50	0.00	9.96	25.76
Plateau	19.57	1.28	31.72	4.36	1.84	0.41	0.05	0.15	5.72	27.15	0.47	7.26	0.03
Reef	0.54	1.35	47.69	0.93	0.02	1.95	0.29	2.61	25.07	13.85	1.41	2.59	1.70
Ridge	0.00	0.44	8.46	0.90	0.33	4.50	50.23	21.49	8.49	3.69	0.00	0.33	1.14
Saddle	0.00	0.00	2.82	0.00	0.00	0.00	0.44	1.04	7.89	34.37	0.00	36.04	17.40
Seamount/guyot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shelf	20.67	1.57	2.61	4.90	3.92	0.94	1.06	9.21	3.34	22.34	7.82	11.46	10.16
Sill	15.26	1.61	0.38	0.29	0.01	0.00	0.00	0.00	0.26	9.56	0.00	42.15	30.48
Slope	1.11	0.42	10.40	17.90	1.03	22.82	20.56	18.67	5.16	1.11	0.02	0.72	0.08
Terrace	18.33	0.30	5.47	2.76	2.43	3.39	6.76	7.67	6.28	24.13	0.76	16.10	5.62
Tidal-sandwave/sand-bank	26.97	1.83	2.42	5.74	0.01	0.00	0.00	0.54	3.08	18.36	32.68	2.07	6.29
Trench/trough	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

b) Off-shelf Seascapes

	Seascape								
Features	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Abyssal plain/deep ocean floor	4.28	0.00	0.26	24.63	3.81	35.82	25.16	0.54	5.51
Apron/fan	27.18	48.05	21.89	0.00	0.00	0.00	0.00	2.88	0.00
Bank/shoals	0.00	8.59	0.77	9.60	56.05	0.00	24.98	0.00	0.00
Basin	14.99	0.01	0.00	1.19	2.18	33.12	0.74	15.52	32.24
Canyon	4.40	1.65	11.25	0.56	34.66	0.17	8.26	2.14	36.92
Continental rise	12.50	0.00	4.28	4.35	0.00	45.93	8.64	0.00	24.31
Deep/hole/valley	26.69	7.60	5.33	0.00	0.01	9.80	7.50	29.21	13.87
Escarpment	0.00	0.00	3.90	0.39	46.36	2.79	15.55	0.00	31.01
Knoll/abyssal-hills/hills/mountains/peak	3.62	0.11	0.17	2.14	6.23	4.76	78.46	1.03	3.48
Pinnacle	19.27	6.62	3.67	4.17	30.24	3.59	12.44	0.72	19.27
Plateau	26.72	5.15	1.67	0.73	6.89	0.36	0.63	38.18	19.68
Reef	10.46	80.70	8.40	0.00	0.00	0.00	0.00	0.15	0.29
Ridge	3.17	0.08	0.46	0.97	14.09	0.31	77.16	0.74	3.01
Saddle	23.80	6.88	1.03	7.83	23.41	5.39	0.00	11.01	20.65
Seamount/guyot	29.71	0.18	12.30	1.96	20.49	0.32	0.42	0.67	33.95
Sill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slope	15.56	7.47	14.00	6.94	14.92	2.80	13.65	3.95	20.70
Terrace	21.51	13.51	26.63	0.05	1.10	0.02	0.65	22.42	14.11
Tidal-sandwave/sand-bank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trench/trough	26.33	5.69	11.63	0.48	1.75	1.61	1.39	45.66	5.43

***Table 8.3**: Description of seascapes for the Australian margin.*

Seascape	Description
On-shelf	
1	Shelf; knoll/abyssal-hills/hills/mountains/peak, tidal sandwave/sand bank; low mud; high primary production; cool; flat
2	Shelf; apron/fan; high effective disturbance; very gravelly; low mud; high primary production
3	Shelf; reef, plateau; gravelly; rugose
4	Shelf; escarpment; very high effective disturbance; low mud; cool; rugose
5	Shelf; escarpment; low gravel; muddy; cold
6	Shelf/upper slope; low effective disturbance; very rugose
7	Shelf; apron/fan, ridge; low effective disturbance; low gravel; muddy; very low primary production
8	Shelf; ridge; high effective disturbance
9	Shelf; bank/shoals, reef; very warm
10	Shelf; saddle, plateau; gravelly; warm
11	Shelf; tidal sandwave/sand bank; very high primary production
12	Shelf; basin, sill saddle; moderate primary production; cool; flat
13	Shelf; basin, sill, pinnacle; very low effective disturbance; very low gravel; very muddy; low primary production; very flat
Off-shelf	
1	Abyssal; seamount/guyot, apron/fan, plateau, deep/hole/valley, trench/trough; very low mud, very low primary production
2	Abyssal; reef, apron/fan; gravelly; low primary production; very warm, flat
3	Abyssal; terrace; high gravel; warm; rugose
4	Bathyal; abyssal plain/deep ocean floor; low mud, high primary production, cold
5	Abyssal; bank/shoal, escarpment, canyon, pinnacle; very gravelly, muddy; very high primary production; rugose
6	Bathyal; continental rise; abyssal plain/deep ocean floor, basin; low gravel; very muddy; cold; flat
7	Bathyal; knoll/abyssal-hill/hill/mountain/peak, ridge, abyssal plain/deep ocean floor; muddy; high primary production; very cold
8	Abyssal; trench/trough, plateau, deep/hole/valley; very low gravel; low primary production; warm; flat
9	Abyssal; canyon, seamount/guyot, basin, escarpment; low gravel; muddy; very rugose

8.4 SEASCAPES FOR THE CEDUNA SUB-BASIN REGION

All of the nine off-shelf seascapes occur in the Ceduna Sub-basin region (dominated by seascape 9), and of these nine seascapes four occur in the Eyre Sub-basin region (Fig. 8.6; Table 8.4).

***Table 8.4**: Area of off-shelf seascapes for the Ceduna Sub-basin region (including the Eyre Sub-basin).*

Seascape	**Area (km^2)**		
Off-shelf			
	Eyre Sub-basin	Ceduna Sub-basin	Total
1	-	30	30
2	320	80	400
3	2,900	32,260	35,160
4	-	270	270
5	-	4,740	4740
6	-	1,090	1,090
7	-	11,890	11,890
8	1,950	26,060	28,010
9	2,960	52,720	55,680

Seascape 1 has a depth range of 1,544-6,285 m and a mean of 4,171 m which puts it in the abyssal zone of Australia's marine region (Vinogradova, 1997; Fig. 8.3). Nationally, it coincides with 29.71% seamount/guyot, 27.18% apron/fan, 26.72% plateau, 26.69% deep/hole/valley, and 26.33% trench/trough geomorphic features (Table 8.2). It is also characterised by the lowest mud content and primary production values. Around the Australian margin, seascape 1 is principally associated with upper- to mid-slope environments in northern Australia, being extensive on the northwest and northeast margins (Fig. 8.3). Seascape 1 covers the smallest area of all the seascapes in the Ceduna Sub-basin region, and is located on the eastern section of the surface of the Eyre-Ceduna terrace (Fig. 8.6; Table 8.4). Given its very restricted spatial distribution in the Ceduna Sub-basin region (i.e., it occurs in a single 30 km^2 patch), the presence of this seascape implies that the seabed environments at this location are quite distinct and unique compared to those over the rest of the region.

Seascape 2 has a depth range 4,688-6,348 m and a mean of 5,964 m which puts it in the abyssal zone of Australia's marine region (Vinogradova, 1997; Fig. 8.3). Nationally, it coincides with 80.70% reef and 48.05% apron/fan geomorphic features (Table 8.2). It is also characterised by the 3rd-highest gravel content, 2nd-lowest primary production values, highest sea floor temperatures, and lowest slope values. Indeed, across the entire Australian margin, seascape 2 is principally associated with tropical margins, being most extensive on the shallow-gradient carbonate ramp of the North West Shelf and shallow water carbonate plateaus on the northeast margin (Fig. 8.5). In the Eyre Sub-basin and Ceduna Sub-basin regions, it occurs on the outer-shelf and upper slope. Seascape 2 covers the 2nd-smallest area in the Ceduna Sub-basin region, and is restricted to several small patches near the centre of the Eyre-Ceduna terrace (Fig. 8.6; Table 8.4). The restricted spatial distribution of this seascape implies that the associated seabed environments are uncommon for this region. Interestingly, this seascape is the only example where the area it covers is greater for the Eyre Sub-basin than for the Ceduna Sub-basin.

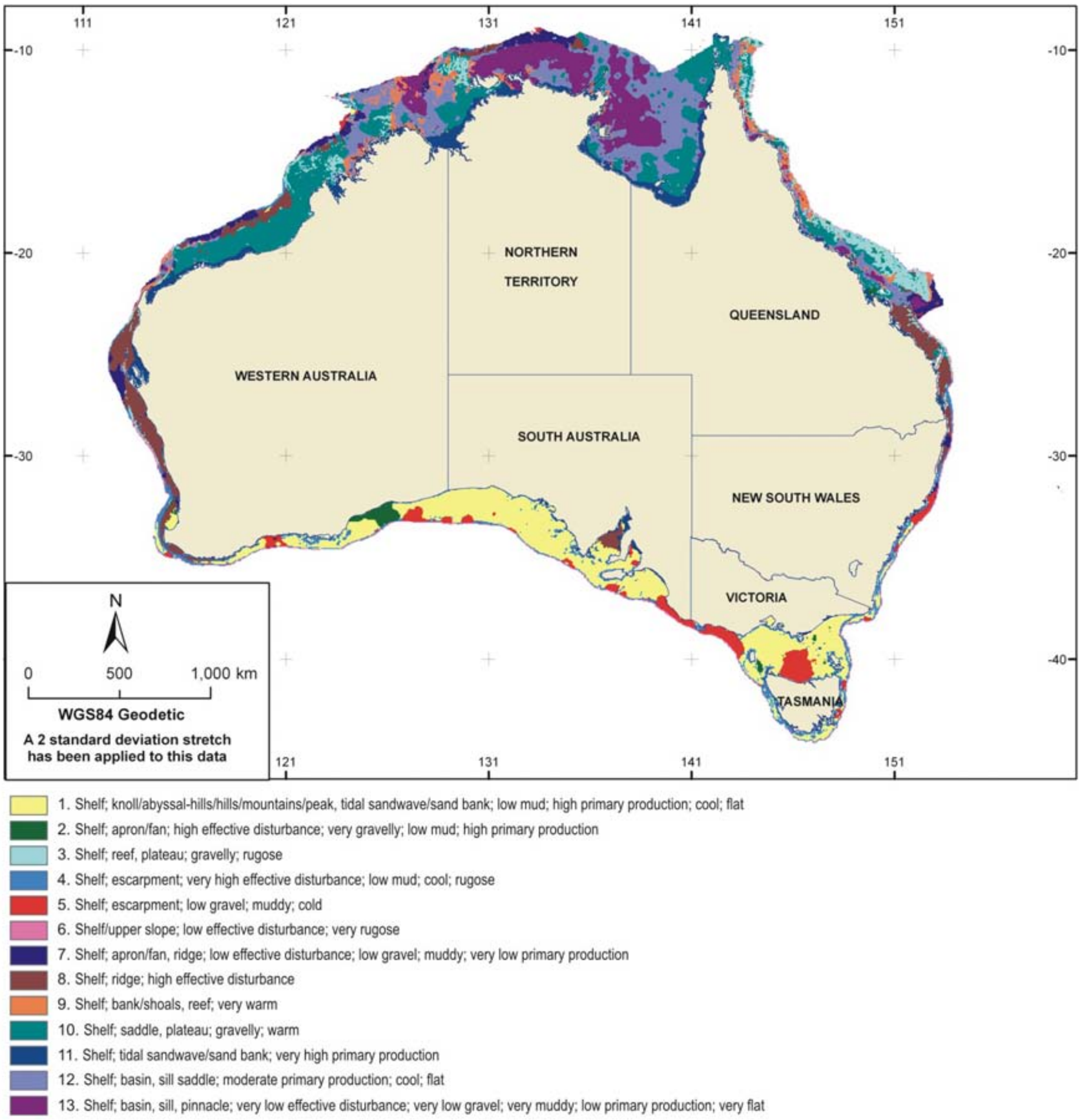


Figure 8.4*: Seascapes for the on-shelf region of Australia. A total of 13 ecologically-meaningful seascapes were identified and are described in Table 8.3.*

Seascape 3 has a depth range of 1,679-6,292 m with a mean of 4,956 m which puts it in the abyssal zone of Australia's marine region (Vinogradova, 1997; Fig. 8.3). Nationally, this seascape coincides with 26.63% terrace geomorphic features (Table 8.2). It is also characterised by the 2nd-highest gravel content and sea floor temperatures, and 3rd-highest slope values. Seascape 3 is the 2nd-most extensive seascape and is associated with the inboard section of the flat to shallow-gradient surface of the Eyre-Ceduna Terrace (Fig. 8.6; Table 8.4). Interestingly, the distribution of this seascape mostly coincides with regions of the margin that contain large offshore marginal plateaus and terraces, including in the Ceduna Sub-basin. This implies that seascape 3 represents upper- to mid-slope environments where offshore features possibly preclude significant up-welling and reduce primary production in the surface waters.

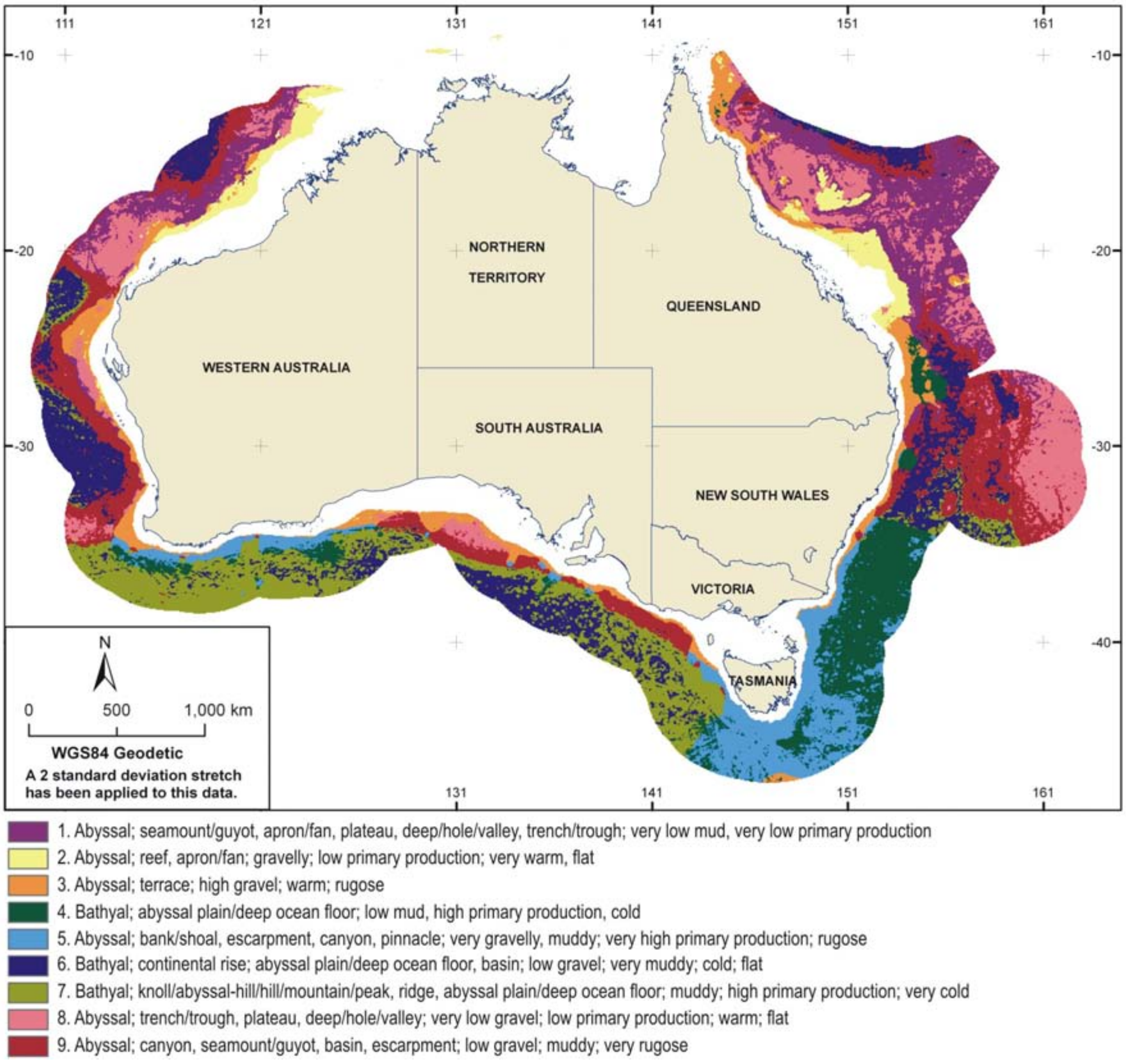


***Figure 8.5**: Seascapes for the off-shelf region of Australia. A total of 9 ecologically-meaningful seascapes were identified and are described in Table 8.3.*

Seascape 4 has a depth range of 705-5,211 m with a mean of 1,763 m which puts it in the bathyal zone of Australia's marine region (Zezina, 1997; Fig. 8.3). Nationally, this seascape coincides with 24.63% abyssal plain/deep ocean floor regions (Table 8.2). It is also characterised by the 3rd-lowest mud content, 2nd-highest primary production values, and 2nd-lowest sea floor temperatures. This seascape associated with the mid- to lower-slope and represents areas of the seabed characterised by coarser grain sizes compared to seascapes 6 and 7 that also represent these types of environments across the Australian margin. Seascape 4 covers the 3rd-smallest area of the seabed in the Ceduna Sub-basin region, and occurs as several patches on the eastern and western margins of the Eyre-Ceduna terrace (Fig. 8.6; Table 8.4). In the Ceduna Sub-basin region this seascape mostly coincides with seascape 5, but is distinguished by slightly lower primary production values. The environments characterised by seascape 4 in the Ceduna Sub-basin region are the same as those that it characterises across the rest of the margin. However, the fact that it occurs only sparsely within the Ceduna Sub-basin region implies that the seabed environments associated with seascape 4 are relatively uncommon compared to the rest of the margin.

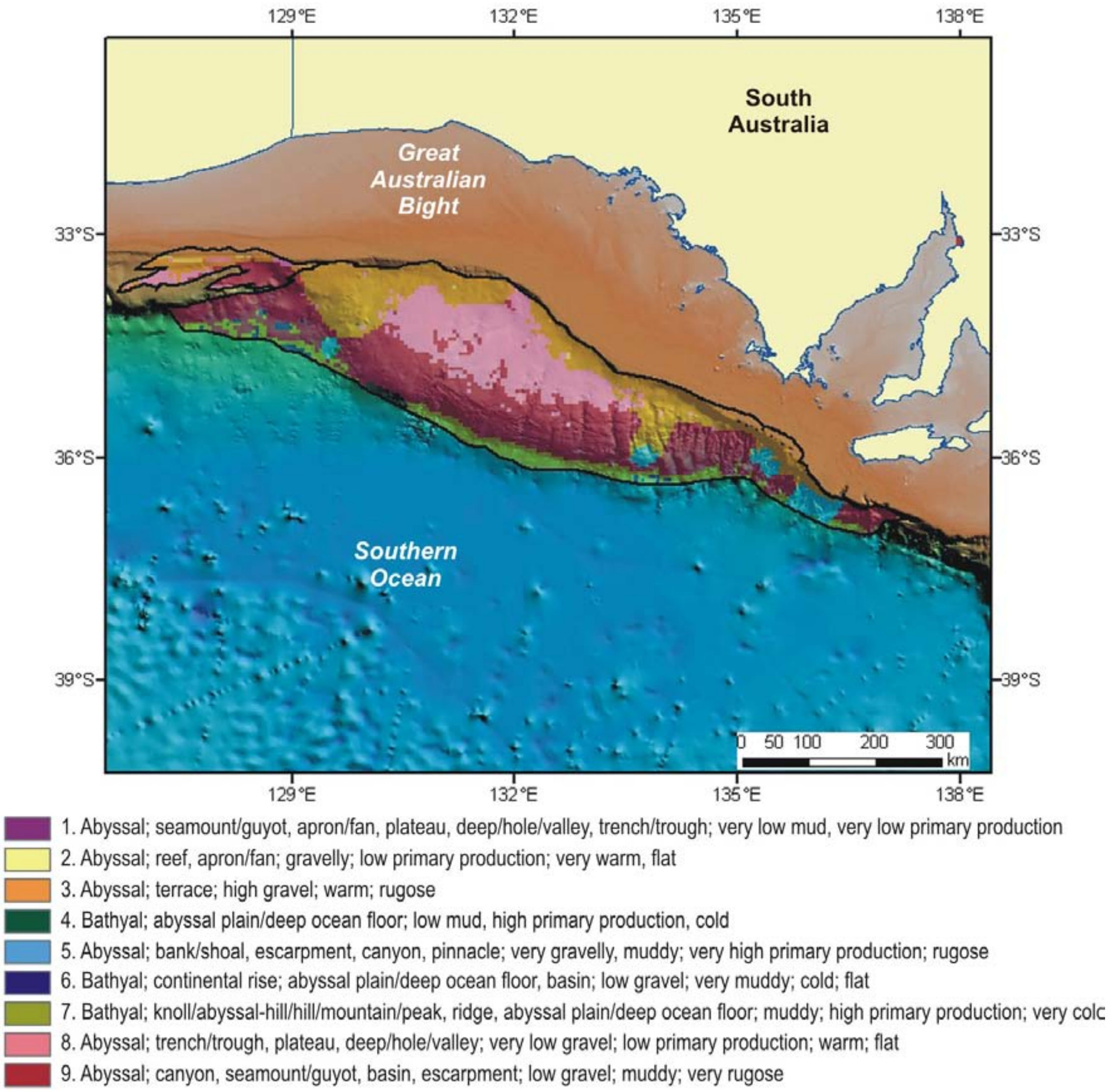


Figure 8.6*: Map of the occurrence and distribution of off-shelf seascapes in the Ceduna Sub-basin (including the Eyre Sub-basin). The region is dominated by seascape 9 associated with the steeper outboard margin of the Ceduna and Eyre terraces.*

Seascape 5 has a depth range of 910-6,133 m with a mean of 3,122 m which puts it in the abyssal zone (Vinogradova, 1997; Fig. 8.3). Interestingly, this seascape occurs only on the southern margin, including the Ceduna Sub-basin region (cf. Fig. 8.5 and 8.6). It coincides with 56.05% bank/shoal, 46.36% escarpment, 34.66% canyon and 30.24% pinnacle geomorphic features (Table 8.2). This seascape is also characterised by the highest gravel content, 2nd-lowest mud content, highest primary production values and 2nd-highest slope values. Seascape 5 is the 5th-most extensive seascape and is associated with the mid- to upper-slope regions of the southern margins (Fig. 8.6; Table 8.4). It coincides with relatively rugose regions of the margin that are dissected by large and numerous submarine canyons, including the well-studied Murray Canyons south of the Gulf of St Vincent and Kangaroo Island. This seascape is mostly discriminated by very high primary production values (Fig. 8.3). These very high values are probably a result of up-welling of deep, cooler, nutrient-rich water from the Southern Ocean on to the upper slope through the numerous submarine canyons. Where the margin is broader and less dissected (e.g., along the outboard margin of the Eyre-Ceduna Terrace), the seabed environments are characterised by seascape 9, which is distinguished by moderate primary production values. This shows that up-welling is less in those regions because there are fewer steep canyons to act as conduits for the deep ocean water. Dissected environments on the western margin of Australia are also characterised more by moderate primary production values, similarly leading to the predominance of seascape 9 (Fig. 8.6). On this margin, up-welling to the surface of deep, nutrient-rich water is probably restricted by the presence of the shallow (<200 m) and southward-flowing Leeuwin Current.

Seascape 6 has a depth range of 390-3,391 m and a mean of 1,359 m which puts it in the bathyal zone of Australia's marine region (Zezina, 1997; Fig. 8.3). Nationally, this seascape coincides with 45.93% continental rise, 35.82% abyssal plain/deep ocean floor, 33.12% basin geomorphic features (Table 8.2). It is also characterised by 3rd-lowest gravel content, highest mud content, 3rd-lowest sea floor temperatures, and second lowest slope values. Seascape 6 is the 6th-most extensive seascape in the Ceduna Sub-basin region and occurs as several small patches on the seaward margin of the Eyre-Ceduna terrace (Fig. 8.6; Table 8.4). Here, it coincides with seascape 7 and represents seabed environments on the vast, mostly sedimented, relatively flat abyssal plains (Fig. 8.4). However, unlike the western and eastern margins where seascape 6 dominates (Fig. 8.5), the deep-seafloor of the Ceduna Sub-basin region is mostly characterised by seascape 7, which is distinguished by having moderate seabed relief compared to seascape 6 (Fig. 8.6).

Seascape 7 has a depth range of 2.3-4,381 m with a mean of 1,425 m which puts it in the bathyal zone (Zezina, 1997; Fig. 8.3). Nationally, it coincides with 78.46% knoll/abyssal hills/hills/mountains/peak, 77.16% ridge and 25.16% abyssal plain/deep ocean floor geomorphic features (Table 8.2). It is also characterised by the 2nd-highest mud content, 3rd-highest primary production values, and lowest sea floor temperatures. Seascape 7 is the 4th-most extensive seascape in the Ceduna Sub-basin region and occurs on the lower-slope/deep ocean floor area (Fig. 8.6; Table 8.4). It forms an almost continuous band along the seaward margin of the Eyre-Ceduna Terrace and is characterised by moderate relief. Within the Ceduna Sub-basin, the features that make up this relief include abyssal hills and ridges that are the product of margin spreading (from when Australia and Antarctica split). The occurrence and distribution of seascape 7 is associated with the occurrence and distribution of seascape 6. Generally, the deep sea environments that are represented by seascapes 6 and 7 are sinks for sediment transported down the slope and off the margin, as well as material that falls out of the water column.

Seascape 8 has a depth range of 2,579-6,323 m and a mean of 4,738 m which puts it in the abyssal zone of Australia's marine region (Vinogradova, 1997; Fig. 8.3). Nationally, it coincides with 45.66% Trench/trough, 38.18% plateau and 29.21% deep/hole/valley geomorphic features (Table 8.2). It is also characterised by the lowest gravel content, 3rd-lowest primary production, 3rd highest sea floor temperatures, and 3rd-lowest slope values. In the Ceduna Sub-basin region, seascape 8 is the 3rd-most extensive seascape and coincides principally with the central, relatively low-gradient regions of the Eyre-Ceduna Terrace (Fig. 8.6; Table 8.4). This seascape is similarly distributed around the entire Australian margin and is associated with offshore marginal plateaus and terraces (Fig. 8.5). This seascape is also characterised by relatively low primary production values. Seabed environments represented by seascape 8 are relatively common across the Australian margin, and this is also the case for the Ceduna Sub-basin region.

Seascape 9 has a depth range of 457-6,058 m and a mean of 3,070 m which puts it in the abyssal zone of Australia's marine region (Vinogradova, 1997; Fig. 8.3). Nationally, it coincides with 36.92% canyon, 33.95% seamount/guyot, 32.24% basin and 31.01% escarpment geomorphic features (Table 8.2). It is also characterised by the 2nd-lowest gravel content, 3rd-highest mud content, and highest slope values. Seascape 9 is the most extensive seascape in the Ceduna Sub-basin region (Fig. 8.6; Table 8.4). It occurs as a semi-continuous strip along the mid- to lower-slope. It is associated with relatively rugose seaward sections of the Eyre-Ceduna terrace and adjacent margins. This seascape is also associated with parts of the margin dissected by submarine canyons. In contrast to seascape 5, the seabed environments associated with seascape 9 are characterised by generally lower primary production values. Seabed environments associated with seascape 9 are relatively common across the Australian margin (Fig. 8.6), and this is also the case for the Ceduna Sub-basin region.

8.5 FOCAL VARIETY ANALYSIS

Focal variety analysis provides a spatial representation of seabed habitat heterogeneity across the Australian margin. This procedure, implemented in ArcGIS, simply counts up the number of different classes within a specified radius (in this case 50 km). Locations where seascapes and a range of geomorphic features intersect imply high potential habitat variability, and therefore high potential biotic variability (Day & Roff, 2000). Focal variety indices were thus calculated as part of the new analysis of seabed habitats to provide an assessment of habitat heterogeneity. The indices were calculated separately on the seascapes (which comprise continuous data) and geomorphic features (which comprise categorical data; Fig. 4.1) and the results combined. Areas of highest habitat heterogeneity are denoted by highest focal variety indices (i.e., where many different seascapes occur). Areas of high seabed habitat heterogeneity have previously been prioritised and targeted as places for the establishment of marine protected areas. Full details of the calculation of the focal variety index are presented in Whiteway et al. (2007). The focal variety analysis was completed for the entire Australian margin, and the results for the off-shelf region have been included here with the results for the Ceduna Sub-basin region for context.

For the off-shelf region, greatest focal variety occurs on the mid- to outer-slope regions, particularly associated with rugose regions of the slope dissected by submarine canyons and the margins of submerged marginal plateaus (Fig. 8.7A). Highest (12-13) focal variety indices occur adjacent to Lord Howe Island, on the Kenn Plateau, near the head of the Townsville and Queensland Troughs and northwest margin of the Queensland Plateau, Offshore of the Sahul Banks, the southern margins of the Exmouth and Naturaliste Plateaus and Eyre Terrace, and the Diamantina Zone. Abyssal plain/deep ocean floor regions are characterised by relatively low (<3) focal variety indices implying that the seabed habitats in these environments are uniform and cover relatively large areas.

For the Ceduna Sub-basin region (including the Eyre Sub-basin), the mid- to lower-slope regions show up as areas of greatest focal variety and seabed habitat heterogeneity (Fig. 8.7B). Indices of >10 coincide with a relatively diverse distribution and large number of seascapes characterised by steep (rugose) environments and moderate primary productivity. These regions are also characterised by numerous submarine canyons and escarpments. Lowest focal variety indices (<3) occur on the relatively low-gradient and featureless top of the terrace.

8.6 DISCUSSION AND SUMMARY

The seascapes and focal variety analyses provide a method to highlight regions where biophysical parameters of the seabed are most diverse. Because the approach is consistent and quantitative at a national scale, it permits robust comparisons to be made between regions. The methods by which these datasets are derived are transparent to all stakeholders, and are based on scientifically-valid methods and assumptions, thus improving its defensibility. As such, these approaches help reduce the level of uncertainty associated with mapping and characterising seabed habitats (and associated seabed biota), and thus help prevent the precautionary principle from being applied too liberally, which is of benefit to all stakeholders in Australia's marine environment.

The Ceduna Sub-basin contains the full suite of seascapes characteristic of Australia's off-shelf territory. The most spatially extensive seascapes in the region are 3 and 9 (Tables 8.2 and 8.3); the former representing the upper to mid-slope region characterised by low gradients and moderate primary productivity, and the latter characterised by the rugose margins of plateaus and terraces (in this case the Ceduna Terrace). The least extensive seascapes represented in the Ceduna Sub-basin are 2 and 4 (Table 8.4); the former representing the flat to shallow-gradient tops of offshore marginal plateaus and terraces with low primary production, and the latter representing the mid- to lower-slope and deep-ocean environments characterised by a relatively coarse grain size.

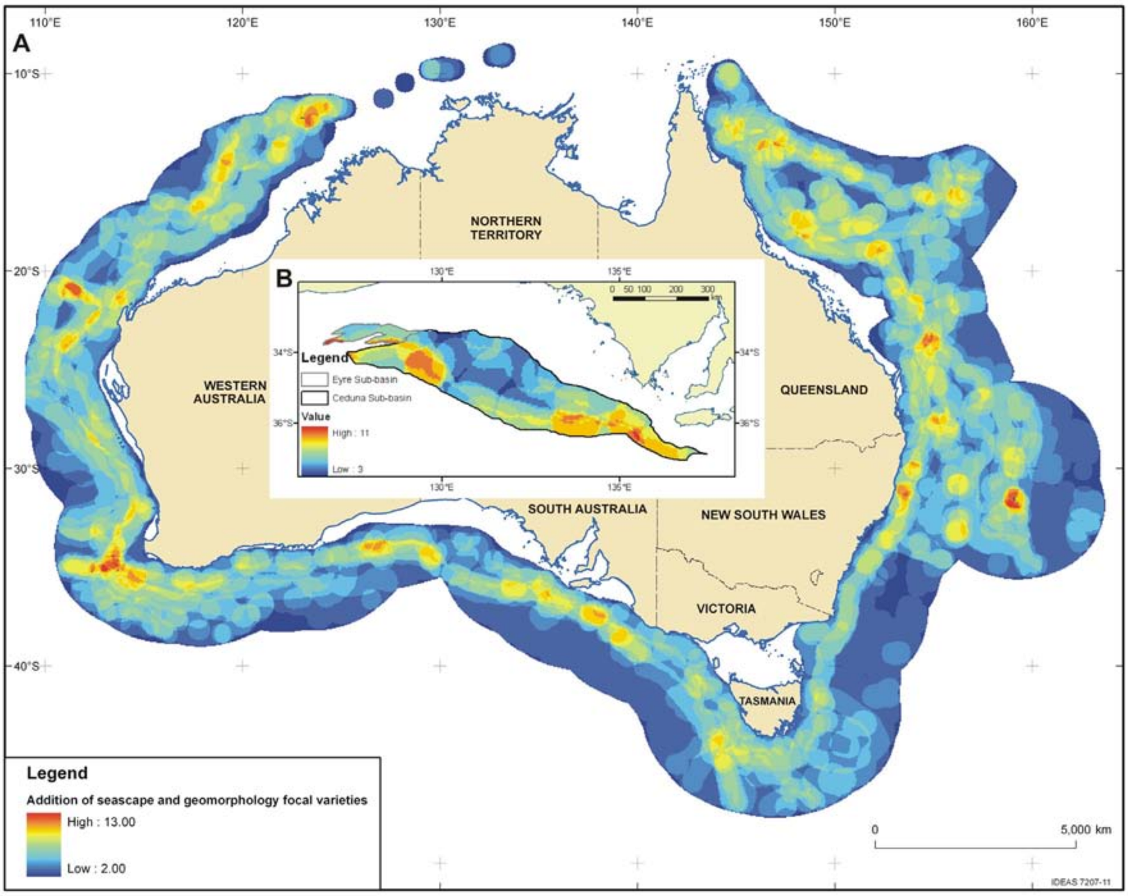


Figure 8.7: A) Focal variety indices for the off-shelf region of the Australian margin. The focal variety shows where the seabed is most heterogeneous. For the off-shelf region, greatest seabed heterogeneity (>10) occurs on the mid- to lower-slope in regions characterised by rugose environments and areas incised by numerous submarine canyons. B) Focal variety indices for the off-shelf region for the Ceduna Sub-basin (including the Eyre Sub-basin). In concert with their distributions around the rest of the Australian margin, greatest focal variety indices (>10) occur on the mid- to lower-slope of the Ceduna-Eyre Terrace, particularly where the margin is characterised by steep (rugose) slopes that are dissected by submarine canyons.

In the Ceduna Sub-basin region, rugose and dissected regions of the mid- to lower-slope show up as regions of greatest focal variety and seabed habitat heterogeneity. Areas of high seabed habitat heterogeneity have previously been prioritised and targeted as places for the establishment of marine protected areas. Targets for possible marine protected areas also include those that are unique (or relatively uncommon) and/or spatially restricted. In the Ceduna Sub-basin region (including the Eyre Sub-basin) these regions coincide with seascapes 1, 2 and 4.

References

ABARE, 2007. Australian Fisheries Statistics 2006. *Australian Bureau of Agricultural and Resource Economics*, Canberra.

Bax, N.J. and Williams, A., 2001. Seabed habitat on the southeast Australian continental shelf - context, vulnerability and monitoring. *Marine and Freshwater Research*, **52**, 491-512.

Beaudoin, J., Hughes Clarke, J.E., Van Den Ameele, E.J., and Gardner, J.V., 2002, Geometric and radiometric correction of multibeam backscatter derived from Reson 8101 systems. *Canadian Hydrographic Conference Proceedings*, 1-22.

Bein, J. and Taylor, M.L., 1981. The Eyre Sub-basin: recent exploration results. *The APEA Journal*, **21**, 91–98.

Bowers, D.G., and Lennon, G.W., 1990. Tidal progression in a near resonant system – a case study from South Australia. *Estuarine Coastal and Shelf Science*, **30**, 17-34.

Bradshaw, B.E., Rollett, N., Totterdell, J.M. and Borissova, I., 2003. A revised structural framework for frontier basins on the southern and southwestern Australian continental margin. *Geoscience Australia Record*, **2003/03**.

Callahan, J.E., 1972. Velocity structure and flux of the Antarctic circumpolar current south of Australia. *Journal of Physical Oceanography*, **76**, 5859-5864.

Church, J.A., Cresswell, G.R., and Godfrey, J.S., 1989. The Leeuwin current. Poleward flows along eastern boundaries. In Neshyba, S.J., Mooers, C.N.K., and Smith, R.L., eds., *Coastal and Estuarine Studies*, **34**, American Geophysical Union, 230-254.

Cirano, M., and Middleton, J.F., 2004. Aspects of the mean wintertime circulation along Australia's southern shelves: Numerical studies. *Journal of Physical Oceanography*, **34**, 668-684.

Cleary, D.F.R. et al., 2005. Variation in the diversity and composition of benthic taxa as a function of distance offshore, depth and exposure in the Spermonde Archipelago, Indonesia. *Estuarine, Coastal and Shelf Science*, **65**, 557-570.

Conolly, J. R. and Von der Borch, C. C. 1967. Sedimentation and physiography of the sea floor south of Australia. *Sedimentary Geology*, **1**, 181-220.

Cresswell, G.R., and Peterson, J.L., 1993. The Leeuwin Current of Western Australia. *Australian Journal of Marine and Freshwater Research*, **44**, 285-303.

Currie, D.R., Mayfield, S., McGarvey, R. and Gardner, C., 2006. South Australia Giant Crab (Pseudocarcinus gigas) Fishery: Fishery Assessment Report for PIRSA. *South Australian Research and Development Institute*, Adelaide.

Davies, H. L., Clarke, J .D. A., Stagg, H. M. J., Shafik, S., McGowran, B., Alley, N. F., Willcox, J. B. 1989. Maastrichtian and younger sediments from the Great Australian Bight. *Bureau of Mineral Resources, Geology and Geophysics Report*, **288,** 40 pp.

Day, J.C. and Roff, J.C., 2000. Planning for Representative Marine Protected Areas: A Framework for Canada's Oceans. *WWF Canada*, Toronto. 147pp.

De Deckker, P. 2006. *Geological and biological investigations of the Murray Canyons Group. Voyage Summary SS02/2006*. http://www.marine.csiro.au/datacentre/process/data_files/cruise_docs/ss200602sum.pdf

Department of the Environment and Heritage (DEH), 2005. Assessment of the Skipjack Tuna Fishery. *Department of Environment and Heritage*, Canberra.

Department of the Environment and Heritage (DEH), 2005. National Marine Bioregionalisation of Australia 2005 DVD. Commonwealth of Australia, Canberra.

Edyvane, K., 1998. Great Australian Bight Marine Park Management Plan, Part B, Resource Information. *Department for Environment, Heritage, and Aboriginal Affairs,* South Australia.

Exon, N. F., Hill, P. J., Mitchell, C. and Post, A. 2005. Nature and origin of the submarine Albany canyons off southwest Australia. *Australian Journal of Earth Sciences*, **52**, 101-115.

Fraser, A.R. and Tilbury, L.A., 1979. Structure and stratigraphy of the Ceduna Terrace region, Great Australian Bight. *The APEA Journal*, **19**, 53–65.

Fonseca, L., and Calder, B. 2005. Geocoder: and efficient backscatter map constructor. *Proceedings of the U.S. Hydrographic 2005*. San Diego, CA.

Fonseca, L., Mayer, L., in prep. Remote estimation of surficial seafloor properties through the application angular range analysis to multibeam sonar data.

Godfrey, J.S., Vaudrey, D.J., Hahn, S.D., 1986. Observations of the shelf edge current south of Australia. *Journal of Physical Oceanography*, **16**, 668-679.

Grassle, J.F. and Morse-Porteous, L.S., 1987. Macrofaunal colonization of disturbed deep-sea environments and the structure of deep-sea benthic communities. *Deep Sea Research*, **34**, 1911-1950.

Gray, J.S., 2001. Marine diversity: the paradigms in patterns of species richness examined. *Scientia Marina*, **65**, 41-56.

Great Australian Bight Marine Park (Commonwealth and State Waters)- A Description of Values and Uses, 2005. Director of National Parks, Department of Environment and Heritage, Canberra.

Hahn, S.D., 1986. Physical structure of the waters of the South Australian continental shelf. *Flinders Institute for Atmospheric and Marine Sciences, Research Report* **45**, Flinders University, South Australia.

Harris, P.T., Heap, A.D., Post, A., Whiteway, T., Potter, A. and Bradshaw, M. 2007. Marine zone management and the EPBC Act: How environmental marine geological information reduces risk in petroleum exploration. *The APPEA Journal*, 329-344.

Hasselman, K., and the WAMDI Group, 1988. The WAM model – a third generation ocean wave prediction model. *Journal of Physical Oceanography*, **18**, 1775-1810.

Heap, A.D., Harris, P.T., Hinde, A. and Woods, M., 2005. Benthic Marine Bioregionalisation of Australia's Exclusive Economic Zone: Report to the Nataional Oceans Office on the Development of a National Benthic Marine Bioregionalisation in Support of Regional Marine Planning, Department of Environment & Heritage, Geoscience Australia, CSIRO, Canberra.

Heap, A.D., Harris, P.T. and Whiteway, T., in press. Seascapes for the Australian margin and adjacent seafloor. *Geoscience Australia Record*, **2008**.

Hemer, M.A., Simmonds, I., and Keay, K., 2008. A classification of wave generation characteristics during large wave events on the Southern Australian margin. *Continental Shelf Research*, **28**, 634-652.

Herzfeld, M., 1997. The annual cycle of sea surface temperature in the Great Australian Bight. *Progress in Oceanography*, **39**, 1-27.

Herzfeld, M., and Tomczak, M., 1999. Bottom-driven upwelling generated by eastern intensification in closed and semi-enclosed basins with a sloping bottom. *Marine and Freshwater Research*, **50**, 613-627.

Hill, A.J., 1995. Bight Basin. *In* Drexel, J.F. and Preiss, W.V., eds., The geology of South Australia. Vol. 2, The Phanerozoic. *South Australia Geological Survey Bulletin*, **54**, 133–149.

Hill, P.J., Rollet, N., Rowland, D., Calver, C.R., and Bathgate, J. 2000. Swath-mapping and geophysical survey of Australia’s south-east marine zone, AUSTREA-1 research cruise using L’Latalante. *Australian Geological Survey Organisation Record*, **2000/4**.

Hill, P., Rollet, N., Symonds, P. 2001. Seafloor mapping of the southeast marine region and adjacent waters – AUSTREA final report: Lord Howe Island, southeast Australian margin (includes Tasmania and South Tasman Rise) and central Great Australian Bight. *Australian Geological Survey Organisation Record*, **2001/08**, 83 pp. + Figs.

Hill, P.J., and De Deckker, P. 2004. AUSCAN seafloor mapping and geological sampling survey on the Australian southern margin by Marion Dufresne in 2003: Final Project Report. *Geoscience Australia Record*, **2004/04**.

Hobday, A., 2001. Rapid Assessment of Australian MPAs using Satellite Remote SEnsing Part 2: Validation of Biological Response to Physical Environment: Report to Environment Australia, CSIRO Marine Research, Hobart.

Hufford, G.E., McCartney, M., and Donohue, K.A., 1997. Northern boundary currents and adjacent recirculations off southwestern Australia. *Geophysical Research Letters*, **24**, 2797-2800.

Hughes Clarke, J.E., Mayer, L.A., Wells, D. 1996. Shallow-Water Imaging Multibeam Sonars: A New Tool for Investigating Seafloor Processes in the Coastal Zone and on the Continental Shelf. *Marine Geophysical Researches*, **18**, 607-629

Hurrell, J.W., van Loon, H., Shea, D.J., 1998. The mean state of the troposphere. Meteorology of the Southern Hemisphere. *Meteorological Monographs*, **vol. 49**, American Meteorological Society, 1-46.

Hutchinson, P.A., 1988. The physical characteristics of ter-diurnal tidal resonance along the east Great Australian Bight. *Flinders Institute for Atmospheric and Marine Sciences, Research Report* **51**, Flinders University, South Australia.

Irish, J.D., and Snodgrass, T.E., 1972. Australian Antarctic tide. Antarctic Oceanology II – The Australian-New Zealand sector. *Antarctic Research Series*, **19**, American Geophysical Union, 101-116.

James, N. P., Bone, Y., Collins, L. B. and Kyser, T. K. 2001. Surficial sediments of the Great Australian Bight: Facies dynamics and oceanography on a vast cool-water carbonate shelf. *Journal of Sedimentary Research,* **71**, 549-567.

James, N. P., Feary, D. A., Betzler, C., Bone, Y., Holbourn, A. E., Li, Q., Machiyama, H., Toni Simo, J. A., Surlyk, F. 2004. Origin of late Pleistocene bryozoan reef mounds: Great Australian Bight. *Journal of Sedimentary Research,* **74**, 20-48.

Kämpf, J., 2006. Transient wind-driven upwelling in a submarine canyon: A process-oriented modelling study. *Journal of Geophysical Research*, **111**, C11011, doi:10.1029/2006JC003497.

Kämpf, J., 2007. On the magnitude of upwelling fluxes in shelf-break canyons. *Continental Shelf Research*, **27**, 2211-2223.

Knight, M., Doonan, A. and Tsolos, A., 2007. South Australian Wild Fisheries Information and Statistics Report. F2007/00571-1, SARDI Aquatic Sciences, West Beach

Krassay, A.A. and Totterdell, J.M., 2003. Seismic stratigraphy of a large, Cretaceous shelf-margin delta complex, offshore southern Australia. *AAPG Bulletin*, **87**, 935–963.

Kukert, H. and Smith, C.R., 1992. Disturbance, colonization and succession in a deep-sea sediment community: artificial-mound experiments. *Deep Sea Research Part A*, **39**, 1349-1371.

Last, P. et al., 2006. Validation of national demersal fish datasets for the regionalisation of the Australian continental slope and outer shelf (> 40 m depth), National Oceans Office, Hobart.

Lennon, G.W., Bowers, D.G., Nunes, R.A., Scott, B.D., Ali, M., Boyle, J., Wenju, C., Herzfeld, M., Johansson, G., Nield, S., Petrusevics, P., Stephenson, P., Suskin, A.A., Wijffels, S.E.A., 1987. Gravity currents and the release of salt from an inverse estuary. *Nature*, **327**, 695-697.

Linnane, A., McGarvey, R. and Feenstra, J., 2007. Northern Zone Rock Lobster (*Jasus edwardsii*) Fishery: Fisheries assessment report to PIRSA. *South Australian Research and Development Institute*, Adelaide, 91 pp.

McClatchie, S., Middleton, J.F., and Ward, T.M., 2006. Water mass analysis and alongshore variation in upwelling intensity in the eastern Great Australian Bight. *Journal of Geophysical Research*, **111**, C08007, doi:10.1029/2004JC002699.

McCreary, J.P., Shetye, S.R., and Kundu, P.K., 1986. Thermohaline forcing of eastern boundary currents: with application to the circulation off the west coast of Australia. *Journal of Marine Research*, **44**, 71-92.

McLeay, L.J., Sorokin, S.J., Rogers, P.J. and Ward, T.M., 2003. Benthic Protection Zone of the Great Australian Bight Marine Park: 1. Literature Review. *South Australia Research and Development Institute* (Aquatic Sciences), Henley Beach.

Messent, B.E.J., 1998. Great Australian Bight: well audit. *Australian Geological Survey Organisation Record*, **1998/37**.

Middleton, J.F., Cirano, M., 2002. A northern boundary current along Australia's southern shelves: The Flinders Current. *Journal of Geophysical Research*, **107**, C9, 3129, doi:10.1029/2000JC000701.

Middleton, J.F., and Platov, G., 2003. The mean summertime circulation along Australia's southern shelves: A numerical study. *Journal of Physical Oceanography*, **33**, 2270-2287.

Middleton, J.F., and Bye, J.A.T., 2007. A review of the shelf-slope circulation along Australia's southern shelves: Cape Leeuwin to Portland. *Progress in Oceanography*, **75**, 1-41.

Mitchell, C., et al., in prep. Cruise report for Southern Surveyor Survey 2007/1. *Geoscience Australia Record*, **2008**.

Norvick, M.S. and Smith, M.A., 2001. Mapping the plate tectonic reconstruction of southern and southeastern Australia and implications for petroleum systems. *The APPEA Journal*, **41**, 15–35.

Noye, B.J., Grzechnik, M., Stevens, J.M., 1999. Modelling currents and dispersion in Boston Bay, South Australia. *In* Noye, B.J., ed., *Modelling Coastal Sea Processes*, vol. 1, 247-272.

Parums, R. 2007. Sub-bottom profile data holdings in the Geoscience Australia repository. *Geoscience Australia Record*, **2007**, 59 pp.

Petrusevics, P.M., 1993. SST fronts in inverse estuaries, South Australia – indicators of reduced gulf-shelf exchange. *Australian Journal of Marine and Freshwater Research*, **44**, 305-323.

Poore, G.C.B., 1995. Biogeography and diversity of Australia's marine biota. *In* L. Sann and P. Kailola, eds., *The State of the Marine Environment Report for Australia Annex 1: The Marine Environment*. Department of Environment, Sport, and Territories, Canberra, pp. 75-84.

Post, A.L., Wassenberg, T.J. and Passlow, V., 2006. Physical surrogates for macrofaunal distributions and abundance in a tropical gulf. *Marine and Freshwater Research*, **57**, 469-483.

Post, A.L., 2008. The application of physical surrogates to predict the distribution of marine benthic organisms. *Ocean and Coastal Management*, **51**, 161-179.

Potter, A., Southby, A., Heap, A.D. 2006. Geomorphology and sedimentology of the South West Planning Region of Australia. *Geoscience Australia Record*, **2006**, 132 pp.

Provis, D.G., and Steedman, R.K., 1985. Wave measurements in the Great Australian Bight. *Australasian Conference on Coastal and Ocean Engineering*, Institute of Engineers Australia, Christchurch, New Zealand.

Raza, A., Hill, K.C. and Korsch, R.J., 1995. Mid-Cretaceous regional uplift and denudation of the Bowen–Surat basins, Queensland and its relation to Tasman Sea rifting. *In* Follington, I.L., Beeston, J.W. and Hamilton, L.H., eds., *Bowen Basin Symposium 1995—150 years on*. Geological Society of Australia, supplement.

Rex, M.A. et al., 1993. Global-scale latitudinal patterns of species diversity in the deep-sea benthos. *Nature*, **365**, 636-639.

Richardson, L., Mathews, E., Heap, A. 2005. Geomorphology and sedimentology of the South Western Planning Area of Australia: Review and synthesis of relevant literature in support of Regional Marine Planning. *Geoscience Australia Record*, **2005/17**, 124 pp.

Ridgeway, K.R., and Condie, S.A., 2004. The 5500-km-long boundary flow off western and southern Australia. *Journal of Geophysical Research*, **109**, C04017, doi:10.1029/2003JC001921.

Rivers, J. M., James, N. P., Kyser, T. K. and Bone, Y. 2007. Genesis of palimpsest cool-water carbonate sediment on the continental margin of southern Australia. *Journal of Sedimentary Research*, **77**, 480-494.

Rochford, D.J., 1986. Seasonal changes in the distribution of Leeuwin Current waters off Southern Australia. *Australian Journal of Marine and Freshwater Research*, **37**, 1-10.

Roff, J.C. and Taylor, M.E., 2000. National frameworks for marine conservation - a hierarchical geophysical approach. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **10**, 209-223.

Roff, J.C., Taylor, M.E. and Laughren, J., 2003. Geophysical approaches to the classification, delineation and monitoring of marine habitats and their communities. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **13**, 77-90.

Rollet, N., Fellows, M., Struckmeyer, H. I. M., Bradshaw, B. E. 2001. Seabed character mapping in the Great Australian Bight. *Geoscience Australia Record*, **2001/042**, 22 pp. + Figs.

Sayers, J., Symonds, P., Direen, N.G. and Bernardel, G., 2001. Nature of the continent–ocean transition on the non-volcanic rifted margin of the central Great Australian Bight. *In* Wilson, R.C.L., Whitmarsh, R.B., Taylor, B. and Froitzheim, N., eds., *Non-volcanic rifting of continental margins: a comparison of evidence from land and sea*. Geological Society of London, Special Publications, **187**, 51–77.

Schodlok, M.P., and Tomczak, M., 1997. Deep sections through the South Australian basin and across the Australian-Antarctic discordance. *Geophysical Research Letters*, **24**, 2781-2784.

Schofield, A. and Totterdell, J.M., in prep. Distribution, dating and origin of magmatism affecting the Bight Basin and implications for hydrocarbon prospectivity. *Geoscience Australia Record*.

Simmonds, I., and Keay, K., 2000. Mean Southern Hemisphere extratropical cyclone behaviour in the 40-year NCEP-NCAR re-analysis. *Journal of Climate*, **13**, 873-885.

Sorokin, S.J., Fromont, J. and Currie, D., in press. Demosponge biodiversity in the benthic protection zone of the Great Australian Bight. *Transactions of the Royal Society of South Australia*.

Sprigg, R. C. 1952. The geology of the southeast province, South Australia, with special reference to Quaternary coast-line migrations and modern beach developments. *Geological Survey of South Australia Bulletin*, **29**, 120 pp.

Sprigg, R. C. 1963. New structural discoveries off Australia's southern coast. *Australasian Oil and Gas Journal*, **10**, 32-42.

Stagg, H.M.V., Cockshell, C.D., Willcox, J.B., Hill, A.J., Needham, D.V.L., Thomas, B., O'Brien, G.W. and Hough, L.P., 1990. Basins of the Great Australian Bight region, geology and petroleum potential. *Bureau of Mineral Resources, Australia, Continental Margins Program Folio*, **5**.

Teasdale, J.P., Pryer, L.L., Stuart-Smith, P.G., Romine, K.K., Etheridge, M.A., Loutit, T.S. and Kyan, D.M., 2003. Structural framework and basin evolution of Australia's southern margin. *The APPEA Journal*, **43**, 13-37.

Thurman, H.V., and Trujillo, A.P., 2004. *Introductory Oceanography*. 10th edition, Pearson, New Jersey, 608 pp.

Tikku, A.A. and Cande, S.C., 1999. The oldest magnetic anomalies in the Australian–Antarctic Basin: are they isochrons? *Journal of Geophysical Research*, B1, **104**, 661–677.

Totterdell, J.M., Blevin, J.E., Struckmeyer, H.I.M., Bradshaw, B.E., Colwell, J.B. and Kennard, J.M., 2000. A new sequence framework for the Great Australian Bight: starting with a new slate. *The APPEA Journal*, **40**, 95–117.

Totterdell, J.M. and Krassay, A.A., 2003a. The role of shale deformation and growth faulting in the Late Cretaceous evolution of the Bight Basin, offshore southern Australia. *In* Van Rensbergen, P., Hillis, R.R.., Maltman, A.J. and Morley, C.K., eds., *Subsurface sediment mobilisation*. Geological Society of London, Special Publications, **216**, 429–442.

Totterdell, J.M. and Krassay, A.A., 2003b. Sequence stratigraphic correlation of onshore and offshore Bight Basin successions. *Geoscience Australia Record*, **2003/02**.

Totterdell, J.M. and Bradshaw, B.E., 2004. The structural framework and tectonic evolution of the Bight Basin. *In* Boult, P.J., Johns, D.R. & Lang, S.C., eds., *Eastern Australasian Basins Symposium II*. Petroleum Exploration Society of Australia, Special Publication, 41-61.

Totterdell, J.M., et al., in prep. Bight Basin geological sampling and seepage survey, R/V Southern Surveyor Survey SS01/2007: post-survey report. *Geoscience Australia Record*, **2008**.

Tyce, R., 1986. Deep Seafloor Mapping Systems – A Review. *Marine Technology Society Journal* **20**.

Veevers, J.J., Powell, C.MCA. and Roots, S.R., 1991. Review of seafloor spreading around Australia. I. Synthesis of the patterns of spreading. *Australian Journal of Earth Sciences*, **38**, 373–89.

Vetter, E.W. and Dayton, P.K., 1998. Macrofaunal communities within and adjacent to a detritus-rich submarine canyon system. *Deep Sea Research Part II: Topical Studies in Oceanography*, **45**, 25-54.

Vetter, E.W. and Dayton, P.K., 1999. Organic enrichment by macrophyte detritus, and abundance patterns of megafaunal populations in submarine canyons. *Marine Ecology-Progress Series*, **186**, 137-148.

Vinogradova, N.G., 1997. Zoogeography of the Abyssal and Hadal Zones. *In*: Blaxter, J.H.S. and Southward, A.J., (Eds.), *Advances in Marine Biology: The Biogeography of the Oceans*, pp. 326-389. Academic Press, London.

Ward, T.M., Sorokin, S.J., Currie, D.R., Rogers, P.J. and McLeay, L.J., 2006. Epifaunal assemblages of the eastern Great Australian Bight: Effectiveness of a benthic protection zone in representing regional biodiversity. *Continental Shelf Research*, **26**, 25-40.

Waschbusch, P., Beaumont, C. and Korsch, R.J., 1999. Geodynamic modelling of aspects of the New England Orogen and adjacent Bowen, Gunnedah and Surat Basins. *In* Flood, P.G., ed., *New England Orogen: regional geology, tectonics and metallogenesis*. Earth Sciences, University of New England, Armidale, 203–210.

Wass, R. E., Conolly, J. R. and Macintyre, R. J. 1970. Bryozoan carbonate sand continuous along southern Australia. *Marine Geology*, **9**, 63-73.

Whiteway, T., Heap, A.D., Lucieer, V., Hinde, A., Ruddick, R. and Harris, P.T., 2007. Seascapes of the Australian Margin and Adjacent Sea Floor: Methodology and Results. *Geoscience Australia Record*, **2007/11**, 133pp.

Willcox, J.B. and Stagg, H.M.J., 1990. Australia’s southern margin: a product of oblique extension. *Tectonophysics*, **173**, 269–281.

Willis, J. and Hobday, A.J., 2007. Influence of upwelling on movement of southern bluefin tuna (*Thunnus maccoyii*) in the Great Australian Bight. *Marine and Freshwater Research*, **58**, 699-708.

Womersley, H.B.S., 1990. Biogeography of Australasian marine macroalgae. *In* M.N. Clayton and R.J. King, eds., *Biology of Marine Plants*. Longman Cheshire, Melbourne, 266-295.

Wright, L.D., 1995. *Morphodynamics of Inner Continental Shelves*. CRC Press, Boca Raton, 241 pp.

Zezina, O.N., 1997. Biogeography of the Bathyal Zone. In: *In*: Blaxter, J.H.S. and Southward, A.J., (Eds.), *Advances in Marine Biology: The Biogeography of the Oceans*, pp. 390-426. Academic Press, London.

Appendix A Sediments

CEDUNA SUB-BASIN

A total of 81 grainsize samples were extracted from the MARS database (Table A.1, Figure A.1). The surface samples were composed mostly of mud and sand with minor components of gravel, which differs considerably from the sediments collected from the shelf immediately to the north, which were composed mostly of sand (Figure A.2). Mud made up an average of 59.4% (0.04–97.3%) of the Ceduna samples. Sand comprised an average of 37.1% (2.7–98.4%) of the samples. Gravel formed a minor component in most samples. There were, however, four samples with gravel content greater than 25% (one of which was 88.5%). The average gravel component was 3.5% (0–88.5%).

There were 74 samples analysed for carbonate content (Table A.2, Figure A.3). Carbonate was a major constituent of the sediments in all size factions. Mud averaged 82.4% (1.28–91.9%) carbonate. Carbonate in the sand sized faction was an average of 87.3% (3–98.2%). Gravel averaged 84.2% carbonate (0–100%). There were four samples that contained gravels with no carbonate content. The bulk sample carbonate analysis contained an average of 83.5% carbonate (1.5–100%). There were five samples containing less than 50% carbonate bulk analysis.

There are an additional 74 surface sediment samples collected from cores, grabs and dredges, collected during the Bight Survey in 2007 (Figure A.1, Table A.3). A selection of these are being analysed for grainsize and carbonate content, the results will be available in mid 2008.

EYRE SUB-BASIN

There were 39 surface sediment samples analysed for grainsize in the Eyre Sub-basin (Table A.4, Figure A.1). The sediments were composed of mud and sand with very little gravel (Figure A.2). Mud ranged from 2 to 89.4 % of the sample, with an average of 51%. Sand ranged from 10.6 to 96.9 % of the sample, with an average of 48%. Gravel ranged from 0 to 8.7 % of the sample, with an average of 0.6 %.

There were 36 samples analysed for carbonate content (Table A.5, Figure A.3). All samples analysed in all of the grainsize fractions were carbonate rich. Carbonate made up 84.7 to 92.7% (and average of 88.1%) of the mud fraction. For the sand fraction carbonate made up 86.3 to 96.44% (and average of 96.44%). The small amounts of gravel present were mostly composed of carbonate; 85 to 100% (average of 98.7%).

An additional 7 samples were collected by dredge from the Eyre Sub-basin during the Bight Survey. These were located adjacent to the Ceduna Sub-basin (Figure A.1, Table A.6).

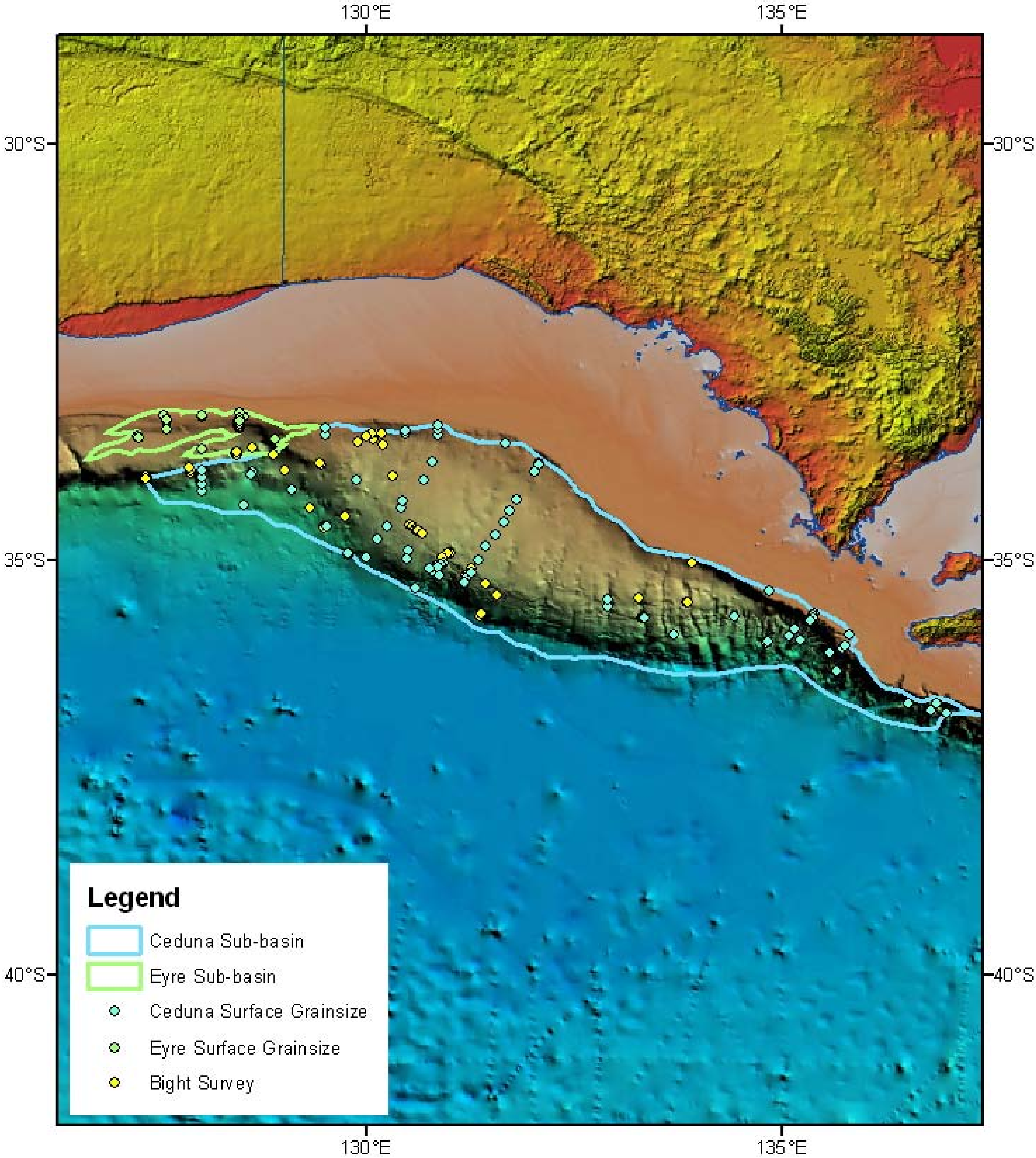


Figure A.1: *Location of surface sediment samples for the Ceduna and Eyre Sub-Basins.*

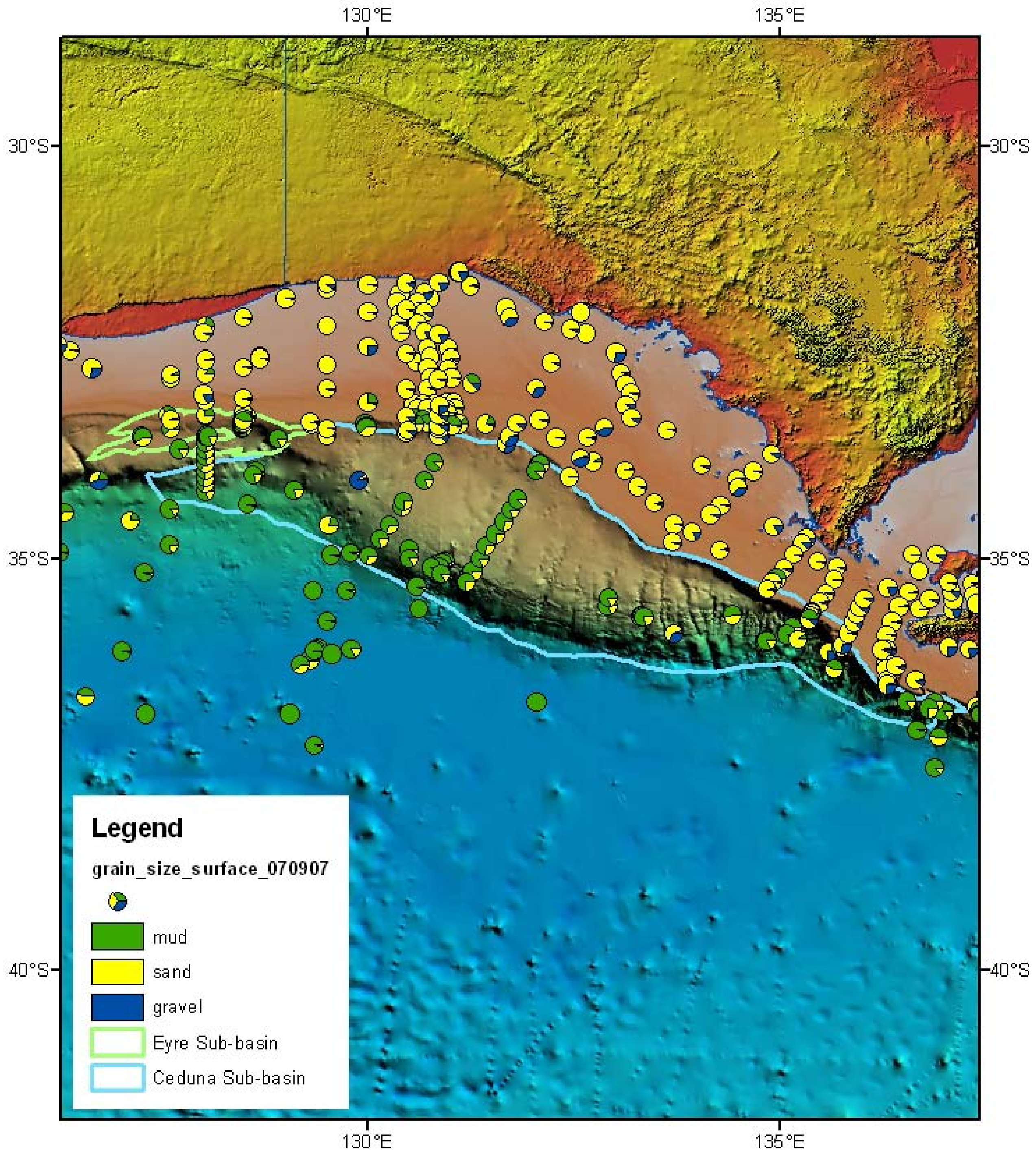


Figure A.2: *Surface sediment grainsize for the region (pie-charts displayed with overlapping of data).*

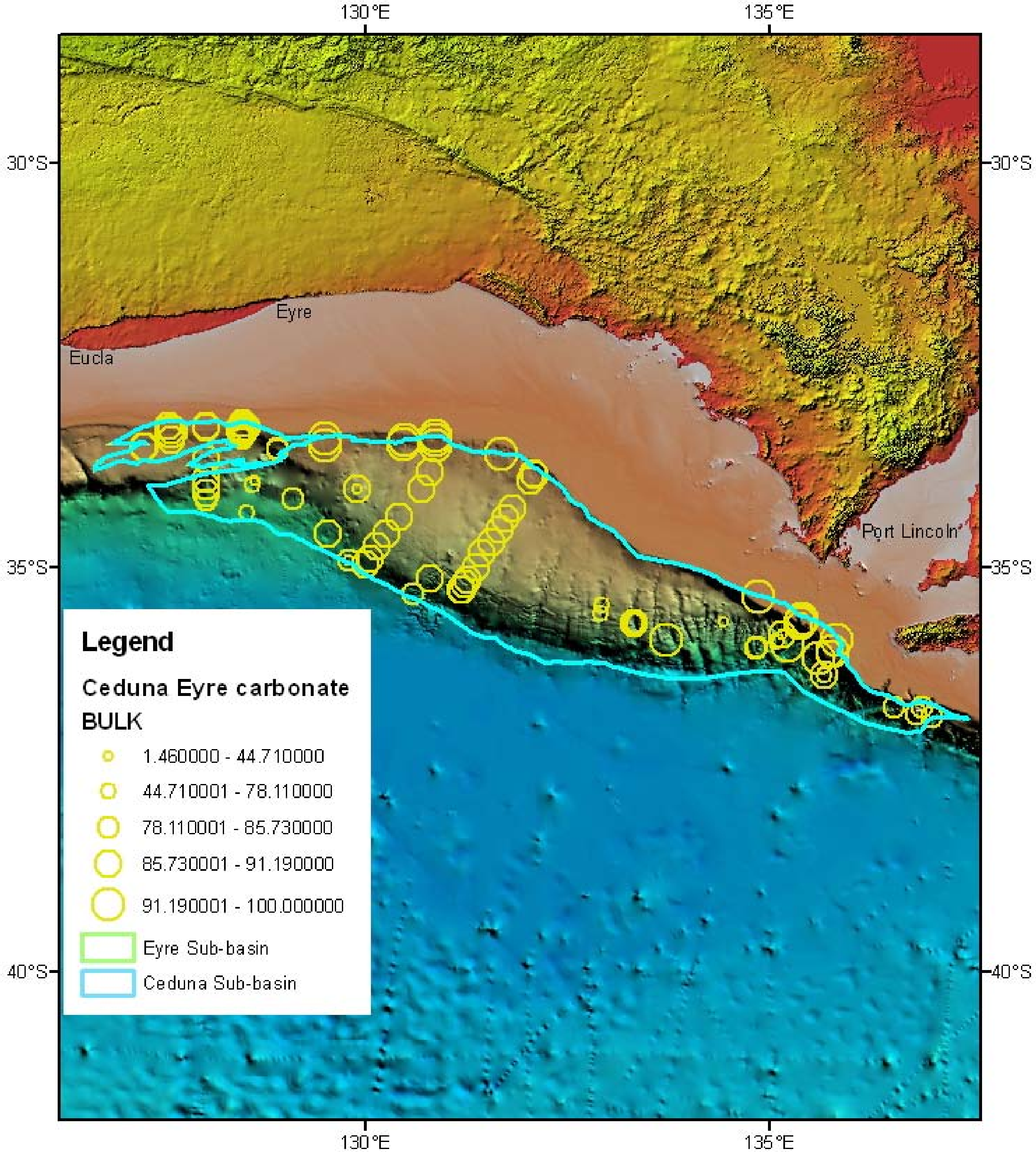


Figure A.3: *Surface sediment % bulk carbonate (bubbles displayed with overlapping of data).*

Table A.1: Ceduna Sub-basin surface samples.

eno	Sample no	Survey id	Survey name	Sample id	Sample Type	Top depth	Base depth	Latitude	Longitude	Mud %	Sand %	Gravel %
4406	1399539	SS 01/2000	Southern Surveyor Cruise 1, 2000	224/DR01	DREDGE UN-SPECIFIED	0.00	0.00	-35.13382	130.80445	78.89	21.11	0.00
4406	1399540	SS 01/2000	Southern Surveyor Cruise 1, 2000	224/DR02	DREDGE UN-SPECIFIED	0.00	0.00	-35.33397	130.59658	93.45	6.55	0.00
386	1411181	GA-66	GAB 2	66/DR01	DREDGE PIPE	0.00	0.00	-33.93307	128.63767	66.35	31.95	1.70
386	1411200	GA-66	GAB 2	66/DR03	DREDGE PIPE	0.00	0.00	-33.97582	128.60867	81.23	18.77	0.00
386	1411209	GA-66	GAB 2	66/DR04	DREDGE PIPE	0.00	0.00	-34.15853	129.10632	79.98	20.02	0.00
386	1411212	GA-66	GAB 2	66/DR06	DREDGE PIPE	0.00	0.00	-35.56683	132.91267	83.74	16.24	0.02
386	1411225	GA-66	GAB 2	66/DR07/A	DREDGE PIPE	0.00	0.00	-35.69957	133.32562	68.88	31.04	0.08
386	1411233	GA-66	GAB 2	66/DR08	DREDGE PIPE	0.00	0.00	-35.67870	134.43253	53.95	46.05	0.00
386	1411241	GA-66	GAB 2	66/DR09	DREDGE PIPE	0.00	0.00	-36.00162	134.82993	87.98	12.02	0.00
386	1411245	GA-66	GAB 2	66/DR10	DREDGE PIPE	0.00	0.00	-35.98958	134.84317	82.57	17.43	0.00
386	1411249	GA-66	GAB 2	66/DR11/A	DREDGE PIPE	0.00	0.00	-35.82735	135.15830	66.46	33.52	0.01
386	1411250	GA-66	GAB 2	66/DR11/B	DREDGE PIPE	0.00	0.00	-35.82735	135.15830	84.52	15.29	0.19
386	1411258	GA-66	GAB 2	66/DR12	DREDGE PIPE	0.00	0.00	-35.91342	135.09045	87.01	12.38	0.61
386	1411272	GA-66	GAB 2	66/DR14	DREDGE PIPE	0.00	0.00	-35.97268	135.22588	10.21	89.34	0.46
386	1411288	GA-66	GAB 2	66/DR15/A	DREDGE PIPE	0.00	0.00	-36.33435	135.66900	83.10	16.90	0.00
386	1411294	GA-66	GAB 2	66/DR15/B	DREDGE PIPE	0.00	0.00	-36.33435	135.66900	44.07	55.90	0.03
459	1412820	GA-102	Southern	102/GC14/	CORE	0.06	0.09	-34.37000	130.41783	73.00	27.00	0.00

			Margins Sampling	6-9cm	GRAVITY							
47372	1445087	FR 01/01	GAB Seeps	231/GC11/ 0-5	CORE GRAVITY	0.00	0.05	-34.29300	130.43400	76.00	24.00	0.00
47372	1445088	FR 01/01	GAB Seeps	231/GC13/ 0-3	CORE GRAVITY	0.00	0.03	-35.07100	130.84100	75.59	24.41	0.00
47372	1445089	FR 01/01	GAB Seeps	231/GC14/ 0-3	CORE GRAVITY	0.00	0.03	-35.02900	130.93200	80.00	20.00	0.00
47372	1445090	FR 01/01	GAB Seeps	231/GC15/ 0-3	CORE GRAVITY	0.00	0.03	-35.05300	130.90400	75.39	24.61	0.00
47372	1445091	FR 01/01	GAB Seeps	231/GC16/ 0-2	CORE GRAVITY	0.00	0.02	-35.05400	130.90300	94.41	5.59	0.00
47372	1445092	FR 01/01	GAB Seeps	231/GC17/ 0-2	CORE GRAVITY	0.00	0.02	-35.09100	130.87100	78.50	21.50	0.00
47372	1445093	FR 01/01	GAB Seeps	231/GC18/ 0-2	CORE GRAVITY	0.00	0.02	-34.88400	130.50300	73.07	26.93	0.00
47372	1445094	FR 01/01	GAB Seeps	231/GC19/ 0-2	CORE GRAVITY	0.00	0.02	-34.98800	130.49900	84.30	15.70	0.00
47372	1445095	FR 01/01	GAB Seeps	231/GC20/ 0-2	CORE GRAVITY	0.00	0.02	-35.10400	130.77100	86.51	13.49	0.00
47372	1445096	FR 01/01	GAB Seeps	231/GC21/ 0-2	CORE GRAVITY	0.00	0.02	-35.18200	130.88800	83.74	16.26	0.00
459	1694733	GA-102	Southern Margins Sampling	102/GC01/ 0-2cm	CORE GRAVITY	0.00	0.02	-34.17000	128.02450	80.97	19.03	0.00
459	1694734	GA-102	Southern Margins Sampling	102/GC02/ 0-2cm	CORE GRAVITY	0.00	0.02	-34.08000	128.02500	68.77	31.23	0.00
459	1694735	GA-102	Southern Margins Sampling	102/GC03/ 0-2cm	CORE GRAVITY	0.00	0.02	-34.00000	128.02467	70.64	29.33	0.03
459	1694736	GA-102	Southern Margins Sampling	102/GC04/ 0-2cm	CORE GRAVITY	0.00	0.02	-33.92000	128.02517	73.55	26.28	0.17
459	1694742	GA-102	Southern Margins Sampling	102/GC13/ 0-2cm	CORE GRAVITY	0.00	0.02	-33.82000	130.80350	86.73	13.27	0.00
459	1694743	GA-102	Southern Margins Sampling	102/GC15/ 0-2cm	CORE GRAVITY	0.00	0.02	-34.59000	130.26083	70.09	29.91	0.00
459	1694744	GA-102	Southern	102/GC16/	CORE	0.00	0.02	-34.75000	130.14100	76.93	23.07	0.00

			Margins Sampling	0-2cm	GRAVITY							
459	1694745	GA-102	Southern Margins Sampling	102/GC18/ 0-2cm	CORE GRAVITY	0.00	0.02	-34.96000	130.00717	72.87	27.13	0.00
459	1694746	GA-102	Southern Margins Sampling	102/GC19/ 0-2cm	CORE GRAVITY	0.00	0.02	-34.92000	129.78667	80.63	17.45	1.92
459	1694747	GA-102	Southern Margins Sampling	102/GC21/ 0-2cm	CORE GRAVITY	0.00	0.02	-34.92000	129.78617	94.88	5.12	0.00
459	1694748	GA-102	Southern Margins Sampling	102/GC22/ 0-2cm	CORE GRAVITY	0.00	0.02	-34.04000	129.88917	3.90	96.10	0.00
459	1694749	GA-102	Southern Margins Sampling	102/GC25/ 0-2cm	CORE GRAVITY	0.00	0.02	-34.04000	129.88883	1.89	9.65	88.46
386	1694812	GA-66	GAB 2	66/GC02/0-2cm	CORE GRAVITY	0.00	0.02	-33.83997	132.07833	86.43	13.33	0.24
386	1694813	GA-66	GAB 2	66/GC03/0-2cm	CORE GRAVITY	0.00	0.02	-33.85115	132.08847	76.67	22.90	0.43
386	1694814	GA-66	GAB 2	66/GC04/0-2cm	CORE GRAVITY	0.00	0.02	-33.93033	132.04068	86.60	12.62	0.78
386	1694815	GA-66	GAB 2	66/GC05/0-2cm	CORE GRAVITY	0.00	0.02	-34.03842	130.69138	80.67	19.33	0.00
386	1694816	GA-66	GAB 2	66/GC07/0-2cm	CORE GRAVITY	0.00	0.02	-34.59063	129.52860	19.68	80.32	0.00
386	1694818	GA-66	GAB 2	66/GC10/0-2cm	CORE GRAVITY	0.00	0.02	-35.27780	131.18162	72.90	26.77	0.33
386	1694819	GA-66	GAB 2	66/GC11/0-2cm	CORE GRAVITY	0.00	0.02	-35.20260	131.22662	73.03	26.88	0.09
386	1694820	GA-66	GAB 2	66/GC12/0-2cm	CORE GRAVITY	0.00	0.02	-35.15360	131.27042	69.01	30.99	0.00
386	1694821	GA-66	GAB 2	66/GC13/0-2cm	CORE GRAVITY	0.00	0.02	-34.99405	131.35902	82.46	17.53	0.01
386	1694822	GA-66	GAB 2	66/GC14/0-2cm	CORE GRAVITY	0.00	0.02	-34.83562	131.43305	74.47	25.53	0.00
386	1694823	GA-66	GAB 2	66/GC15/0-2cm	CORE GRAVITY	0.00	0.02	-34.69535	131.55093	75.68	24.32	0.00
386	1694824	GA-66	GAB 2	66/GC16/0-2cm	CORE GRAVITY	0.00	0.02	-34.54213	131.65453	73.38	25.46	1.16

386	1694825	GA-66	GAB 2	66/GC17/0-2cm	CORE GRAVITY	0.00	0.02	-34.40418	131.73492	78.88	21.12	0.00
386	1694826	GA-66	GAB 2	66/GC18/0-2cm	CORE GRAVITY	0.00	0.02	-34.27057	131.81805	86.41	13.59	0.00
386	1694827	GA-66	GAB 2	66/GC19/0-2cm	CORE GRAVITY	0.00	0.02	-35.47200	132.91737	83.13	16.87	0.00
386	1694828	GA-66	GAB 2	66/GC20/0-2cm	CORE GRAVITY	0.00	0.02	-35.69572	133.31268	79.01	20.83	0.16
386	1694829	GA-66	GAB 2	66/GC21/0-2cm	CORE GRAVITY	0.00	0.02	-35.68805	133.33112	84.83	15.17	0.00
386	1694830	GA-66	GAB 2	66/GC22/0-2cm	CORE GRAVITY	0.00	0.02	-35.69968	133.35378	76.74	23.26	0.00
386	1694831	GA-66	GAB 2	66/PC01/0-2cm	CORE PISTON	0.00	0.02	-35.27665	131.19242	73.03	26.95	0.03
1537	1746419	V3303	Vema Cruise 33, Leg 3	VM33-38P-0-1cm	CORE PISTON	0.00	0.01	-34.33300	128.53300	97.29	2.71	0.00
364062	1747032	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM27	DREDGE BENTHIC	0.00	0.00	-36.12533	135.59667	0.45	73.61	25.93
364062	1747038	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM54	DREDGE BENTHIC	0.00	0.00	-33.59700	131.68183	3.41	68.62	27.97
364062	1747048	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM64	DREDGE BENTHIC	0.00	0.00	-33.49983	130.86550	2.94	86.23	10.83

364062	1747049	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM65	DREDGE BENTHIC	0.00	0.00	-33.42000	130.86733	2.88	94.20	2.92
364062	1747050	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM66	DREDGE BENTHIC	0.00	0.00	-33.37400	130.86533	1.15	89.02	9.83
364062	1747063	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM79	DREDGE BENTHIC	0.00	0.00	-33.47267	130.46883	0.29	96.61	3.10
364062	1747064	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM80	DREDGE BENTHIC	0.00	0.00	-33.43500	130.48183	0.11	88.86	11.03
364062	1747065	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM81	DREDGE BENTHIC	0.00	0.00	-33.49850	129.50150	0.10	94.68	5.22
364062	1747066	FR 03/98	Cool Water	FR03/98	DREDGE	0.00	0.00	-33.41733	129.50333	0.04	98.36	1.60

			Carbonate Sedimentation, Bonny and Lacepede Shelves and	ACM82	BENTHIC							
575	1840234	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL08	DREDGE PIPE	0.00	0.00	-35.90433	133.71400	6.43	60.38	33.19
575	1840241	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL18	DREDGE PIPE	0.00	0.00	-35.36883	134.85683	5.35	92.05	2.60
575	1840246	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL28	DREDGE PIPE	0.00	0.00	-35.64667	135.40000	4.79	91.94	3.27
575	1840247	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL29	DREDGE PIPE	0.00	0.00	-35.65833	135.39083	6.52	89.76	3.72
575	1840248	FR 06/94	Southern Australian	FR06/94/PL30	DREDGE BENTHIC	0.00	0.00	-35.68883	135.37950	3.68	94.15	2.16

			Margin, Cool-Water Carbonates and Geological History									
575	1840249	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL31	DREDGE PIPE	0.00	0.00	-35.73150	135.35650	43.80	43.67	12.53
575	1840250	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL35	DREDGE PIPE	0.00	0.00	-36.07183	135.74683	64.68	35.24	0.08
575	1840251	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL36	GRAB UN-SPECIFIED	0.00	0.00	-36.04100	135.77167	1.02	70.09	28.89
575	1840253	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL38	DREDGE PIPE	0.00	0.00	-35.90000	135.83133	1.25	97.58	1.17
362784	1920312	SS02/2006	AUSCAN 2006 - Geological	SS02/06/DR3	DREDGE UN-SPECIFIED	0.00	0.00	-36.85305	136.99795	85.59	14.41	0.00

			and biological investigation of the Murray Canyons Group									
362784	1920313	SS02/2006	AUSCAN 2006 - Geological and biological investigation of the Murray Canyons Group	SS02/06/DR4	DREDGE UN-SPECIFIED	0.00	0.00	-36.73282	136.88382	72.08	27.92	0.00
48046	1920335	MD131	AUSCAN - Marion Dufresne Cruise 131	MD 03-2610 1-4cm	CORE UN-SPECIFIED	0.01	0.04	-36.81517	136.81400	74.24	25.66	0.10
48046	1920336	MD131	AUSCAN - Marion Dufresne Cruise 131	MD 03-2612 1-4cm	CORE UN-SPECIFIED	0.01	0.04	-36.72717	136.54617	83.70	16.30	0.00

Table A.2: *Ceduna Sub-basin surface carbonate analysis.*

eno	Survey id	Survey name	Sample id	Sample no	Sample type	Top depth	Base depth	Latitude	Longitude	Mud CaCO3 %	Sand CaCO3 %	Gravel CaCO3 %	Bulk CaCO3 %
459	GA-102	Southern Margins Sampling	102/GC25/0-2cm	1694749	CORE GRAVITY	0.00	0.02	-34.04000	129.88883			5.00	1.46
459	GA-102	Southern Margins Sampling	102/GC19/0-2cm	1694746	CORE GRAVITY	0.00	0.02	-34.92000	129.78667	1.28	3.00	25.00	13.28
386	GA-66	Great Australian Bight 2	66/DR11/B	1411250	DREDGE PIPE	0.00	0.00	-35.82735	135.15830	14.05	22.70	0.00	20.30
386	GA-66	Great Australian Bight 2	66/DR01	1411181	DREDGE PIPE	0.00	0.00	-33.93307	128.63767	53.19	30.40	0.00	34.00
386	GA-66	Great Australian Bight 2	66/DR08	1411233	DREDGE PIPE	0.00	0.00	-35.67870	134.43253	75.88	22.70		44.71
386	GA-66	Great Australian Bight 2	66/DR03	1411200	DREDGE PIPE	0.00	0.00	-33.97582	128.60867	79.99	87.96		65.61
386	GA-66	Great Australian Bight 2	66/GC19/0-2cm	1694827	CORE GRAVITY	0.00	0.02	-35.47200	132.91737	75.03	43.56		66.63
386	GA-66	Great Australian Bight 2	66/DR15/A	1411288	DREDGE PIPE	0.00	0.00	-36.33435	135.66900	70.23	49.25		76.14
386	GA-66	Great Australian Bight 2	66/DR06	1411212	DREDGE PIPE	0.00	0.00	-35.56683	132.91267	81.19	72.03	0.00	77.34
386	GA-66	Great Australian Bight 2	66/DR12	1411258	DREDGE PIPE	0.00	0.00	-35.91342	135.09045	86.42	85.13	0.00	77.54
1537	V3303	Vema Cruise 33, Leg 3	VM33-38P-0-1cm	1746419	CORE PISTON	0.00	0.01	-34.33300	128.53300				78.11
4406	SS 01/2000	Southern Surveyor Cruise 1, 2000	224/DR02	1399540	DREDGE UN-SPECIFIED	0.00	0.00	-35.33397	130.59658	79.60	90.90		80.30

362784	SS02/2006	AUSCAN 2006 - Geological and biological investigation of the Murray Canyons Group	SS02/06/DR3	1920312	DREDGE UN-SPECIFIED	0.00	0.00	-36.85305	136.99795	83.89	89.51		81.43
48046	MD131	AUSCAN - Marion Dufresne Cruise 131	MD 03-2612 1-4cm	1920336	CORE UN-SPECIFIED	0.01	0.04	-36.72717	136.54617	85.08	88.15		81.85
48046	MD131	AUSCAN - Marion Dufresne Cruise 131	MD 03-2610 1-4cm	1920335	CORE UN-SPECIFIED	0.01	0.04	-36.81517	136.81400	84.32	89.00	90.00	82.87
386	GA-66	Great Australian Bight 2	66/DR10	1411245	DREDGE PIPE	0.00	0.00	-35.98958	134.84317	84.11	91.90		83.08
459	GA-102	Southern Margins Sampling	102/GC21/0-2cm	1694747	CORE GRAVITY	0.00	0.02	-34.92000	129.78617	86.59			83.33
362784	SS02/2006	AUSCAN 2006 - Geological and biological investigation of the Murray Canyons Group	SS02/06/DR4	1920313	DREDGE UN-SPECIFIED	0.00	0.00	-36.73282	136.88382	84.06	92.40		84.06
386	GA-66	Great Australian Bight 2	66/DR04	1411209	DREDGE PIPE	0.00	0.00	-34.15853	129.10632	85.90	95.67		84.28
459	GA-102	Southern Margins Sampling	102/GC01/0-2cm	1694733	CORE GRAVITY	0.00	0.02	-34.17000	128.02450	85.22	93.87		84.28
386	GA-66	Great Australian Bight 2	66/DR09	1411241	DREDGE PIPE	0.00	0.00	-36.00162	134.82993	85.90	94.55		84.62
386	GA-66	Great Australian	66/GC20/0-2cm	1694828	CORE GRAVITY	0.00	0.02	-35.69572	133.31268	85.73	91.75	100.00	85.65

		Bight 2											
386	GA-66	Great Australian Bight 2	66/GC22/0-2cm	1694830	CORE GRAVITY	0.00	0.02	-35.69968	133.35378	87.10	93.28		85.65
386	GA-66	Great Australian Bight 2	66/GC21/0-2cm	1694829	CORE GRAVITY	0.00	0.02	-35.68805	133.33112	86.59	91.75		85.73
386	GA-66	Great Australian Bight 2	66/PC01/0-2cm	1694831	CORE PISTON	0.00	0.02	-35.27665	131.19242	89.07	93.01	100.00	86.50
459	GA-102	Southern Margins Sampling	102/GC16/0-2cm	1694744	CORE GRAVITY	0.00	0.02	-34.75000	130.14100	88.05	96.35		86.93
386	GA-66	Great Australian Bight 2	66/GC10/0-2cm	1694818	CORE GRAVITY	0.00	0.02	-35.27780	131.18162	89.50	94.29	100.00	87.02
459	GA-102	Southern Margins Sampling	102/GC02/0-2cm	1694734	CORE GRAVITY	0.00	0.02	-34.08000	128.02500	86.59			87.27
386	GA-66	Great Australian Bight 2	66/GC03/0-2cm	1694813	CORE GRAVITY	0.00	0.02	-33.85115	132.08847	88.56	95.31	100.00	87.27
386	GA-66	Great Australian Bight 2	66/GC14/0-2cm	1694822	CORE GRAVITY	0.00	0.02	-34.83562	131.43305	89.33	97.33		87.27
386	GA-66	Great Australian Bight 2	66/DR11/A	1411249	DREDGE PIPE	0.00	0.00	-35.82735	135.15830	75.88	89.59	100.00	87.45
386	GA-66	Great Australian Bight 2	66/GC16/0-2cm	1694824	CORE GRAVITY	0.00	0.02	-34.54213	131.65453	89.50	90.23	100.00	87.45
459	GA-102	Southern Margins Sampling	102/GC03/0-2cm	1694735	CORE GRAVITY	0.00	0.02	-34.00000	128.02467	86.25	95.07	100.00	87.53
386	GA-66	Great Australian Bight 2	66/GC15/0-2cm	1694823	CORE GRAVITY	0.00	0.02	-34.69535	131.55093	90.02	93.28		87.53
459	GA-102	Southern Margins Sampling	102/GC13/0-2cm	1694742	CORE GRAVITY	0.00	0.02	-33.82000	130.80350	89.16			87.70
459	GA-102	Southern	102/GC15/0-	1694743	CORE	0.00	0.02	-34.59000	130.26083	87.79			87.70

		Margins Sampling	2cm		GRAVITY								
386	GA-66	Great Australian Bight 2	66/GC11/0-2cm	1694819	CORE GRAVITY	0.00	0.02	-35.20260	131.22662	89.84	97.33	100.00	87.70
386	GA-66	Great Australian Bight 2	66/GC13/0-2cm	1694821	CORE GRAVITY	0.00	0.02	-34.99405	131.35902	90.87	91.25	100.00	87.96
459	GA-102	Southern Margins Sampling	102/GC18/0-2cm	1694745	CORE GRAVITY	0.00	0.02	-34.96000	130.00717	86.85	96.61		88.13
386	GA-66	Great Australian Bight 2	66/GC02/0-2cm	1694812	CORE GRAVITY	0.00	0.02	-33.83997	132.07833	90.87		95.00	88.22
459	GA-102	Southern Margins Sampling	102/GC22/0-2cm	1694748	CORE GRAVITY	0.00	0.02	-34.04000	129.88917		94.73		88.30
386	GA-66	Great Australian Bight 2	66/GC05/0-2cm	1694815	CORE GRAVITY	0.00	0.02	-34.03842	130.69138	88.82			88.30
459	GA-102	Southern Margins Sampling	102/GC04/0-2cm	1694736	CORE GRAVITY	0.00	0.02	-33.92000	128.02517	87.02	94.73	100.00	88.47
386	GA-66	Great Australian Bight 2	66/GC18/0-2cm	1694826	CORE GRAVITY	0.00	0.02	-34.27057	131.81805	88.99	94.29		88.47
4406	SS 01/2000	Southern Surveyor Cruise 1, 2000	224/DR01	1399539	DREDGE UN-SPECIFIED	0.00	0.00	-35.13382	130.80445	87.90	90.80		88.50
386	GA-66	Great Australian Bight 2	66/DR15/B	1411294	DREDGE PIPE	0.00	0.00	-36.33435	135.66900	87.53	94.47	100.00	88.56
386	GA-66	Great Australian Bight 2	66/GC12/0-2cm	1694820	CORE GRAVITY	0.00	0.02	-35.15360	131.27042	89.93	96.32		88.56
386	GA-66	Great Australian Bight 2	66/DR07/A	1411225	DREDGE PIPE	0.00	0.00	-35.69957	133.32562	87.62	94.64	100.00	88.64
386	GA-66	Great Australian	66/GC17/0-2cm	1694825	CORE GRAVITY	0.00	0.02	-34.40418	131.73492	89.50	96.32		88.99

		Bight 2											
459	GA-102	Southern Margins Sampling	102/GC14/0-3cm	1412809	CORE GRAVITY	0.00	0.03	-34.37000	130.41783				89.00
459	GA-102	Southern Margins Sampling	102/GC17/3-5cm	1412867	CORE GRAVITY	0.03	0.05	-34.89000	130.05550				89.00
386	GA-66	Great Australian Bight 2	66/GC04/0-2cm	1694814	CORE GRAVITY	0.00	0.02	-33.93033	132.04068	91.90	92.26	60.00	89.93
459	GA-102	Southern Margins Sampling	102/GC14/6-9cm	1412820	CORE GRAVITY	0.06	0.09	-34.37000	130.41783				90.00
459	GA-102	Southern Margins Sampling	102/GC17/8-10cm	1412878	CORE GRAVITY	0.08	0.10	-34.89000	130.05550				90.00
575	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL31	1840249	DREDGE PIPE	0.00	0.00	-35.73150	135.35650	90.14	94.23	100.00	90.14
575	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL35	1840250	DREDGE PIPE	0.00	0.00	-36.07183	135.74683	90.14	93.10	100.00	90.14
386	GA-66	Great Australian Bight 2	66/GC07/0-2cm	1694816	CORE GRAVITY	0.00	0.02	-34.59063	129.52860		94.29		90.27
386	GA-66	Great Australian Bight 2	66/DR14	1411272	DREDGE PIPE	0.00	0.00	-35.97268	135.22588	90.10	95.15	100.00	92.16
575	FR 06/94	Southern Australian Margin, Cool-	FR06/94/PL29	1840247	DREDGE PIPE	0.00	0.00	-35.65833	135.39083		95.10	100.00	93.54

		Water Carbonates and Geological History										
364062	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM54	1747038	DREDGE BENTHIC	0.00	0.00	-33.59700	131.68183	95.36	100.00	94.14
364062	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM27	1747032	DREDGE BENTHIC	0.00	0.00	-36.12533	135.59667	95.19	100.00	94.49
575	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL18	1840241	DREDGE PIPE	0.00	0.00	-35.36883	134.85683	95.71	100.00	94.58
364062	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM65	1747049	DREDGE BENTHIC	0.00	0.00	-33.42000	130.86733	95.71	100.00	94.67
575	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL08	1840234	DREDGE PIPE	0.00	0.00	-35.90433	133.71400	96.58	100.00	94.93
364062	FR 03/98	Cool Water Carbonate	FR03/98 ACM64	1747048	DREDGE BENTHIC	0.00	0.00	-33.49983	130.86550	96.15	100.00	95.01

		Sedimentatio n, Bonny and Lacepede Shelves and										
575	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL28	1840246	DREDGE PIPE	0.00	0.00	-35.64667	135.40000	95.97	100.00	95.36
575	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL36	1840251	GRAB UN-SPECIFIED	0.00	0.00	-36.04100	135.77167	95.01	100.00	95.36
364062	FR 03/98	Cool Water Carbonate Sedimentatio n, Bonny and Lacepede Shelves and	FR03/98 ACM79	1747063	DREDGE BENTHIC	0.00	0.00	-33.47267	130.46883	96.32	100.00	95.54
364062	FR 03/98	Cool Water Carbonate Sedimentatio n, Bonny and Lacepede Shelves and	FR03/98 ACM66	1747050	DREDGE BENTHIC	0.00	0.00	-33.37400	130.86533	96.41	100.00	95.62
575	FR 06/94	Southern Australian Margin, Cool-Water Carbonates and Geological History	FR06/94/PL30	1840248	DREDGE BENTHIC	0.00	0.00	-35.68883	135.37950	95.88	95.00	95.71
575	FR 06/94	Southern	FR06/94/PL38	1840253	DREDGE	0.00	0.00	-35.90000	135.83133	95.71	100.00	96.49

		Australian Margin, Cool-Water Carbonates and Geological History			PIPE							
364062	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM80	1747064	DREDGE BENTHIC	0.00	0.00	-33.43500	130.48183	97.97	100.00	97.36
364062	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM81	1747065	DREDGE BENTHIC	0.00	0.00	-33.49850	129.50150	97.97	100.00	98.41
364062	FR 03/98	Cool Water Carbonate Sedimentation, Bonny and Lacepede Shelves and	FR03/98 ACM82	1747066	DREDGE BENTHIC	0.00	0.00	-33.41733	129.50333	98.23	100.00	100.00

Table A.3: *Bight Survey, Ceduna Sub-basin surface sediment samples.*

ENO	SAMPLE ID	SAMPLE TYPE	LATITUDE	LONGITUDE	ACQUIRE DATE	COMMENTS
433074	01GC01	GRAVITY CORE	-35.02623	133.93298	25/02/2007	Bagged sample
433074	01GC02	GRAVITY CORE	-35.02632	133.93283	25/02/2007	Bagged sample
433074	01GR01	GRAB	-35.02617	133.93300	25/02/2007	Sed sample
433074	02GC03	GRAVITY CORE	-34.37412	132.77767	25/02/2007	Bagged sample
433074	02GC04	GRAVITY CORE	-34.37402	132.77840	9/03/2007	Bagged sample
433074	02GR02	GRAB	-34.37403	132.77810	25/02/2007	Sed sample
433074	03GC05	GRAVITY CORE	-34.37852	132.78860	25/02/2007	Bagged sample
433074	03GC06	GRAVITY CORE	-34.37868	132.78838	25/02/2007	Bagged sample
433074	03GR03	GRAB	-34.37843	132.78832	25/02/2007	Sed sample
433074	04GC07	GRAVITY CORE	-33.98178	130.31755	25/02/2007	Disruptor
433074	04GC08	GRAVITY CORE	-33.98172	130.31723	25/02/2007	Bagged sample
433074	04GR04	GRAB	-33.98175	130.31770	26/02/2007	Sed sample
433074	05GC09	GRAVITY CORE	-33.60500	130.19950	26/02/2007	Bagged sample
433074	05GC10	GRAVITY CORE	-33.60527	130.19987	27/02/2007	Disruptor
433074	05GR05	GRAB	-33.60500	130.19917	2/03/2007	Sed sample
433074	06GC11	GRAVITY CORE	-33.55165	130.08567	2/03/2007	Bagged sample
433074	06GC12	GRAVITY CORE	-33.55175	130.08600	8/03/2007	Bagged sample
433074	06GR06	GRAB	-33.55167	130.08638	5/03/2007	Sed sample
433074	07GC13	GRAVITY CORE	-33.47755	130.17908	5/03/2007	Bagged sample
433074	07GC14	GRAVITY CORE	-33.47728	130.17958	27/02/2007	Bagged sample
433074	07GR07	GRAB	-33.47708	130.17905	27/02/2007	see parent description
433074	08GC15	GRAVITY	-33.46825	130.06985	27/02/2007	Bagged sample

		CORE				
433074	08GC16	GRAVITY CORE	-33.46845	130.06978	27/02/2007	Bagged sample
433074	08GR08	GRAB	-33.46825	130.06947	28/02/2007	see parent description
433074	09GC17	GRAVITY CORE	-33.42718	130.06065	28/02/2007	Bagged sample
433074	09GC18	GRAVITY CORE	-33.42768	130.06068	27/02/2007	Bagged sample
433074	09GR09	GRAB	-33.42708	130.05982	28/02/2007	Sed sample
433074	10GC19	GRAVITY CORE	-33.50778	129.99945	28/02/2007	Core catcher
433074	10GC20	GRAVITY CORE	-33.50803	129.99953	28/02/2007	Bagged sample
433074	10GR10	GRAB	-33.50790	129.99908	28/02/2007	Sed sample
433074	11GC21	GRAVITY CORE	-33.43592	130.05000	28/02/2007	Bagged sample
433074	11GC22	GRAVITY CORE	-33.43590	130.05195	28/02/2007	Bagged sample
433074	12GC23	GRAVITY CORE	-33.57483	129.89860	28/02/2007	Bagged sample
433074	12GC24	GRAVITY CORE	-33.57452	129.89880	28/02/2007	Bagged sample
433074	12GR11	GRAB	-33.57475	129.89887	28/02/2007	see parent description
433074	13DR01	DREDGE	-33.85290	129.45627	28/02/2007	Mudstone - light grey silaceous mudstone with abundant sponge spicules, minor calcareous content, partially lithified to friable, massive fabric with no layering, moderate to poorly sorted, silt-sized sponge spicules (visible under handlens), possible fo
433074	14DR02	DREDGE	-33.83960	129.44560	1/03/2007	Mudstone - light grey silaceous mudstone with abundant sponge spicules, minor calcareous and clay content, partially lithified to friable, massive fabric with no layering, moderate to poorly sorted, silt-sized sponge spicules (visible under handlens).
433074	45GC35	GRAVITY CORE	-34.57422	130.52252	12/03/2007	Bagged sample
433074	45GR17	GRAB	-34.57425	130.52235	12/03/2007	Sed sample
433074	46GC37	GRAVITY CORE	-34.57708	130.53003	12/03/2007	Bagged sample
433074	46GC38	GRAVITY CORE	-34.57695	130.52975	12/03/2007	Bagged sample

433074	47GC39	GRAVITY CORE	-34.60225	130.55955	12/03/2007	Bagged sample
433074	47GC40	GRAVITY CORE	-34.60175	130.55933	12/03/2007	Bagged sample
433074	48GC41	GRAVITY CORE	-34.63180	130.59947	12/03/2007	Bagged sample
433074	48GC42	GRAVITY CORE	-34.63173	130.59988	4/03/2007	Bagged sample
433074	49GC43	GRAVITY CORE	-34.63930	130.60973	13/03/2007	Disruptor
433074	49GC44	GRAVITY CORE	-34.63973	130.60978	3/03/2007	Bagged sample
433074	50GC45	GRAVITY CORE	-34.65320	130.62865	2/03/2007	Bagged sample
433074	50GC46	GRAVITY CORE	-34.65328	130.62883	19/03/1908	Bagged sample
433074	51GC47	GRAVITY CORE	-34.68475	130.67058	12/03/2007	Bagged sample
433074	51GC48	GRAVITY CORE	-34.68455	130.67068	15/03/2007	Bagged sample
433074	52DR35	DREDGE	-35.04662	130.91437	12/03/2007	Argillaceous limestone - very dark grey (when fresh), well lithified, with soft clayey weathering skin or encrusted in botroidal brown ?calcite, fine grained matrix supporting sand sized black to brown flattened grains or uncertain origin, poorly sorted,
433074	53DR36	DREDGE	-34.91862	130.01868	13/03/2007	Chalk - white, very fine grained, friable massive limestone
433074	54GC49	GRAVITY CORE	-34.91543	130.97773	13/03/2007	Bagged sample
433074	54GC50	GRAVITY CORE	-34.91577	130.97782	13/03/2007	Bagged sample
433074	55GC51	GRAVITY CORE	-34.97418	130.91758	2/03/2007	Bagged sample
433074	55GC52	GRAVITY CORE	-34.97377	130.91740	2/03/2007	Bagged sample
433074	55GR18	GRAB	-34.97412	130.91747	2/03/2007	Cream coloured fine to very fine grained foraminiferal calcareous/siliceous ooze/mud.
433074	56GC53	GRAVITY CORE	-35.18495	131.21147	2/03/2007	Bagged sample
433074	56GC54	GRAVITY CORE	-35.18452	131.21117	12/03/2007	Bagged sample
433074	57GC55	GRAVITY	-35.09628	131.27573	16/03/2007	Bagged sample

		CORE				
433074	57GC56	GRAVITY CORE	-35.09587	131.27545	13/03/2007	Bagged sample
433074	58GC57	GRAVITY CORE	-35.28280	131.43770	13/03/2007	Bagged sample
433074	58GC58	GRAVITY CORE	-35.28267	131.43795	13/03/2007	Bagged sample
433074	59GC59	GRAVITY CORE	-35.42547	131.58115	14/03/2007	Bagged sample
433074	59GC60	GRAVITY CORE	-35.42552	131.58122	14/03/2007	Bagged sample
433074	60DR37	DREDGE	-35.67482	131.37007	14/03/2007	Mudstone - silt-sized quartz, mica with clay, siliciclastic, lithified but quite friable, weak irregular horizontal bedding in some, mottled bedding, poor sorting
433074	61GC61	GRAVITY CORE	-35.65152	131.38523	14/03/2007	Core catcher sample
433074	62GC62	GRAVITY CORE	-35.56570	132.91015	14/03/2007	Bagged sample
433074	62GC63	GRAVITY CORE	-35.56565	132.91073	14/03/2007	Bagged sample
433074	63GC64	GRAVITY CORE	-35.46050	133.27803	14/03/2007	Core catcher, missing
433074	63GC65	GRAVITY CORE	-35.46037	133.27822	12/03/2007	Core catcher sample
433074	64GC66	GRAVITY CORE	-35.51130	133.86718	12/03/2007	Core catcher sample
433074	64GC67	GRAVITY CORE	-35.51132	133.88312	15/03/2007	Core catcher sample

Table A.4: Eyre Sub-basin surface samples grainsize

eno	Sample no	Survey id	Survey name	Sample id	Sample type	Top Depth m	Base Depth m	Latitude	Longitude	Mud %	Sand %	Gravel %
47372	1445084	FR 01/01	GAB Seeps	231/GC5/0-5	CORE GRAVITY	0.00	0.05	-33.41700	128.47300	65.15	34.85	0.00
47372	1445085	FR 01/01	GAB Seeps	231/GC6/0-2	CORE GRAVITY	0.00	0.02	-33.39500	128.46700	73.23	26.77	0.00
47372	1445086	FR 01/01	GAB Seeps	231/GC7/0-5	CORE GRAVITY	0.00	0.05	-33.40000	128.48100	67.71	32.29	0.00
459	1694739	GA-102	Southern Margins Sampling	102/GC07/0-2cm	CORE GRAVITY	0.00	0.02	-33.67000	128.02417	76.72	23.28	0.00
459	1694759	GA-102	Southern Margins Sampling	102/VC02/0-2cm	CORE VIBRO	0.00	0.02	-33.27000	128.02550	13.46	77.88	8.66
459	1694760	GA-102	Southern Margins Sampling	102/VC03/0-2cm	CORE VIBRO	0.00	0.02	-33.27000	128.02550	35.30	64.63	0.07
459	1694761	GA-102	Southern Margins Sampling	102/VC04/0-2cm	CORE VIBRO	0.00	0.02	-33.25000	128.02500	25.30	74.66	0.04
515	1694766	GA-173	ODP Site Survey, GAB	173/GC02/0-2cm	CORE GRAVITY	0.00	0.02	-33.51200	127.24800	61.20	38.61	0.19
515	1694767	GA-173	ODP Site Survey, GAB	173/GC03/0-2cm	CORE GRAVITY	0.00	0.02	-33.51200	127.24800	75.91	24.09	0.00
515	1694768	GA-173	ODP Site Survey, GAB	173/GC05/0-2cm	CORE GRAVITY	0.00	0.02	-33.42000	127.60200	65.73	34.27	0.00
515	1694769	GA-173	ODP Site Survey, GAB	173/GC06/0-2cm	CORE GRAVITY	0.00	0.02	-33.42000	127.60200	62.89	37.09	0.02
515	1694772	GA-173	ODP Site Survey, GAB	173/GC09/0-2cm	CORE GRAVITY	0.00	0.02	-33.35800	128.48100	74.49	25.51	0.00
515	1694773	GA-173	ODP Site Survey, GAB	173/GC10/0-2cm	CORE GRAVITY	0.00	0.02	-33.35800	128.48100	73.51	26.36	0.13
515	1694774	GA-173	ODP Site Survey, GAB	173/GC11/0-2cm	CORE GRAVITY	0.00	0.02	-33.35800	128.48100	71.76	28.14	0.10
515	1694775	GA-173	ODP Site Survey, GAB	173/GC12/0-2cm	CORE GRAVITY	0.00	0.02	-33.35800	128.48100	73.97	26.03	0.00
515	1694776	GA-173	ODP Site Survey,	173/GC16/0-2cm	CORE	0.00	0.02	-33.54000	128.90500	83.93	15.79	0.28

			GAB		GRAVITY							
515	1694777	GA-173	ODP Site Survey, GAB	173/GC17/0-2cm	CORE GRAVITY	0.00	0.02	-33.53900	128.90500	85.36	14.61	0.03
515	1694785	GA-173	ODP Site Survey, GAB	173/VC08/0-2cm	CORE VIBRO	0.00	0.02	-33.28900	128.48100	22.11	77.89	0.00
515	1694786	GA-173	ODP Site Survey, GAB	173/VC09/0-2cm	CORE VIBRO	0.00	0.02	-33.29000	128.48100	24.73	75.18	0.09
515	1694788	GA-173	ODP Site Survey, GAB	173/VC12/0-2cm	CORE VIBRO	0.00	0.02	-33.31600	127.60300	14.36	83.01	2.63
47372	1694791	FR 01/01	GAB Seeps	231/GC05/0-2cm	CORE GRAVITY	0.00	0.02	-33.41700	128.47300	75.35	24.18	0.47
47372	1694792	FR 01/01	GAB Seeps	231/GC06/0-2cm	CORE GRAVITY	0.00	0.02	-33.39500	128.46700	89.39	10.61	0.00
47372	1694793	FR 01/01	GAB Seeps	231/GC07/0-2cm	CORE GRAVITY	0.00	0.02	-33.40000	128.48100	83.96	16.04	0.00
26991	1698942	FR 07/95	Cool-Water Carbonate Sedimentation, GAB and Phytoplankton Productivity	GAB-021	DREDGE PIPE	0.00	0.00	-33.36667	128.46667	69.33	29.94	0.73
26991	1698944	FR 07/95	Cool-Water Carbonate Sedimentation, GAB and Phytoplankton Productivity	GAB-023	DREDGE PIPE	0.00	0.00	-33.31667	128.46667	41.10	58.90	0.00
26991	1698945	FR 07/95	Cool-Water Carbonate Sedimentation, GAB and Phytoplankton Productivity	GAB-024	DREDGE PIPE	0.00	0.00	-33.33333	128.46667	32.21	67.13	0.66
26991	1698946	FR 07/95	Cool-Water Carbonate Sedimentation,	GAB-025	DREDGE PIPE	0.00	0.00	-33.31667	128.48333	26.81	71.96	1.23

			GAB and Phytoplankton Productivity									
26991	1698947	FR 07/95	Cool-Water Carbonate Sedimentation, GAB and Phytoplankton Productivity	GAB-026	DREDGE PIPE	0.00	0.00	-33.31667	128.48333	42.39	56.65	0.96
26991	1698949	FR 07/95	Cool-Water Carbonate Sedimentation, GAB and Phytoplankton Productivity	GAB-028	DREDGE PIPE	0.00	0.00	-33.30000	128.48333	15.79	83.63	0.59
26991	1698950	FR 07/95	Cool-Water Carbonate Sedimentation, GAB and Phytoplankton Productivity	GAB-029	DREDGE PIPE	0.00	0.00	-33.26667	128.53333	2.31	94.11	3.58
26991	1698951	FR 07/95	Cool-Water Carbonate Sedimentation, GAB and Phytoplankton Productivity	GAB-030	DREDGE BENTHIC	0.00	0.00	-33.21667	128.48333	1.95	96.90	1.15
1698	1746379	V1812	Vema Cruise 18, Leg 12	VM18-219P-0-10cm	CORE PISTON	0.00	0.10	-33.25000	127.56700	33.23	66.77	0.00
407338	1920650	ODP182	GAB: Cenozoic Cool-Water Carbonates	IODP/182/1127A/0-2cm	CORE UNSPECIFIED	0.00	0.02	-33.35000	128.48200	70.26	29.74	0.00
407338	1920652	ODP182	GAB: Cenozoic Cool-Water Carbonates	IODP/182/1129A/0-2cm	CORE UNSPECIFIED	0.00	0.02	-33.29000	128.48200	21.05	78.95	0.00
407338	1920654	ODP182	GAB: Cenozoic	IODP/182/1131A/0-	CORE	0.00	0.02	-33.32000	128.48200	43.12	56.88	0.00

			Cool-Water Carbonates	2cm	UNSPECIFIED							
407338	1920655	ODP182	GAB: Cenozoic Cool-Water Carbonates	IODP/182/1132A/0-2cm	CORE UNSPECIFIED	0.00	0.02	-33.31000	127.60200	6.04	93.96	0.00
407338	1920656	ODP182	GAB: Cenozoic Cool-Water Carbonates	IODP/182/1133A/0-2cm	CORE UNSPECIFIED	0.00	0.02	-33.54000	128.90500	82.82	17.18	0.00
407338	1920657	ODP182	GAB: Cenozoic Cool-Water Carbonates	IODP/182/1134A/0-2cm	CORE UNSPECIFIED	0.00	0.02	-33.52000	127.26300	61.27	38.73	0.00

Table A.5: *Eyre Sub-basin surface samples carbonate analysis.*

eno	Survey id	Survey name	Sample id	Sample no	Sample type	Top depth	Base depth	Latitude	Longitude	Mud CaCO3 %	Sand CaCO3 %	Gravel CaCO3 %	Bulk CaCO3 %
459	GA-102	Southern Margins Sampling	102/GC07/ 0-2cm	1694739	CORE GRAVITY	0.00	0.02	-33.6700	128.0242	87.70	95.75		87.10
459	GA-102	Southern Margins Sampling	102/VC02/ 0-2cm	1694759	CORE VIBRO	0.00	0.02	-33.2700	128.0255		94.47	100	90.79
459	GA-102	Southern Margins Sampling	102/VC03/ 0-2cm	1694760	CORE VIBRO	0.00	0.02	-33.2700	128.0255	89.59	94.64	100	89.59
459	GA-102	Southern Margins Sampling	102/VC04/ 0-2cm	1694761	CORE VIBRO	0.00	0.02	-33.2500	128.0250	91.04	94.64	100	90.36
515	GA-173	ODP Site Survey, GAB	173/GC02/ 0-2cm	1694766	CORE GRAVITY	0.00	0.02	-33.5120	127.2480	89.50	96.27	100	89.33
515	GA-173	ODP Site Survey, GAB	173/GC03/ 0-2cm	1694767	CORE GRAVITY	0.00	0.02	-33.5120	127.2480	89.59	94.64		87.36
515	GA-173	ODP Site Survey, GAB	173/GC05/ 0-2cm	1694768	CORE GRAVITY	0.00	0.02	-33.4200	127.6020	88.39	92.93		87.02
515	GA-173	ODP Site Survey, GAB	173/GC06/ 0-2cm	1694769	CORE GRAVITY	0.00	0.02	-33.4200	127.6020	88.22	92.76	100	87.96
515	GA-173	ODP Site Survey, GAB	173/GC09/ 0-2cm	1694772	CORE GRAVITY	0.00	0.02	-33.3580	128.4810	88.30	88.22		84.88
515	GA-173	ODP Site Survey, GAB	173/GC10/ 0-2cm	1694773	CORE GRAVITY	0.00	0.02	-33.3580	128.4810	87.19	88.64	100	83.93
515	GA-173	ODP Site Survey, GAB	173/GC11/ 0-2cm	1694774	CORE GRAVITY	0.00	0.02	-33.3580	128.4810	87.87	88.71	100	84.36
515	GA-173	ODP Site Survey, GAB	173/GC12/ 0-2cm	1694775	CORE GRAVITY	0.00	0.02	-33.3580	128.4810	87.19	88.71		85.05
515	GA-173	ODP Site Survey, GAB	173/GC16/ 0-2cm	1694776	CORE GRAVITY	0.00	0.02	-33.5400	128.9050	87.45	93.28	100	85.13

515	GA-173	ODP Site Survey, GAB	173/GC17/ 0-2cm	1694777	CORE GRAVITY	0.00	0.02	-33.5390	128.9050	87.62	92.26	100	85.56
515	GA-173	ODP Site Survey, GAB	173/VC08/ 0-2cm	1694785	CORE VIBRO	0.00	0.02	-33.2890	128.4810	89.16	95.24		90.87
515	GA-173	ODP Site Survey, GAB	173/VC09/ 0-2cm	1694786	CORE VIBRO	0.00	0.02	-33.2900	128.4810	89.33	94.73	100	92.84
515	GA-173	ODP Site Survey, GAB	173/VC12/ 0-2cm	1694788	CORE VIBRO	0.00	0.02	-33.3160	127.6030	92.67	96.44	100	92.16
4737 2	FR 01/01	GAB Seeps	231/GC05/ 0-2cm	1694791	CORE GRAVITY	0.00	0.02	-33.4170	128.4730	86.50	91.25	95	85.05
4737 2	FR 01/01	GAB Seeps	231/GC06/ 0-2cm	1694792	CORE GRAVITY	0.00	0.02	-33.3950	128.4670	86.85			81.19
4737 2	FR 01/01	GAB Seeps	231/GC07/ 0-2cm	1694793	CORE GRAVITY	0.00	0.02	-33.4000	128.4810	87.87			85.73
2699 1	FR 07/95	Cool-Water Carbonate Sedimentation, Great Australian Bight and Phytoplankton Productivity	GAB-021	1698942	DREDGE PIPE	0.00	0.00	-33.3667	128.4667	84.66	86.28	85	83.30
2699 1	FR 07/95	Cool-Water Carbonate Sedimentation, Great Australian Bight and Phytoplankton Productivity	GAB-023	1698944	DREDGE PIPE	0.00	0.00	-33.3167	128.4667	84.91	89.25		85.30

2699 1	FR 07/95	Cool-Water Carbonate Sedimentation, Great Australian Bight and Phytoplankton Productivity	GAB-024	1698945	DREDGE PIPE	0.00	0.00	-33.3333	128.4667	87.81	90.62	100	87.00
2699 1	FR 07/95	Cool-Water Carbonate Sedimentation, Great Australian Bight and Phytoplankton Productivity	GAB-025	1698946	DREDGE PIPE	0.00	0.00	-33.3167	128.4833	84.74	89.51	100	85.70
2699 1	FR 07/95	Cool-Water Carbonate Sedimentation, Great Australian Bight and Phytoplankton Productivity	GAB-026	1698947	DREDGE PIPE	0.00	0.00	-33.3167	128.4833	85.00	90.27	100	85.40
2699 1	FR 07/95	Cool-Water Carbonate Sedimentation, Great Australian Bight and Phytoplankton Productivity	GAB-028	1698949	DREDGE PIPE	0.00	0.00	-33.3000	128.4833	86.53	91.38	100	88.70

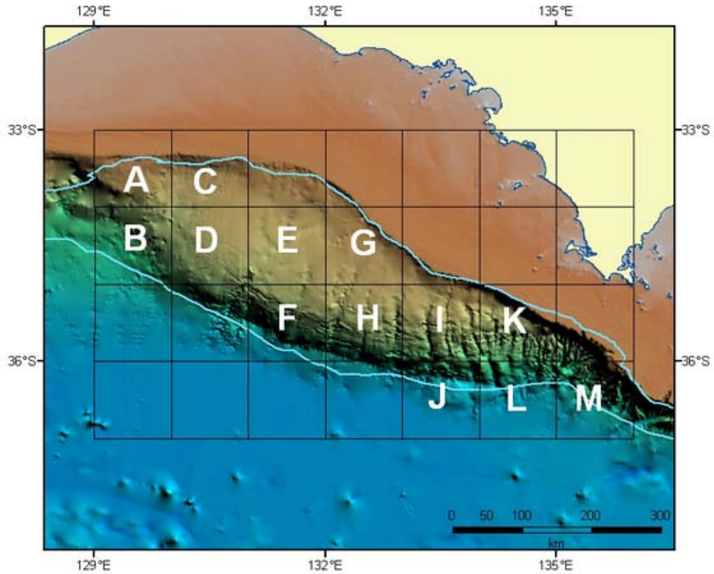
26991	FR 07/95	Cool-Water Carbonate Sedimentation, Great Australian Bight and Phytoplankton Productivity	GAB-029	1698950	DREDGE PIPE	0.00	0.00	-33.2667	128.5333		92.06	100	91.00
26991	FR 07/95	Cool-Water Carbonate Sedimentation, Great Australian Bight and Phytoplankton Productivity	GAB-030	1698951	DREDGE BENTHIC	0.00	0.00	-33.2167	128.4833		92.49	95	91.00
1698	V1812	Vema Cruise 18, Leg 12	VM18-219P-0-10cm	1746379	CORE PISTON	0.00	0.10	-33.2500	127.5670	90.96	92.40		90.79
407338	ODP182	GAB: Cenozoic Cool-Water Carbonates. Sites: 1126-1134	IODP/182/1127A/0-2cm	1920650	CORE UNSPECIFIED	0.00	0.02	-33.3500	128.4820	87.97	87.88		84.66
407338	ODP182	GAB: Cenozoic Cool-Water Carbonates. Sites: 1126-1134	IODP/182/1129A/0-2cm	1920652	CORE UNSPECIFIED	0.00	0.02	-33.2900	128.4820		95.28		90.49
407338	ODP182	GAB: Cenozoic Cool-Water Carbonates. Sites: 1126-1134	IODP/182/1130A/0-2cm	1920653	CORE UNSPECIFIED	0.00	0.02	-33.4200	127.6020				86.75

407338	ODP182	GAB: Cenozoic Cool-Water Carbonates. Sites: 1126-1134	IODP/182/1131A/0-2cm	1920654	CORE UNSPECIFIED	0.00	0.02	-33.3200	128.4820	88.31	91.80	86.75
407338	ODP182	GAB: Cenozoic Cool-Water Carbonates. Sites: 1126-1134	IODP/182/1132A/0-2cm	1920655	CORE UNSPECIFIED	0.00	0.02	-33.3100	127.6020		94.93	91.19
407338	ODP182	GAB: Cenozoic Cool-Water Carbonates. Sites: 1126-1134	IODP/182/1133A/0-2cm	1920656	CORE UNSPECIFIED	0.00	0.02	-33.5400	128.9050	88.31		85.36
407338	ODP182	GAB: Cenozoic Cool-Water Carbonates. Sites: 1126-1134	IODP/182/1134A/0-2cm	1920657	CORE UNSPECIFIED	0.00	0.02	-33.5200	127.2630	90.84	94.67	89.53

Table A.6: *Eyre Sub-basin sample locations, Bight Survey.*

ENO	SAMPLE ID	SAMPLE TYPE	LATITUDE	LONGITUDE	ACQUIRE DATE	COMMENTS
433074	16DR06	DREDGE	-33.64502	128.62768	1/03/2007	Igneous - very fine-grained grey igneous rock, probably weathered basalt, lithified, veins of calcite and chert, limonite, curved shapes and vesicles (spherical to elongate infilled) suggest pillow basalts.
433074	17DR07	DREDGE	-33.63843	128.63065	1/03/2007	?Phosphate nodules - grey, fine grained, well lithified, with iron oxide weathering skin
433074	19DR09	DREDGE	-33.71000	128.43147	3/03/2007	Mudstone - bluish black, comprising clay, quartz and fine mica, weakly lithified and very friable, massive, clay to silt grain size
433074	19DR10	DREDGE	-33.71010	128.43233	3/03/2007	?Phosphate nodules - grey, fine-grained ?phosphatic matrix supporting 5% dark tabular grains, poorly sorted, lithified but weathering to soft clay at margins
433074	20DR11	DREDGE	-33.73040	128.44028	3/03/2007	Mudstone - very dark greyish brown, comprising clay, minor quartz and fine mica, partially lithified and very friable, massive, dominantly clay with minor silt grain size; mashed in with some pelagic sediment
433074	21DR12	DREDGE	-33.73167	128.43867	3/03/2007	Volcano-clastic vitric tuff - Fine grained elongate mafic phenocrysts + minor medium grained feldspar phenocrysts in a fine - very fine grained grey groundmass (also contains some calcite veining). Elongate mafic crystals exhibit preferred orientation (in
433074	21DR13	DREDGE	-33.69900	128.43900	4/03/2007	Siltstone - Dark, organic rich siltstone. Siliciclastic and contains quartz, organic components and mica. Well lithified and well indurated. Planar thin bedding with slight internal lamination. Moderate to well sorted and matrix supported. Silt grains

Appendix B Species in the Ceduna Sub-basin



Species found in and near the Ceduna Sub-basin based on records from 1° lat/long quadrats in the Ocean Biogeographic Information System. An 'X' indicates that the species was found in the corresponding lettered quadrat within the map to the right. * represents commercially targeted species, and † represents species with minor commercial importance (bycatch or regional focus elsewhere). Depth and habitat information for fish was obtained from www.fishbase.org.

Scientific Name	Group	Common Name	Habitat	Depth (m)	A	B	C	D	E	F	G	H	I	J	K	L	M
*Jasus edwardsii**	Arthropod	Northern Rock Lobster	Benthic												X		
Neolithodes brodieia	Arthropod	Decapod					X										
Parapallene australiensis	Arthropod	Sea Spider					X										
Caryophyllia planilamellata	Cnidarian	Stony Coral	Benthic									X					X
Cladopathes plumosaa	Cnidarian	Black coral	Benthic												X		
Corallimorphus rigidusa	Cnidarian	Anemone	Benthic												X		
Culicia australiensisa	Cnidarian	Black coral	Benthic														X
Dendrobathypathes isocrada	Cnidarian	Coral	Benthic		X								X				
Parantipathes helicosticha	Cnidarian	Black coral	Benthic		X				X								
Parantipathes triadocrada	Cnidarian	Black coral	Benthic								X						
Trissopathes tetracrada	Cnidarian	Coral	Benthic		X												
Trissopathes tristicha	Cnidarian	Coral	Benthic						X								
Ophiomyxa australis	Echinoderm	Brittlestar	Benthic				X										
Allomycterus pilatus	Fish	Deepwater Burrfish	Demersal	40-270	X		X										
*Alopias vulpinus**	Fish	Thintail Thresher	Pelagic	0-550													X

Anoplocapros lenticularis	Fish	High-backed Boxfish	Demersal	10-220		X					
Antimora rostrata†	Fish	Blue Antimora	Bathypelagic	350 – 3277		X					
Apogonops anomalus	Fish	Three-spined Cardinalfish	Demersal	0-600	X	X					
Aptychotrema vincentiana†	Fish	Southern Shovel-nosed Ray	Demersal	0-32	X	X					
Argentina australiae†	Fish	Silverside	Benthopelagic	30-400	X	X					
Argyripnus iridescensa	Fish				X	X					
Argyropelecus aculeatus	Fish	Atlantic Silver Hatchetfish	Bathypelagic	100-600		X					
Asymbolus occiduus†	Fish	Western Spotted Catshark	Pelagic	98-400	X						
*Azygopus pinnifasciatus**	Fish	Banded-fin Flounder	Demersal	120-900	X	X					
Aulopus purpurissatus	Fish	Sargent Baker's Fish	Reef	0-100	X	X		X			
Brama brama†	Fish	Atlantic Pomfret	Bathypelagic	0-1000						X	
Caelorinchus fasciatus†	Fish	Banded Whiptail	Bathydemersal	73-1086	X						
Caelorinchus innotabilis†	Fish	Notable Whiptail	Bathydemersal	554-1463	X						
Caesioperca razor†	Fish	Barber Perch	Demersal	0-180	X	X					
Callanthias allporti	Fish	Splendid Sea Perch	Reef	20-100	X	X					
Callanthias australis	Fish	Magnificent Splendid Perch	Reef	15-365			X				
*Callorhinchus milii**	Fish	Ghost Shark	Demersal	0-227	X	X					
Capropygia unistriata	Fish	Black-banded Pigmy Boxfish	Demersal	60-200			X				
Carcharhinus brachyurus	Fish	Copper Shark	Reef	0-100	X	X	X			X	
*Carcharhinus longimanus**	Fish	Oceanic Whitetip Shark	Reef	0-230			X			X	
Carcharias taurus	Fish	Sand Tiger Shark	Reef	1-191	X						
Centriscops humerosus	Fish	Banded Yellowfish	Bathydemersal	35-1000						X	
Centroberyx affinis†	Fish	Redfish	Benthopelagic	10-450							X
*Centroberyx gerrardi**	Fish	Bight Redfish	Demersal	10-500	X	X	X				
Centroberyx lineatus†	Fish	Swallowtail	Benthopelagic	15-280	X	X	X				
*Centrolophus niger**	Fish	Blackfish	Bathypelagic	40-1050			X		X	X	
Cephaloscyllium laticeps	Fish	Australian Swellshark	Demersal	0-220	X						

Ceratias holboelli	Fish	Kroyer's Deepsea Anglerfish	Bathypelagic	?-3400			X			X	
Chauliodus sloani	Fish	Needletooth	Bathypelagic	473-2800						X	
Chaunax endeavouri	Fish	Coffinfish	Bathydemersal	50-300			X		X	X	
*Chelidonichthys kumu**	Fish	Bluefin Gurnard	Demersal	1-200	X	X		X			
Chrysphys auratusa	Fish	Snapper	Pelagic	0-200	X	X		X			
*Coryphaena hippurus**	Fish	Common Dolphinfish	Pelagic	0-85				X		X	X
Coryphaenoides armatus	Fish	Abyssal Grenadier	Bathydemersal	282-5180						X	
Coryphaenoides serrulatus†	Fish	Serrulate Whiptail	Bathydemersal	540-2070						X	
Cristiceps aurantiacus	Fish	Golden Weedfish	Demersal	0-30					X		
*Cyttus australis**	Fish	Silver Dory	Demersal	10-350	X	X		X			
*Cyttus traverse**	Fish	Bight Dory	Bathydemersal	200-800	X	X					X
Dalatias licha†	Fish	Kitefin Shark	Bathydemersal	37-1800						X	
Dannevigia tusca†	Fish	Australian Tusk	Benthopelagic	115-400	X	X		X			
Dasyatis brevicaudata	Fish	Short-tail Stingray	Demersal	0-476		X					
Diaphus coeruleus†	Fish	Blue Lanternfish	Bathypelagic	457-549	X						
Dipturus lemprieria	Fish					X					
Dipturus sp.	Fish				X						
Diretmichthys parini	Fish	Parin's Spiny Fin	Bathypelagic	?-2000			X				
Etmopterus lucifer	Fish	Blackbelly Lanternshark	Bathydemersal	15-1250		X					
*Etrumeus teres**	Fish	Rond Herring	Pelagic	0-150		X					
Eubalichthys mosaicus†	Fish	Mosaic Leatherjacket	Reef	?-140	X	X					
Euclichthys polynemus†	Fish	Eucla Cod	Bathydemersal	250-920	X	X					
Fistularia petimba	Fish	Red Cornetfish	Reef	10-200		X					
*Furgaleus macki**	Fish	Whiskery Shark	Demersal	?-220		X				X	
*Galeorhinus galeus**	Fish	Tope Shark	Benthopelagic	0-1100	X	X		X		X	
Galeus boardmani†	Fish	Australian Sawtail Catshark	Bathydemersal	128-	X	X					X

				823							
Gasterochisma melampus†	Fish	Butterfly Kingfish	Pelagic	200-?							X
*Genypterus blacodes**	Fish	Pink Cusk Eel / Ling	Bathydemersal	22-1000	X	X		X			X
Gigantactis paxtoni	Fish		Bathypelagic						X		
Halosauropsis macrochir	Fish	Abyssal Halosaur	Bathydemersal	1100-3300			X	X			
Halosaurus pectoralis	Fish	Goanna Fish	Bathydemersal	600-1270		X			X		
Helicolenus percoides†	Fish	Red Gurnard Perch	Demersal	50-750	X	X		X			X
Heterodontus portusjacksoni†	Fish	Port Jackson Shark	Demersal	0-275		X					
Heteropriacanthus cruentatus†	Fish	Glasseye	Reef	3-300				X			
Hoplichthys haswelli†	Fish	Armoured Flathead	Bathydemersal	140-700	X						
*Hoplostethus atlanticus**	Fish	Orange Roughy	Bathypelagic	180-1809		X					
Hydrolagus lemurs†	Fish	Blackfin Ghostshark	Bathydemersal	146-510	X						
Hydrolagus ogilbyi†	Fish	Ghostshark	Bathydemersal	120-350	X						
*Hyperoglyphe antarctica**	Fish	Antarctic Butterfish / Trevalla	Benthopelagic	40-1500							X
Irolita waitii†	Fish	Round Skate	Demersal	50-200		X					
Isurus oxyrinchus†	Fish	Shortfin Mako	Reef	0-740				X	X	X	X
Kathetostoma nigrofasciatum	Fish	Deepwater Stargazer	Demersal	130-270	X	X		X			
*Katsuwonus pelamis**	Fish	Skipjack Tuna	Pelagic	0-230	X	X		X			
*Lamna nasus**	Fish	Beaumaris Shark	Pelagic	0-715							X
Lepidocybium flavobrunneum†	Fish	Escolar	Bathypelagic	200-1100				X			
Lepidoperca pulchella†	Fish	Orange Perch	Demersal	50-400	X	X					
Lepidopus caudatus	Fish	Scabbard Fish	Bathydemersal	42-620	X	X					X
Lepidorhynchus denticulatus	Fish	Javelinfish	Bathypelagic	180-1000	X						
Lepidotrigla vanessa	Fish	Butterfly Gurnard	Demersal	10-100		X					

Lucigadus nigromaculatus†	Fish	Blackspotted Grenadier	Bathydemersal	200-1463	X						
Macrorhamphosus scolopax†	Fish	Longspine Snipefish	Demersal	25-600		X		X			X
*Macruronus novaezelandiae**	Fish	Blue Grenadier	Benthopelagic	0-1000	X	X		X			X
Metavelifer multiradiatus	Fish	Spinyfin Velifer	Benthopelagic	40-240	X	X					
Mola mola	Fish	Ocean Sunfish	Pelagic	30-480				X		X	X
Mora moro†	Fish	Common Mora	Bathypelagic	450-2500	X	X					X
*Mustelus antarcticus**	Fish	Gummy Shark	Demersal	?-350	X	X		X		X	
Myliobatis australis	Fish	Eagle Ray	Reef	?-85	X						
*Nemadactylus macropterus**	Fish	Tarakihi	Demersal	22-450	X	X		X			X
*Nemadactylus valenciennesi**	Fish	Sea Carp	Demersal	40-240	X	X		X			
Neocyttus rhomboidalis†	Fish	Spikey Oreo	Bathypelagic	200-1240	X						
Neoscopelus macrolepidotus	Fish	Glowingfish	Bathypelagic	300-1180					X		
Neosebastes bougainvillii	Fish	Gulf Gurnard Perch	Reef	10-100	X	X					
Neosebastes nigropunctatus	Fish	Black-spotted Gurnard Perch	Reef	60-556	X	X					
Neosebastes pandus	Fish	Bighead Gurnard Perch	Reef	15-593	X	X		X			
Neosebastes thetidis	Fish	Gurnard Perch	Demersal	45-288	X	X		X			
Notorynchus cepedianus†	Fish	Broadnose Sevengill Shark	Demersal	0-570		X				X	
Notoscopelus resplendens†	Fish	Patchwork Lampfish	Bathypelagic	0-2121		X					
Omegophora armilla	Fish	Ringed Pufferfish	Demersal	?-146	X	X					
Ophisurus serpens†	Fish	Serpent Eel	Reef	?-300		X					
Oplegnathus woodwardi	Fish	Knifejaw	Demersal	50-400	X	X		X			
Orectolobus ornatus	Fish	Ornate Wobbegong	Reef	0-100	X						
Oxynotus bruniensis	Fish	Prickly Dogfish	Bathydemersal	45-1070	X						
Paraliparis dewittia	Fish							X			
Paraliparis lastia	Fish				X						
Paratrachichthys trailli	Fish	Sandpaper Fish	Bathypelagic	70-327						X	
Paraulopus nigripinnis	Fish	Cucumberfish	Demersal	80-600	X						
Paristiopterus gallipavo	Fish	Yellow-spotted Boarfish	Demersal	60-260	X	X		X			
Pentaceros decacanthus	Fish	Bigspined Boarfish	Bathydemersal	37-460	X	X					

Phosichthys argenteusa	Fish					X		X			
Plagiogeneion macrolepis†	Fish	Rubyfish	Demersal	95-390		X		X			
Platycephalus bassensis†	Fish	Bay Flathead	Demersal	?-100	X	X					
*Platycephalus conatus**	Fish	Deepwater Flathead	Demersal	70-490	X	X		X			
*Platycephalus richardsoni**	Fish	Tiger Flathead	Demersal	10-400	X						
Polymetme corythaeola	Fish				X						
*Polyprion oxygeneios**	Fish	Grouper	Demersal	50-584	X	X		X			
Prionace glauca†	Fish	Blue Shark	Pelagic	1-350				X	X	X	X
*Pristiophorus cirratus**	Fish	Common Sawshark	Demersal	37-310		X					
Pristiophorus nudipinnis†	Fish	Shortnose Sawshark	Demersal	37-165	X	X				X	
*Pseudocaranx dentex**	Fish	White Trevally	Reef	10-200	X	X		X			
*Pseudocyttus maculatus**	Fish	Smooth Dory	Bathydemersal	400-1500	X	X					
Pterygotrigla polyomata†	Fish	Flying Gurnard / Latchet	Demersal	35-400	X	X		X		X	
Remora remora	Fish	Common Remora	Reef	0-100				X			
*Rexea solandri**	Fish	Silver Gemfish	Bathydemersal	100-800	X	X		X			X
Ruvettus pretiosus	Fish	Oilfish	Benthopelagic	100-800	X			X		X	X
*Sardinops sagax**	Fish	South American Pilchard	Pelagic	0-200	X	X					
Scobinichthys granulatus†	Fish	Rough Leatherjacket	Reef			X					
*Scomber australasicus**	Fish	Blue Mackerel	Pelagic	87-200	X	X		X			
Seriola hippos†	Fish	Samson Fish	Pelagic		X	X		X			
Seriola lalandi†	Fish	Yellow Amberjack	Benthopelagic	3-825	X	X					
*Seriolella brama**	Fish	Common Warehou	Benthopelagic	22-400	X	X		X			
*Seriolella punctata**	Fish	Silver Warehou	Benthopelagic	27-650				X			X
Simenchelys parasitica	Fish	Slime Eel	Bathydemersal	136-2620		X					
Sphyrna lewini†	Fish	Bronze Hammerhead Shark	Reef	0-512	X	X				X	
Sphyrna zygaena†	Fish	Common Hammerhead Shark	Reef	0-200				X		X	
*Squalus acanthias**	Fish	Piked Dogfish	Benthopelagic	0-1460		X					
Squalus megalops†	Fish	Shortnose Spurdog	Bathydemersal	30-750	X	X		X			X
Squatina australis†	Fish	Australian Angelshark	Demersal	?-256	X	X		X			X
Squatina tergocellata†	Fish	Ornate Angelshark	Bathydemersal	128-	X	X		X			

				400								
*Thunnus alalunga**	Fish	Albacore Tuna	Pelagic	0-600					X	X	X	X
*Thunnus maccoyii**	Fish	Southern Bluefin Tuna	Pelagic	50-2743		X			X		X	X
*Thunnus obesus**	Fish	Bigeye Tuna	Pelagic	0-250					X	X	X	X
*Thyrsites atun**	Fish	Snoek / Barracouta	Benthopelagic	0-550		X						X
Tilodon sexfasciatus	Fish	Moonlighter	Demersal	?-120		X						
*Trachurus declivis**	Fish	Greenback Horse Mackerel	Benthopelagic	27-460	X	X			X			
*Trachurus novaezelandiae**	Fish	Yellowtail Horse Mackerel	Pelagic	22-500		X						
Trachyscorpia capensis	Fish	Cape Rockfish	Bathydemersal	450-1025						X		
Trygonoptera testacea†	Fish	Common Stingaree	Demersal	?-135	X	X						
Trygonorrhina fasciata†	Fish	Banjo Shark	Demersal	?-180	X	X						
Uranoscopus cognatus	Fish	Two-spined Yellow Stargazer	Demersal		X							
Urolophus bucculentus	Fish	Sandyback Singaree	Demersal	100-230		X						
Urolophus viridis	Fish	Greenback Stingaree	Demersal	20-200	X	X			X			
Urolophus westraliensis†	Fish	Brown Stingaree	Demersal	60-210		X						
*Xiphias gladius**	Fish	Swordfish	Pelagic	0-800					X	X	X	X
Zanclistius elevatus	Fish	Longfin Boarfish	Demersal	30-500	X	X			X			
*Zenopsis nebulosus**	Fish	Mirror Dory	Bathydemersal	30-800	X							
*Zeus faber**	Fish	John Dory	Benthopelagic	5-400	X	X			X		X	
Abraliopsis gilchristia	Mollusc	Squid					X			X		
Creseis virgula	Mollusc	Curved Needle Pteropod	Pelagic								X	
Cuspidaria hindsiana	Mollusc	Bivalve				X						
Cyclochlamys favusa	Mollusc	Bivalve									X	
Cystiscus cymbalum	Mollusc	Gastropod									X	
Eledone palari	Mollusc	Spongetip Octopus				X						
Euprymna tasmanica	Mollusc	Southern Bobtail Squid	Benthopelagic		X							
Histioteuthis miranda	Mollusc	Jewel Squid				X		X				
*Nototodarus gouldi**	Mollusc	Arrow Squid			X	X			X			X
Octopus berrima	Mollusc	Southern Keeled Octopus				X						
Paphia undulata	Mollusc	Bivalve				X						

Persicula pulchella	Mollusc	Flat-Topped Margin Shell	Benthic				X
Pyroteuthis margaritifera	Mollusc	Fire Squid			X	X	
*Sepioteuthis australis**	Mollusc	Southern Calamary	Benthopelagic	X			
Tanea sagittata	Mollusc	Gastropod					X
Tricolia fordiana	Mollusc	Gastropod					X
Umbraculum umbraculum	Mollusc	Atlantic Umbrella Slug	Benthic				X

Appendix C Invertebrates in the Ceduna Sub-basin

***Table C.1**: Invertebrates found in Ceduna sub-basin based on records from Museum of Victoria.*

Scientific Name	Group	Common Name	Latitude	Longitude	Number Found
Glyphus marsulialis	Arthropod	Shrimp	34 56 00 S	133 07 12 E	1
Neolithodes brodiei	Arthropod	Decapod	33 44 42 S	130 33 00 E	1
Nephropsis serrata	Arthropod	Decapod	33 52 30 S	131 19 36 E	1
Nephropsis suhmi	Arthropod	Red and White Lobsterette	33 58 42 S	131 18 06 E	1
Paguristes aciculus	Arthropod	Hermit crab	33 20 48 - 33 18 48 S	127 29 42 - 127 19 18 E	1
Parapagurus bouvieri	Arthropod	Hermit crab	33 28 S	129 51 36 E	2
			33 28 00 S	127 24 06 E	1
Strigopagurus sp.	Arthropod	Hermit crab	33 51 - 33 41 18 S	132 19 - 132 10 18 E	1
Amphiophiura urbana	Echinoderm	Brittlestar	33 20 48 - 33 18 48 S	127 29 42 - 127 19 18 E	5
Echinocucumis sp.	Echinoderm	Sea cucumber	33 20 48 - 33 18 48 S	127 29 42 - 127 19 18 E	1
Henricia compacta	Echinoderm	Seastar	33 20 48 - 33 18 48 S	127 29 42 - 127 19 18 E	1
*Holothuria*sp.	Echinoderm	Sea cucumber	33 20 48 - 33 18 48 S	127 29 42 - 127 19 18 E	1
Ophiomusium anisacanthum	Echinoderm	Brittlestar	33 20 48 - 33 18 48 S	127 29 42 - 127 19 18 E	13
Ophiomusium australe	Echinoderm	Brittlestar	33 20 48 - 33 18 48 S	127 29 42 - 127 19 18 E	5
Ophiomyxa sp.	Echinoderm	Brittlestar	33 20 48 - 33 18 48 S	127 29 42 - 127 19 18 E	1
Ophiozonella bispinosa	Echinoderm	Brittlestar	33 20 48 - 33 18 48 S	127 29 42 - 127 19 18 E	32
Benthoctopus sp.	Mollusc	Octopus	33 57 42 - 33 57 34 S	131 26 25 - 131 26 56 E	1
Capulid	Mollusc	Snail	33 20 48 - 33 18 48 S	127 29 42 - 127 19 18 E	3
Grimpoteuthis sp.	Mollusc	Dumbo Octopus	34 01 - 34 06 S	131 54 - 131 57 E	
Histioteuthis miranda	Mollusc	Squid	34 01 - 34 06 S	131 54 - 131 57 E	
			33 48 - 33 42 S	130 33 - 130 31 E	1
Iridoteuthis sp.	Mollusc	Bobtail Squid	33 25 - 33 24 S	129 35 - 129 32 E	1
Sepia cultrata	Mollusc	Cuttlefish	33 20 - 33 20 S	128 18 - 128 15 E	6
Sepia hedleyi	Mollusc	Cuttlefish	33 20 - 33 22 S	128 10 - 128 08 E	1