Australian Government

Department of Sustainability, Environment,
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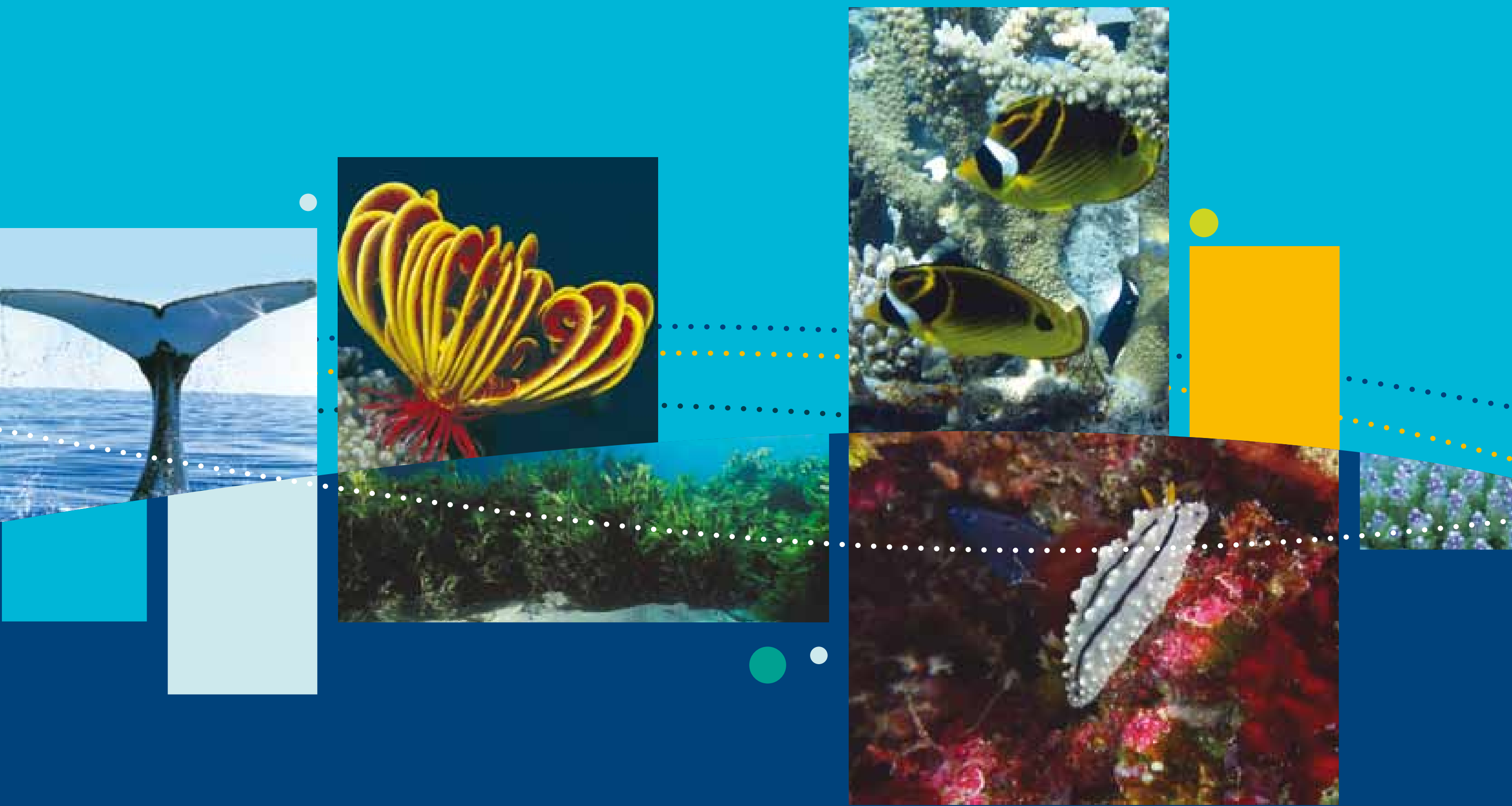

Commonwealth marine environment report card

Supporting the draft marine bioregional plan for the North-west Marine Region

prepared under the *Environment Protection and Biodiversity Conservation Act 1999*

Images:
Striped Nudibranch – C.Zwick and DSEWPaC, Raccoon butterfly fish – N.Wolfe, Display of colourful coral – Tourism WA, Red and yellow feather star (crinoids) – Tourism WA, Whale tail – Tourism WA, Snorkelling in Ningaloo Marine Park – Tourism WA, Green Turtle – Tourism WA, Black tip reef shark – N.Wolfe, Whale Shark – GBRMPA, Sea Grass Meadow – Lochman Transparencies

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COMMONWEALTH MARINE ENVIRONMENT REPORT CARD – NORTH-WEST MARINE REGION

Supporting the draft marine bioregional plan for the North-west Marine Region prepared under the *Environment Protection and Biodiversity Conservation Act 1999*

Report cards

The primary objective of report cards is to provide accessible and up-to-date information on the conservation values found in marine regions. This information is maintained by the Department of Sustainability, Environment, Water, Population and Communities and is available online through the department's website (**www.environment.gov.au**).

Reflecting the categories of conservation values, there are three types of report cards:

- species group report cards
- marine environment report cards
- heritage places report cards.

Commonwealth marine environment report card

Commonwealth marine environment report cards describe features and ecological processes in marine regions and identify key ecological features as conservation values. Key ecological features are of regional importance for either biodiversity or ecosystem function and integrity within the Commonwealth marine environment and have been identified through the marine bioregional planning process.

The Commonwealth marine environment is a matter of national environmental significance under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). An action requires approval from the environment minister if it has, will have or is likely to have a significant impact on a matter of national environmental significance. The identification of key ecological features therefore assists decision-making about the Commonwealth marine environment under the EPBC Act.

While the focus of this report card is the Commonwealth marine environment, in some instances features and ecological processes occurring in state waters are referred to where there is connectivity between features and ecological processes in state and Commonwealth waters.

Commonwealth marine environment report cards:

- describe the relevant marine region
- describe existing Commonwealth marine reserves
- describe each key ecological feature, outline its conservation values and details the current state of knowledge on each feature
- assesses pressures to each key ecological feature and identifies the level of concern the pressure places on the conservation of the feature.

1. The Commonwealth marine environment of the North-west Marine Region

The North-west Marine Region comprises Commonwealth waters and seabed from the Western Australia – Northern Territory border to Kalbarri, south of Shark Bay. The inshore boundary of the region is the outer jurisdictional boundary of the state waters of Western Australia, while the outer boundary is the Australian exclusive economic zone boundary (Figure 1).

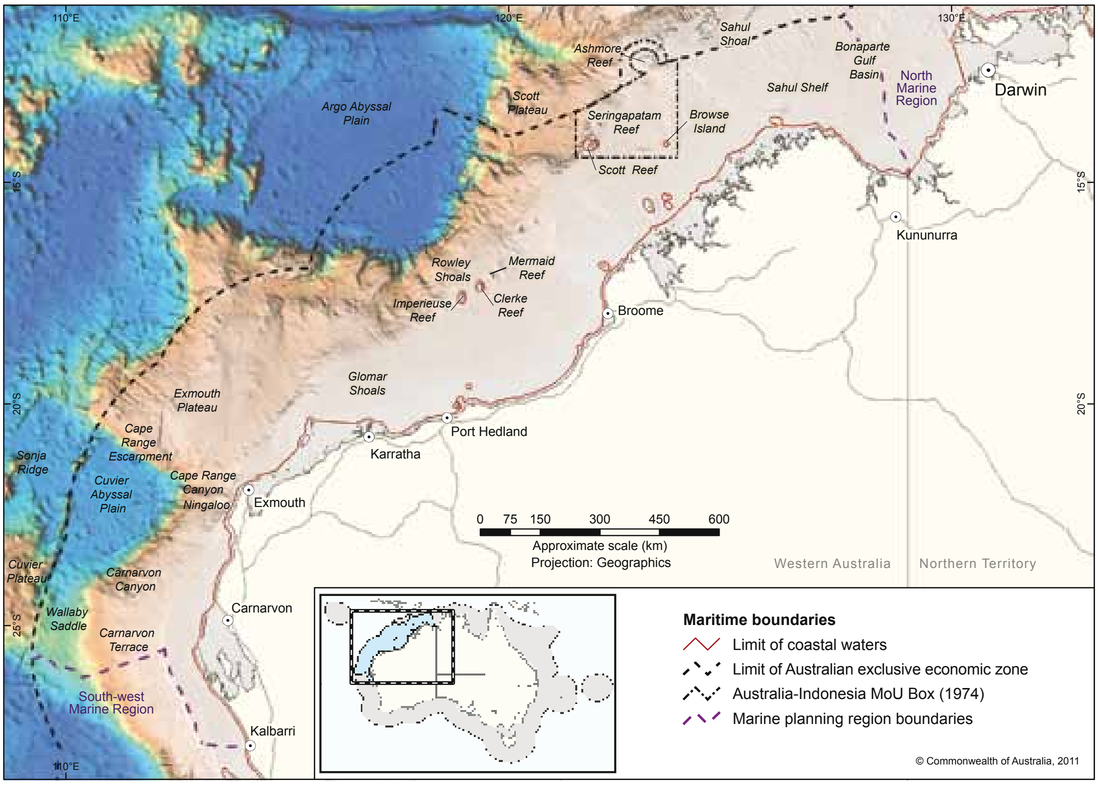

Figure 1: The North-west Marine Region

The North-west Marine Region is distinguished by its predominantly wide continental shelf, very high tidal regimes (especially in the north), very high cyclone incidence, unique current systems and warm, low-nutrient surface waters. The region supports high species-richness of tropical Indo-west Pacific biota, but low levels of endemism.

Physical structure of the region

The region consists primarily of continental slope and continental shelf. The region also contains abyssal plains and a small area of continental rise. Other features such as canyons, plateaux, terraces, ridges, reefs, banks and shoals occupy less space in the region but have relatively high importance for productivity and biodiversity (DEWHA 2008). Overall, the region is relatively shallow, with water depths of less than 200 metres over more than 40 per cent of its area. More than 50 per cent of the region has a depth of less than 500 metres, reflecting the region's large areas of continental shelf and slope (Baker et al. 2008).

Extensive carbonate banks and coral reefs are important focal points for biodiversity in the region. A string of submerged carbonate banks and carbonate reefs on the outer North West Shelf includes Ashmore Reef, Cartier Island, Scott Reef, Seringapatam Reef and the Rowley Shoals. Reefs of the inner shelf, including those in state waters, are dominated by hard corals and include Ningaloo Reef, Montgomery Reef and the reefs of the Dampier Archipelago (Baker et al. 2008).

Ecosystem drivers

The main drivers of ecosystem function in the North-west Marine Region are strong surface currents, a monsoonal climate, cyclones and tides. The oceanography of the North-west Marine Region combined with temperature, salinity and other water-column properties influence sediment transport and turbidity patterns, primary production in the water column and bottom sediments, and distribution and recruitment patterns for marine organisms (DEWHA 2008).

The major surface currents influencing the region include the Indonesian Throughflow and the Leeuwin Current (Domingues et al. 2007) and the recently named Holloway Current, which flows south-west across the North West Shelf in May and June (D'Adamo et al. 2009). These currents are warm, low salinity and low in nutrients and exert a strong influence over the region's biophysical and ecological processes. They suppress productivity at the sea surface by preventing upwelling, except in some predictable locations and times. The annual weakening of the Leeuwin Current during summer is known to facilitate the movement of cold nutrient-rich slope waters from the Indian Ocean onto the shelf. These waters are subsequently mixed by the region's strong tides, stimulating primary productivity below the shallow surface layer but within the photic zone (DEWHA 2008).

The seasonal reversal in wind currents supports the development of currents such as the Ningaloo Current (Taylor and Pearce 1999). When this current combines with the weakening of the Leeuwin Current, mixing and upwelling occurs, producing areas of higher biological productivty in the waters adjacent to Cape Range Peninsula (Hanson et al. 2005). Sea-floor canyons in this area, such as the Cloates Canyon and Cape Range Canyon are also important sites for enhanced biological productivity associated with Ningaloo Reef (Brewer et al. 2007).

Seasonal freshwater input is important in the far north of the region off the Kimberley and in the Joseph Bonaparte Gulf, where large river systems pump huge volumes of water into the coastal environment during the wet season (November to March).

Tropical cyclones are a common feature in the region and are also significant agents in the initiation of sediment movement and deposition (Baker et al. 2008). Cyclones enhance oceanic mixing and upwelling and at their extreme can also have a major effect on habitats, ecological communities and individual species. Observations following past cyclonic events have included changes in the dispersal and distribution of plankton. Species of fish and zooplankton have reportedly been transported into areas they had not previously occupied as a result of changed current, wind and wave patterns (McKinnon et al. 2003).

The tidal regime in the North-west Marine Region is extreme, particularly in the Kimberley, with semi-diurnal tides ranging from 3 metres at neap tide to over 10 metres at springs (Brewer et al. 2007). The bottom stress brought about by strong tidal currents influences the composition of benthic communities—in areas where sediment movement is great, few organisms can survive. These tides can generate internal waves that can break and contribute to the availability of nutrients in shelf waters.

Biological diversity

The biota of the North-west Marine Region is predominantly tropical and typical of the Indo-west Pacific. The vast size of the region and its range of geomorphic features and habitats are reflected in its high species diversity, unique ecosystems and associated trophic interactions and communities.

Hard substrate habitats such as the limestone pavements of the North West Shelf, coral reefs of the Kimberley, pinnacles and reefs on the edge of the shelf in the far north of the region support a high diversity of benthic filter-feeders and associated species. Elsewhere, soft substrates support seagrass along the Pilbara coast, muddy infaunal communities in the Joseph Bonaparte Gulf and deep sessile communities of filter and deposit feeders in the abyssal plains (DEWHA 2008).

The North-west Marine Region supports internationally significant populations of a number of threatened and migratory marine animals. Thousands of humpback whales migrate through the region each year to give birth along the Kimberley coast, especially around Camden Sound. This coast is the only known breeding ground for the Western Australian population of humpback whales.

Coastal beaches and offshore islands in and adjacent to the region support significant rookeries of endangered and vulnerable marine turtles. The region also marks the endpoint of the East-Australasian Flyway for millions of shorebirds that migrate every year from breeding grounds in the Northern Hemisphere. Shark Bay supports the largest remaining dugong population in the world, with around 14 000 individuals present in the bay (Gales et al. 2004). Annual aggregations of whale shark at Ningaloo Reef every autumn are also internationally significant as they are the largest density of whale sharks in the world (Martin 2007).

There is still much unknown about the natural systems of the North-west Marine Region and its biodiversity. Our understanding of the biodiversity of the deeper parts of the region (on the continental slope, continental rise and abyssal plain) is poor compared with our knowledge of shallower coastal and shelf environments.

Bioregional framework

The North-west Marine Region has eight provincial bioregions[1] (Figure 2):

- Northwest Shelf[2] Transition
- Timor Province
- Northwest Shelf Province
- Northwest Transition
- Northwest Province
- Central Western Transition
- Central Western Shelf Transition
- Central Western Shelf Province.

These provincial bioregions were identified as part of the Integrated Marine and Coastal Regionalisation of Australia version 4.0 (IMCRA v.4.0), which classifies Australia's entire marine environment into broadly similar ecological regions. The purpose of regionalisation is to simplify the complex relationship between the environment and species distributions, and to characterise the distribution of species and habitats at differing scales.

Provincial bioregions represent regional classifications at the largest scale and largely reflect biogeographic patterns in the distribution of bottom-dwelling fish (DEH 2006). Mesoscale bioregions are a finer-scale regional classification of the continental shelf. They were defined using biological and physical information and geographic distance along the coast.

1 For the purpose of this document, in dealing with the Commonwealth marine area, 'bioregion' means provincial bioregion as defined in the Integrated Marine and Coastal Regionalisation of Australia (version 4.0).

2 IMCRA v.4.0 uses the term 'IMCRA' to identify those bioregions that lie over the continental shelf. For the purposes of this report card, the term 'IMCRA' has been replaced with 'Shelf' to distinguish shelf bioregions from those offshore.

IMCRA v4.0 provides a framework that is useful for regional planning and is the basis for establishing a national representative network of marine reserves across all Australian waters.

Further information about each bioregion is available in the North-west Marine Bioregional Profile at **www.environment.gov.au/coasts/mbp/north-west/bioregional-profile.html**.

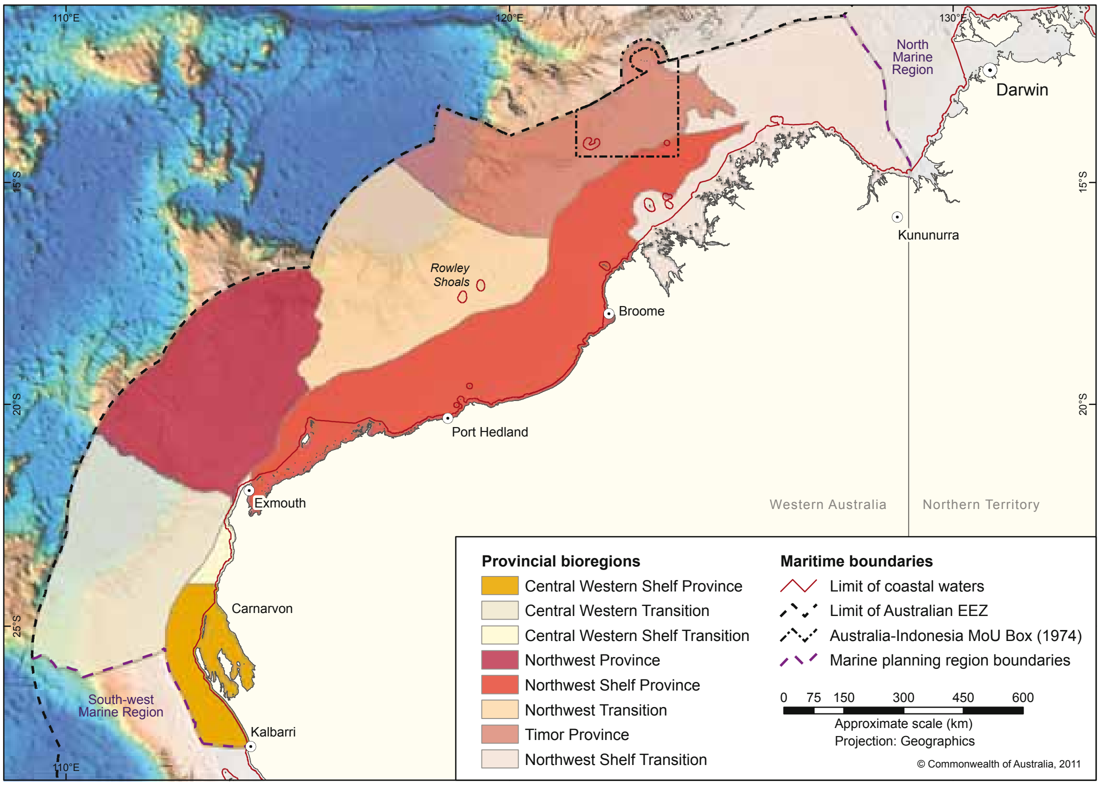

Figure 2: Provincial bioregions in the North-west Marine Region

2. Key ecological features

Key ecological features define areas and features of ecological importance in the Commonwealth marine environment. They are elements of the North-west Marine Region that, based on current scientific understanding, are considered to be of regional importance for either biodiversity or ecosystem function and integrity. Key ecological features of the North-west Marine Region have been identified by the Australian Government on the basis of advice from scientists about the ecological processes and characteristics of the area. Attachment 1 provides a detailed description of each feature and outlines its national and/or regional importance. It also reports on the assessment of environmental pressures on the key ecological features and outlines the relevant existing protection measures.

3. Protected places in the Commonwealth marine environment—North-west Marine Region

Protected places include marine reserves and heritage places. Heritage places are described in the heritage places report card available at **www.environment.gov.au/coasts/mbp**.

Within the North-west Marine Region there are currently four Commonwealth marine reserves: Ashmore Reef National Nature Reserve, Cartier Island Marine Reserve, Mermaid Reef Marine National Nature Reserve and Ningaloo Marine Park (Commonwealth waters).

Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve

Ashmore Reef National Nature Reserve (Ashmore) is located on Australia's North West Shelf in the Indian Ocean, about 450 nautical miles (840 kilometres) west of Darwin, 330 nautical miles (610 kilometres) north of Broome and 60 nautical miles (110 kilometres) south of the Indonesian island of Roti. Ashmore covers 583 square kilometres and includes two extensive lagoons, shifting sand flats and cays, seagrass meadows and a large reef flat covering an area of 239 square kilometres. Within Ashmore are three small islands known as East, Middle and West Islands.

Cartier Island Marine Reserve (Cartier) is located 25 nautical miles (45 kilometres) south-east of Ashmore Reef. Covering an area of 167 square kilometres, Cartier includes an unvegetated sand island (Cartier Island) and the area within a 4 nautical mile radius of the centre of the island, to a depth of 1 kilometre below the sea floor. The area around the island includes a variety of habitats including a mature reef flat, a small submerged pinnacle (known as Wave Governor Bank) and two shallow pools to the north-east of the island.

Ashmore and Cartier support large numbers of marine species including sea snakes, dugongs, reef-building corals, fish and other marine invertebrate fauna. The reserves also provide important nesting sites for seabirds and marine turtles and provide staging points and feeding areas for large populations of migratory shorebirds. Ashmore was designated a Ramsar Wetland of International Importance in 2003 due to the importance of its islands providing a resting place for migratory shorebirds and supporting large seabird breeding colonies.

Ashmore and Cartier have a high diversity of reef-building and non-reef building corals. The 255 species of reef-building corals identified at Ashmore is thought to be the greatest number of reef-building species of any reef area off the Western Australian coast. There are three species of mollusc that are only found at Ashmore (*Amoria spenceriana, Cymbiola baili* and *Conus morrisoni*). Recent research has indicated that the total number of fish species at Ashmore and Cartier may be as high as 650 species. The high density and diversity of fish is linked to the diversity of habitat types.

It is estimated that Ashmore and Cartier support approximately 11 000 marine turtles, including significant populations of green, loggerhead and hawksbill turtles. The Ashmore and Cartier population of green turtles is genetically distinct from the other two breeding populations in the region.

Ashmore also supports a small dugong population of less than 50 individuals. It is thought that this population is genetically distinct from other Australian populations and the extent to which this population interacts with Indonesian populations is unknown. It is possible that the population's range extends to Cartier and other submerged shoals in the region.

Historically, Ashmore and Cartier have been recognised internationally for their high diversity and density of sea snakes. It is estimated that before 2000 there were 40 000 sea snakes from at least 13 species present at Ashmore, representing the greatest number of sea snake species recorded globally. Three of the species at Ashmore are endemic to Australia's North West Shelf, which means they are not found anywhere else in the world. Recent research has shown a decline in sea snakes at Ashmore, with further research required to identify the cause of this decline.

Mermaid Reef Marine National Nature Reserve

Mermaid Reef Marine National Nature Reserve (Mermaid) surrounds Mermaid Reef, which is located about 150 nautical miles (290 kilometres) north-west of Broome, Western Australia. Mermaid is located near the edge of Australia's continental slope and is surrounded by waters that extend to a depth of more than 500 metres.

Mermaid Reef is the most north-easterly of three reef systems forming the Rowley Shoals. Mermaid Reef is totally submerged at high tide and therefore falls under Australian Government jurisdiction. The other two reefs of the Rowley Shoals (Clerke Reef and Imperieuse Reef) are managed by the Western Australian Government as the Rowley Shoals Marine Park.

The Rowley Shoals, including Mermaid Reef, have an abundance and variety of marine wildlife that is in a relatively undisturbed condition, as well as spectacular and unusual underwater topography. Mermaid Reef is listed on Australia's Commonwealth Heritage List and all three reefs of the Rowley Shoals have been registered on the Register of the National Estate.

Mermaid Reef is the most north-easterly of the reef systems of the Rowley Shoals. All three of the reefs are similar in shape, size, orientation and distance from each other. Each has a large lagoonal area containing small sand cays or islands, narrow lagoon entrance channels on the eastern side and an outer reef edge dropping off relatively steeply into oceanic waters between depths of 500–700 metres. Oval in shape, the reefs follow a south-west to north-east alignment along the edge of the continental shelf and lie 30–40 kilometres apart. The three reefs of the Rowley Shoals have been described as some of the best examples of shelf-edge reefs occurring in Australian waters.

Mermaid Reef is considered the 'youngest' of the three reefs, each of which shows a different stage in the development of a shelf atoll reef. There is no permanent land at Mermaid but a large sand bank near the northern edge of the lagoon and a series of small banks to the west become exposed at low tides.

These sandbanks are thought to be important resting sites for migratory birds. Nineteen species have been sighted at the Rowley Shoals and three of these are known to breed on Bedwell and Cunningham islands in the nearby Rowley Shoals Marine Park (under Western Australian jurisdiction).

The Rowley Shoals, including Mermaid Reef, are thought to be sites of enhanced biological productivity, as breaking internal waves cause mixing and the resuspension of nutrients in surface waters. The area supports a great variety of marine species in a relatively undisturbed condition. A number of species are at the limit of their distribution, and some are found nowhere else in Western Australia.

Ningaloo Marine Park (Commonwealth waters)

Ningaloo Marine Park (Commonwealth waters) stretches approximately 300 kilometres along the west coast of the Cape Range Peninsula near Exmouth, Western Australia, approximately 1200 kilometres north of Perth. The total area of the reserve is 2435 square kilometres. Ningaloo Reef, the longest fringing barrier reef in Australia, and the only example in the world of extensive fringing coral reef on the west coast of a continent, is adjacent to the reserve and is protected by the Ningaloo Marine Park (State waters), which lies between the reserve and the WA coast. The combined state and Commonwealth waters of the Ningaloo Marine Park cover a total area of 5070 square kilometres.

The reserve is located in a transition zone between tropical and temperate waters and sustains tropical and temperate plants and animals, with many species at the limit of their distribution. The reserve's water depths range from a relatively shallow 30 metres to oceanic waters more than 500 metres.

Ningaloo Marine Park (Commonwealth waters) has a diverse range of marine species and unique geomorphic features. The reserve provides essential biological and ecological links that sustain Ningaloo Reef, which occurs in the state waters of the Ningaloo Marine Park, including the supply of nutrients to reef communities from deeper waters further offshore.

Whales are a major feature of the reserve, with humpback whales migrating through twice a year on their annual migration between calving grounds off the Kimberley and feeding grounds in Antarctica. Blue and sperm whales have been observed in the offshore regions of the reserve as have minke, Bryde's, southern right and killer whales. Dolphins are also relatively common in the reserve.

The reserve is recognised internationally for its annual aggregations of whale sharks. It is thought that between 300 and 500 whale sharks visit each year. Aggregations generally occur between March and June, coinciding with mass coral spawning events and seasonal localised increases in productivity.

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Attachment 1: Key Ecological Features of the North-west Marine Region

Key ecological features are elements of the Commonwealth marine environment that are considered to be of regional importance for either a region's biodiversity or its ecosystem function and integrity.

Key ecological features of the North-west Marine Region have been identified by the Australian Government on the basis of existing information and scientific advice about the ecological processes and functioning. As new data about ecosystems and their components becomes available, the role of key ecological features in regional biodiversity and ecosystem functioning will be refined.

For the purpose of marine bioregional planning, key ecological features of the marine environment meet one or more of:

- a species, group of species or community with a regionally important ecological role, where there is specific knowledge about why the species or species group is important to the ecology of the region, and the spatial and temporal occurrence of the species or species group is known
- a species, group of species or community that is nationally or regionally important for biodiversity, where there is specific knowledge about why the species or species group is regionally or nationally important for biodiversity, and the spatial and temporal occurrence of the species or species group is known
- an area or habitat that is nationally or regionally important for
  - enhanced or high biological productivity[3]
  - aggregations of marine life
  - biodiversity and endemism
- a unique sea-floor feature with ecological properties of regional significance.

Thirteen key ecological features have been identified in the North-west Marine Region (Figure A1). Sections 1 to 13 below provide a detailed description of each of these key ecological features and outline their national or regional importance. An analysis of the pressures affecting key ecological features in the North-west Marine Region is presented in Section 14. Section 15 outlines the environmental management and regulation measures currently in place to provide protection to the region's ecosystems.

A glossary at the end of this attachment provides definitions of scientific and technical terms.

3 Productivity (or biological productivity) is the process through which algae and seagrasses transform inorganic nutrients into organic matter through photosynthesis. This process is at the basis of the ocean's food web, as phytoplankton and algae are consumed respectively by zooplankton and grazing organisms and these in turn are consumed by larger and larger predators. Nutrient-rich waters promote and support productivity.

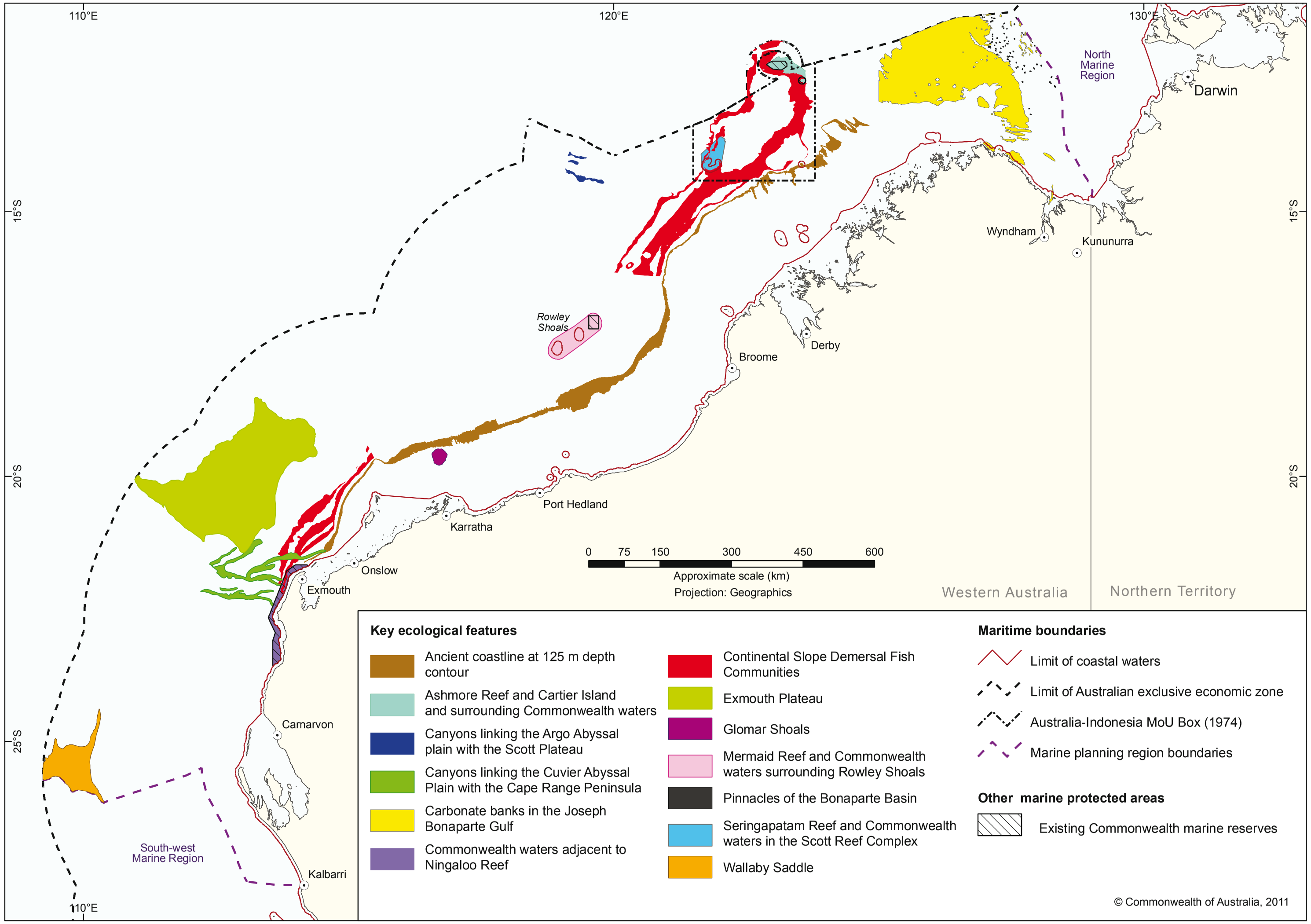

Figure A1: The key ecological features of the North-west Marine Region

1. Carbonate bank and terrace system of the Sahul Shelf

National and/or regional importance

The carbonate banks and terrace system of the Sahul Shelf are regionally important because of their role in enhancing biodiversity and local productivity relative to their surrounds. Little is known about the banks, terraces and associated channels but they are believed to be areas of enhanced productivity and biodiversity due to the upwellings of cold nutrient-rich water at the heads of the channels (Brewer et al. 2007).

Values description

The carbonate banks and terrace system of the Sahul Shelf are located in the western Joseph Bonaparte Gulf and to the north of Cape Bougainville and Cape Londonderry. The banks consist of a hard substrate and flat tops at depths of 150–300 metres. Each bank occupies an area generally less than 10 square kilometres and is separated from the next bank by narrow sinuous channels with depths up to 150 metres (Brewer et al. 2007). The Sahul Banks are the single most extensive region of banks and shoals in the Australian exclusive economic zone forming a nearly continuous chain of complex submerged algal banks on the middle and outer shelf (Heap & Harris 2008).

The origin of the banks may be related to hydrocarbon seeps and *Halimeda* (calcareous algae-derived carbonates) (Heyward et al. 1997; O'Brien et al. 2002). The carbonate banks provide the hard substrate required for colonisation by reef-building organisms. Elevated hard substrates provide ideal habitats as they provide substrate to which organisms can adhere and expose filter-feeders to the maximum amount of passing nutrients.

The banks are known to be foraging areas for loggerhead, olive ridley and flatback turtles (Donovan et al. 2008). Humpback whales, and green and freshwater sawfish are likely to occur in the area (Donovan et al. 2008). The banks are thought to support a high diversity of organisms including reef fish, sponges, soft and hard corals, gorgonians, bryozoans, ascidians and other sessile filter-feeders (Brewer et al. 2007).

This enhanced productivity and subsequent species richness associated with the banks may be facilitated by bathymetric features such as the Timor Trough that runs parallel to the Island of Timor, and the deepwater channels that bisect the banks. Warm water from the Indonesian Throughflow is thought to drive nutrients from deepwater to shallower water within the euphotic zone up to 100 metres in depth. The heads of channels are likely to be areas of localised high primary productivity which in turn supports secondary productivity, due to the convergence of ocean currents, tidal flows and upwellings of cold nutrient-rich water (Brewer et al. 2007). Such productivity may also be influenced by seasonal weather patterns such as monsoonal storms and winds (Brewer et al. 2007). Cyclones and north-westerly winds during the north-west monsoon (approximately November–March) and the strong offshore (south-easterly) winds of the south-east monsoon (approximately April–September) facilitate the upwelling of nutrients from deepwater to shallow-water environments (Brewer et al. 2007).

2. Pinnacles of the Bonaparte Basin

National and/or regional importance

The limestone pinnacles in the western Bonaparte Depression are likely to be of important conservation value as they are expected to support a diverse community in an otherwise oligotrophic system. More than 110 pinnacles occur in the Bonaparte Depression, covering a total area of more than 520 square kilometres (Heap & Harris 2008).

Values description

The limestone pinnacles of the Bonaparte Basin lie on the mid-outer shelf in the western Joseph Bonaparte Gulf. The surrounding area is relatively featureless soft sediments (Brewer et al. 2007). The pinnacles can be up to 50 metres high and are thought to be remnants of calcareous shelf and coastal features from previous low sea-level stands (Baker et al. 2008, Heyward et al. 1997). As they provide areas of hard substrate in an otherwise soft sediment environment they are presumed to be important for sessile species; however, more research is required to better understand the species richness and diversity of these structures (Brewer et al. 2007).

Communities are likely to include sessile benthic invertebrates including hard and soft corals and sponges, and aggregations of demersal fish species such as snappers, emperors and groupers (Brewer et al. 2007). The pinnacles are thought to be a feeding area for flatback, loggerhead and olive ridley turtles while green turtles may traverse the area (Donovan et al. 2008). Freshwater and green sawfish and humpback whales may also occur in the area (Donovan et al. 2008).

The oceanographic influence of the Indonesian Throughflow brings warm, low-salinity water into the region which is oligotrophic for much of the year. Primary productivity is largely from phytoplankton and zooxanthellae within the hard corals located on the limestone pinnacles and through sporadic upwelling across the Sahul Shelf. Other nutrient inputs may occur as a result of mixing and resuspension from storms and cyclones (Brewer et al. 2007).

3. Ashmore Reef and Cartier Island and surrounding Commonwealth waters

National and/or regional importance

Ashmore Reef is the largest of only three emergent oceanic reefs present within the north-eastern Indian Ocean and is the only oceanic reef in the region with vegetated islands. Emergent reefs are areas of enhanced primary productivity in an otherwise oligotrophic environment (Stambler 2011). Ashmore Reef and Cartier Island and the surrounding Commonwealth waters are regionally important for feeding and breeding aggregations of seabirds and shorebirds (Milton 2005), and other marine life. Ashmore Reef supports the highest number of coral species of any reef off the Western Australian coast (Veron 1993). The marine habitats among the reefs are nationally and internationally significant supporting diverse and abundant marine reptile (Limpus 2008) and mammal populations, including dugong (Whiting 1999).

Values description

Ashmore Reef and Cartier Island are situated on the shallow upper slope of the Sahul Shelf, north of Scott and Seringapatam reefs. They form part of a series of submerged reef platforms along the outer edge of the continental slope of the North-west Marine Region.

Ashmore contains a large reef shelf, two large lagoons, several channelled carbonate sand flats, shifting sand cays, an extensive reef flat, three vegetated islands—East, Middle and West islands—and surrounding waters. Rising from a depth of more than 100 metres, the reef platform is at the edge of the North West Shelf and covers an area of 239 square kilometres. Ashmore Reef National Nature Reserve encloses an area of about 583 square kilometres of seabed (EA 2002).

Cartier Island Marine Reserve (Cartier) is located in the West Sahul region of the Indian Ocean. The island is about 350 kilometres off Australia's Kimberley coast, 115 kilometres south of the Indonesian island of Roti and 45 kilometres south-east of Ashmore Reef National Nature Reserve. Cartier Island Marine Reserve covers 167 square kilometres and contains one unvegetated sand cay and mature reef flat with two shallow pools to the north-east of the cay (EA 2002).

The reefs are richer in coral species than anywhere else on the Western Australian coast and provide varied habitat that attracts a diverse range of primary and secondary consumers, including a particularly diverse fish fauna. Similarly, toothed whales, dolphins and whale sharks are found in the Commonwealth waters around these reefs, as is a genetically distinct dugong population around Ashmore Reef.

Species at Ashmore and Cartier include more than 225 reef-building corals, 433 molluscs, 286 crustaceans, 192 echinoderms, and the most diverse variety of fish of any region in Western Australia with 709 species (EA 2002). Thirteen species of sea snakes occur in high numbers at Ashmore and Cartier reefs but are believed to have experienced recent declines, the cause of which is not known. Ashmore and Cartier also attract feeding and breeding aggregations of marine and other fauna. An estimated 11 000 green and hawksbill turtles feed over seagrass beds present on reef flats throughout the year (M Guinea, pers. comm., 2009). Sandy beaches provide important habitat for nesting green and hawksbill turtles throughout the year. Seagrass present at Ashmore Reef provides critical breeding (April–May) and foraging (throughout the year) habitat for a genetically distinct population of dugong with their range probably extending to other submerged shoals within the area (Brown & Skewes 2005; Whiting 1999).

The emergent habitat at Ashmore also provides important nesting sites for seabirds, many of which are migratory. Ashmore's islands are regarded as supporting some of the most important seabird rookeries on the North West Shelf seasonally supporting up to 50 000 seabirds (26 species) and up to 2000 waders (30 species, representing almost 70 per cent of wader species that regularly migrate to Australia; Milton 2005). Large colonies of sooty terns, crested terns, bridled terns and common noddies breed on the east and middle islands. Smaller breeding colonies of little egrets, eastern reef egrets, black noddies and possibly lesser noddies also occur. Migratory wading birds include eastern curlews, ruddy turnstones, whimbrels, bar-tailed godwits, common sandpipers, Mongolian plovers, red-necked stints and tattlers, during October–November and March–April as part of the migration between Australia and the Northern Hemisphere (Milton 2005).

High primary productivity, species richness and subsequent aggregations of marine life on the reefs and in the surrounding Commonwealth waters are primarily due to the mixing of nutrient-rich waters from below the thermocline (about 100 metres) with the warmer, relatively nutrient-poor tropical surface waters of the Indonesian Throughflow. This mixing is due to interactions between internal waves and sea-floor structures (Brewer et al. 2007). Seasonal weather patterns also influence the delivery of nutrients from deepwater to shallow water. Cyclones and north-westerly winds during the north-west monsoon (approximately November–March) and the strong offshore (south-easterly) winds of the south-east monsoon (approximately April–September) facilitate upwelling and mixing of nutrients from deepwater to shallow-water environments (Brewer et al. 2007).

4. Seringapatam Reef and Commonwealth waters in the Scott Reef complex

National and/or regional importance

Seringapatam Reef and Commonwealth waters in the Scott Reef complex are regionally important as they support diverse aggregations of marine life, have high primary productivity relative to other parts of the region, are relatively pristine and have high species richness.

Values description

Scott and Seringapatam reefs are part of a series of submerged reef platforms that rise steeply from the sea floor between the 300–700 metre contours on the Northwest Continental Slope (Falkner et al. 2009). Scott Reef consists of two separate reef formations: North Scott Reef and South Scott Reef. The key ecological feature encompasses only the waters beyond the 3 nautical mile limit at South Scott Reef, but includes the reefs and surrounding waters at North Scott and Seringapatam reefs.

The coral communities at Scott and Seringapatam reefs play a key role in maintaining species richness and aggregations of marine life. Scott Reef is a particularly biologically diverse system and includes more than 300 species of reef-building corals, approximately 400 mollusc species, 118 crustacean species, 117 echinoderm species, around 720 fish species and several species of sea snakes (Woodside 2009).

Scott and Seringapatam reefs and the waters surrounding them attract aggregations of marine life including humpback whales on their northerly migration, Bryde's whales, pygmy blue whales, Antarctic minke whales, dwarf minke whales, minke whales, dwarf sperm whales and spinner dolphins (Jenner et al. 2008; Woodside 2009). Whale sharks and several species of sea snakes have also been recorded in this key ecological feature (Donovan et al. 2008). Green and hawksbill turtles nest during the summer months on Sandy Islet on South Scott Reef. These species also internest and forage in the surrounding waters (Guinea 2006). This key ecological feature also provides foraging areas for seabird species such as lesser frigate birds, wedge-tailed shearwaters, the brown booby and the roseate tern (Donovan et al. 2008).

Corals and fish at Scott Reef have higher species diversity than the Rowley Shoals, (Done et al. 1994). Recent studies suggest that the capacity for coral dispersal between Scott Reef and other offshore reefs in the region may be limited (Underwood et al. 2009). Genetic studies of two coral species at Scott Reef indicate that the majority of coral larvae are retained close to their spawning site. Consequently, coral communities at Scott Reef are largely self-seeded and rely on the reproductive output of Scott Reef resident corals to maintain populations and facilitate recovery (Underwood et al. 2009). Reef fish populations at Scott Reef and adjacent reef systems may be more connected as fish larvae remain in the water column longer before settling onto reefs (Woodside 2009). Research on the coral trout species *Plectropomus leopardus* suggests that populations at Scott Reef contribute approximately 50 per cent of larval recruits to the population of this species at the Houtman Abrolhos Islands, 2500 kilometres away (van Herwerden 2009).

Aggregations of marine life, high primary productivity and species richness on the reefs and in the surrounding Commonwealth waters are likely due to the steep rise of the reef from the seabed. This causes nutrient-rich waters from below the thermocline (about 100 metres) to mix with the warmer, relatively nutrient-poor tropical surface waters via the action of internal waves and from mixing and higher productivity in the lee of emergent reefs (Brewer et al. 2007). Seasonal weather patterns also influence the delivery of nutrients from deepwater to shallow water. Cyclones and north-westerly winds during the north-west monsoon (approximately November–March) and the strong offshore winds of the south-east monsoon (approximately April–September) facilitate the upwelling and mixing of nutrients from deepwater to shallow-water environments (Brewer et al. 2007).

5. Continental slope demersal fish communities

National and/or regional importance

The diversity of demersal fish assemblages on the Australian continental slope from North West Cape to the edge of the region is high. Specifically, the continental slope between North West Cape and the Montebello Trough has more than 500 fish species, 76 of which are endemic, which makes it the most diverse slope bioregion in the whole of Australia (Last et al. 2005). The Timor Province and Northwest Transition bioregions are the second-richest areas for demersal fish across the entire continental slope.

Values description

The Australian continental slope provides important habitat for demersal fish communities. Specifically, the continental slope in the Timor Province, the Northwest Transition, and the Northwest Province support demersal fish communities characterised by high endemism and species diversity. The Northwest Province, between Northwest Cape and Montebello Trough, has more than 500 fish species, 76 of which are endemic. The slope of the Timor Province and the Northwest Transition also contains more than 500 species of demersal of which 64 are considered endemic (Last et al. 2005).

The demersal fish species occupy two distinct demersal community types (biomes) associated with the upper slope (water depth of 225–500 metres) and the mid-slope (750–1000 metres). Although poorly known, it is suggested that the demersal-slope communities rely on bacteria and detritus-based systems comprised of infauna and epifauna, which in turn become prey for a range of teleost fish, molluscs and crustaceans (Brewer et al. 2007). Higher-order consumers may include carnivorous fish, deepwater sharks, large squid and toothed whales (Brewer et al. 2007). Pelagic production is phytoplankton based, with hot spots around oceanic reefs and islands (Brewer et al. 2007).

Although the reasons for the high levels of endemism are not fully understood, the presence of such a diversity of fish and high numbers of endemic species in these bioregions suggests there are important interactions occurring between the physical processes and trophic structures (P Last & A Williams, pers. comm., 2009). The data to support high endemism is scarce and the assumption of high endemism could reflect the small sample size.

6. Canyons linking the Argo Abyssal Plain with Scott Plateau

National and/or regional importance

The canyons linking the Argo Abyssal Plain and Scott Plateau are likely to be important features due to their historical association with sperm whale aggregations.

Values description

The Bowers and Oates canyons are the largest canyons connecting the Scott Plateau with the Argo Abyssal Plain. The canyons cut deeply into the south-west margin of the Scott Plateau at an approximate depth of 2000–3000 metres, and act as conduits for transport of sediments to depths of more than 5500 metres on the Argo Abyssal Plain (Stagg 1978, cited in Falkner et al. 2009). The water masses at these depths are deep Indian Ocean water on the Scott Plateau and Antarctic bottom water on the Argo Abyssal Plain. Both water masses are cold, dense and nutrient-rich (Lyne et al. 2006).

Benthic communities at these depths are most likely dependent upon particulate matter from the pelagic zone falling to the sea floor. Whaling records from the 19th century (Bannister et al. 2007) indicate that sperm whales occurred on Scott Plateau; however, the reasons for these historical aggregations of marine life remains unclear (DEWHA 2008a).

7. Ancient coastline at 125 metre depth contour

National and/or regional importance

Parts of the ancient coastline, particularly where it exists as a rocky escarpment, are thought to provide biologically important habitats in areas otherwise dominated by soft sediments. The topographic complexity of these escarpments may also facilitate vertical mixing of the water column providing a relatively nutrient-rich environment for species present on the escarpment.

Values description

The shelf of the North-west Marine Region contains several terraces and steps which reflect changes in sea level that occurred over the last 100 000 years. The most prominent of these features occurs as an escarpment along the North West Shelf and Sahul Shelf at a depth of 125 metres.

Where the ancient submerged coastline provides areas of hard substrate it may contribute to higher diversity and enhanced species richness relative to soft sediment habitat. Little detailed knowledge is available, but the hard substrate of the escarpment is likely to include sponges, corals, crinoids, molluscs, echinoderms and other benthic invertebrates representative of fauna of hard substrates in the North West Shelf bioregion.

The escarpment may also facilitate increased availability of nutrients off the Pilbara by interacting with internal waves and enhancing vertical mixing of water layers. Enhanced productivity associated with the sessile communities and increased nutrient availability may attract larger marine life such as whale sharks and large pelagic fish (DEWHA 2008a).

Humpback whales appear to migrate along the ancient coastline (C Jenner, pers. comm., 9 June 2011).

8. Glomar Shoals

National and/or regional importance

The Glomar Shoals are regionally important for their high biological diversity and high localised productivity. Biological data specific to the Glomar Shoals is limited; however, the fish of of the shoals are probably a subset of reef-dependent species and anecdotal evidence suggests they are particularly abundant.

Values description

The Glomar Shoals are a submerged feature located approximately 150 kilometres north of Dampier on the Rowley Shelf at a depth of 33–77 metres (Falkner et al. 2009). They consist of a high percentage of marine-derived sediments with high carbonate content and gravels of weathered coralline algae and shells (McLoughlin & Young 1985). The area's higher concentrations of coarse material compared to surrounding areas are indicative of a high-energy environment subject to strong sea-floor currents (Falkner et al. 2009).

While the biodiversity associated with the Glomar Shoals has not been studied, the shoals are known to be an important area for a number of commercial and recreational fish species such as rankin cod, brown striped snapper, red emperor, crimson snapper, bream and yellow-spotted triggerfish (Falkner et al. 2009; Fletcher & Santoro 2009). Catch rates at the Glomar Shoals are high, indicating that the area is a region of high productivity.

9. Mermaid Reef and Commonwealth waters surrounding Rowley Shoals

National and/or regional importance

Mermaid Reef and the Commonwealth waters surrounding Rowley Shoals are regionally important in supporting high species diversity, enhanced productivity and aggregations of marine life (Done et al. 1994).

Values description

The Rowley Shoals are a collection of three atoll reefs—Clerke, Imperieuse and Mermaid reefs—located about 300 kilometres north-west of Broome. Mermaid Reef lies 29 kilometres north of Clerke and Imperieuse reefs and is totally submerged at high tide. Mermaid Reef falls under Commonwealth jurisdiction. Clerke and Imperieuse reefs constitute the Rowley Shoals Marine Park, which falls under Western Australian Government jurisdiction (EA 2000).

Rowley Shoals' reefs are different from other reefs in the chain of reefs on the outer shelf of the North-west Marine Region, both in structure (Done et al. 1994) and genetic diversity (Underwood et al. 2009). There is little connectivity between Rowley Shoals and other outer-shelf reefs (Hooper & Ekins 2004; Underwood 2009; Underwood et al. 2009). An additional difference is that sea snakes do not occur there (Done et al. 1994).

The reefs are areas of enhanced productivity and high species richness. The Rowley Shoals contain 214 coral species and approximately 530 species of fishes (Gilmour et al. 2007), 264 species of molluscs and 82 species of echinoderms (Done et al. 1994; Gilmour et al. 2007).

Enhanced productivity is thought to be facilitated by the breaking of internal waves in the waters surrounding the reefs, causing mixing and resuspension of nutrients from water depths of 500–700 metres into the photic zone. The steep changes in slope around the reef also attract a range of migratory pelagic species including dolphins, tuna, billfish and sharks.

10. Exmouth Plateau

National and/or regional importance

The Exmouth Plateau is a regionally and nationally unique tropical deep sea plateau that may serve an important ecological role by acting as a very large topographic obstacle that modifies the flow of deep waters that generate internal tides, causing upwelling of deeper-water nutrients closer to the surface (Brewer et al. 2007).

Values description

The Exmouth Plateau is located in the Northwest Province and covers an area of 49 310 square kilometres in water depths of 800–4000 metres (Heap & Harris 2008). The plateau's surface is rough and undulating at 900–1000 metres depth. The northern margin is steep and intersected by large canyons (e.g. Montebello and Swan canyons) with relief greater than 500 metres. The western margin is moderately steep and smooth and the southern margin is gently sloping and virtually free of canyons (Falkner et al. 2009).

The Exmouth Plateau is overlaid by an oceanic frontal system between the Indonesian Throughflow and the Indian Ocean Central Water. Thus the water overlying the Exmouth Plateau is a mixture and the frontal zone that overlays it can be expected to display substantial temporal variability at seasonal and longer time-scales associated with fluctuations in the Indonesian Throughflow and other climate variability (Brewer et al. 2007). Internal tides are strongest during January–March (Brewer et al. 2007).

Satellite observations suggest that productivity is enhanced along the northern and southern boundaries of the plateau and along the shelf edge which in turn suggests that the plateau is a significant contributor to the productivity of the region (Brewer et al. 2007).

The Exmouth Plateau is generally an area of low habitat heterogeneity; however, it is likely to be an important area for biodiversity as it provides an extended area offshore for communities adapted to depths of around 1000 metres. Sediments on the plateau suggest that biological communities include scavengers, benthic filter feeders and epifauna. Whaling records from the 19th century suggest that the Exmouth Plateau may have supported large populations of sperm whales (Bannister et al. 2007). Fauna in the pelagic waters above the plateau are likely to include small pelagic species and nekton (Brewer et al. 2007).

11. Canyons linking the Cuvier Abyssal Plain with the Cape Range Peninsula

National and/or regional importance

The canyons that link the Cuvier Abyssal Plain with the continental slope off Cape Range Peninsula are believed to support the productivity and species richness of Ningaloo Reef.

Values description

The largest canyons on the slope linking the Cuvier Abyssal Plain and Cape Range Peninsula are the Cape Range Canyon and Cloates Canyon which are located along the southerly edge of Exmouth Plateau adjacent to Ningaloo Reef. The canyons are unusual because their heads are close to the coast of North West Cape.

The Leeuwin Current interacts with the heads of the canyons to produce eddies resulting in delivery of higher-nutrient, cool waters from the Antarctic intermediate water mass to the shelf (Brewer et al. 2007). Strong internal tides also create upwelling at the canyon heads (Brewer et al. 2007). Thus the canyons, Exmouth Plateau and Commonwealth waters adjacent to Ningaloo Reef operate as a system to create the conditions for enhanced productivity seen in this region (Sleeman et al. 2007). The canyons are also repositories for particulate matter deposited from the shelf and sides of the canyons and serve as conduits for organic matter between the surface, shelf and abyssal plains.

The hard substrates of the canyons' sides provide habitat for deepwater snappers and other species (Brewer et al. 2007). Aggregations of whale sharks, manta rays, humpback whales, sea snakes, sharks, large predatory fish and seabirds are known to occur in this area and are related to productivity (Sleeman et al. 2007).

12. Commonwealth waters adjacent to Ningaloo Reef

National and/or regional importance

Ningaloo Reef is globally significant as the only extensive coral reef in the world that fringes the west coast of a continent and as a seasonal aggregation site for whale sharks. The Commonwealth waters adjacent to Ningaloo Reef and associated canyons and plateau are interconnected and support the high productivity and species richness of Ningaloo Reef.

Values description

Ningaloo Reef is the only extensive reef in the world that fringes the western coast of a continent. It extends more than 260 kilometres along Cape Range Peninsula with a landward lagoon 200 metres to 6 kilometres wide. The outer reef is marked by a well-developed spur and groove system of fingers of coral formations penetrating into the ocean with coral sand channels in between. The spurs support coral growth, while the grooves experience strong scouring surges and tidal run-off and have little coral growth. Seaward of the reef crest, the reef drops gently to depths of 8–10 metres. The waters reach 100 metres depth, 5–6 kilometres beyond the reef edge. Commonwealth waters over the narrow shelf (10 kilometres at its narrowest) and shelf break are contiguous with Ningaloo Reef and connected via oceanographic and trophic cycling (Brewer et al. 2007; DEWHA 2008b).

Upwellings associated with canyons on the adjacent slope and interactions between the Ningaloo and Leeuwin currents are thought to support the rich aggregations of large marine species present at Ningaloo Reef. The narrow shelf means that the nutrients channelled to the surface via canyons are immediately available to reef species. Low terrestrial nutrient input means that this deepwater source is a major source of nutrients for Ningaloo Reef and therefore very important in maintaining this system (DEWHA 2008b).

The Ningaloo system supports aggregations and migration pathways of whale sharks, manta rays, humpback whales, sea snakes, sharks, large predatory fish and seabirds (Donovan et al. 2008; Gunn et al. 1999; Waples & Hollander 2008). Detrital input from phytoplankton production in surface waters and from higher trophic consumers cycles back to the deeper waters of the shelf and slope (Brewer et al. 2007). Deepwater biodiversity includes fish, molluscs, sponges, soft corals and gorgonians. Some of these sponge and filter-feeding communities appear to be significantly different to those of the Dampier Archipelago and Abrolhos Islands, indicating that the Commonwealth waters adjacent to Ningaloo Reef have some particular areas of potentially high and unique sponge biodiversity (Rees et al. 2004).

13. Wallaby Saddle

National and/or regional importance

The Wallaby Saddle is a unique habitat that may have been associated with historical aggregations of sperm whales (DEWHA 2008a).

Values description

The Wallaby Saddle is an abyssal geomorphic feature that connects the north-west margin of the Wallaby Plateau with the margin of the Carnarvon Terrace on the upper continental slope at a depth of 4000–4700 metres (Falkner et al. 2009). The Wallaby Saddle is located within the Indian Ocean water mass and is thus differentiated from systems to the north that are dominated by transitional fronts or the Indonesian Throughflow. Little is known about the Wallaby Saddle; however, the area is considered one of enhanced productivity and low habitat diversity (Brewer et al. 2007).

Historical sperm whale aggregations in the area of Wallaby Saddle (Bannister et al. 2007) may be attributable to higher productivity and aggregations of baitfish.

14. Vulnerabilities and pressures

Analysis of pressures on key ecological features is limited by knowledge of ecological functioning and structures and the vulnerability of ecosystems to human activities. Information available on the implications of environmental pressures on ecosystems at different spatial, temporal and ecological scales in the North-west Marine Region is scant. As a consequence, the analysis on the pressures affecting the key ecological features of the region is an initial assessment intended to guide further consideration and research.

The results of the pressure analysis are summarised in Table A1. Only those pressures identified as *of concern* or *of potential concern* are discussed in further detail in this report card. Further information on the methods, categories and criteria of the pressure analysis is provided in the *Overview of marine bioregional plans* (**www.environment.gov.au/coasts/mbp/publications/pubs/mbp-plans.pdf**).

Table A1: Assessment of the level of concern associated with the effects of pressures on key ecological features of the North-west Marine Region

Pressure	Source	Carbonate bank and terrace system of the Sahul Shelf	Pinnacles of the Bonaparte Basin	Ashmore Reef and Cartier Island and surrounding Commonwealth waters	Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	Continental slope demersal fish communities
Sea level rise	Climate change	not of concern	of less concern	of potential concern	of potential concern	data deficient/not assessed
Changes in sea surface temperature	Climate change	of potential concern	of potential concern	of potential concern	of potential concern	of potential concern
Changes in oceanography	Climate change	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed
Ocean acidification	Climate change	of potential concern	of potential concern	of potential concern	of potential concern	of potential concern
Marine debris	Shipping Vessels (other) Land-based activities	of less concern	of less concern	of potential concern	of potential concern	data deficient/not assessed
Noise pollution	Seismic exploration	not of concern	not of concern	not of concern	of less concern	not of concern
Noise pollution	Shipping Vessels (other)	not of concern	not of concern	not of concern	of less concern	not of concern
Noise pollution	Onshore and offshore construction; urban development	not of concern	not of concern	not of concern	of less concern	not of concern
Physical habitat modification	Tourism, recreational vessels	not of concern	not of concern	data deficient/not assessed	of less concern	data deficient/not assessed
Physical habitat modification	Vessels anchorage (shipping, fishing, tourism, traditional Indonesian fishers)	not of concern	not of concern	of less concern	of potential concern	data deficient/not assessed
Physical habitat modification	Fishing gear (active and derelict)	of less concern	of less concern	not of concern	not of concern	of potential concern
Physical habitat modification	Offshore construction (e.g. oil rigs, pipelines)	of less concern	of less concern	of less concern	of potential concern	of less concern
Physical habitat modification	Fishing practices—traditional Indonesian	not of concern	not of concern	data deficient/not assessed	of potential concern	data deficient/not assessed
Physical habitat modification	Storm events	data deficient/not assessed	data deficient/not assessed	of potential concern	of potential concern	data deficient/not assessed
Human presence at sensitive sites	Tourism Recreational and charter fishing	not of concern	not of concern	data deficient/not assessed	of less concern	data deficient/not assessed
Extraction of living resources	Commercial fishing (domestic)	of less concern	of less concern	data deficient/not assessed	of less concern	data deficient/not assessed
Extraction of living resources	Commercial fishing (non-domestic)	not of concern	not of concern	of less concern	of concern	data deficient/not assessed
Extraction of living resources	Recreational and charter fishing	not of concern	not of concern	data deficient/not assessed	of less concern	of less concern
Extraction of living resources	Illegal, unregulated and unreported fishing (domestic and non-domestic)	of potential concern	of potential concern	of potential concern	of less concern	data deficient/not assessed
Bycatch	Commercial fishing	of less concern	not of concern	data deficient/not assessed	data deficient/not assessed	of potential concern
Oil pollution	Shipping	not of concern	not of concern	of less concern	of less concern	not of concern
Oil pollution	Oil rigs	not of concern	not of concern	of potential concern	of potential concern	data deficient/not assessed
Invasive species	Shipping Fishing vessels Vessels (other) Land-based activities	not of concern	not of concern	of potential concern	of potential concern	of less concern

Legend — of concern | of potential concern | of less concern | not of concern | data deficient/not assessed

Table A1 continued: Assessment of the level of concern associated with the effects of pressures on key ecological features of the North-west Marine Region

Pressure	Source	Canyons linking the Argo Abyssal Plain with the Scott Plateau	Ancient coastline at 125 m depth contour	Glomar Shoals	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	Exmouth Plateau	Canyons linking the Cuvier Abyssal Plain with the Cape Range Peninsula	Commonwealth waters adjacent to Ningaloo Reef	Wallaby Saddle
Sea level rise	Climate change	not of concern	data deficient/not assessed	data deficient/not assessed	of potential concern	not of concern	data deficient/not assessed	of less concern	data deficient/not assessed
Changes in sea surface temperature	Climate change	not of concern	data deficient/not assessed	of potential concern	of potential concern	not of concern	data deficient/not assessed	of potential concern	data deficient/not assessed
Changes in oceanography	Climate change	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed
Ocean acidification	Climate change	of potential concern	of potential concern	of potential concern	of potential concern	of potential concern	of potential concern	of potential concern	of potential concern
Marine debris	Shipping Vessels (other) Land-based activities	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	not of concern	data deficient/not assessed	of less concern	data deficient/not assessed
Noise pollution	Seismic exploration	of less concern	of less concern	not of concern	not of concern	not of concern	not of concern	not of concern	not of concern
Noise pollution	Shipping Vessels (other)	of less concern	of less concern	not of concern	not of concern	not of concern	not of concern	not of concern	not of concern
Noise pollution	Onshore and offshore construction; urban development	of less concern	of less concern	not of concern	not of concern	not of concern	not of concern	not of concern	not of concern
Physical habitat modification	Tourism, recreational vessels	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed
Physical habitat modification	Vessels anchorage (shipping, fishing, tourism, traditional Indonesian fishers)	not of concern	data deficient/not assessed	data deficient/not assessed	of less concern	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed
Physical habitat modification	Fishing gear (active and derelict)	not of concern	not of concern	of less concern	of less concern	not of concern	not of concern	not of concern	not of concern
Physical habitat modification	Offshore construction (e.g. oil rigs, pipelines)	not of concern	not of concern	of less concern	of less concern	of less concern	not of concern	of less concern	not of concern
Physical habitat modification	Fishing practices—traditional Indonesian	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed
Physical habitat modification	Storm events	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	of potential concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed
Human presence at sensitive sites	Tourism Recreational and charter fishing	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	not of concern	data deficient/not assessed	not of concern	data deficient/not assessed
Extraction of living resources	Commercial fishing (domestic)	not of concern	of less concern	of potential concern	of less concern	not of concern	of less concern	of less concern	of less concern
Extraction of living resources	Commercial fishing (non-domestic)	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed
Extraction of living resources	Recreational and charter fishing	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed
Extraction of living resources	Illegal, unregulated and unreported fishing (domestic and non-domestic)	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	not of concern	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed
Bycatch	Commercial fishing	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed	data deficient/not assessed
Oil pollution	Shipping	not of concern	not of concern	of less concern	of less concern	not of concern	not of concern	of less concern	not of concern
Oil pollution	Oil rigs	not of concern	of less concern	of less concern	of potential concern	not of concern	of less concern	of potential concern	not of concern
Invasive species	Shipping Fishing vessels Vessels (other) Land-based activities	not of concern	not of concern	of potential concern	of potential concern	not of concern	not of concern	of potential concern	not of concern

Legend — of concern (red); of potential concern (yellow); of less concern (green); not of concern (grey); data deficient/not assessed (white)

Sea level rise

Global sea levels rose about 20 centimetres between 1870 and 2008. Sea levels have been rising at approximately 7.1 millimetres per year in the North-west Marine Region since the 1990s, the largest increase in Australia (NTC 2010). Global sea levels have risen by 20 cm between 1870 and 2004 and predictions estimate a further rise of 5–15 cm by 2030, relative to 1990 levels (Church et al. 2009). Longer term predictions estimate increases of 0.5 m to 1.0 m by 2100, relative to 2000 levels (Climate Commission 2011). The main concern with rising sea levels is the increased risk of extreme sea-level risks when sea level rise is combined with increasing cyclone frequency (Climate Commission 2011; DCC 2009). Predictions for the North-west Marine Region in 2100 are for a hundred-fold increase in extreme sea-level events in the Pilbara, up to a thousand-fold increase in the Kimberley (DCC 2009).

Sea level rise is *of potential concern* for key ecological features with shallow reefs. Under pre-climate change conditions, reefs could be expected to grow upward to match sea level rise. However, the cumulative effects of coral bleaching (sea temperature) and decline in calcification in corals (ocean acidification) may render corals incapable of recovery to match sea level rise (Hoegh-Guldberg 2011). Water depth is likely to increase over the reef complex; however, the extent to which coral growth will keep pace with the rate of sea level rise is dependent on the interplay between physical, biological and chemical parameters (Smithers et al. 2007). Sediment production, erosion and sediment transport will depend on water depth and wave-generated forces, and the micro-topography of reef crests will change with effects on the habitat of biota (Sheppard et al. 2002). Critically, the growth of reefs greater than depths of 30–40 metres will not likely match sea level rise regardless of calcification rates. During the Holocene transgression, sea levels rose at 10–20 millimetres per year and corals reef growing at depths below the critical 30–40 metres failed to flourish and mature (Grigg & Epp 1989).

Changes in sea temperature

Sea temperatures have warmed by 0.7 °C between 1910–1929 and 1989–2008, and current projections estimate ocean temperatures will be 1 °C warmer by 2030 (Lough 2009). Change in sea temperature is *of potential concern* for:

- Carbonate bank and terrace system of the Sahul Shelf
- Pinnacles of the Bonaparte Basin
- Ashmore Reef and Cartier Island and surrounding Commonwealth waters
- Seringapatam Reef and Commonwealth waters in the Scott Reef Complex
- Continental slope demersal fish communities
- Glomar Shoals
- Mermaid Reef and Commonwealth waters surrounding Rowley Shoals
- Commonwealth waters adjacent to Ningaloo Reef.

Key ecological features supporting coral reef communities are vulnerable to bleaching and mortality from elevated sea temperatures. In 1998, high sea surface temperature led to widespread bleaching of corals at Ashmore and Cartier reefs, the Rowley Shoals and Scott and Seringapatam reefs (Gilmour et al. 2007; Pittock 2003). At Scott and Seringapatam reefs, corals bleached at depths up to 30 metres and hard coral cover decreased from 41 per cent before the event to 15 per cent (Pittock 2003). Ningaloo Reef bleached for the first time in February 2011 (Ridgeway 2011) due to prolonged high sea surface temperatures. In 2005, elevated sea temperatures resulted in a minor bleaching event at the Rowley Shoals, which impacted a large proportion of benthic organisms including, corals, clams and anemones (Gilmour et al. 2007).

Coral communities at Scott Reef showed few signs of recovery up to three years after the bleaching. Smith et al. (2003) postulated that recovery relied on the successful reproduction of the few corals that survived the disturbance and was not supplemented by a supply of new recruits from other reefs in the region. Further genetic studies have confirmed low levels of connectivity among reefs in the North-west Marine Region (Underwood 2009).

Corals are the foundation of reef ecosystems and severe impacts on corals have significant flow-on effects throughout the reef community. There is evidence that there was a change in fish communities at Scott Reef following the coral bleaching event in 1998 (Woodside 2009). Turfing algae replaced coral as the dominant benthic organism. The numbers of fish species reliant on hard coral for food and/or shelter remained low shortly after the bleaching (1998–2004), but have reportedly shown signs of increasing as hard corals recovered (2005–08). Conversely, the increased abundance of fish species shortly after the bleaching (1998–2004), with a dietary preference for algae, has since (2005–08) declined (Woodside 2009).

A study of the supply and survival of reef fish larvae and high sea temperatures during an El Niño event in the 1990s showed that fish survival on coral reef habitats declined; it also predicted negative effects on reef fish communities under climate change scenarios (Lo-Yat et al. 2011).

While the effects of increased sea temperatures are likely to vary greatly across communities and ecosystems, there is a high level of agreement from different datasets that warming is affecting distributional ranges and larval phase of tropical marine fishes (Munday et al. 2009). Changes in sea temperature may also result in changes to phytoplankton and zooplankton communities, with implications for trophic dynamics (Richardson et al. 2009) and fish larval supply and survival (Lo-Yat et al. 2011).

Increases in ocean water temperature may also affect deeper water fish species such as those within the demersal slope fish key ecological feature. Climate change modelling predicts that by 2070, ocean water temperatures at 500 metres depth will warm by 0.5–1 °C, which could adversely impact larval fish development and survival (Hobday et al. 2006). Fish living in these colder deepwater habitats may be impacted as their temperature-limited metabolic tolerances are reached (Neuheimer et al. 2011). The range of benthic and demersal fish species may shift south and some populations may decline where ranges are bounded to the south (Hobday et al. 2006). Structurally complex epifauna (e.g. sponges, alga and coralline algae) may also suffer mortality from elevated water temperatures (Lawrence et al. 2007).

The nature and strength of the thermocline is likely to change with increased temperatures, becoming shallower and stronger. While this will further depress the transfer of nutrients into the euphotic zone, potentially limiting primary productivity, increased photosynthesis due to increased temperature may offset productivity declines (Behrenfeld 2011).

Ocean acidification

Ocean acidification is *of potential concern* for all key ecological features in the region. Driven by increasing levels of atmospheric CO_2 and subsequent chemical changes in the ocean, acidification is already underway and detectible. Since pre-industrial times, acidification has lowered ocean pH by 0.1 units (Howard et al. 2009). Furthermore, climate models predict this trend will continue with a further 0.2–0.3 unit decline by 2100 (Howard et al. 2009).

Ocean acidification will compromise carbon accretion and, together with increasing ocean temperatures, may result in loss of ecosystems based on geologic features formed from coral or coralline algae (Hoegh-Guldberg 2011; Hoegh-Guldberg et al. 2007; Kleypas & Yates 2009; Kuffner et al. 2008). Increasing acidity impairs the ability of species with calcareous shells such as echinoderms, crustaceans and molluscs to maintain shell integrity, resulting in reductions of the overall abundance and biodiversity of these species (Kleypas & Yates 2009). A decrease in the abundance of fauna with carbonate-based skeletons, coral and coralline algal, and the complex structural habitats they create, could lead to changes in ecosystem structures, processes and connectivity between the reef complex and the adjacent deeper waters. These impacts will be particularly relevant to:

- Carbonate banks of the Sahul Shelf
- Pinnacles of the Bonaparte Basin
- Ashmore Reef and Cartier Island and surrounding Commonwealth waters
- Seringapatam Reef and Commonwealth waters in the Scott Reef Complex
- Glomar Shoals
- Mermaid Reef and Commonwealth waters surrounding Rowley Shoals
- Commonwealth waters adjacent to Ningaloo Reef.

Marine debris

Marine debris is *of potential concern* at Ashmore Reef and Cartier Island and surrounding Commonwealth waters and at Seringapatam Reef and the Commonwealth waters in the Scott Reef Complex. Marine debris is defined as any persistent, manufactured or processed solid material that has been disposed of, or abandoned, in the marine and coastal environment (UNEP 2005). This includes a range of material from plastics (e.g. bags, bottles, ropes, fibreglass and insulation) to derelict fishing gear and ship-sourced, solid non-biodegradable floating materials (DEWHA 2009). Region-specific information on marine debris is limited; key vectors for the introduction and spread of debris (e.g. shipping, commercial fishing, traditional Indonesian fishing vessels and illegal vessels) are present within or adjacent to these key ecological features suggesting a potentially high degree of overlap with this pressure. The aggregations of marine life identified as values associated with these key ecological features could be adversely affected by ingestion of or entanglement with marine debris.

Physical habitat modification

Physical habitat modification is a pressure *of potential concern* for Seringapatam Reef and Commonwealth waters in the Scott Reef Complex. This key ecological feature is the location of oil and gas resources including the Torosa field below North and South Scott reefs. If this field is developed it may involve the drilling of numerous wells and the installation of platforms and an extensive series of pipelines (Woodside 2008).

The benthic communities at Scott Reef and surrounding waters are diverse and include hard and soft corals, seagrasses, macroalgae, infaunal communities and marine invertebrates such as ascidians, sponges, whips and gorgonians (Smith et al. 2006). A taxonomic survey in 2004 found a number of scleractinian species that had not previously been recorded on Western Australian reefs (e.g. *Acropora indonesia*) (Woodside 2007).

The installation of infrastructure may directly affect the benthic communities associated with this key ecological feature. Construction, commissioning and operation of offshore gas facilities may also result in the release of discharges and effluents that could potentially affect the quality of receiving marine waters at localised scales. Suspended solids (generated from the disturbance to the seabed by the installation of infrastructure and from the discharge of drilling cuttings) and muds may directly affect the physical and chemical properties of the receiving waters. In turn, this could indirectly affect flora and fauna in the area via physiological or toxicological impacts and may also result in the smothering of some benthic communities and a reduction in light availability (Woodside 2008).

It is unclear what effect, if any, the modification of benthic habitats could have on the broader functioning and integrity of this key ecological feature. However, the effects of construction and installation activities may have both direct and indirect impacts on the listed threatened species of marine mammals, turtles, birds and whale sharks that may occur in this area. These impacts may include avoidance behaviour, potential physiological effects and direct impact on foraging areas (Woodside 2008).

Physical habitat modification can also result from traditional Indonesian fishing practices. Traditional Indonesian fishers access Scott and Seringapatam reefs to fish for holothurians, trochus, molluscs and finfish including shark. Some fishing involves walking the reef at low tide to hand-collect species such as holothurians and the turning over of coral boulders. Corals are left upturned as 'markers' to indicate they have searched that area. As a result, this practice may result in the death of other organisms left exposed and may degrade and/or reduce habitat for other marine organisms. It is not known what effect this has on the coral ecosystem. However, since hundreds of traditional fishers walk the same reefs for extended periods it is possible this fishing practice is placing pressure on the reef environment. While there are possibly some negative implications for the reef, these need to be also be understood in the context of the other destructive natural processes such as severe cyclones, rising sea temperatures and ocean acidification.

Vessel anchorage may also modify or damage the benthic communities of this key ecological feature. Around 80 traditional Indonesian fishing vessels annually anchor in the waters of this key ecological feature but there are currently no restrictions on where or how they can anchor. Petroleum industry and Australian surveillance vessels also use the area and, due to their size, must have appropriate anchoring systems in place and follow anchorage procedures to ensure the safety of crew and surrounding environment (Australian Transport Commission 2010). The North West Slope Trawl Fishery operates in the area and targets deepwater species on muddy benthos. It is not known what impact the anchoring of these vessels is having on the values of this key ecological feature.

Habitat damage from fishing gear is *of potential concern* for continental slope demersal fish communities. Trawling is potentially damaging to benthic habitat and causing a loss of demersal fish and other fauna. The continental slope provides a habitat for a rich and diverse range of demersal fish species, many of which are endemic to the North-west Marine Region (Last et al. 2005). Loss of benthic habitat along the continental slope at depth ranges known to support demersal fish communities (225–500 metres and 750–1000 metres) could lead to a decline in species richness, diversity and endemism associated with this feature.

Habitat modification through physical damage as a result of increased intensity of storm events from climate change is *of potential concern* for

- Ashmore Reef and Cartier Island and surrounding Commonwealth waters
- Seringapatam Reef and Commonwealth waters in the Scott Reef Complex
- Mermaid Reef and Commonwealth waters surrounding the Rowley Shoals.

One of the predictions for climate change is the increase in the severity and frequency of severe storm events (Hyder Consulting 2008). In conjunction with a more fragile matrix structure of corals and then slower growth (recovery) due to ocean acidification, reefs may become more vulnerable to severe storm events, leading to severe flow-on effects for communities dependent on coral reef habitats.

Extraction of living resources

Illegal, Unregulated and Unreported (IUU) fishing is a pressure *of potential concern* for:

- Carbonate bank and terrace system of the Sahul Shelf
- Pinnacles of the Bonaparte Basin
- Ashmore Reef and Cartier Island and surrounding Commonwealth waters.

IUU fishing has been a significant issue in the North-west Marine Region and posed a major threat to target species and the conservation of the broader marine environment. In 2005, 13 018 illegal fishing vessels were sighted in Australian waters and of those, 600 were apprehended by Australian officials (Vince 2007). Sharks are the species predominantly targeted for the valuable fin market. The Australian Government is also concerned with the issues of border security and quarantine that coincide with IUU fishing activities (Vince 2007). Sharks are a high-order predator in the marine environment and hence play an important role in regulating community dynamics. The effect on the marine environment of these key ecological features following the removal of sharks is unknown. However, it is hypothesised that an increase in large reef fish species at Scott Reef is a result of the decline in abundance of shark species (Gilmour et al. 2009, cited in Woodside 2009). The level of IUU activity in the region has dropped sharply since 2005; however, due to the life history characteristics of sharks (long life, slow to mature, small numbers of offspring) it may take some time before the effects of overfishing on sharks in the region is reversed.

The extraction of living resources by traditional Indonesian fishers is *of concern* for Seringapatam Reef and Commonwealth waters in the Scott Reef complex. In 1974, a Memorandum of Understanding (MoU) was signed between the Australian and Indonesian governments that recognised traditional fishing in the area, and permitted Indonesians to fish in the offshore areas surrounding Scott Reef. The MoU requires Indonesian fishers to use traditional sail-powered fishing vessels and non-motorised equipment and prohibits them from taking protected species such as turtles, dugongs and clams. Fishers target a range of animals, including sea cucumbers (bêche-de-mer), trochus (topshell), reef fish and sharks. Indonesian fishing effort is high at Scott

Reef. In 2008, approximately 80 Indonesian fishing vessels were observed at Scott Reef (ERM 2008, cited in Woodside 2009). Given the level of fishing pressure, many target species are considered to be over-exploited (Meekan et al 2006; Skewes et al 1999). Studies show that shark populations were severely depleted at Scott Reef compared to the Rowley Shoals, and that the most plausible reason was overfishing (Meekan et al 2006). Fishers are increasingly harvesting large reef fish species such as the bumphead parrotfish and humphead wrasse. The bumphead parrotfish is a large herbivorous species which is thought to be important in regulating the growth of coral and algae in reef communities, hence its removal could have implications for system functioning and reef resilience to other pressures (Bellwood et al. 2003).

Extraction of living resources via commercial fishing is *of potential concern* for the Glomar Shoals key ecological feature. The main trawl fishery operating in the vicinity of the Glomar Shoals is the Pilbara Demersal Finfish Fishery, which operates in water depths of 50–200 metres (Fletcher & Santoro 2010). Data from this fishery indicates that catch is greatest in the 60 nautical mile grid that includes the Glomar Shoals. The fishery as a whole retained 1044 tonnes of demersal finfish species in 2009 and this level of catch is considered sustainable (Fletcher & Santoro 2010). However, it is not known if the catch of non-retained species is sustainable or what the impact of the removal of target and non-target species has on the ecological functioning or biodiversity of the Glomar Shoals. A study by Moran and Stephenson (2000) found that the gear used in the fishery removed large epibenthos (organisms greater than 20 centimetres) density by 15.5 per cent per trawl pass. The removal of biomass and benthic communities has the potential to adversely impact on the values of this key ecological feature.

Bycatch

Bycatch as a result of commercial fishing is a pressure *of potential concern* for the continental slope demersal fish communities key ecological feature. The North West Slope Trawl Fishery operates in waters at a depth of 250–800 metres on muddy substrates. Target species include scampi and deepwater prawns (Wilson et al. 2010). There are currently seven permits to fish and the fishery operates over the entire continental slope of the region. The fishery is considered to be sustainable as far as the harvest of target species (Wilson et al. 2010). However, there is little information available on the composition and volume of bycatch in the North West Slope Trawl Fishery. Bycatch diversity is reputedly high and, according to logbook data for 2001–04, between a third and a half of the total catch is discarded (Wayte et al. 2007). It is not known what impact trawling has on the continental slope demersal fish communities and whether it has the potential to diminish the species richness, diversity and endemism of these communities.

Oil pollution

The North-west Marine Region is an area subject to significant petroleum exploration, development and production and this is likely to increase (DEWHA 2008b). Shipping is likely to continue to expand in the region as a result of the growth of the resources sector. Oil spills from oil rigs and shipping are unpredictable events and their likelihood is low, particularly in the context of the international and domestic regulatory mitigation measures that apply in Australia. Their consequences, however, can be severe, particularly for some ecosystems and at times of biological significance for important and/or threatened species.

Oil pollution is *of potential concern* for key ecological features with values vulnerable to the impacts of an oil spill, including highly diverse coral communities that support an abundant array of marine species in:

- Ashmore Reef and Cartier Island and surrounding Commonwealth waters
- Seringapatam Reef and Commonwealth waters in the Scott Reef Complex
- Mermaid Reef and Commonwealth waters surrounding the Rowley Shoals
- Commonwealth waters adjacent to Ningaloo Reef.

Coral reef communities are highly sensitive to oil and oil–dispersant mixtures (Shafir et al. 2007). Oil spills are particularly significant for corals at spawning time since broadcast coral gametes collect at the surface and may be exposed to petroleum products. Coral eggs and larvae are buoyant for the first few days after spawning and may suffer significant mortality if any oil or oil/dispersant mixture is encountered in significant concentrations. There is also evidence that metamorphosis (around 1–3 weeks following spawning) is particularly susceptible to oil (Negri & Heyward 2000). Scott and Seringapatam reefs and the Rowley Shoals are likely to be self-seeding over ecological timescales (Underwood 2009; Underwood et al. 2007). Therefore, recovery from damage by oil is likely to be far slower in such isolated reefs than in coastal settings and/or interconnected groups of reefs.

Chemical dispersants (powerful detergents) are often applied to oil slicks on the surface to accelerate weathering processes, disperse the oil into the water column and minimise the surface transport of oil to sensitive habitats such as foreshores. These dispersants contain toxic elements that can be harmful to coral (Shafir et al. 2007). Gulec and Holdway (2000, cited in Fandry et al. 2006) found that when certain dispersants were combined with crude oil the toxicity of oil to species of fish and invertebrates increased. However, dispersants are only used when all environmental effects have been considered and are generally not used in close proximity to coral reefs (AMSA 2011).

The coral reefs and surrounding waters at Scott and Seringapatam, Ashmore, Mermaid and Ningaloo reefs support a diverse array of marine species, including turtles, sea snakes, whales and dolphins (DEWHA 2008b). These species are all surface breathers and could be more susceptible to serious impact if they encountered a surface oil slick. These key ecological features are also important for a number of seabird species which could also be adversely impacted should a spill occur.

Oil spills are rare and the level of impact that actually occurs depends on a number of factors including concentration of oil, chemical and physical properties of the oil (or oil/dispersant mixture), the timing of breeding cycles and seasonal migrations of species, the time of contact, susceptibility of particular species and the health, age and reproductive status of the individuals (AMSA 2011).

Invasive species

An invasive species is a species occurring, as a result of human activities, beyond its accepted normal distribution and which threatens valued environmental, agricultural or other social resources by the damage it causes. Invasive species have the potential to impact directly on benthic communities, coral and fish via competition for habitat and food resources. They are *of potential concern* at:

- Ashmore Reef and Cartier Island and surrounding Commonwealth waters
- Seringapatam Reef and Commonwealth waters in the Scott Reef Complex
- Glomar Shoals
- Mermaid Reef and Commonwealth waters surrounding the Rowley Shoals
- Commonwealth waters adjacent to Ningaloo Reef.

The two primary mechanisms for the inadvertent introduction and spread of invasive marine species are ballast water discharge and vessel biofouling. Key ecological features in areas of high international and domestic shipping traffic are at greater risk of an invasive species incursion. Offshore petroleum development also has the potential to introduce invasive species through the installation of rigs and subsea infrastructure.

Seringapatam Reef and Commonwealth waters in the Scott Reef Complex, and Ashmore Reef and Cartier Island are also visited by traditional Indonesian fishing vessels and illegal vessels. These foreign vessels have the potential to carry invasive species on their hulls which could endanger the relatively pristine marine environments of these two offshore reef systems.

15. Current protection measures

Alongside the EPBC Act, a broad range of sector-specific management measures to address environmental issues and mitigate impacts apply to activities that take place in Commonwealth marine areas. These measures give effect to regulatory and administrative requirements under Commonwealth and state legislation for activities such as commercial and recreational fishing, oil and gas exploration and production, port activities and maritime transport. In some instances, as in the case of shipping, these measures also fulfil Australia's obligations under a number of international conventions for the protection of the marine environment from pollution and environmental harm.

Details about protection measures under the EPBC Act (e.g. recovery plans) or threatening processes (e.g. threat abatement plans) relevant to species that are components of the key ecological features can be found in the species groups report cards **www.environment.gov.au/coasts/mbp/north-west/index.html.**

Under the EPBC Act, all fisheries managed under Commonwealth legislation, and state/-managed fisheries that have an export component, must be assessed to ensure that they are managed in an ecologically sustainable way over time. Fishery assessments are conducted using the *Guidelines for the ecologically sustainable management of fisheries* (**www.environment.gov.au/coasts/fisheries/publications/guidelines.html**). In particular, Principle 2 of the Guidelines requires that fishing operations should be managed to minimise their impact on the structure, productivity, function and biological diversity of the ecosystem.

Glossary

aggregating behaviour
The concentration of fish because of direct causes such as a concentration of food organisms or spawning or for unknown reasons

algae
A major group of plants without a vascular or 'vein' system, living in fresh or marine water. *See also* macroalgae, microalgae

amphipod
A small crustacean of the order Amphipoda, such as the beach flea, having a laterally compressed body with no carapace

anti-cyclonic
Rotation about a vertical axis that is clockwise in the Northern Hemisphere and counter-clockwise in the Southern Hemisphere

ascidians
Members of the class Ascidiacea (sea squits), a group of sessile marine filter-feeding animals characterised by a tough outer sac or 'tunic'. Ascidian species may be solitary, communal or colonial

assemblage
A collection of plants and/or animals characteristically associated with a particular environment that can be used as an indicator of the health of that environment

Australian margin
Refers to the Australian continental margin, the offshore zone, consisting of the continental shelf, slope, and rise, that separates the dry-land portion of a continent from the deep ocean floor

bathymetry
The measurement of ocean depths to determine the sea-floor topography

benthic
Refers to all marine organisms living upon or in the bottom of the sea

biodiversity
Variability among living organisms from all sources (including terrestrial, marine and other ecosystems and ecological complexes of which they are part), which includes diversity within species and between species and diversity of ecosystems

biogeographic
Relating to large regions with distinct fauna and flora

biological or ecological productivity
The ability of an ecosystem to produce, grow or yield products

biomass
The quantity of organic matter within an ecosystem

bioregion
An area of the ocean that is classified as having similar types of plants, animals and ocean conditions, compared to other similarly sized areas

biota
All of the organisms at a particular locality

bryozoans
Marine animals commonly known as moss animals, sea mats or (for some forms) lace coral. The majority of living bryozoans are encrusting, forming flat sheets that spread out over the substrate, but others grow upwards into the water column

bycatch
All non-targeted catch, including by-product, discards and gear interactions. By-product refers to the unintended catch that may be kept or sold by the fisher. Discards refer to the product that is returned to the sea. Gear interactions refer to all species and habitat affected by the fishing gear

carbonate organisms
Life forms that incorporate calcium and carbon from sea water into their skeletons or shells. They include a range of organisms such as algae, corals and bivalves, and can be microscopic

cetaceans
Members of the mammalian group Cetacea, including whales, dolphins and porpoises

coccolithophore
Coccolithophores (also called coccolithophorids) are single-celled algae, protists and phytoplankton belonging to the division of haptophytes

continental rise
The gently sloping surface located at the base of a continental slope

continental shelf
The section of the seabed from the shore to the edge of the continental slope

ontinental slope
The region of the outer edge of a continent between the relatively shallow continental shelf and the deep ocean

convergence front
An interface or zone of transition between two dissimilar water masses

copepod
Any small aquatic crustacean belonging to the subclass Copepoda, characterised by compound eyes and the lack of a carapace, usually having six pairs of limbs on the thorax. Can be found in freshwater or marine environments

crinoid
Any of various echinoderms of the class Crinoidea, including the sea lilies and feather stars, that are characterised by a cup-shaped body, feathery radiating arms, and either a stalk or claw-like structure with which they are able to attach to a surface

crustacean
A type of arthropod that has gills and a body covered by a hard shell (including crabs, lobsters and shrimps)

cumacean
Cumacea is an order of small marine crustaceans, occasionally called hooded shrimp. Their unique appearance and uniform body plan makes them easy to distinguish from other crustaceans

dinoflagellate
A single-celled organism found in fresh and marine waters, which combines characteristics of both plants (e.g. photosynthesis) and animals (e.g. uses external organic sources of nutrition)

decapod
An order of Crustacea comprising lobsters, crabs and shrimps. Decapods have a fused head and thorax covered by a dorsal exoskeleton made from chitin and five pairs of legs

demersal
Living on or near the bottom of the sea

detritus
Any loose, unconsolidated debris that is either finely divided rock or the finely divided remains of animal or plant tissue, or both

echinoderms
Marine animals with an internal skeleton of calcite plates and a water-vascular system that allows movement, breathing, nutrition or perception. Echinoderms include starfishes, sea cucumbers, sand dollars, brittle-stars, basket stars, sea lilies, feather stars and sea urchins

ecological community
According to the *Environment Protection and Biodiversity Conservation Act 1999*, an ecological community is an assemblage of native species that: (a) inhabits a particular area in nature; and (b) meets the additional criteria specified in the regulations (if any) made for the purposes of this definition. More broadly, an ecological community is a group of species that commonly occur together in a way that is recognisably different from other groups

ecosystem
A dynamic complex of plant, animal and microorganism communities and their non-living environment that interacts as a functional unit

eddy (pl. eddies)
Circular movements of water formed on the side of a main current

El Niño
Warming of the surface of the tropical east Pacific Ocean accompanied by high air surface pressure in the western Pacific. El Niño is often associated with drier conditions in eastern Australia

endemic
Native to a particular area and found nowhere else

epibenthic
Living on the top surface of the sea floor. Epibenthic organisms may be freely moving (motile) or permanently attached to a surface (sessile)

epifauna
Animals living attached to rocky reefs or on the seafloor. They include hydroids, sea-pens, small bryozoans and sponges (compare to infauna)

exclusive economic zone
The sovereign waters of a nation, recognised internationally under the United Nations Convention on the Law of the Sea as generally extending out 200 nautical miles from shore

fauna
The entire group of animals found in an area

flora
The entire group of plants found in an area

gastropod
A marine snail

geomorphology
The study of landforms and the processes which shape them

heterogenous
Consisting of elements that are not of the same kind or nature

infauna
Animals that inhabit the sandy or muddy surface layers of the ocean bottom, i.e., those that live buried or dig into the substrate (compare to epifauna)

invasive species
A species occurring, as a result of human activities, beyond its accepted normal distribution and which threatens valued environmental, agricultural or other social resources by the damage it causes

invertebrates
An animal without a backbone composed of vertebrae (including insects, worms, snails, mussels, prawns and cuttlefish)

karst
Landscape underlain by limestone that has been eroded by dissolution, producing ridges, towers, fissures, sinkholes, and other characteristic landforms

lacustrine
Of or relating to lakes. Living or growing in or along the edges of lakes

La Niña
Warming of the western equatorial Pacific warm pool, north of New Guinea, accompanied by cooling in the equatorial eastern Pacific Ocean. La Nina is often associated with above average rainfall in eastern Australia

macroalgae
The algae are a major group of plants without a vascular or 'vein' system, living in fresh or marine water. Macro-algae are the large, visible algae, such as kelps, as opposed to micro-algae, the microscopic algae that form phytoplankton

megabenthic/megabenthos
Megabenthic organisms are defined as species large enough to be identified on photographs

mesoscale
Of intermediate size (e.g. hundreds of kilometres)

microalgae
Microscopic algae that form phytoplankton

molluscs
Any invertebrate of the phylum *Mollusca,* having a soft unsegmented body and often a shell, secreted by a fold of skin (the mantle). The group includes the gastropods (e.g. snails, slugs), bivalves (e.g. clams, mussels), and cephalopods (e.g. cuttlefish, octopuses)

octocorals
Octocorallia (also known as Alcyonaria) is a subclass of Anthozoa comprising ~3,000 species of water-based organisms formed of colonial polyps with 8-fold symmetry

oligotrophic
Refers to any environment that offers little to sustain life. This term is usually used to describe bodies of water with very low nutrient levels (compare to eutrophic)

ontogenetic
The origin and development of an individual organism from embryo to adult. Also called ontogenesis

ostracods
Any of various minute, chiefly freshwater crustaceans of the subclass Ostracoda, having a bivalve carapace

pedunculate
Having or growing on or from a peduncle or stalk. A pedunculate barnacle is attached to the substrate by a fleshy foot or stalk

pelagic
Associated with the surface or middle depths of the water column, e.g. fish swimming freely in the open sea

phytoplankton
Small plants, mostly microscopic, which are suspended in water and free-drifting

polychaete
Members of the class Polychaetae, a group of mainly marine annelid worms, also known as bristle worms. There are more than 10 000 known species in this class

productivity
The ability of an ecosystem to produce, grow or yield products. Productivity can be biological or ecological

propagule
A dispersive structure, such as a seed, fruit, eggs or sperm, released from a parent organism for reproductive purposes

prospective
Referring to the likelihood of finding commercial mineral deposits

province
A large-scale biogeographic unit determine by evolutionary processes in which suites of endemic species co-exist

pteropod
A small mollusk (class Gastropoda) with winglike extensions to its body that it uses for swimming. There are two orders: Thecosomata (with shells) and Gymnosomata (lacking shells)

recruitment
The influx of new members into a population by reproduction or immigration

sediment
Naturally occurring material that is broken down by processes of weathering and erosion, and is subsequently transported by the action of fluids such as wind, water, or ice, and/or by the force of gravity acting on the particle itself

shelf break
The area of the seabed where the continental shelf meets the steeper slope; commonly around depths of 200 metres

spawning
A reproductive strategy where eggs and sperm are released into water

stock
A group of individuals of a species, usually occupying a particular spatial range

subtropical
Relating to or occurring in a region intermediate between tropical and temperate

tanaids
An order of eumalacostracans of the crustacean superorder Peracarida; the body is linear, more or less cylindrical or dorsoventrally depressed, and the first and second thoracic segments are fused with the head, forming a carapace

terriginous
Sediments derived from the erosion of rocks on land, consisting of sand, mud and silt carried out to sea by rivers. Deposition of these sediments is largely limited to the continental shelf

trophic level
The position an organism occupies in a food chain. Levels include primary producers, herbivores, primary, secondary and tertiary carnivores, and decomposers

tunicate
Any of various chordate marine animals of the subphylum Tunicata or Urochordata having a cylindrical or globular body enclosed in a tough outer covering and including the sea squirts and salps

turbidity
The cloudiness in water that is caused by particles, usually of fine sediment or microscopic particles of biological material

upwelling
The phenomenon of deep ocean water rising to the surface, usually bringing nutrients that can increase biological productivity

zooplankton
Animal component of the plankton community

zooxanthellae
Unicellular yellow-brown algae that live in the gastrodermis of reef-building corals

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