Australian Heritage Database

Places for Decision

Class : Natural

Identification

List:	**National Heritage List**
Name of Place:	Ningaloo Coast National Heritage Place
Other Names:	Ningaloo Reef, Cape Range Area
Place ID:	105881
File No:	5/14/192/0013
Nomination Date:	13/10/2005
Principal Group:	Coastal environments

Status

Legal Status:	17/10/2005 - Nominated place
Admin Status:	05/08/2008 - Assessment by AHC completed

Assessment

Recommendation:	Place meets one or more NHL criteria
Assessor's Comments:	
Other Assessments:	:

Location

Nearest Town:	Ningaloo
Distance from town (km):	
Direction from town:	
Area (ha):	615000
Address:	Ningaloo Rd, Ningaloo, WA, 6707
LGA:	Exmouth Shire WA Carnarvon Shire WA Ashburton Shire WA

Location/Boundaries:

About 615,000ha, at Learmonth, comprising:
1. Ningaloo Marine Park (Commonwealth Waters),
2. Ningaloo Marine Park (State Waters),
3. Muiron Islands Marine Management Area,
4. The following pastoral lease areas that are to be excluded from those leases by the Western Australian Government in 2015 and converted to conservation and recreation areas (as described in the 'Ningaloo Coast Regional Strategy Carnarvon to Exmouth August 2004, Western Australian Planning Commission':

- Part Quobba Station Exclusion, being that part of the exclusion zone to the north of Latitude 24 degrees 03 minutes 00 seconds S.
- Gnaraloo Station Exclusion
- Warroora Station Exclusion
- Cardabia Station Exclusion
- Ningaloo Station Exclusion, and

5. An area bounded by a line commencing at the south west corner of Lot 97 DP213189, then northerly via the eastern boundary of Ningaloo Marine Park to its intersection with the western boundary of Lot 44

DP209471, then south easterly via the south west boundary of Lot 44 DP209471 to its southern most point, then southerly via the coastline to its intersection with the north east corner of Lot 79 DP211955, then westerly via the northern boundary of Lot 79 DP211955 and its alignment to its intersection with the eastern boundary of Lot 43 DP209471 (approximate MGA point Zone 50 203750E 7577490N), then northerly, westerly and southerly via the boundary of Lot 43 DP209471 to its intersection with the northern boundary of Lot 78 DP211955 (approximate MGA point Zone 50 202925E 7576980N), then westerly, southerly and easterly via the boundary of Lot 78 DP211955 to its intersection with the western boundary of Lot R34055 (approximate MGA point Zone 50 199525E 7574560N), then southerly via the western boundary of Lot R34055 to it intersection with MGA northing 7564455N (approximate MGA point Zone 50 198715E 7564455E), then westerly to MGA point 197690E 7564450N, then southerly to MGA point 197690E 7563750N, then easterly to the intersection of the western boundary of Lot R34055 with MGA northing 7563780N (approximate MGA point Zone 50 198720E 7563780N), then southerly via the western boundary of Lot R34055 and its alignment to its intersection with the northern boundary of Lot 164 DP220081 (approximate MGA point Zone 50 198860E 7557320N), then westerly via the northern boundary of Lot 164 DP220081 to its intersection with the eastern boundary of the Exmouth Gulf Station Exclusion (approximate MGA point Zone 49 817148E 7557000N), then southerly via the eastern boundary of the Exmouth Gulf Station Exclusion to its intersection with MGA northing 7538015M (approximate MGA point Zone 50 194165E 7538015N), then easterly to MGA point 193240E 7538010N, then southerly to MGA point 193240E 7537025N, then easterly to the intersection of the eastern boundary of the Exmouth Gulf station Exclusion with MGA northing 7537025N (approximate MGA point Zone 50 194060E 7537025N), then southerly to the south east corner of the Exmouth Gulf Station Exclusion, then south westerly directly to the south east corner of Lot 97 DP213189, then westerly via the southern boundary of Lot 97 DP213189 to the point of commencement.

Assessor's Summary of Significance:

Natural Values
The integration of the Ningaloo Reef and Exmouth Peninsula karst system as a cohesive limestone structure is at the heart of the natural heritage significance of the Ningaloo Coast. The modern Ningaloo Reef, Exmouth Peninsula karst, and the wave-cut terraces, limestone plains, Pleistocene reef sediments of Exmouth Peninsula and associated marine, terrestrial and subterranean ecosystems, including the Muiron Islands, demonstrate a geological, hydrological and ecological unity which harmonises the region's present ecosystem functions with its evolutionary history as a time-series of coral reefs and an evolving karst system.

The western half of the Australian continent is characterized by extensive areas of low relief, tectonic stability and a very long history of landscape evolution under essentially stable conditions. Exmouth Peninsula is a major exception, and is the only Tertiary orogenic (resulting from uplift and warping) karst in Australia. Most of the geological and geomorphological features of Exmouth Peninsula reflect a history of uplift and warping that commenced in the late Tertiary (middle Miocene to late Pliocene) and which has continued to the present. As a result, the karst systems of Cape Range extend over a large vertical range (at least 300 metres), which is not reflected anywhere else in Australia. Cape Range houses a high concentration of karst features and subterranean ecosystems of global importance, unparalleled in Australia.

The presence of active karst solution as a result of seawater incursion is rare in Australia, and Ningaloo Coast is the best example in Australia of this globally significant karst solution process.

The history of coral reefs during the last 26 million years is chronicled in the limestone parapets and wave-cut terraces of Cape Range, which record previous high water levels. Demonstrating late Quaternary deformation at a passive continental margin, the uplifted Neogene wave-cut terraces and fossil reefs which fringe Exmouth Peninsula and the submerged fossil reef terraces which form the substrate of the modern reef, in immediate juxtaposition with the undeformed modern Ningaloo Reef, contribute to an understanding of the mechanisms which led to the modern character of the west coast of Australia.

The subterranean faunas and rangeland communities of Cape Range peninsula illustrate the intimate ties between ecology and geology more vividly than any other place in Australia. The aquatic cave fauna has evolved in isolation since the break-up of the supercontinent Gondwana and the opening of the ancient

Tethys Sea from more than 180 million years ago. Terrestrial fauna in the karst system are most closely related to rainforest fauna in north-eastern Australia, showing how Australia's climate has dried over the last 25 million years as the continent drifted slowly north. Rangeland communities provide refuge for flora and vertebrate fauna at the limits of their ranges, and a number of regional endemic species showing a marked disjunct distribution, contributing to the story of biogeographic change over time.

The taxonomic composition of the anchialine (aquatic) community of Bundera Sinkhole is unique in the southern hemisphere and Indo-West Pacific region. There are no directly comparable sites in Australia. Anchialine communities characterised by the presence of remipede crustaceans are limited to Exmouth Peninsula, the volcanic anchialine setting of Lanzarote in the Canary Islands, and some sites in the Caribbean and Mediterranean Seas, Cuba and Mexico. Bundera Sinkhole is outstanding for its unique anchialine community, reflecting its unusual hydrology, geological history, and stable environment over thousands of millennia.

Indigenous Values

Records of early human occupation have been drowned elsewhere in Australia, with the post-glacial return of the sea over the broad coastal areas that were exposed during the last glacial maximum around 25,000 years ago. Exmouth Peninsula's proximity to the continental shelf during the harsh climatic conditions of the last ice age, when sea levels were lower, means that the place was never far from marine resources. The steep topography of the Cape Range has protected Pleistocene occupation sites from the destructive effects of rising sea levels and the non-acidic environment of the limestone geology has preserved evidence of human occupation.

Archaeological deposits in the rock shelters on Cape Range show Aboriginal people had a comprehensive and sophisticated knowledge of edible and non-edible marine resources between 35,000 and 17,000 years ago. The rock shelters of Exmouth peninsula are outstanding because they provide the best evidence in Australia for the use of marine resources during the Pleistocene, including their uses as food and for personal adornment.

The evidence for standardisation in size and manufacture of the shell beads found at Mandu Mandu Creek rock shelter, coupled with the fact they provide the earliest unequivocal evidence for the creation of personal ornaments in Australia, demonstrates a high degree of creative and technical achievement.

Draft Values:

Criterion	***Values***	***Rating***
A Events, Processes	**Natural Values**	AT

Demonstrating late Quaternary deformation at a passive continental margin, the uplifted Neogene wave-cut terraces and fossil reefs which fringe Exmouth Peninsula and the submerged fossil reef terraces which form the substrate of the modern reef, in immediate juxtaposition with the undeformed modern Ningaloo Reef, and late Pleistocene Tantabiddi terrace, have outstanding heritage value to the nation under criterion (a) for their contribution to understanding mechanisms which led to the modern character of the west coast of Australia (van de Graaff et al. 1976; Veeh et al. 1979; Stirling et al. 1998).

The story of Australia during the Neogene period (beginning about 25 million years ago) is a story of increasing post-Gondwanan isolation and the expansion of aridity. The subterranean faunas and rangeland communities of Exmouth Peninsula exemplify both these evolutionary drivers and accentuate the intimate ties between ecology and geological history more vividly than any other place in Australia. Demonstrating speciation and adaptation since the break up of the supercontinent Gondwana and the opening of the ancient Tethys sea more than 250 million years ago, the expansion of aridity in Australia and continued biogeographic isolation during the Quaternary (the last 2.6 million years), the subterranean and terrestrial ecosystems of Exmouth

Peninsula help translate a complicated biogeographical story. These communities have outstanding heritage value to the nation under criterion (a) for their importance in demonstrating the pattern of Australia's natural history (Humphreys and Collis 1990; Kendrick 1993; Jaume et al. 2001; Russell 2004; Humphreys 2006; Spate 2006).

Indigenous Values

Elsewhere in Australia records of early human occupation have been drowned with the post-glacial return of the sea over the broad coastal areas exposed during the last glacial maximum. Exmouth Peninsula's proximity to the continental shelf during the harsh climatic conditions of the last ice age, when sea levels were lower, means that Cape Range was never far from marine resources (Morse 1993c).

Archaeological deposits in the rock shelters on Cape Range show Aboriginal people had a comprehensive and sophisticated knowledge of edible and non-edible marine resources between 35,000 and 17,000 years BP (Morse 1993a; Przywolnik, 2005). The rock shelters of Exmouth peninsula have outstanding heritage value to the nation under criterion (a) because they provide the best evidence in Australia for the use of marine resources during the Pleistocene including their uses as food and for personal adornment.

B Rarity **Natural Values** AT

Anchialine communities characterised by the presence of remipede crustaceans are internationally rare, limited to Bundera Sinkhole on the Ningaloo Coast, the volcanic anchialine setting of Lanzarote in the Canary Islands, and some sites in the Caribbean and Mediterranean Seas, Cuba and Mexico (Gillieson, Humphreys and Spate 2006). The taxonomic composition of the anchialine community of Bundera Sinkhole, while characteristic of remipede communities, is unique in the southern hemisphere and Indo-West Pacific. Bundera Sinkhole is outstanding for its unique anchialine community, reflecting its unusual hydrology, geological history, and stable environment over thousands of millennia.

The presence of active karst solution as a result of seawater incursion is rare in Australia. The Ningaloo Coast is one of the best examples in Australia of this globally significant process (Gillieson, Humphreys and Spate 2006). As the only example in Australia of a Tertiary orogenic karst and a rare example of active marine karst solution, the Ningaloo Coast contains rare aspects of Australia's natural history.

C Research **Natural values** AT

Anchialine and groundwater ecosystems are of considerable scientific interest globally, yielding important information about the evolution of life on earth. The Exmouth Peninsula subterranean estuary has outstanding heritage value to the nation for supporting the most diverse and the richest anchialine and groundwater fauna in Australia, among the richest in the world. These ecosystems and the troglobites and stygofauna they support have the potential to yield information about biogeography, evolution and changing climates in Australia over hundreds of millions of years, from the late Palaeozoic to the present (AHDB 2002; Humphreys and Danielopol 2005; Humphreys 2006; Spate 2006).

Indigenous Values

	Research on the freshwater subterranean fauna of the Ningaloo Coast (Humphreys and Adams 1991; Poore and Humphreys 1992) suggests that even in times of greater aridity than the present day semi-desert terrestrial environment, freshwater may have been widely available across the emergent coastal plain bordering Cape Range. The steep topography of Cape Range has protected Pleistocene occupation sites from the destructive effects of rising sea levels; while the alkaline environment of the limestone geology has acted to preserve archaeological evidence of human occupation. Given that only a handful of the caves and rock shelters of the Exmouth Peninsula region has been investigated (O'Connor, 2007) the place has outstanding heritage value to the nation under criterion (c) because of its potential to provide further insights into marine resource use by Aboriginal people in the Pleistocene and the less well understood last glacial maximum.	
D Principal characteristics of a class of places	**Natural Values** Biologically unique in the southern hemisphere and the Indo-Pacific region, characteristic of the remipede crustacean-type of anchialine community, the Ningaloo Coast has outstanding heritage value to the nation under criterion (d) for demonstrating the principal characteristics of a Tertiary karst environment in Australia, including a high concentration of karst features and subterranean ecosystems of global importance, unparalleled in Australia (Humphreys 2006; Spate 2006). The integration of the Ningaloo Reef and Exmouth Peninsula karst system as a cohesive limestone structure is at the heart of the natural heritage significance of the Ningaloo Coast. The modern Ningaloo Reef, Exmouth Peninsula karst, and the wave-cut terraces, limestone plains, Pleistocene reef sediments of Exmouth Peninsula and associated marine, terrestrial and subterranean ecosystems, including the Muiron Islands, have outstanding heritage value to the nation under criterion (d) for demonstrating a geological, hydrological and ecological unity which harmonises the region's present ecosystem functions with its evolutionary history as a time-series of coral reefs and an evolving karst system (Carter 1987; Allen 1993; Wyrwoll et al. 1993; Hamilton-Smith et al. 1998; EPA 1999; Humphreys 2006; Spate 2006).	AT
F Creative or technical achievement	**Indigenous Values** The evidence for standardisation in size and manufacture of the shell beads found at Mandu Mandu Creek rock shelter, coupled with the fact they provide the earliest unequivocal evidence for the creation of personal ornaments in Australia, demonstrates a high degree of creative and technical achievement. On this basis, Exmouth Peninsula and the shell beads that were found in association with the place have outstanding heritage value to the nation under criterion (f).	AT

Historic Themes:

Nominator's Summary of Significance:
Ningaloo Reef and the adjoining Cape Range are of great importance to Australia. Of outstanding natural beauty, the reef and its adjoining terrestrial areas are in relatively pristine condition because of relatively isolation and lesser impacts of human pressures than are found on the east coast and elsewhere. Ningaloo Reef is the largest fringing coral reef in Australia and one of the largest in the world. The sparkling turquoise waters of the shallow enclosed lagoon, the white surf breaks on the reef as it tops the steeply sloping continental shelf beyond which lies the deep blue waters of the open ocean, all contrasting sharply with the red soils of the ancient and rugged limestone Cape Range with its scattered acacia scrub

and spinifex vegetation.
The area is of outstanding significance to Aboriginal people, who have a long association with the region. Archaeological evidence from the Cape Range peninsula indicates that Aboriginal people inhabited the area for over 30,000 years and it is from here that the earliest evidence of the use of marine resources comes. It is also from this area that Aboriginal use of shells and other items for decorative purposes is found.
Fossil records and more recent geological evidence tells us much about the natural history of the area and from this, aspects of Australia's evolution as a continent can be traced back to the break-up of the super-continent Pangaea, around 180 million years ago, through Gondwanan times, to the more recent Last Interglacial age.
Perhaps most significant is the rich diversity of marine life in the area, which lies at the interface between warm tropical and cooler temperate regions, under the strong influence of the warm tropical Leeuwin Current. Together these influences result in coral reef and associated ecological communities as rich in abundance and diversity as the better known Great Barrier Reef More than 500 species of fish, 300 species of corals, 600 species of mollusc and many other marine invertebrates are reported from the area.
The regular congregation in significant numbers of the giant whale shark (the largest fish species in the world, and one which has until recent years been little understood) makes the area significant to scientists and those in the wider community who have an interest in nature and wildlife. But it is not simply these awesome creatures that make the Ningaloo-Cape Range area important. The region is home to a rich diversity of rare and threatened species, several of which in their own right bring importance to the area. These include six species of toothed whales, eight species of baleen whales, four of the world's seven species of turtles, and two species of dolphins, along with the majestic manta rays and shy dugong. To these are added a diversity of migratory birds recognised under bilateral agreements with both China and Japan.
The Cape Range, with its massive system of deep sinkholes and caves is home to rare and unusual cave-dwelling species, both aquatic and terrestrial. While the terrestrial 'troglobites' adapted to millions of years living underground are related to species found in Australia's cool temperate forests, the equally rare 'stygofauna' relate most closely to ancient species from the Canary Islands off Africa, and the Caribbean. Extending over approximately 300km, and being a fringing reef located unusually close to the shoreline, Ningaloo Reef is relatively accessible and as such offers good opportunities for research likely to reveal new information about Australia's natural and cultural history.

Description:
On the western hip of Australia, the 83,800 km2 Carnarvon bioregion in Western Australia's Gascoyne and Pilbara regions follows the Western Australian coast north from Denham to Onslow. Most of its permanent human population lives in the towns of Carnarvon in the south and Exmouth 300 kilometres to the north. Pastoralism is the prevailing land use. Tourism is increasingly important on the coast, and mineral and petroleum exploration and extraction have contributed to regional and state economies since at least the 1950s. An arid to semi-arid climate and low, gently undulating country with open drainage predominate while the region's principal geology includes Miocene to Quaternary age alluvial, aeolian and marine sediments overlying Cretaceous limestone. Rugged Tertiary limestone ranges, extensive red Pleistocene dune fields, mud flats and playa lakes define the topography and ephemeral rivers wind through the region, flowing only after rare heavy rainfall (Kendrick and Mau 2002; DEWHA 2007a). The north of the bioregion presents a mosaic of interdependent ecosystems. The integrated limestone structure of Ningaloo Reef and Exmouth Peninsula contrasts biologically, structurally and topographically with the giant salina of Lake Macleod, whose geological history as an embayment of the Indian Ocean is the source of its interesting hydrology. The congeneric anticlines of Cape, Rough and Giralia Ranges present the highest relief in the region, their incised gorges dramatically overshadowing the sunkland bordering Exmouth Gulf and its associated islands, mud flats, mangal and inundated dunes.

The Ningaloo Coast National Heritage Place (Ningaloo Coast) is approximately 8,000 km2, including a marine area of approximately 5500 km2, incorporating the Ningaloo Marine Park (Commonwealth and state waters) and the state-managed Muiron Islands Marine Management Area. The terrestrial extent of the Ningaloo Coast encompasses the adjoining Exmouth Peninsula (including Cape Range, its fringing wave-cut terraces, coastal plain, beach dunes, Pleistocene dune fields, karst and subterranean estuary), Bundegi and Jurabi Coastal Parks (managed jointly by the Exmouth Shire Council and the Western Australian Department of Environment and Conservation), the Commonwealth Heritage listed Learmonth Air Weapons Range Facility on the west of Exmouth Peninsula, the 2015 exclusion area of Exmouth Gulf

pastoral lease, part of the south west corner of Exmouth Gulf Station, and the 2015 coastal exclusion areas from the Ningaloo, Cardabia, Warroora, Gnaraloo and Quobba pastoral leases. Tenure includes government-owned land and conservation reserves (including Department of Defence land and Commonwealth and state marine and terrestrial protected areas), Commonwealth Heritage listed places, areas subject to Native Title claims, exploration and pastoral leases, and freehold land. A Ramsar nomination is currently in preparation for Bundera Sinkhole (located in the buffer area of the Learmonth Air Weapons Range) and its associated karst areas (WAPC 2004). The listed area excludes the towns of Coral Bay in the south and Exmouth, which overlooks the gulf at the north-eastern end of the peninsula, most of the Commonwealth Heritage listed Harold E Holt Naval Communications Station and the Department of Defence-owned Learmonth Air Base on the western shore of Exmouth Gulf. The Western Australian Government has begun de-gazettal of the Mauds Landing town site preliminary to reserving the area for conservation and recreation (WAPC 2004).

Five pastoral leases, Ningaloo, Cardabia, Warroora, Gnaraloo and Quobba Stations, share boundaries with the Ningaloo Marine Park. In 2015, ownership of a roughly two kilometre coastal strip formerly included within these leases will revert to the state government. The Environmental Protection Authority identified these exclusions between 1975 and 1984 along with a number of other areas of leasehold across Western Australia with high conservation value (WHCCC 2004; DOIR 2007). The Western Australian Government recently purchased a 50 per cent share of the Ningaloo Station lease for inclusion in the conservation estate. Leasehold of Cardabia Station is vested in the Baiyangu Aboriginal Corporation, which has suspended its Native Title rights over the two kilometre coastal strip in return for tourism concessions (ATNS 2007; WAPC 2004).

The whole of the Ningaloo Marine Park (Commonwealth and state waters) and surrounding waters, including Exmouth Gulf, is subject to a native title claim registered with the National Native Title Tribunal. The claim also includes the entire Exmouth Peninsula and extensive areas inland, in total some 338,000 km2. However, within the boundaries of the claim, several classes of exclusion exist, relating to existing leases and extinguishing acts that apply to terrestrial areas (LeProvost et al. 2000).

Natural environment

The Ningaloo Coast straddles the northern and southern Carnarvon basins. The heavily dissected Cape Range anticline dominates the terrestrial geology in the north of the area. North east of Exmouth Peninsula, the Muiron Islands continue the anticline which shapes Cape Range (Allen 1993). Widespread red aeolian sand dune fields support sparse eucalypt and shrubby acacia steppe over spinifex grassland, and mantle the limestone bedrock at the northern end of Exmouth Peninsula. Coastal sand plains and dunes, tidal mud and sand flats, saline alluvial plains and playas support samphire and mangroves (Kendrick and Mau 2002; Russell 2004).

The Ningaloo Coast experiences an arid, semi-desert to subtropical climate, with variable summer and winter rainfall. Cyclonic activity along the Western Australian coast can be significant and may affect the coast and hinterland areas annually. Annual evaporation rates in the region of about 2,700 millimetres far exceed its annual rainfall, of between 200 to 300 millimetres along the coast. In an average year, maximum rain will fall in May and minimum rain, of less than two millimetres, will fall in the spring months. Mean summer maxima in Exmouth town range from 36 to 38 degrees Celsius; mean summer minima range between 21 and 25 degrees Celsius. Over the winter months, mean maximum temperature is about 25 degrees Celsius, and mean minimum temperatures range from 11 to 13 degrees Celsius (Kendrick and Mau 2002; CALM 2005a; CALM 2005b; BoM 2007a).

South-east trade winds dominate most of the year. Cyclonic winds may be severe, exceeding speeds of 150 kilometres per hour. In 1999 Tropical Cyclone Vance, one of the strongest cyclones to affect mainland Australia since records began, crossed the Pilbara coast near Exmouth, causing damage to infrastructure, serious coastal erosion and sedimentation in Exmouth Gulf, disruption to ecosystems, power and water supplies and cuts to the main rail and road links to the eastern states (BoM 2007b).

Extremely low average annual rainfall and lack of run-off have contributed to Ningaloo Reef's proximity to the mainland, together with Exmouth Peninsula's position relative to the edge of the continental shelf: off the peninsula the shelf is very narrow; between North West Cape and Coral Bay it is only around ten kilometres wide. The Leeuwin Current is one of the greatest biogeographic influences on Western

Australia's marine environments, bringing a flow of tropical water down the coast. The current is strongest and closest to the coast during autumn and winter, in the absence of opposing southerly winds and the associated nearshore northward flowing Cape and Ningaloo currents, which occur during late spring and summer. The warmth of the Leeuwin Current supports tropical species at latitudes where these species are not typically found. The west coasts of the other continents lack a comparable warm annual current, and consequently the growth of modern coral reefs at high latitudes is reduced compared to Australia. The Indo-West Pacific region is the centre of diversity for tropical coral reefs. Ningaloo Reef is one of a number of Western Australian reefs of moderate diversity, dependent on the Leeuwin Current and each other for survival and dispersal (CALM 2005a).

From the shelf and slope communities and coral reefs of the Ningaloo Marine Park to the aquifers of the Exmouth Peninsula karst, from the mangrove and estuarine habitat of Yardie Creek and Mangrove Bay to the rugged gorges and wave-cut limestone escarpments and platforms of Cape Range, the Ningaloo Coast is characterised by a number of biologically and structurally interconnected landforms and seascapes. Coastal dunes extend west of Lake Macleod along the shore, north to Exmouth Gulf. Soils in the region range from deep calcareous sands along the coast to siliceous sands of varying depth to the east. Longitudinal dunes, last active during the Pleistocene epoch, occur across the area, over limestone or calcrete, with younger deposits closest to the coast. Cliffs, wavecut platforms, narrow beaches and mobile sand drifts also feature in the coastal dune landscape. The Cape Range anticline outcrops in the north and sustains *Acacia* and *Triodia* shrubland (Kendrick and Mau 2002; Russell 2004). Its geological history includes marine sedimentation, and subsequent uplift and exposure of Tertiary strata. Reactivation of faults since the Miocene folded the range into its modern shape (Iasky and Glikson 2005, WAPC 2004).

Ningaloo Marine Park encompasses a series of interconnected habitats, from the continental shelf and slope communities of the Commonwealth waters to the reef and onshore ecosystems of Ningaloo Reef. Stretching from Red Bluff north, around North West Cape to Bundegi Reef in Exmouth Gulf, and extending up to 25 kilometres offshore, the park is 5076 km2 including Commonwealth (2436 km2) and state waters (2640 km2) (EA 2002a; DEWHA 2007a). The reef is a discontinuous barrier over approximately 260 kilometres south to north along the coast of Western Australia, enclosing a lagoon which varies in width from 200 metres to about seven kilometres. In total, the reef extends over 300 kilometres from Bundegi Reef, north east encircling the Muiron Islands, south west to Jurabi Point and along the coast to Red Bluff. On average the reef flat is several hundred metres wide and becomes partly exposed at spring low tide (AHDB 2002; AHDB 2004). North of Jurabi Point at the extreme northern end of the park, the barrier reef is discontinuous and eventually disappears, to reappear in the waters of the Muiron Islands. The southern end of the reef is closer to shore and less continuous. It becomes a shoreline fringing reef at Red Bluff. Most of Ningaloo Reef lies within the tropical belt of the Indo-Pacific Faunal Region. The Tropic of Capricorn crosses the southern end of the park (CALM 2005a).

The park protects diverse ecosystems. The state waters include shoreline communities, lagoon, fore reef, reef flat and the waters extending three nautical miles out to sea from the outer edge of the reef. Important habitats of the Commonwealth waters include the waters and seabed of the continental shelf and slope which extend three to nine nautical miles seaward from the boundary of the state waters. The Commonwealth waters protect sponge gardens, deepwater corals, and provide habitat for cetaceans, whale sharks (*Rhincodon typus*), billfish, tuna and marine reptiles. The deeper waters display a diversity of epibenthic decapod crustacea, with more species recorded than on any other continental shelf.

A dugong (*Dugong dugon*) community of up to a thousand animals feeds in the waters of the lagoon, eating the seagrass beds in Norwegian Bay and the lagoon north of Bruboodjoo Point. Seven cetacean species regularly visit the park: the humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*), fin whale (*B. physalis*), blue whale (*B. musculus*), bottle-nosed dolphin (*Tursiops truncatus*), Indo-Pacific humpback dolphin (*Sousa chinensis*) and killer whale (*Orcinus orca*). The southern right whale (*Eubalaena australis*) may still be present, but it is unreported since whaling ceased. Humpback whales move through the park from June to October on their annual migration to and from breeding grounds further north. Outside the park, Exmouth Gulf provides an important humpback nursery area as well as habitat for several hundred dugongs. Four species of turtle live in the waters of the park, some of which breed outside the park, on the beaches of Exmouth Peninsula and the Muiron Islands (CALM 2005a).

Whale sharks congregate in numbers around the reef and in the deeper Commonwealth waters in April and May during the mass spawning of coral. This giant fish, the world's largest at up to 18 metres, is beautifully patterned with pale lines and spots on a dark background. They are increasingly a focus for ecotourism around the world, and swimming with whale sharks is regarded as the signature experience of Ningaloo. The activity is compared to 'swimming with the stars'. Marine biologist Brad Norman has described individual whale sharks as a starfield underwater: 'As you swim above, the shark's body seems to disappear and its white spots light up like stars in the night sky. It's an awe-inspiring sight'. Others speak in wonder of the experience as 'spiritual' (Underwater Australasia 2007).

The Muiron Islands group (including North Muiron, South Muiron and Sunday Island) are structurally contiguous with the Cape Range anticline. The islands are sandy with a limestone base; their vegetation is characteristically coastal, including spinifex and acacia species. Flora is similar to Exmouth Peninsula, and limited plant collections reveal several species unknown on the mainland. South Muiron is an important loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) turtle nesting place. Hawksbill (*Eretmochelys imbricata bissa*) and the occasional flatback (*Natator depressus*) turtles have been recorded on the beaches. Reefs surrounding the islands are diverse and display good coral cover (CALM 1999; Kendrick and Mau 2002).

Stretching from Vlamingh Head at the northern tip of peninsula south to Point Cloates, Cape Range dominates the terrestrial landscape of the peninsula, forming a spine approximately 70 kilometres long, fringed by wave cut platforms and coastal plain on its eastern and western flanks. Rising abruptly from sea level to over 300 metres, the range is a heavily dissected, asymmetric limestone anticline that has eroded over millions of years into plateaux, hills, ridges, gorges and steep stony slopes. The eastern slope of the range features canyons up to 120 metres deep, and the western side is cut by four terraces of Plio-Pleistocene age, from six to about 60 metres above sea level. Eroded into former beaches and near-shore reef sediments, the terraces record past sea levels. Narrow creek beds on the flanks of the range fall from cliffs and scree slopes, flowing only rarely after heavy rain. The crest of the range undulates gently. There is external drainage down the deeply dissected flanks of the range and centripetal drainage towards the large sinkholes. South of Learmonth Air Weapons Range, Cape Range grades into undulating limestone and sand plain. The outlets of the larger creeks have developed spectacular alluvial fans. The coastal plain is narrow in comparison to the range at one to five kilometres wide. Its west side consists of the lowest and youngest of the wave-cut platforms, the Tantabiddi terrace (Le Provost et al. 2000; AHDB 2002; AHDB 2004). At Mangrove Bay there is a small, well-developed mangal. It is flushed by tidal action through one channel. Mangroves occur in other creek mouths which are normally barred, particularly at Yardie Creek, the only permanent freshwater creek along the Ningaloo Coast (AHDB 2002; AHDB 2004).

The Carnarvon bioregion is a transition zone between tropical and temperate marine and terrestrial species. This has led to a diverse flora colonising the peninsula. Up to 630 taxa of vascular plants have been recorded. Vertebrate fauna of the peninsula include 30 mammal, 84 reptile, five amphibian and around 200 bird species. This relatively rich fauna is supported by a range of available habitats, from mangrove to inter-tidal marine, sand ridge to alluvial plain, dune field to rocky limestone range (Kendrick 1993; Kendrick and Mau 2002; AHDB 2002).

The middle Miocene (24-25 million years) Cape Range Group provides the main carbonate deposits of Exmouth Peninsula, consisting of three limestone units deposited in different marine environments. The oldest of the group, the Mandu Limestone, is overlain by the Tulki Limestone which makes up the bulk of Cape Range. The youngest of the group, the Trealla Limestone, caps the northern and western parts of the range. Offshore, carbonate deposition continues in Ningaloo Reef, which maintains a close geomorphic and hydrologic relationship with the terrestrial and subterranean parts of Exmouth Peninsula (Gillieson, Humphreys and Spate 2006).

A network of hidden caves and tunnels underlies the plateaux, canyons and coastal plain of Exmouth Peninsula. The high relief of Cape Range and lower sea levels in the past have encouraged significant karst development. The hard Miocene Tulki limestone is the main cavernous limestone but younger Pleistocene to Holocene age limestones also display karst erosion. There are 826 karst features including 535 caves, 180 dolines (large, characteristically funnel-shaped depressions or basins in karst limestone), and 11 miscellaneous features recorded from Exmouth Peninsula. Extensive karren (furrows or fissures eroded into karst limestone), gorges, dolines and springs pit the surface of the range and fringing plains. Tertiary

karst like the Exmouth Peninsula system, while relatively common internationally, is almost unknown in Australia (Gillieson, Humphreys and 2006).

Perforated by a network of subterranean waterways, the Exmouth Peninsula system shelters a unique collection of cave-dwelling animals (Gillieson, Humphreys and Spate 2006; DEC 2008a). Stygofaunal communities, epitomised by the Bundera Sinkhole remipede community (remipedes are eyeless, unpigmented, free-swimming, subterranean, marine crustaceans, varying in size from 9-45 millimetres), consist of specialist subterranean aquatic species. Troglobitic communities are characteristically terrestrial or amphibious (Hamilton-Smith et al. 1998).

The hydrology of the karst system is poorly understood. Rainfall on the range is believed to drain through the limestone to the boundary of the Tulki limestone with the younger Mandu limestone, sometimes following large open conduits occurring near a coastal freshwater lens, and then discharging below sea level. A Ghyben-Herzberg groundwater system, in which a layer of freshwater floats on saltwater, underlies the peninsula. Because of the lack of surface flow in the range and on the coastal plain (apart from Yardie Creek), the groundwater discharges to the ocean, except when cyclones bring heavy rainfalls causing normally dry creeks to flow (Gillieson, Humphreys and Spate 2006).

Rare in Australia, coastal anchialine systems are typically formed in porous limestone or volcanic rock, flooded with seawater. Limestone anchialine pools or cenotes like Bundera Sinkhole are land-locked at the surface, with subterranean connections to the ocean via coastal aquifers. Anchialine habitats like those of Exmouth Peninsula are remarkable for their complex, chemically and thermally stratified hydrology and very diverse but predictable faunal communities, especially those restricted to the oligoxic (low oxygen) reaches of the water column, where most genera represent biogeographic and/or phylogenetic relicts. Crustaceans form the richest group of stygofaunal invertebrates, with the greatest biogeographic significance.

Anchialine crustacean communities characteristically include many different crustacean groups. Regardless of distance and isolation, a new anchialine locality is likely to contain a high proportion of taxa congeneric with those known from other anchialine communities around the world (Danielopol et al. 2000; Jaume et al. 2001). Bundera Sinkhole, on the coastal plain south of Yardie Creek, is the only known remipede (*Lasionectes exleyi*) community in the southern hemisphere or the Indo-west Pacific region, and one of only seven localities in the world. The others are in Mexico, Cuba, the north Atlantic Ocean and the Caribbean and Mediterranean Seas. Bundera Sinkhole contains a rich and diverse stygobiont fauna, including amphipods, copepods and ostracods, which are crustacean species typically accompanying remipedes. The adjacent aquifer contains other species which may also live in the sinkhole; atyid shrimp, diverse amphipods, members of the Thermosbaenacea (a blind crustacean order), the blind eel Ophisternon, which is endemic to Exmouth Peninsula, and the blind gudgeon, *Milyeringa veritas*, widespread in the Exmouth Peninsula karst system, but almost unknown outside the peninsula. Distinct communities have evolved to depend on the stratification of the water table, suggesting its stability over millennia. The peninsula is also celebrated for its unique and diverse amphibious and terrestrial subterranean troglobite communities, which include several threatened species and a greater number of undescribed species (Kendrick and Mau 2002).

Indigenous environment

The Ningaloo Coast-Exmouth Gulf region represents the westernmost extent of the semi arid/arid zone of Western Australia, and is an extremely dry and harsh environment. Exmouth Peninsula is of exceptional heritage interest as the steep topography and limestone geology of the region provides a unique environment in which evidence of human occupation has been well preserved. The place is also the nearest point on the continent to the edge of the continental shelf so that even during the height of the last glacial maximum, the coast was never more than ten to twelve kilometres away (Morse 1993a). The limestone rock shelters and caves contain evidence of past Indigenous occupation including rock art. Open shell middens also occur in the coastal sand dunes of the peninsula.

Within the nominated area there are over 140 Aboriginal sites registered on the WA Department of Indigenous Affairs (DIA) Register of Aboriginal Sites. These range from artefact scatters, middens, engravings, ceremonial and mythological areas, grinding patches and grooves, burial sites, and man made structures. Registered sites are protected under the Western Australian *Aboriginal Heritage Act 1972*.

Analysis:

Cover note

The nomination received by the Australian Heritage Council in October 2005 for Ningaloo Reef, Cape Range, Exmouth Gulf and associated areas encompassed approximately 25,000 km2.

At the Might Have Value decision in March 2008 the Council decided that a large part of the nominated area does not have outstanding national heritage significance, including Rough Range, Lake Macleod, Exmouth Gulf and its associated islands, mud flats, mangal and inundated dunes, the intervening dune fields, country on the eastern shore of Exmouth Gulf and the rangeland south of Exmouth Peninsula.

The following assessment report refers to the place as the Ningaloo Coast National Heritage Place (Ningaloo Coast). The Council found that the late Cretaceous and early Palaeogene marine fossils and K-T boundary contact of Giralia Range might have outstanding national heritage value under criteria (a) and (d), but agreed that this feature may be assessed independently as part of a series of fossil nominations rather than included in the Ningaloo Coast story, which focuses on the functional and historical integrity of the Exmouth Peninsula – Ningaloo Reef limestone structure.

The peninsula, which separates Exmouth Gulf from the Indian Ocean, is variously known as North West Cape, North West Cape Peninsula, Cape Range Peninsula and Exmouth Peninsula. This report uses Exmouth Peninsula to avoid confusion with Cape Range, which forms the spine of the peninsula, and with the tip of the peninsula (Point Murat), also commonly known as North West Cape.

Following additional information provided by karst experts which was unavailable at the Might Have Value decision, the underground communities of Bundera Sinkhole and the Tertiary orogenic karst features of the Exmouth Peninsula karst system are now assessed as having outstanding heritage value to the nation under criterion (b).

Claims

The nominator claimed that the nominated area has outstanding natural and historic heritage value to the nation under criteria (a), (b), (c), (d) and (e). These claims have been tested against other places in Australia using available literature, expert opinion and the Australian Natural Heritage Assessment Tool (ANHAT) to assess claims of outstanding biological heritage. Criteria (g) and (h) were considered, but there is insufficient evidence for any value approaching threshold.

The nominator claimed that the Indigenous heritage values of the Ningaloo Coast area are outstanding at a national level under criterion (i). While the nominator made no specific claims for Indigenous values against other criteria, the matters raised under criterion (i) relating to archaeological evidence have been assessed against criteria (a), (c) and (f).

Where the nominator has not made specific claims against large tracts of land or noteworthy features within the nominated area, the analysis considers some of the claims in two reports commissioned in 2004 by the WA Department of Conservation and Land Management (Russell 2004) and the Australian Government Department of the Environment and Heritage (Done et al. 2004). The former author analysed the World Heritage values of the geological and geomorphic features of the Lake Macleod – Ningaloo Reef – Cape Range – Exmouth Gulf – Giralia Range area. The latter authors produced a comparative analysis of the World Heritage values of the region against other similar places around the globe. Both these studies recommend a boundary comparable to the original National Heritage-nominated area.

The nomination included substantial areas that are unlikely to have National Heritage values. At more than two and a half million hectares, it encompassed the towns Exmouth and Coral Bay, along with limestone, salt and gypsum operations, known hydrocarbon reserves, exploration and pastoral leases, fishing and aquaculture and freehold land.

The Council found that the late Cretaceous and early Palaeogene marine fossils and Cretaceous-Tertiary (K-T) boundary contact of Giralia Range might have outstanding national heritage value under criteria (a) and (d), but agreed that this feature may be assessed independently as part of a series of fossil nominations rather than included in the Ningaloo Coast story, which focuses on the functional and historical integrity of the Exmouth Peninsula – Ningaloo Reef limestone structure.

CRITERION (a) – ***The place has outstanding heritage value because of the place's importance in the course, or pattern of Australia's natural or cultural history.***

Natural values

The nominator claimed that the Ningaloo Coast is nationally significant for illustrating aspects of Australia's evolution as a continent, including the break-up of the supercontinent Pangaea around 180 million years ago, and through fossil records in the limestone of the area and more recent geological information dating from the Last Interglacial stage around 125 million years ago, which provide important information about the Australian coastline and its responses to sea level rise and fall over prolonged periods. The nominator also claimed that wave-cut terraces on the western seaboard at Cape Range and at Lake Macleod, the anticlinal Cape, Gnargoo, Rough and the fossil-rich Giralia Ranges, the karst areas and associated anchialine ecosystems, and the stromatolites of Lake Macleod have outstanding heritage value to the nation under criterion (a) for their contribution to ongoing research which reveals much about the formation of the west coast of Australia.

Further to these claims, Russell (2004) claimed that value in the region is embedded in evidence of regional geological and biological co-evolution. The emergence of the Ningaloo Reef – Cape Range – Exmouth Gulf area is the result of sea level changes, and tectonic activity over the last 65 million years (the Cenozoic era).

These claims cannot easily be demonstrated. The last interglacial in its broadest sense has been correlated to deep-sea oxygen isotope Stage 5, approximately 135,000-80,000 years ago, not 125 million years ago (Muhs 2006). Furthermore, the boundaries between land and ocean are in constant flux. Coasts respond to and record the interaction of climate, tectonic, sedimentary and biological (including anthropogenic) processes over long and short timescales. The geological record provides persuasive evidence all over the world of sea level change over time, driven by a variety of processes including changes in sediment load, climate, continental ice storage and ocean basin volume. Many of these processes continue today (Boyd 2007a).

For example, the imprint in the landscape of long parallel ridges in the Murray Basin, representing relict shorelines, preserves evidence of a retreating Mio-Pliocene sea from four to six million years ago (Paine et al. 2004; Miranda and Wallace 2006). Coast landscapes and seascapes, such as the National and World Heritage listed Fraser Island in Queensland and Western Australia's Shark Bay, parts of the Sydney Basin (including Sydney Harbour and the rivers which feed it), and Port Campbell National Park in Victoria, vividly illustrate sea level rise and fall and processes of coast erosion since the last interglacial (Boyd 2007b; Haworth et al. 2004; DPI 2007).

Nevertheless, while evidence of changes in relative sea level over time are ubiquitous in coasts around the world, studies of the uplifted marine terraces of Cape Range are significant for challenging the assumption that vertical (isostatic or tectonic) uplift and subsidence of land along coasts bordering passive continental margins like the west coast of Australia should be insignificant compared to sea level changes brought about by changes in global ice volume (eustatic changes). The Western Australian coast was traditionally regarded as an area of relative tectonic stability. The marine terraces which stretch for long distances along this coast underpinned calculations of global Pleistocene sea level rise and fall, on the assumption that any uplift would be negligible (Veeh et al. 1979; Lambeck and Nakada 1992). Detailed mapping, stratigraphic and isotopic analysis of these terraces over the last three decades has cast doubt on such suppositions, establishing that some marine terraces of late to post-Miocene age (from six million years ago) between Shark Bay and the northern end of Exmouth Peninsula are warped and tilted in relation to others, indicating that significant tectonic activity and uplift along the Western Australian coast may have continued into the Quaternary sub-era (the last 2.6 million years). The Cape Range wave-cut terraces are the clearest expression of these morphotectonic relationships, due to the presence of multiple platforms in close geographic and stratigraphic proximity to each other and to Ningaloo Reef (van de Graaff et al. 1976; Veeh et al. 1979; Kendrick et al 1991).

On the west side of the range and extending about 90 kilometres from Vlamingh Head south to Norwegian Bay, four stepped terraces and associated terrace deposits have eroded into the Miocene limestone bedrock of the peninsula above the modern reef and lagoon. Muiron Terrace, the highest and oldest terrace, reaches

an elevation of 50 metres above sea level. Ningaloo Reef can be considered the modern extension of the time series represented by the terraces. The youngest and topographically lowest terrace at Cape Range, the Tantabiddi terrace, cut into the Tantabiddi member of the Bundera calcarenite, dated to the Last Interglacial (around 125,000 years ago), appears to be little deformed, like the modern reef. In contrast, stratigraphically older terraces demonstrate distinct warping. Tantabiddi Terrace forms a continuous terrace from about 800 to 1,500 metres wide. On the eastern side of the peninsula, only Tantabiddi Terrace is clearly identified (van de Graaff et al. 1976; Denman and van de Graaff 1977; Veeh et al. 1979; Kendrick et al. 1991; Lambeck and Nakada 1992; Stirling et al. 1998).

There is no evidence to suggest that the events which shaped the nominated area are more or less important than those which shaped any other stretch of the modern Australian coast, or that they can be considered outside a wider context of global tectonism and climate change. However, in changing geologists' assumptions about the development of coasts along passive continental margins, the wave-cut terraces of the Ningaloo Coast contribute an important west coast chapter to the story of the assembling of Australia.

Contributing considerably to understanding the mechanisms which led to the modern character of the west coast of Australia, the Neogene wave-cut terraces and fossil reefs which fringe Cape Range and Ningaloo Reef from Vlamingh Head to Norwegian Bay have outstanding heritage value to the nation as they vividly demonstrate late Quaternary warping at a passive continental margin.

Russell claimed that the Pleistocene dune fields of the nominated area, including the inundated dunes of Exmouth Gulf, are significant internationally for demonstrating how non-glaciated regions responded to the major glacial-interglacial cycles of the Pleistocene epoch (from 1.8 million to 12,000 years ago). The formerly extensive, now partly inundated Pleistocene dune desert's disjunct remains, together with fluvial outwash plains and claypans, comprise more than half the terrestrial part of the nominated area. They occur at the northern end of Exmouth Peninsula, at the southern end of Cape Range running south almost to Lake Macleod, and east of Giralia Range extending northward into Exmouth Gulf and its eastern shore. These dunes reflect the very arid, windy and cold climate of the last glacial maximum (between about 17-25,000 years ago).

Pleistocene dunes identical to the dune fields of the nominated area are widespread across coastal, arid and semi-arid Australia. The dune geomorphology and stratigraphy of two National and World Heritage listed places – the Willandra Lakes in New South Wales and Queensland's Fraser Island – are unparalleled in Australia for documenting the expansion and retreat of the arid zone as the continent responded to the sea level and climate changes of the last glacial-interglacial cycle. The Willandra Lakes contain a suite of different dune forms at the boundary of the Riverine Plain (formed predominantly by ancient river action) and the wind-shaped landscapes of the Mallee region. The dry lakes, lunettes and dune fields of the area exemplify environmental change in Pleistocene Australia during the period of human settlement. Fraser Island presents one of the best examples in Australia of Quaternary coastal processes. The sequence of sand dunes formed over more than 120,000 years, from before the last interglacial to the Holocene epoch (beginning 12,000 years ago), and extend to more than 50 metres below current sea level, vividly illustrating sea level changes of the last ice age.

Both Fraser Island and the Willandra Lakes region are recognised and celebrated nationally and internationally for demonstrating the interdependence of landforms and pedogenesis, palaeochemistry, climatology, archaeology and palaeoecology, representing landmarks in Pleistocene research in Australasia (Bowler 1982a; IUCN 1981; IUCN 1992; WCMC 1996B; WHC 2007). Although it helps to tell a regionally interesting story about arid zone expansion and sea level change, and the inundated dunes of Exmouth Gulf are visually striking from the air, these stories are better recorded elsewhere in Australia.

There is insufficient evidence to demonstrate that the Pleistocene dune desert of the nominated area has outstanding heritage value to the nation under criterion (a) because of its importance in the course or pattern of Australia's natural history.

Russell claimed that the nominated area is 'pivotal to the complex story of Gondwanan fragmentation, both in the tectonic sense of transposed and rotated oceanic spreading centres and in the biological sense of the change from pandemism to endemism' (Russell 2004). The nominator claimed that the region 'illustrates the break-up of the supercontinent Pangaea' and the anticlinal Cape, Gnargoo, Rough and Giralia Ranges

reveal 'much about the formation of the west coast of Australia'. The geological record of the wider region reflects continental rifting, ice ages, major changes in ocean currents, uplift of new continental margins and changed depositional regimes, as well as major climate fluctuations, all over less than 200 million years (from the middle Mesozoic era).

With the exception of the biological and specific karst values, which are addressed elsewhere, these claims are difficult to verify. The entire Australian continent has undergone complex evolution over the past 4.6 billion years, a result of processes in the lithosphere, of uplift, isostatic rebound, erosion, glaciation and eustatic sea-level change. These changes are recorded in rocks and sediments across the country. Isolating as 'pivotal' a region whose overall landform demonstrates particular geological activity at a particular time, such as the Cape, Rough and Giralia anticlines, weakens the larger continental story. The two following examples narrate Australia's broad morphotectonic history, changing shape and shifting climates across geological eras in settings which are more tangible and conceptually accessible than the physical geology of the Cape, Gnargoo, Rough and Giralia Ranges, and the Lake Macleod graben.

The landforms at the beach and cliff top of Hallett Cove Conservation Park near Adelaide in South Australia span 600 million years of earth history and have been recognised by the geological community in Australia and overseas as 'a world renowned area of geology'. Celebrated as an outdoor museum or laboratory, the 50 hectare park vividly conveys the drama of the building and erosion of the trans-Antarctic Delamarian Mountains, ancient global glaciation, and the gradual reshaping of Australia's coast due to plate tectonics, as Gondwana split apart and Australia drifted north from Antarctica (Caldicott and Geering 1974; GSA(SA) 1977; McBriar 2000).

The exhumed fossil reef complex of Windjana Gorge in the Kimberley once extended hundreds of kilometres along the coast of Late Devonian Gondwana. It evokes superbly the development of coral reefs in warm tropical seas between 390-370 million years ago (the largest pre-Holocene reef-building episode), and their demise at the end of the Devonian, showing fundamental changes to the outline of Australia in an intimate setting (Wood 2000).

There is no clear expression of the nominator's claims in specific and visible features in the nominated area. The physical geology of other places represents the development of the modern shape of Australia more accessibly.

Thus the claim that the regional morphotectonic geology of the nominated area has outstanding heritage value to the nation under (a) for illustrating aspects of Australia's evolution as a continent cannot be demonstrated.

The nominator claimed that the karst areas and associated anchialine ecosystems of the Ningaloo Coast have outstanding heritage value to the nation under criterion (a) for their contribution to ongoing research which reveals much about the formation of the west coast of Australia.

The national heritage significance of the karst and associated anchialine ecosystems lies less in their specific contribution to research on the formation of the west coast of Australia, than in the contribution of the karst biota to a story that is both more global and more local. The biogeographical associations of the underground fauna of Exmouth Peninsula reveal climate changes over thousands of millennia on a local and regional scale, and they chronicle the geotectonic meandering of Australia across hemispheres and hundreds of millions of years, contributing to the reconstruction of supercontinents and vanished oceans. Locally, the rangeland communities of Exmouth Peninsula tell a story of continued botanical and faunal isolation during the Quaternary (Kendrick 1993).

As Russell (2004) claimed, biologically the Ningaloo Coast may be a fundamental part of the complex story of Gondwanan fragmentation, demonstrating the change from pandemism to endemism, as populations of invertebrates broadly distributed along the shores of the Tethys sea were separated by plate tectonic activity to evolve in isolation. The Exmouth Peninsula anchialine system permits a unique understanding of the origins and biogeography of anchialine systems throughout the world (Gillieson, Humphreys and Spate, 2006).

The Ningaloo Coast, like much of the west coast of Australia, formed part of the south-eastern margin of

the Tethys Sea during the late Palaeozoic to early Mesozoic eras (Done et al. 2004), when Australia was part of the supercontinent Gondwana. The anchialine system of Exmouth Peninsula houses highly endemic, rare and unusual aquatic species (stygofauna), some of which have Tethyan affiliations. For example, distantly or unrelated taxa, whose closest relatives are only known from far-flung locations along the former Tethyan shore around 250-150 million years ago, coexist in the deeper high salinity layers of Bundera Sinkhole, an anchialine cenote (a sinkhole or natural well, typically occurring in karst systems) in Exmouth Peninsula. The closest living relatives of many species of crustacean inhabiting the sinkhole are distributed in the Canary, Balearic and Philippine archipelagos, Cuba, Mexico and the Caribbean Sea. One crustacean species, *Bunderia misophaga*, a species of copepod, is the first of its family to be found in Australia. Its closest known relative inhabits a single anchialine cave in the Bahamas, suggesting both its relict status and the former close geographical connection of the two places. Other species found in Bundera Sinkhole, sometimes the only representatives of their orders, have congeners in the Balearics (in the western Mediterranean), Bermuda and Mexico's Yucatan peninsula. *Danielopolina kornickeri*, a primitive, cave-dwelling ostrocod (a class of tiny crustacean whose adult form is typically contained in a calcareous bivalved carapace), is the first occurrence of the Danielopolina genus in the Southern Hemisphere and the Indo-west Pacific region. Two of the three known Australian cave vertebrates are represented in the anchialine community at the base of Cape Range (a blind eel, *Ophisternon candidum*, and the blind or cave gudgeon *Milyeringa veritas*).

The taxonomic predictability of these assemblages across hemispheres, the modern barriers to their dispersal and the strictly stygobiont conditions in which they live suggests their distribution results from separation of ancestral populations formerly widely distributed along the shallow, warm-water margins of Mesozoic seas and separated by plate tectonic activity (Danielopol et al. 2000; Jaume and Humphreys 2001; Jaume et al. 2001). These Tethyan lineages have probably been divided from each other and restricted to subterranean environments since their separation by the movement of tectonic plates during the Mesozoic Era (Gillieson, Humphreys and Spate, 2006).

The troglobitic terrestrial and amphibious invertebrate fauna of beetles, spiders, cockroaches, slaters, crickets, scorpions and millipedes, once part of an extensive Miocene tropical rainforest leaf litter community, are now completely adapted to, and confined to their deep cave habitat. Forty troglobite species have been recorded from Exmouth Peninsula, with a number of others yet to be formally identified. The troglobitic fauna of the peninsula demonstrate affiliations with fauna inhabiting rainforest litter. The closest such conditions now occur 1200 kilometres to the north, an indication of the major changes in climate which have occurred in Australia over the last 26 million years. It is clear that the Exmouth Peninsula troglobites represent a relict community of great antiquity, helping build a picture of Australian climates since the Miocene period (Humphreys and Collis 1990; Russell 2004; Gillieson, Humphreys and Spate, 2006).

The rangeland flora and fauna of Exmouth Peninsula are not necessarily nationally significant in numerical terms, but they contribute to the important biogeographic story of disjunct populations at the limit of their ranges that resonates with and expands upon the biogeographical significance of the peninsula's underground faunas. The Ningaloo Coast is part of a transition zone between the tropical and temperate flora of Western Australia, containing 30 species with tropical affinities approaching the southern end of their ranges, and 50 temperate species at the northern ends of their ranges. Within Cape Range, 630 species of plant, or close to 50 per cent of all plants known for the Carnarvon Botanical District, have been recorded. Twelve plant species are endemic or near endemic to Exmouth Peninsula. The Ningaloo Coast is rich in vertebrate species, with approximately 200 bird and 84 reptile species recorded. Several species of vertebrate fauna are of biogeographic importance, including one mammal, one frog, 11 bird and 21 reptile species which are either at the limit of their geographic range or occur as geographically isolated populations. The reptile fauna is particularly noteworthy, especially in aeolian units on the peninsula. Twelve species are restricted to Exmouth Peninsula. Two 1:100,000 mapsheets in the nominated area rank among the top eight in the country for reptile endemism (Kendrick 1993; AHDB 2002; AHDB 2002; AHDB 2004; ANHAT).

The story of Australia during the Neogene period (beginning about 25 million years ago) is a story of increasing post-Gondwanan isolation and the expansion of aridity. The subterranean faunas and rangeland communities of Exmouth Peninsula exemplify both these evolutionary drivers and accentuate the intimate ties between ecology and geological history more vividly than any other place in Australia.

Demonstrating speciation and adaptation since the break up of Gondwana and the opening of the Tethyan seaway, the expansion of aridity in Australia since the Miocene period, and continued biogeographic isolation during the Quaternary sub-era, the rangeland communities and karst ecosystems of Exmouth Peninsula have outstanding heritage value to the nation under criterion (a) for their importance in demonstrating the pattern of Australia's natural history.

Ningaloo Reef demonstrates moderate diversity by Indo-West Pacific standards. It is typical of a Western Australian reef in terms of coral, mollusc, crustacean and marine vertebrate diversity. Ashmore Reef and the reefs of the Dampier Archipelago are slightly richer in recorded corals and fish and Dampier Archipelago is much richer in recorded mollusc species, while Rowley Shoals is comparable to Ningaloo, richer in fish species but poorer in mollusc species. The Great Barrier Reef in comparison is much richer faunally than any of the Western Australian reefs, reflecting the evolution in relatively stable conditions over millions of years of an ecosystem on the north east shelf of Australia (WCMC 1997; EA 2002b; Wilkinson 2004; DEC 2007; MPRA and DEC 2007; DEC 2008b).

The marine fauna of Ningaloo Reef is unlikely to have outstanding heritage value to the nation under criterion (a) because of its importance in the course or pattern of Australia's natural history.

The nominator claimed that the stromatolites of Lake Macleod have outstanding heritage value to the nation under criterion (a) for their contribution to ongoing research which reveals much about the formation of the west coast of Australia.

Although Lake Macleod contains stromatolites (Done 2004), it is not widely known for them. There is little evidence in the literature that they have been widely studied. In contrast, the living stromatolites of Hamelin Pool, part of the Shark Bay World Heritage Area, are well-known and studied internationally (Cook ed. 2007; IUCN 1991). Extant stromatolite communities in the Gambier karst region in South Australia represent a hotspot for stromatolite diversity, with preliminary research identifying more than 26 different types present in a range of sites that includes nine cenotes or sinkholes, the Blue Lake and saline/hypersaline groundwater-fed lakes. Each location has its own unique suite of microbes and stromatolite types.

While extant stromatolites are rare worldwide, and have great potential for important research, there is insufficient evidence to show that Lake Macleod has outstanding value to the nation because of the contribution of its stromatolite communities to research on the formation of the west coast of Australia.

The nominator claimed that the fossil-rich Giralia Range has outstanding heritage value to the nation under criterion (a) for its contribution to ongoing research which tells us much about the formation of the west coast of Australia.

Within the boundaries of the nominated area, roughly 40 kilometres to the south east of Cape Range, the Late Cretaceous marine fauna in the Miria Formation, exposed in Giralia Range demonstrate biogeographical and evolutionary processes which are internationally rare and scientifically significant. The formation extends about 80 kilometres north-north west and varies from 600-2,100 millimetres thick (Craig 2002).

Providing a snapshot of life on a marine shelf in the southern hemisphere at the very end of the Cretaceous period (which is known as the Maastrichtian epoch), the ammonite localities in Giralia Range help palaeontologists answer questions about species diversity just before the catastrophic extinction at the Cretaceous-Tertiary boundary (the K/T boundary), at the close of the upper Maastrichtian, 65 million years ago. This event wiped out most dinosaurs and their giant aquatic and winged relatives, as well as countless marine taxa. Many geoscientists consider that an enormous asteroid which landed in the modern Gulf of Mexico caused these extinctions (Raup 1999).

Ammonites are a formerly abundant group of molluscs akin to the living pearly nautilus. These important and widely-collected global biostratigraphic markers suddenly disappear from the fossil record all over the world at the close of the upper Maastrichtian. Their presence in the Miria Formation helps to date it to the Maastrichtian, 71-65 million years ago. Palaeontologists have described more than 60 other species of marine mollusc in addition to nearly 30 species of ammonite. The site also includes Australia's most

diverse late Cretaceous shark tooth assemblage and the most diverse assemblage of corals from the Mesozoic era in Australia. These coral species only occur elsewhere in Cretaceous rocks in Antarctica and southern India, which during the Mesozoic era were connected to Australia as part of Gondwana. The invertebrate diversity of the Miria formation is among the highest known in the world for upper Maastrichtian strata and presents invaluable data on the health of a marine ecosystem that was just about to be annihilated (Cook ed. 2007; Russell 2004).

The contact between stratigraphic layers representing the actual K/T boundary is vividly exposed in Giralia Range, but nowhere else in Australia: a thin bed of the Boongerooda Greensand overlies two metres of soft fossiliferous limestone. The greensand was almost certainly formed in a cold ocean, but the immediately-underlying limestone must have formed in much warmer waters. This contact demonstrates that in a virtual geological instant, the marine fauna changed on a scale not seen since the Permo-Triassic extinction 180 million years earlier, at the close of the Palaeozoic era 250 million years ago (McNamara 1997; Craig 2002).

The end-Palaeozoic (Permo-Triassic or P/T) extinction horizon (250 million years ago) is nowhere represented in Australia as dramatically as the Giralia Range exposure presents the end-Mesozoic boundary (65 million years ago). P/T boundary deposits are rare in Gondwana in general, because the boundary is difficult to correlate with the marine standard sections of northern hemisphere deposits, hampered by the rarity of marine index fossils (Foster et al. 1999). P/T boundary sites like Coalcliff and Wybung Head near Sydney are identified predominantly by isotopic analysis rather than their specific fossil content (Retallack et al. 1998; Retallack 1999) and do not provide the dramatic contrast of pre- and post-extinction sediments and fossil ecosystems as displayed so strikingly at the contact of the Miria formation with the Boongerooda Greensand in Giralia Range. Furthermore, the K/T boundary is irrevocably associated with the extinction of charismatic megafauna like the dinosaurs and marine reptiles, and among invertebrate fossils with historically important, iconic and beautiful ammonites and belemnites.

The Giralia Range fossil sites warrant full assessment, which will require analysis against all criteria. Including Giralia Range within the boundaries of the Ningaloo Coast National Heritage place weakens the focus on the Ningaloo Reef – Exmouth Peninsula system as an integrated limestone structure.

As the most abundant and one of the most diverse Late Cretaceous marine macrofossil assemblages in the world, shedding light on marine environments just before the iconic extinction events that mark the end of the Mesozoic Era, marine invertebrate fossil sites in the Miria Formation of Giralia Range, and its contact with the overlying Boongerooda Greensand, might have outstanding heritage value to the nation under criterion (a).

Historic values

The nominator claimed (against criterion (e)) that the wreck of the Portuguese *Correio da Azia*, or 'Asian ship', has outstanding heritage value to the nation as an important part of Western Australia's pre-colonial history.

The National Heritage listed *Batavia* shipwreck (1629) in the Houtman Abrolhos Island Group is the oldest known wreck of a Dutch East India vessel in Western Australian waters. It has a unique place in Australian shipwrecks. The *Batavia* and its associated sites are a critical part of the story of the discovery and delineation of the Western Australian coastline and the wreck sites have outstanding cultural heritage significance to the wider Australian community.

The early nineteenth-century *Correio da Azia* is one of many historic shipwrecks in the state waters of Ningaloo Marine Park. Others include the nineteenth-century American ship the *Rapid* (1811), the Austro-Hungarian ship the *Stefano* (1875) and the early twentieth-century wreck of the *Mildura* (1907). There is insufficient evidence to demonstrate that any of these wrecks have outstanding heritage value to the nation compared to the *Batavia* wreck. There are no known historic wrecks in the Commonwealth waters (EA 2002a).

The claim that the Portuguese wreck* Correio da Azia *has outstanding heritage value to the nation for illustrating the course or pattern of Australia's pre-colonial or maritime history cannot be demonstrated.

The nominator claimed (against criterion (e)) that the lighthouse at Vlamingh Head has outstanding heritage value to the nation for its role in maritime navigation, as it used to be 'one of the main navigation aids as ships travelled from Asia and western ports down the west coast of Australia'.

Lighthouses exist to provide navigational aid to vessels at sea. Approximately 175 are located prominently around the Australian coast, including nearly 30 in Western Australia. Some lighthouses in Australia have been operational since the early nineteenth century. Most Western Australian signals date from the twentieth century (LoA Inc. 2007). Between 1907 and 1910 the Western Australian Government established lighthouses at Point Cloates (Exmouth Peninsula), Cape Inscription (Dirk Hartog Island), Cape Leveque (Shire of Broome), Vlamingh Head (North West Cape) and Fraser Island (off North West Cape). They are all (except Fraser Island) on the Western Australian register of historic places (Shire of Exmouth 2006; Stone 2006). There is insufficient evidence to show that the lighthouse at Vlamingh Head has greater heritage significance than the other three lighthouses in the region on the Western Australian register of historic places (Heritage Council of Western Australia 2008), or that any of them is of outstanding heritage value to the nation.

There is insufficient evidence to support the claim that the Vlamingh Head lighthouse is of greater heritage value to the nation than many other extant Australian lighthouses for its role in the course or pattern of Australia's maritime navigation and trade history.

The nominator claimed that the Ningaloo Coast had outstanding heritage value to the nation for its pastoral history.

A thematic study on pastoralism by Dr Jane Lennon and Dr Mike Pearson did not find that the Ningaloo Coast and Exmouth Gulf region has outstanding heritage value to the nation for its pastoral history (Lennon and Pearson in prep.).

There is insufficient evidence to support a claim of outstanding heritage value to the nation for the pastoral history of the Ningaloo Coast.

Indigenous values

The steep topography of Exmouth Peninsula has protected occupation sites from the destructive effects of rising sea levels after the last glacial maximum; while the alkaline environment of the limestone rock shelters has acted to preserve an exceptional sequence of archaeological evidence from 35,000 to 17,000 years before present (BP). The rich assemblage of edible and non-edible marine faunal remains recovered from the rock shelters of Exmouth Peninsula provide a unique insight into how Indigenous people used coastal resources at this early time. Indigenous people had a comprehensive and sophisticated knowledge of marine resources that provided both sustenance and a symbolic language (Morse 1993a).

Pleistocene occupation and abandonment during the Last glacial maximum

Evidence of occupation during this period is provided by a number of rock shelter excavations carried out by Morse (1988, 1993a, 1993b, 1993c) and Przywolnik (2002, 2003, 2005).

Mandu Mandu Creek is one of a series of small limestone rock shelters located in the western foothills of Cape Range. The shelter faces west, and is just over a kilometre from the modern shoreline. Excavated by Morse over two seasons (1985 and 1989), this rock shelter provides evidence of two main phases of occupation separated by a hiatus coinciding with the last glacial maximum. Stratigraphic units returned dates of 30,000 and 34,200 years BP. The oldest date was obtained from a fragment of baler shell subsequently found to have been contaminated by groundwater carbon dioxide; so that the date was revised to 32,000 years BP (Morse 1993a).

During the Pleistocene, Mandu Mandu Creek rock shelter would have overlooked a gently sloping coastal plain stretching some six kilometres to the shore (Morse 1988). Occupants of the rock shelter collected a diverse range of marine fauna including crab, fish, sea urchins and mollusc shells. A predominance of sandy bottom mollusc species including baler shell (*Melo sp.*), pearl shell (*Pinctada sp.*), tusk shell (*Dentalium sp*.) and bilvalves in the basal Pleistocene layers suggest a reefed or rocky shore was not a dominant shoreline feature as in the later Holocene (Morse 1999, 74). There is also evidence that a variety of arid plains fauna were exploited prior to the last glacial maximum. The stone tool assemblage at this

time included large flakes and flaked pieces of poor quality silcrete and limestone most of which appear to have been sourced locally (Morse 1988). It appears that Mandu Mandu Creek rock shelter was used episodically from 32,000 to 17,000 BP; people were primarily utilising the marine resources of the retreating shoreline and incorporating a small amount of terrestrial fauna into their diet (Morse 1999).

Pilgonaman Creek rockshelter, also excavated by Morse (1993a, 1993c), provides evidence of a similar resource exploitation strategy to Mandu Mandu Creek, although there appears to be a greater reliance on terrestrial resources. Shellfish, crab and sea urchins dominate the marine assemblage. Analysis of shell remains from the lowest stratigraphic levels of the site returned dates of 31,770 BP and 17, 410 BP suggesting contrary to most archaeological evidence from northwest Australia (O'Connor 1996, 1999, 2007; Veth 1993) that people may have remained in the area, perhaps following the retreating shoreline in the increasingly arid conditions at the height of the last glacial maximum (Morse 1993a, 160). While dating of this site is recognised by Morse (1993a, 1993b) as being problematic due to stratigraphic inversions and possible contamination of the sample, the evidence shows that Pilgonaman Creek rock shelter was occupied seasonally during the Pleistocene and may have been used by Indigenous people at the height of the last glacial maximum (Morse 1999).

Like Mandu Mandu Creek, the C99 and Jansz rockshelters located five kilometres from the northern tip of Exmouth Peninsula, also show an occupational hiatus coinciding with the span of the last glacial maximum. These rock shelters are part of a complex of sites situated two kilometres from the current coastline. While the faunal remains (turtles, fish, shellfish, macropods and emu eggshell,) recovered from these sites by Przywolnik (2002, 2003, 2005) in 1997-98 are extremely fragmentary, the remains of baler shell at C99 and Jansz have been dated to 33,930 BP and 35,230 BP, respectively. Evidence of stone tool production in the form of flakes, flaking debris and cores is present and appears to have been sourced from local outcrops (Przywolnik 2005, 190). Like, Mandu Mandu Creek, both Jansz and C99 were abandoned during the height of the last glacial maximum, with Jansz abandoned between 31,000-11,000 BP, and C99 abandoned much later at around 21,000 BP and reoccupied slightly later at ca. 8,000 BP.

Rock shelters on Cape Range provide evidence for Indigenous use of marine resources at an early date. The only other sites in Australia with similar evidence are found on the coast immediately north and south of Exmouth Peninsula. They include rock shelters on the Montebello Islands and on the Kimberley coast, and an open midden site at Shark Bay.

The Montebello Islands located some 120 kilometres off the present Pilbara coast, were at one time joined to the mainland and surrounded by coastal plains. Faunal remains recovered from a number of caves on the islands were predominately terrestrial including macropods, murids (rats) and reptiles, with some marine bivalves (*Polymesoda coaxans*) and fish. A radiocarbon date of 27,220 BP was returned from shell remains recovered from Noala Cave 2 (Veth 1993). Like Exmouth Peninsula, there is a hiatus in occupation until the terminal Pleistocene at around 10,030 BP. O'Connor's (1990, 1996) archaeological investigations along the Kimberley coast and offshore islands provide a similar chronological story. Excavations at Koolan Shelter 2 on Koolan Island and on the mainland (Widgingarri Shelters 1 and 2) show discontinuous occupation, with the Koolan shelter being occupied at 26,500 BP and then abandoned from around 23,000 BP until 10,550 BP. At Widgingarri Shelter 2 occupation starts a little earlier at about 28,000 BP and is abandoned later at about 18,000 BP and reoccupied at around 7,700 BP.

At Shark Bay, approximately 500 kilometres south of Exmouth Peninsula, the Silver Dollar open midden site returned a date from baler shell remains of 30,240 BP. Like the Cape Range rock shelters, it appears that Silver Dollar was occupied in two phases; initially between 30,000 BP and 18,000 BP when the coast would have been between 100 and 50 kilometres away, then a long hiatus until the second period of occupation from 7,000 – 6,000 BP (Bowdler 1999). Silver Dollar contains a mix of marine and terrestrial faunal remains in the Pleistocene levels, including emu eggshell and macropod teeth. There are, however, very few marine shell remains, presumably due to Silver Dollar's distance from the shoreline during the Pleistocene. Marine remains only appear abundant after 6,000 BP (Flood 1999).

The dates returned for the sites on Montebello Island, the Kimberley coast and Shark Bay are not as old as those for Cape Range, and their occupation deposits do not contain the diversity of marine resources as those found in the rock shelters on Cape Range.

Pleistocene shell beads have also been recovered from Riwi, a small rock shelter in the Kimberley region dated to ca. 30,000 years. Tusk shell beads have also been recovered from Carpenter's Gap Shelter 1, a cave located a further 200 kilometres to the west of Riwi. However, the precise age of these shell beads is not available (O'Connor 1995).

There are few coastal sites with Pleistocene occupation dates outside of northwest Western Australia. Those on the eastern seaboard and on the Tasmanian coast are all dated to around 20,000 BP. As noted by many workers in the field, the Holocene sea level transgression would have drowned much of the Pleistocene coast and evidence of human occupation along with it (Mulvaney 1975; Lampert 1981; White and Connell 1982; Beaton 1985). The steep topography of Cape Range protected occupation sites from the destructive effects of rising sea levels, and the unusual alkaline environment of the limestone rock shelters acted to preserve the archaeological evidence of human occupation back to 35,000 BP; the earliest evidence of coastal occupation in Australia.

Exmouth Peninsula provides us with a unique insight into early Indigenous use of marine resources between 35,000 and 17,000 BP. The place is outstanding because it provides the best evidence for early Indigenous use of marine resources during the Pleistocene - Indigenous people living on Exmouth Peninsula at this time had a comprehensive and sophisticated knowledge of resources found along the Ningaloo coast (Morse 1993a).

The diversity of marine resources used by Indigenous people at this time has not been found elsewhere in Australia. On this basis, Exmouth Peninsula and the shell beads that were found in association with the place have outstanding Indigenous heritage value at the national level under criterion (a).

Holocene occupation

Following the last glacial maximum, the warming of the atmosphere led to the slow rise of sea levels. During this period people returned to utilise areas within the nominated area. The coastline would have been considerably different to that prior to glaciation. Rock shelters occupied during this period show a similar resource use pattern to the Pleistocene, with people exploiting marine and terrestrial resources. At Pilgonaman Creek and Yardie Well rock shelters, terrestrial fauna dominate the assemblage, with an increased diversity in marine resources at the end of the Pleistocene and early Holocene, when the coast was only two to three kilometres from the rock shelters. According to Przywolnik (2005, 190) evidence of mangroves appear for the first time on the northern part of the peninsula at around 10,730 BP, when fragments of mud whelk (*Terebralia palustra*) appear in the Jansz deposit. With the advancing sea levels, the early Holocene coastline would have provided a variety of marine habitats (mangroves, rocky coasts and sandy bottoms), a rich resource base to sustain human populations. Both Jansz and C99 are abandoned for a second time, ca. 8,000 BP coinciding with the decline of mangrove habitat on the peninsula. Mandu Mandu Creek rock shelter was not occupied at all during this period (Morse 1999). The earliest shell middens in the nominated area are dated to around the early mid-Holocene on the Warroora coast and nearby Coral Bay. The Warroora midden dated to 7,810 BP and the Mulanda Bluff midden (7,210 BP) both contain remains of *Terebralia* shell (Morse 1996).

Archaeological evidence suggests that an intensification of occupation started to occur during the mid-Holocene period, around 6,000 years ago when sea levels stabilised at their current levels. Morse (1993a) found at Mandu Mandu Creek rock shelter, re-occupied after a 14,500 year gap in occupation, and at the Pilgonaman Creek and Yardie Well rock shelters that a similar marine faunal assemblage to that of the Pleistocene with shell, a higher proportion of turtle bone, and an expanded terrestrial faunal assemblage (Morse 1993a).

Przywolnik's excavations revealed a more intensive occupation of C99, Jansz and Wobiri rock shelters during the late Holocene than at any other time. There is also a change in the type of stone used with exotic fine-grained stone being introduced to sites along with the development of a new tool assemblage that included tula adzes, burren adzes and backed artefacts and points. Tula adzes and burren adzes were used for woodworking, while backed artefacts and points were used for hunting. Turtle and fish predominate the faunal remains and desert walnuts (*Owenia reticulate*) appear in deposits for the first time. Both turtles and walnuts are seasonal food sources available during the warmer months from December to May (Przywolnik, 2005, 192).

Between 8,000 and 4,000 years ago, the mangrove whelk (*Terebralia palustris*) was the most abundant species deposited in shell middens across northern Australia, with *Andara granosa* and a range of other rocky foreshore species dominating deposits younger than 4,000 years old (Beaton 1985; Bailey 1999; AHDB 2007). As Bradshaw (1995) points out, evidence for this change in the Indigenous use of shellfish is found throughout the coastal regions of northern Australia, including the Ningaloo Coast.

The history of occupation, including changes in technology and food preferences in the nominated place conform to the established Holocene sequence in the Pilbara and northern Australia more broadly.

On this basis, the archaeology of Exmouth Peninsula from the end of the last glacial maximum to the late Holocene is unlikely to have outstanding national heritage value under criterion (a).

CRITERION (b) – ***The place has outstanding heritage value to the nation because of the place's possession of uncommon, rare or endangered aspects of Australia's natural or cultural history.***

Natural Values

The nominator claimed that the nominated area is nationally significant under criterion (b) because of the presence of a number of species listed as endangered, vulnerable or threatened, and for migratory species listed under bilateral and multilateral agreements which Australia has signed, and the EPBC Act.

The habitats of the Ningaloo Coast and Exmouth Gulf region support a number of rare, threatened or migratory animal species. However, this number is smaller than for areas of similar size elsewhere in Australia. For example ANHAT analyses of large regions such as Cape York Peninsula, regions around Sydney, south-western Australia, the north coast of NSW and southern Queensland demonstrate that these regions support significantly more rare and threatened species than the nominated area. An ANHAT analysis revealed that in Western Australia, the Broome area, parts of the Kimberley coast and areas in the south west support as many as or more species protected under JAMBA/CAMBA.

Although the nominated area contributes to the conservation of the rare or endangered EPBC, CAMBA and JAMBA-listed species, and the conservation of these species is itself a separate matter of national environmental significance under the EPBC Act, their threatened or migratory status and their presence within the nominated area is not in itself considered to be of outstanding heritage significance to the nation under criterion (b).

The nominator claimed that Ningaloo Reef is nationally significant under several criteria for the regular congregation in significant numbers of the whale shark, as it is the largest fish in the world.

The presence of a single species, keystone, rare, threatened or otherwise, is unlikely in itself to be sufficient justification for National Heritage listing. ***Therefore, the regular congregation of whale sharks in significant numbers at Ningaloo Reef is unlikely to have outstanding heritage significance to the nation.***

The nominator claimed that Ningaloo Reef is nationally significant under criterion (b) for the presence of 14 species of cetacean, dugongs, and four species of marine turtles.

Only eight species of cetaceans have been regularly recorded in the area. The regular congregation of marine vertebrate species is not unusual in Australian waters. The World Heritage Listed Shark Bay south of Ningaloo Reef is celebrated for the regular congregation of wild dolphins at Monkey Mia and the world's largest dugong community (Preen et al. 1997). Other migratory cetaceans regularly gather at sites around the Australian coast, notably southern right whales and humpback whales (for example, IUCN 1991; WCMC 1997). Notable marine invertebrate migrations include the mass spawning of the giant Australian cuttlefish (*Sepia apama*) in South Australia's Spencer Gulf (Steer and Hall 2005) and the annual forest to coast breeding migrations of red crabs on Christmas Island (DEW n.d.).

The Great Barrier Reef World Heritage Area supports dugong (*Dugong dugon)* habitat of major importance, 26 species of cetacean, as well as six species of marine turtle (including populations of world significance for loggerhead, *Chelonia mydas*, and green turtles, *Caretta caretta*) and whale sharks (WCMC 1997). Shark Bay supports 12 per cent of the world population of the dugong, a large turtle population and sizeable populations of other small and large cetaceans (Preen et al. 1997; Gales et al. 2004). The Dampier

Archipelago-Cape Preston region supports a similar suite of marine megafauna to Ningaloo Reef (DEC 2007).

On the above basis Ningaloo Reef is unlikely to have outstanding heritage value to the nation under criterion (b) for the regular presence of migratory, protected or endangered marine megafauna.

The nominator claimed that the nominated area is nationally significant for providing habitat for rare and unusual cave-dwelling species, including species of terrestrial troglobites which are adapted to millions of years living underground, and aquatic stygofauna, which are most closely related to ancient species from the Canary Islands off Africa, and the Caribbean.

Groundwater habitats like those occurring in Exmouth Peninsula are characterised by the diversity, richness and large numbers of endemic taxa they shelter. Their members are frequently biogeographic and/or phylogenetic relicts isolated from their nearest relatives by past plate tectonic activity (as in the case of much of the Exmouth Peninsula stygofauna) or by climate change (as in the case of many of the Exmouth Peninsula troglobites) (Danielopol et al. 2000; Jaume et al. 2001).

Although the cave fauna of Exmouth Peninsula includes rare, unusual and biogeographically interesting taxa, this is a distinguishing feature of anchialine and groundwater faunas across the continent and around the world. For example, Barrow Island shelters an internationally significant troglofauna which shares elements with the Exmouth Peninsula fauna, but includes Australia's only known troglobitic snake, the blind snake *Ramyphotyphlops longissimus* (Aplin 1998; Kendrick and Mau 2002).

In this case, the quality of rareness does not does not establish the outstanding heritage value of all the subterranean communities in the nominated area. Collectively their outstanding heritage value to the nation lies in their contribution to an evolutionary story which is addressed under criterion (a), and as an outstanding example of an integrated karst-coral reef system, addressed under criterion (d).

However, the taxonomic composition of the anchialine community of Bundera Sinkhole is unique in the southern hemisphere and Indo-West Pacific, though it shares characteristics of anchialine communities elsewhere in the world. There are no directly comparable sites in Australia. Anchialine communities characterised by the presence of remipede crustaceans are limited to Exmouth Peninsula, the volcanic anchialine setting of Lanzarote in the Canary Islands, and some sites in the Caribbean and Mediterranean Seas, Cuba and Mexico (Gillieson, Humphreys and Spate 2006).

Bundera Sinkhole has outstanding heritage value to the nation under criterion (b) for its unique anchialine community, reflecting its unusual hydrology, geological history, and stable environment over thousands of millennia.

The Exmouth Peninsula karst is the only Tertiary orogenic karst in Australia. Orogenic karst forms when the hydrological system evolves in a setting of continued uplift, driven by sea level changes as the result of glacial and interglacial cycles. The western half of the Australian continent is characterized by extensive areas of low relief, tectonic stability and a very long history of landscape evolution under essentially stable conditions (Wyrwoll et al. 1993). Exmouth Peninsula is a major exception. Most of the geological and geomorphological features of Exmouth Peninsula reflect a history of uplift and warping that commenced in the late Tertiary (middle Miocene to late Pliocene) and which has continued to the present. The karst systems of Cape Range extend over a vertical range of at least 300 metres. There is no other karst site in Australia that has this relief. Very minor coastal upwarping of less than ten metres has been recorded in the late Tertiary karsts of the Myall Lakes in New South Wales and the onshore Otway basin in southeastern South Australia and western Victoria (Gillieson, Humphreys and Spate 2006).

The intimate interconnection between the contemporary hydrological system of Exmouth Peninsula, and the former glacial age karst hydrological network, now drowned by the sea, is reflected by the ongoing influence of the tides which fluctuate with the shallow groundwater of the coastal limestone adjacent to the Cape Range. This interconnection has two consequences. First, the mixing and layering of saline and freshwater creates opportunities for the increased solution of limestone at the Ghyben-Herzberg interface. Seawater has high concentrations of dissolved carbon dioxide which combines with tidal pumping to create a maze of interconnected tubes invading pre-existing cavities in the raised reef limestone. Second, the

creation of a water-filled network of cave passages in both freshwater and anchialine conditions has allowed for the movement of stygofaunal species from the nearshore marine to the karst environment.

The presence of active karst solution as a result of seawater incursion is rare in Australia. This is the dominant mode of limestone solution in the extensive platform karsts of Florida, the Yucatan Peninsula and many Pacific islands. The Ningaloo Coast is the best example in Australia of this globally significant karst solution process. The only other examples are in the syngenetic karsts of the Margaret River area of Western Australia and the southeast of South Australia (Gillieson, Humphreys and Spate 2006).

The karst of the Ningaloo Coast system has outstanding heritage value to the nation under criterion (a) for its importance in demonstrating the pattern of Australia's natural history, as the only example in Australia of a Tertiary orogenic karst, which has led to conditions favourable to the evolution of distinct and extraordinary stygofaunal communities.

The nominator claimed that the Muiron Islands, a continuation of Cape Range inundated by rising seas, are of outstanding heritage value to the nation under criterion (b), for their outstanding faunal and geological diversity, providing 'important aggregation and nesting areas for turtle populations, including the loggerhead, green, flatback and hawksbill turtles'.

Rising sea levels during the Holocene isolated a number of landforms from the Australian mainland, most notably Tasmania, the Bass Strait Islands and Kangaroo Island. The islands of Sydney Harbour were once hills before the sea flooded the Parramatta and Hawkesbury Rivers. The Great Barrier Reef World Heritage Area includes 618 continental islands which were once part of the mainland, before rising sea levels inundated low-lying coastal areas (Pardoe 1991; Short 1988; Haworth et al. 2004; WCMC 1997).

As an example of a region separated from the mainland by marine inundation, the Muiron Islands are unlikely to have outstanding heritage value to the nation under criterion (b). However the Muiron Islands are not an independent system, and are therefore considered elsewhere under other criteria, as an integral part of the Ningaloo Coast integrated system.

The nominator claimed that mangal communities on the eastern shore of Exmouth Gulf from Lockyer Point to Giralia Bay are nationally significant under criterion (b) for their 'distinctive character'; as one of the largest mangal systems in Western Australia they provided nutrients to support the gulf's fisheries and acts as a nursery for other species. Nearby seagrasses support turtles and a large population of dugongs.

Numbers of dugongs in Exmouth Gulf are equivalent to those in the Ningaloo Reef Marine Park. A 2004 study indicates that dugong numbers have steeply declined in the Ningaloo Reef – Exmouth Gulf region between 1997 and 2004, while the population in Shark Bay appears to have risen significantly. Tropical Cyclone Vance, which caused widespread regional damage to seagrass feeding grounds in Exmouth Gulf in March 1999, may have precipitated this change (Preen et al. 1997; Gales et al. 2004).

Nationally, mangroves cover a total area of 1,150,000 hectares across Australia. The highest species richness occurs in the wet tropics of Queensland (CSIRO 2001). The most extensive areas of mangal occur along the northern coastline, particularly in the Gulf Country of Queensland and the Northern Territory, around the Top End of the Northern Territory and in the Kimberley (Bridgewater and Creswell 1999). While the mangrove community in Exmouth Gulf numbers among the largest systems in Western Australia at 140,000 hectares, there are larger areas further north and on the east coast.

Mangrove communities occur along the Western Australian coast from Exmouth Gulf north to the Northern Territory border. The Kimberley, the Gulf Country and the Top End contain the three most diverse and extensive mangrove areas in Australia both in terms of species richness and landscape diversity (Bridgewater and Cresswell 1999). There has been no comprehensive national assessment of mangrove landforms, communities or assemblages (Bridgewater and Cresswell 1999).

Therefore the nominator's claim that this community has outstanding heritage value to the nation for its 'distinctive character' is not testable.

The nominator claimed that Lake Macleod has outstanding Heritage value to the nation under criterion (b)

as an outstanding and unique example of a major coastal lake that is episodically inundated by fresh water, including permanent saline wetlands and inland mangrove swamps maintained by subterranean waterways believed to connect both to the Indian Ocean and to Exmouth Gulf. While elements of this claim would be better addressed under criterion (d), the lake as a rare system, with all its attendant features, is analysed under (b).

Done (2004) and Russell (2004) describe Lake Macleod as a large, saline coastal lagoon, and the surface expression of an unusual hydrogeological groundwater system. In his report, Russell states that the outstanding feature of this lake is its principal recharge mechanism (Russell 2004). Hydrological recharge involves the lateral movement of seawater from the coast to the lake, through highly permeable, karst limestone aquifers over a distance of up to 20 kilometres. The difference in water level between the ocean and basin generates hydrostatic pressure, forcing seawater inland to the lake, ultimately discharging as springs and maintaining several permanent pools and brine sheets. There is also episodic freshwater recharge via surficial drainages, that becomes significant following heavy rainfall events in the catchment (Russell 2004).

The rich underground fauna of the Exmouth Peninsula karst system is recognised as nationally and internationally significant and has been described as the most significant subterranean feature of the region (Hamilton-Smith et al. 1998). No link has been demonstrated between the anchialine system that sustains this fauna and the communities that are maintained at Lake Macleod. While the hydrogeological recharge mechanism of Lake Macleod is unusual, and one of only six such locations in the world (Russell 2004), the literature does not demonstrate that the lake is hydrologically connected to Cape Range or to Exmouth Gulf. In a paper addressing the hydrology of Cape Range, the author asserts that the Cape Range groundwater is separated from the regional water table of Carnarvon Basin in the vicinity of Yardie Creek, over 150 kilometres north of Lake Macleod (Allen 1993).

There is insufficient evidence to support the nominator's claim that Lake Macleod has outstanding heritage value to the nation under criterion (b) as an outstanding and unique example of a major coastal wetland.

The primary value of the lake revolves around its hydrological connection with the adjacent reef. Sea water flows through the intervening karst between the sea and the lake for up to 18 kilometres, to create an inland marine environment at the northern end of the lake with mangroves, marine fish and other marine organisms (WHCCC 2004).

The nominator claimed that Lake Macleod is one of the largest areas of inland mangroves in the world.

The Lake Macleod mangal represents the larger of Australia's only two inland mangrove communities (the other being Western Australia's Mandora Salt Marshes). Occurrence of mangroves inland is rare in the world, and the mangroves of Lake Macleod form fringes around pools of permanent water connected to the Indian Ocean over 20 kilometres away via subterranean recharge mechanisms (Ellison and Simmonds 2003). However, while the mangroves at Lake Macleod represent the largest inland mangrove community, Mandora Marsh, near Eighty Mile Beach south of Broome, features a mangrove community that lies over 50 kilometres inland, where the white mangrove (*Avicennia marina*) is found cut off from the ocean by extensive grassland plains (AHDB 2001).

Examples of species at the extreme of their biogeographical range are common and widespread across the continent, and the inland location of the Lake Macleod mangrove community does not constitute a value of outstanding significance to the nation.

The nominator claimed that Lake Macleod has outstanding heritage value to the nation for under criterion (b) for its unusual hydrology.

In his report to the then Western Australian Department of Conservation and Land Management, Russell (2004) stated that the Lake Macleod hydrological seawater recharge system is highly unusual, and in excellent functional condition. However, Russell added that the interaction of freshwater recharge in the anchialine zone and its importance in habitat and species maintenance is not well studied, and that further scientific investigations are required. Furthermore, Australia possesses a wide variety of lakes of

interesting hydrology. To quote the eminent geomorphologist Jim Bowler, 'Saline lakes present a range of habitats for study… rich in scientific potential… An extraordinary array of physical, chemical and biological diversity in basins throughout the continent combines with a rich variety of landscape settings' (Bowler 1982b).

Other Australian lakes with an unusual hydrology and resulting unusual biological assemblages include South Australia's Mt Gambier cenotes, fed by groundwater and supporting highly unusual stromatolite communities of a variety of types; the alpine cirques in Tasmania and the Australian Alps, with their highly restricted invertebrate communities and distinct thermal layering; and the perched lakes of Fraser Island and associated invertebrate and amphibian faunas. Other water bodies associated with artesian groundwaters include the Lake Eyre Basin, and the mound springs of the Great Artesian Basin, with their attendant endemic faunas. Lake Eyre (South Australia) is of international significance as the focus of one of the world's largest drainage basins and represents an outstanding example of a hydrological cycle.

While Lake Macleod is structurally, hydrologically and biologically interesting, there is insufficient information to demonstrate that the place has outstanding value to the nation under criteria (b) or (d).

The nominator claimed that Lake Macleod is important as a stopover for migratory species. The 58 species of birds recorded for the area include 26 species listed under international treaties (CAMBA, JAMBA) (Done et al. 2004).

Other sites in Western Australia that are at least as significant for migratory waders include Roebuck Bay, and Eighty Mile Beach south of Broome, which is a major connection in the migratory bird pathway between the northern hemisphere and Australia. Eighty Mile Beach is one of the most important migration stop-over areas in the Australasian region (ANCA 1996). In addition, Shark Bay provides habitat for a greater diversity of waterbird species than Lake Macleod, with 69 species recorded, and 34 species listed under international treaties.

Other areas in southern Australia, such as Port Phillip and Western Port in Victoria, are among the richest recorded areas in Australia for migratory species based on an equal area systematic, spatial analysis (ANHAT 2005). Another study that lists 138 internationally significant sites for migratory shorebirds in Australia (Bamford et al. 2005) proposes Eighty Mile Beach and Roebuck Bay in Western Australia and the Southern Gulf Plains in Queensland as the most important wetlands for migratory shorebirds in Australia (Bamford et al. in prep. and D Watkins, Director Wetlands International, pers. comm. October 2004, both cited in AHDB 2005a).

While Lake Macleod supports relatively high numbers of migratory and resident shorebirds, there are other more important sites in northern Australia, and claims of outstanding significance in the national context under criterion (b) are not supported by current evidence.

CRITERION (c) – ***The place has outstanding heritage value to the nation because of the place's potential to yield information that will contribute to an understanding of Australia's natural or cultural history.***

Natural Values

The nominator claimed that the nominated area is nationally significant under criterion (c) for offering unusual opportunities for access and scientific research as 'one of only a few large coral reefs in the world that are found so close to a continental landmass', providing opportunities for understanding many interactions of coral reef ecological communities.

Coral reefs around Australia and around the world have been well studied. The Great Barrier Reef offers excellent opportunities for access, being much closer to urban centres, and to the Townsville-based Australian Institute of Marine Science than Ningaloo Reef. Accessibility is unlikely in itself to be sufficient justification for National Heritage listing. Furthermore, the Great Barrier Reef is possibly the best studied coral reef in the world. Its extensive, state-of-the-art monitoring program is a model for projects elsewhere, attracting 'very high capacity in all areas of coral reef science, management and education' (Wilkinson 2004).

Therefore compared to other Australian reefs and marine areas, and in particular the Great Barrier Reef, the nominated area does not have outstanding heritage value to the nation under criterion (c) for offering unusual opportunities for access and scientific research.

The nominator claimed that the nominated area is nationally significant under criterion (c) because the Leeuwin current encourages migratory vertebrates including the whale shark and a diversity of tropical species into the area.

The Leeuwin Current affects the entire Western Australian coast, bringing marine megafauna and a diversity of tropical species close to Shark Bay, many other Western Australian mainland sites, reefs and islands as well to Ningaloo Reef (EA 2002b; CALM 2005a).

Therefore it cannot be demonstrated that the nominated area has outstanding heritage value to the nation under criterion (c) for the action of the Leeuwin Current in bringing migratory vertebrates and a diversity of tropical species into the area.

The nominator claimed that Cape Range and associated limestone ranges are nationally significant under criterion (c) for their rich diversity of subterranean fauna with ancient links to both Pangaea and Gondwanan species, providing opportunities to understand the changing face of our continent as it evolved from the break-up of former supercontinents.

The greatest biological significance of the Ningaloo Coast lies in the subterranean fauna of Exmouth Peninsula. Anchialine and groundwater ecosystems are of considerable scientific interest globally, yielding important information about the evolution of life on earth, biostratigraphy, geochronology and palaeoclimate (Gillieson, Humphreys and Spate, 2006). The stygofauna and troglobitic fauna of Exmouth Peninsula gives insights into changes in climate since the Miocene epoch (up to 26 million years ago), and the biogeographic history of the continent. Exmouth Peninsula contains a wealth of bioclimatic information in the cave formations, and in the Tethyan affinities of the stygofauna. Together with the relictual tropical rainforest fauna found in the caves, these ecosystems make an unparalleled contribution to improving understanding of evolutionary processes and climate changes. The rate of discovery of new species at Exmouth Peninsula is rapid and ongoing, and the values for the place will require continual updating (AHDB 2002; AHDB 2004). Exmouth Peninsula has the highest level of troglomorphic diversity for a single karst area in Australia, and one of the highest in the world. More than 40 publications have addressed the remipede-type anchialine system of the Bundera Sinkhole. It is likely that with further study, known diversity of these ecosystems will increase, revealing more information about the break-up of supercontinents and increasing aridity in Australia (Humphreys and Danielopol 2005; Gillieson, Humphreys and Spate, 2006).

Exmouth Peninsula is an internationally important scientific research area which has outstanding heritage value to the nation under criterion (c) for the potential of its subterranean ecosystems to yield important information about biogeography, evolution and changing climates in Australia.

The nominator claimed that the place has outstanding heritage value to the nation under criterion (c) because fossil evidence from the Sandalwood Peninsula on Giralia Station, together with recent studies of the biogeography of cowrie shells suggests that what is now Exmouth Peninsula was once an island, with Exmouth Gulf connecting through a channel to the ocean near Lake Macleod.

While the Sandalwood Peninsula Pleistocene fossil reef is congeneric with other Pleistocene reefs in the wider region, Pleistocene and Holocene reefs have been well-studied all over Australia (Veeh and Veevers 1970; Tudhope 1989; Harriott 1998; Collins et al. 1993; Collins et al. 1996; Kuhnert et al. 1999; Greenstein et al. 2005; Collins et al. 2006). The reefs of the Abrolhos Islands are the best studied of the Western Australian Pleistocene reefs. Substantial work has also been undertaken on Pleistocene and Holocene reefs in the Great Barrier Reef World Heritage Area.

There is insufficient evidence to demonstrate that the fossil reef on the Sandalwood Peninsula has outstanding heritage value to the nation under criterion (c).

Indigenous values

Although the nominator made no specific claims for Indigenous National Heritage values against criterion (c), there is evidence to suggest that Exmouth Peninsula has outstanding heritage value to the nation because of the place's potential to yield information that will contribute to an understanding of Australia's cultural history.

General archaeology
Exmouth Peninsula's proximity to the continental shelf during the harsh climatic conditions that started around 19,000 years BP, and ended about 10,000 years ago means that the place was never far from marine resources. Research on the freshwater subterranean fauna of the area (Humphreys and Adams 1991; Poore and Humphreys 1992) suggests that even in times of considerable aridity, freshwater may have been widely available across the emergent coastal plain bordering Cape Range. As noted by Morse (1993c) this clearly has important implications for an understanding of patterns of human use of the Cape Range region during glacial conditions. The coastal fringe of Exmouth Peninsula during the height of the last glacial maximum could have been a refugium with a permanent source of fresh water and abundant marine resources given the place's close proximity to the continental shelf.

Evidence from Pilgonaman Creek rock shelter lends some support to the refugium hypothesis. Dating of this site is recognised as being problematic due to stratigraphic inversions and possible contamination of the sample. However, the date of 17,410 ± 330 years BP obtained from shell suggests contrary to most archaeological evidence from northwest Australia, that people may have remained in the area, perhaps following the retreating shoreline in the increasingly arid conditions at the height of the last glacial maximum (Morse 1993a, 160).

For many years archaeologists have debated the importance of marine resource use in Pleistocene human economies in Australia and overseas. While some (Osborne 1977; Perlman 1980; Bailey and Parkington 1988) argue that a lack of evidence in coastal areas inhabited during the Pleistocene is a result of these areas not being colonised until sea levels stabilised around 6,000 years ago. Others have pointed out that the apparent world-scarcity of archaeological evidence for occupation of the Pleistocene coast may be more apparent than real, because the evidence has been drowned by subsequent sea level rise (Mulvaney 1975; Bowdler 1977; White and O'Connell 1982).

The rich assemblage of materials recovered from the rock shelters of Cape Range coupled with the probable availability of freshwater even during the arid period means that Pleistocene archaeological deposits at Cape Range have the potential to provide further insights into the use of marine resources at this early time. Current gaps in the Cape Range chronology may be filled through future archaeological investigations, building a detailed chronology of coastal occupation from the Pleistocene into the Holocene; a chronology not likely to be found anywhere else on the continent.

Exmouth Peninsula has national heritage values under criterion (c) for its potential to yield information that will build a detailed chronology of coastal occupation from the Pleistocene to Holocene, contributing to an understanding of Australia's cultural history.

CRITERION (d) – ***The place has outstanding heritage value to the nation because of the place's importance in demonstrating the principal characteristics of:***
(i) a class of Australia's natural or cultural places; or
(ii) a class of Australia's natural or cultural environments.

The nominator claimed that as the largest fringing reef in Australia and one of the longest in the world, extending over approximately 300 kilometres, Ningaloo Reef is an important class of Australian environment, suggesting that the reef is 'almost as ecologically rich and certainly more pristine' than the Great Barrier Reef.

The majority of Western Australia's reefs are, like Ningaloo, close to shore in embayments or islands around the coast. 'Fringing' reefs like Ningaloo predominate, as well as patch reefs, among a variety of other reef types. The many smaller reefs that constitute Ningaloo Reef vary in size from seven kilometres to less than 200 metres long, while the entire reef complex extends approximately 300 kilometres from North West Cape to Red Bluff. The description 'fringing' or 'barrier' reef is not in this case significant, as the distinction is primarily determined by geography, lagoon-size and position relative to the shore and the

continental shelf, rather than by biology, substrate or structure, and much of Ningaloo Reef has a strong barrier expression with a deep, wide lagoon (Wyrwoll et al. 1993).

Coral reefs are the most diverse of all marine ecosystems (Paulay 1997). This biodiversity is most pronounced in the Indo-West Pacific reefs, decreasing with distance from the Indo-Australian archipelago (Knowlton 2001). The Great Barrier Reef World Heritage Area contains 3,400 individual reefs, consisting of a great variety of forms: wall, patch and platform, including more than 750 fringing reefs ranging in size from less than one hectare to greater than 10,000 hectares. It also contains 300 coral cays and 618 continental islands. Undoubtedly the largest coral reef assembly, and possibly the greatest area of faunal diversity in the world, the Great Barrier Reef reflects an ecosystem which has evolved in relative stability over millions of years (WCMC 1997).

In comparison to the Western Australian reefs (including Ningaloo), the Great Barrier Reef includes 400 species of coral (compared to around 250 at Ningaloo), 1,500 fish species including whale, reef and other sharks and several species of ray (compared to around 500 fish species at Ningaloo) and 4,000 mollusc species (compared to about 600 species at Ningaloo), up to 250 bird species as well as a rich and diverse collection of sponges, anemones, marine worms, crustaceans and other invertebrates, and important cetacean populations. It also includes nationally important dugong habitat, and globally important nesting grounds for green and loggerhead turtles. The other four marine turtles found in Australian waters also nest in the Great Barrier Reef. While Ningaloo Reef may shelter a comparable number by species of marine mammals, turtles and birds, it lacks the great diversity of fish, invertebrates and corals of the Great Barrier Reef (WCMC 1997; Storrie and Morrison 1998). The Great Barrier Reef is undoubtedly the richest, most diverse reef in the world, structurally and biologically (WCMC 1997). Therefore, although it does not have the structural and species diversity or richness of the Great Barrier Reef, it is appropriate to assess Ningaloo Reef against other reefs off the Western Australian coast.

Ningaloo Reef demonstrates moderate diversity compared with other Indo-West Pacific reefs. Much the same suite of species is found throughout the eastern Indian Ocean and west Pacific, including the reefs of northern Queensland (Done et al. 2004). With more than 700 species recorded, Ashmore Reef has the most diverse fish fauna off the Western Australian coast. The reef is particularly abundant in marine reptiles, with up to 17 species of sea snake (compared to around seven species at Ningaloo) and significant populations of green, hawksbill and loggerhead turtles. Ashmore and nearby Cartier Reef shelter 136 species of sponge, 286 species of crustaceans and 433 mollusc species, with more than 190 species of echinoderm (sea star, urchin and sea cucumber) in Ashmore Reef alone. Its 255 species of hermatypic (hard) coral from 56 genera, and many non-reef-building corals make Ashmore Western Australia's richest reef. With 229 species of hard coral, as well as 543 crustacean species, 1227 mollusc, 286 echinoderm, 275 sponge, 182 marine algae and 650 fish species, the Dampier Archipelago has biodiversity comparable to northern Queensland. A total of 233 species of hard corals from 56 genera have been recorded at the Rowley Shoals, comparable with Ningaloo, along with 264 mollusc species, 82 species of echinoderm and 688 fish species (from 232 genera and 75 families). Up to 13 cetacean species use the waters adjacent to Rowley Shoals (EA 2002b; Wilkinson 2004; DEC 2007; MPRA and DEC 2007; DEC 2008b).

The nominator also claimed that Ningaloo Reef has outstanding heritage value to the nation under criterion (d) for its pristine condition.

Australia contains nearly 20 per cent of the world's coral reefs. These reefs are predominantly in good condition due to relatively limited human pressure, and they are well-supported by research and monitoring. Their size and diversity of habitats promotes exceptional biodiversity.

The inshore areas of the Great Barrier Reef are threatened by sediment and nutrients contained in terrestrial runoff. Other potential or actual threats include commercial and recreational fishing, tourism, ship-sourced pollution, invasive species such as crown-of-thorns starfish (GBRMPA 2002).

In contrast, nurtured by the warm Leeuwin Current, Western Australia's many coral reefs are spread along its 3,000 kilometres of coast. Most of them are remote from major industry and population centres, while a few, such as Ashmore Reef, 840 kilometres west of Darwin at the edge of the North West Shelf, are remote from land (EA 2002b). Ningaloo Reef is in 'relatively pristine' condition because of the lower human pressure in the area compared to elsewhere. However, most Western Australian reefs are in good condition,

subject as they are to fewer local impacts, minimal coastal development, and with fewer river systems draining into them than other reefs around the world and on the east coast of Australia (Wilkinson 2004).

Therefore Ningaloo Reef is unlikely to have outstanding heritage value to the nation for demonstrating the principal characteristics of an Australian reef. The importance of the reef as part of a functioning terrestrial-anchialine-marine limestone system is considered below.

The nominator claimed that Cape Range is nationally significant under (d) because its karst systems have an immense potential to demonstrate the ecology and evolution of limestone environments in Australia.

This claim is also addressed under criteria (a), (b) and (c).

As a Tertiary karst, Cape Range is younger than most Australian karst systems and structurally unusual for being uplifted and folded. Although such karst systems are common elsewhere in the world, there are no comparable systems elsewhere in Australia. The only similar aged karsts on the continent occur on the Nullarbor Plain and South Australia's Gambier karst. The high relief of the area, combined with lower sea levels in the past, has allowed significant karstification. The hard Miocene Tulki limestone is the main cavernous limestone. Younger Pleistocene to Holocene age limestones also contain abundant karst features. There are 826 karst features (535 caves, 180 dolines, and 11 miscellaneous features) recorded from Exmouth Peninsula. Surface features include gorges, karren, dolines, and springs. Its caves provide habitat for an extraordinarily diverse and abundant cave fauna. Despite only preliminary investigations, Exmouth Peninsula has one of the most diverse cave faunas known in the world (AHDB 2002; Gillieson, Humphreys and Spate, 2006).

Karst development may extend more than 120 metres below present sea level (Gillieson, Humphreys and Spate 2006). The high density of karst features in Cape Range and probable evolutionary relationships between the modern Exmouth Peninsula troglobites and fauna inhabiting much more humid environments in the north east of the continent combine to suggest that landscape development occurred under much wetter conditions than currently prevail.

The taxonomic composition of the anchialine community of Bundera Sinkhole is unique in the southern hemispheres and Indo-West Pacific, though it shares characteristics of remipede communities elsewhere in the world. There are no directly comparable sites in Australia. Anchialine communities characterised by the presence of remipede crustaceans are limited to Exmouth Peninsula, the volcanic anchialine setting of Lanzarote in the Canary Islands, and some sites in the Caribbean, Cuba and Mexico. While Western Australia's Barrow Island offers a sub-set of the subterranean fauna of Exmouth Peninsula, it is biologically much less diverse (Gillieson, Humphreys and Spate 2006).

This unusually high concentration of subterranean animals is likely to be a direct consequence of the combination of diverse terrestrial, freshwater and anchialine habitats of Exmouth Peninsula, and the influence of past and present climates and environmental conditions.

Unparalleled in Australia, Exmouth Peninsula has outstanding heritage value to the nation under criterion (d) for demonstrating the principal characteristics of a Tertiary karst environment in Australia, including a high concentration of karst features and subterranean ecosystems of global importance.

The nominator claimed that Ningaloo Reef is nationally significant under criterion (d) because viewed as an integrated system with the adjoining Cape Range, the subject area is a complex system reflecting coastal retreat and inundation during periods of sea level rise and fall.

The question of the significance of the range-reef complex as a demonstration of sea level change over time is addressed under criterion (a).

The singularity of the Ningaloo Coast lies not in the status of Ningaloo Reef as a fringing reef with barrier characteristics (or vice versa) close to a continental margin, nor simply in the outstanding karst system of Exmouth Peninsula, but in the close relationship between the two, and their demonstration of past and ongoing relationships between marine and terrestrial environments (Russell 2004; Done 2004; Allen 1993; Wyrwoll et al. 1993). From Cape Range to the edge of the continental slope, from the coastal plain to the

Muiron Islands, the Ningaloo Coast encompasses habitats demonstrating the principal biological, structural, geomorphological and hydrologic characteristics of a complex limestone structure.

Exmouth Peninsula has been described as 'one of the great geological set pieces of the state' (Carter 1987). Its magnificent limestone canyons and escarpments, karst geomorphology, coastal dunes, alluvial fans, tidal estuaries and structural and geographic proximity to Ningaloo Reef are among its outstanding landscape values, and accentuate the connection between land and sea (Carter 1987; EPA 1999). Several of the area's physiographic units can be included in a functioning karst system (Hamilton-Smith et al. 1998), including Cape Range, the coastal plain, near shore environments and the reefs of Ningaloo and the Muiron Islands. These environments are connected hydrologically, providing a range of environments from elevated dry habitats to entirely aquatic ecosystems. The best preserved karst habitats are along the crest of Cape Range and the coastal plain karst, extending offshore some distance and including the Ningaloo Reef – Muiron Islands system (Russell 2004).

The western side of Cape Range includes a striking series of four limestone terraces, extending 90 kilometres along the range. These emergent reef complexes represent several periods of coral reef development. The modern reef provides the most recent phase of reef-building. The lowest and youngest of the four principal terrestrial terraces (the coastal plain, or Tantabiddi Terrace which is from 800-1,600 metres wide and six metres above sea level) includes fossil reef fauna with strong species overlap with the adjacent living reef (Ningaloo Reef). The intervening terraces are Jurabi Terrace, Milyering Terrace and Muiron Terrace. Muiron, the highest, reaches 55 metres above sea level. They record the uplift and still-stand history of Exmouth Peninsula and the responses of reef fauna to environmental changes over time (Russell 2004). The sediments deposited in the modern reefs and lagoons of Ningaloo Reef are believed to be very similar to the younger terrace deposits fringing Cape Range (van de Graaf et al. 1976). The soil cover, associated algae and plant communities of the peninsula, as well as the chemistry of sea water and terrestrial run-off are important components in the maintenance of the unique subterranean ecosystems of Exmouth Peninsula (EPA 1999). The hydrological and structural setting extends far beyond the reef and range. Consequently, ecosystem function and the resilience of the limestone system from karst to reef depends on maintenance of trophic structure and protection of marine and terrestrial diversity.

Anchialine systems characteristically consist of a freshwater lens floating above saline water, with subterranean connections to the sea. The chemical and thermal properties of the water cause distinct stratification, supporting highly specialised ground-water species. Many of these species are restricted to a narrow chemical or temperature range within the system, preventing them moving above or below a particular water layer (Gillieson, Humphreys and Spate 2006). The Ningaloo Coast demonstrates exceptional biodiversity as an integrated terrestrial-marine-anchialine limestone system. The caves, subterranean waterways, associated marine hydrological system and surface drainage of the Ningaloo Coast are critical for maintaining the internationally important cave fauna of Exmouth Peninsula.

There is no directly comparable area in Australia or the world. The Great Barrier Reef World Heritage Area contains no significant karst areas. The Barrow Island subterranean fauna is not as rich as the Exmouth Peninsula system (Gillieson, Humphreys and Spate 2006). Structurally comparable cenotes of the Gambier region in South Australia do not form part of an integrated limestone system with a coral reef.
The best comparable international site is the World Heritage listed Reserva de la Biosfera de Sian Ka'an, Mexico, which incorporates cenotes, limestone coast and coral reefs. However, it is a wet tropical region, unlike the semi-arid Ningaloo Coast. Furthermore, the subterranean faunas of Cape Range and the marine habitats of Ningaloo Reef are of comparable richness to the Mexican site (WCMC 1996a; Gillieson, Humphreys and Spate, 2006).

The integration of the Ningaloo and Muiron Island Reefs and Exmouth Peninsula karst system as a cohesive limestone structure is at the heart of the natural heritage significance of the Ningaloo Coast. As a time-series of coral reefs and an evolving karst system, its geological, ecological and hydrological unity harmonises its present ecosystem functions with its evolutionary history.

Unique in Australia, the Ningaloo Coast karst, the wave-cut terraces, limestone plains, Pleistocene reef sediments of Exmouth Peninsula and associated terrestrial, marine and subterranean ecosystems have outstanding heritage value to the nation under criterion (d) for demonstrating the principal characteristics of a complex, geologically and biologically integrated limestone system.

The nominator claimed that rich Cretaceous fossil outcrops in Giralia Range provide outstanding examples of both marine and terrestrial biogeography, zoogeography and evolutionary processes.

Some of the richest Maastrichtian marine sediments in the world are exposed in Giralia Range. They preserve index fossils which are invaluable tools for global stratigraphic correlation, as well as a collection of fossil marine macro-invertebrates and corals of exceptional richness and diversity, unmatched in Cretaceous sediments in Australia. The site also preserves the only example in Australia of the Cretaceous-Tertiary (K/T) boundary contact, the geological embodiment of the transition between the Mesozoic and Cenozoic eras marked by the extinction of the dinosaurs, their flying and marine relatives, and countless marine invertebrates.

The Giralia Range fossil sites warrant a full assessment, which will require analysis against all criteria. Including Giralia Range within the boundaries of the Ningaloo Coast National Heritage Place weakens the focus on the Ningaloo Reef – Exmouth Peninsula system as an integrated limestone structure.

The fossil outcrops in Giralia Range might have outstanding heritage value to the nation under criterion (d) for demonstrating the principal characteristics of an end-Cretaceous marine reef environment about to be annihilated, and as the only exposed Cretaceous-Tertiary boundary contact found in Australia.

CRITERION (e) – ***The place has outstanding heritage value to the nation because of the place's importance in exhibiting particular aesthetic characteristics valued by a community or cultural group.***

The nominator claimed the Ningaloo Coast is of outstanding natural beauty, with Ningaloo Reef being the largest fringing coral reef in Australia. The claim included a description of the sparkling blue waters in the shallow enclosed lagoon, clean sand beaches, the white surf breaks on the reef as it tops the steeply sloping continental shelf, beyond which lies the deep blue waters of the open ocean, all contrasting sharply with the red soils of the ancient and rugged limestone Cape Range with its scattered acacia scrub and spinifex vegetation.

While a comparative study of the aesthetic value of Australian landscapes ranked the Ningaloo Coast of low to medium significance to the nation against a set of aesthetic indicators (Crocker and Davies 2005), the authors added the caveat that remote sites may warrant later reassessment as they become better known and visitation increases. The reef's profile within Western Australia, nationally and internationally has increased since acclaimed novelist Tim Winton fronted a campaign to prevent a controversial tourist development at Coral Bay between 2000-2003 (Winton 2003). Images of the reef juxtaposed against Cape Range exhibit striking topographic and colour contrast. Colourful reef species in the marine park provide a spectacular attraction to swimmers, glass-bottomed boats and light planes. The reef's accessibility makes it an important site for human interaction with colourful, attractive reef biota (DEW 2007a). While observers appreciate the visual beauty of coral reefs throughout the Indo-Pacific region, the proximity of Exmouth Peninsula distinguishes Ningaloo from other reefs; the superposition of the steeply rising range above the narrow coastal plain, together with the juxtaposition of blue water, white sand and red cliffs and gorges makes a splendid contrast (Done 2004; Russell 2004; WHCCC 2004).

However, while the local community may value the aesthetic characteristics of the Ningaloo Coast, there is insufficient information to demonstrate that this is of outstanding heritage value to the nation when compared with other local attractions elsewhere in Australia. While tourists and divers may value the experience of swimming with reef biota, there is insufficient evidence to demonstrate that this experience has outstanding heritage value to the nation.

More work needs to be undertaken to assess whether the aesthetic characteristics of the Ningaloo Coast are sufficiently valued by a particular community or cultural group to find the place has outstanding heritage value to the nation under criterion (e).

The nominator claimed the Ningaloo Coast has outstanding heritage value to the nation under criterion (e) as 'a cherished part of Western Australia's coastal heritage' because of its accessibility, its importance to both tourists and scientists, its extensive marine history, its important association with early exploration and with maritime navigation. The nominator further claimed that the wreck of the Portuguese *Correio da*

Azia has outstanding heritage value to the nation under criterion (e) as an important part of Western Australia's pre-colonial history and the lighthouse at Vlamingh Head has outstanding heritage value to the nation as it used to be 'one of the main navigation aids as ships travelled from Asia and western ports down the west coast of Australia'.

These claims communicate community and historic values rather than aesthetic value and have been considered respectively under criteria (g), (h) and (a).

CRITERION (f) – ***The place has outstanding heritage value to the nation because of the place's importance in demonstrating a high degree of creative or technical achievement at a particular period.***

Evidence from Cape Range shows that Indigenous people used marine resources as food and modified marine shells for personal adornment. Personal ornamentation has long been recognised as a hallmark of modern human behaviour (d'Errico *et al*. 2005; Mellars 2005), and beads and pendants are among the oldest unambiguous evidence of this symbolic behaviour (Balme and Morse 2006, 799).

Twenty two small cone shell beads recovered from Mandu Mandu Creek rock shelter show evidence of deliberate modification, including perforations and holes which would have allowed for the threading of string. Dating of baler shell found in the same stratigraphic unit as the shells and beads provides a date of more than 32,000 years BP (Balme and Morse 2006). The shells were identified as *Conus dorreensis*, a species of mollusc not normally consumed by humans as they are venomous, further strengthening the argument for ornamental use. Ochre and fragments of tusk shell (*Dentalium sp.*) and pearl shell (*Pinctada sp.*), material typically associated with human decoration, were found in later Pleistocene levels at Mandu Mandu Creek (Balme and Morse 2006).

Balme and Morse (2006) note the high level of standardisation in the manufacture of the Mandu Mandu Creek shell beads. The techniques used to manufacture the beads ensured standardisation in the size distribution within each group of beads. Cultural modification of marine shell was practiced by the people of Exmouth Peninsula into the Holocene period - artefacts including cone shell beads, baler shell pendants, knives and dishes, and flaked giant clam adzes have all been recovered from shell middens (Morse 1993; Morse 1996; Przywolnik 2003). Tusk shell beads are still made in coastal parts of the Kimberley today (Balme and Morse 2006, 806).

Pleistocene shell beads have also been recovered from Riwi, a small rock shelter in the Kimberley region dated to ca. 30,000 years. Tusk shell beads have also been recovered from Carpenter's Gap Shelter 1, a cave located a further 200 kilometres to the west of Riwi. However, the precise age of these shell beads is not available (O'Connor 1995).

The only other examples of personal ornaments with a Pleistocene date are beads and a perforated stone object recovered at Devil's Lair in the southwest of Western Australia. These items are dated to between 19,000 and 12,700 BP (Dortch 1979). The beads were made from the limb bones of macropods and were manufactured by cutting the bone shafts into short segments and grinding them smooth on abrasive stone (Morse 1993, 882; Marwick 2007, 85).

The evidence for standardisation in size and manufacture of the shell beads found at Mandu Mandu Creek rock shelter, coupled with the fact they provide the earliest unequivocal evidence for the creation of personal ornaments in Australia, demonstrates a high degree of creative and technical achievement.

On the above basis, Exmouth Peninsula and the shell beads that were found in association with the place have outstanding heritage value at the national level under Criterion (f) for demonstrating a high degree of creative and technical achievement during the Pleistocene epoch.

CRITERION (g) – The place has outstanding heritage value to the nation because of the place's strong association with a particular community or cultural group for social, cultural or spiritual reasons.

The nominator claimed (under criterion e) that the Ningaloo Coast has outstanding heritage value to the nation as 'a cherished part of Western Australia's coastal heritage' because of its accessibility and importance to both tourists and scientists.

Tourists and scientists do not appear to meet the definition for a community or cultural group. They do not reside in, or share a heritage in a specific locality, and they do not share a common ethnicity or cultural background required for a cultural group. Accessibility is unlikely in itself to be sufficient justification for National Heritage listing.

There is insufficient evidence to support the claim that the Ningaloo Coast has outstanding heritage value to the nation for its accessibility and importance to scientists and tourists.

CRITERION (h) – ***The place has outstanding heritage value to the nation because of the place's special association with a person, or group of persons, of importance in Australia's natural or cultural history.***

The nominator claimed that the Ningaloo Coast has outstanding heritage value to the nation because of its important association with early exploration and with maritime navigation.

Many sites along the Australian coast, from the National Heritage listed Kurnell Peninsula and Recherche Bay (respectively in New South Wales and Tasmania) to Encounter Bay in South Australia to Albany and the National Heritage listed *Batavia* sites in Western Australia have associations with early explorers and maritime navigation, and there is insufficient evidence to demonstrate that the Ningaloo Coast is more important than any of these places (AHDB 2005a; AHDB 2005b; AHDB 2006).

There is insufficient evidence to support a claim of outstanding heritage value to the nation under criterion (h).

CRITERION (i) – ***The place has outstanding heritage value to the nation because of the place's importance as part of Indigenous tradition.***

The nominator claimed that the Indigenous heritage values of the place are 'of outstanding significance to Indigenous people who have a long association with the coastal waters and the Cape Range, particularly the western coastal margin'. The nominator's evidence under this criterion has been dealt with under Criteria (a) and (c).

There are six places within the nominated area that are registered on the WA DIA Register of sites as ceremonial and or mythological site types.

There is currently insufficient evidence to demonstrate that the place has outstanding heritage value to the nation as part of Indigenous tradition.

History:

Geological history

Australia's western margin is 'one of the classic passive continental margins in the world' (Kendrick et al. 1991). It originated as a rifted margin, opening progressively from north to south during the successive break-up of the supercontinents Pangaea and Gondwana from about 160 to 50 million years ago, as the Indian Ocean opened, the Indian and Australian plates separated and the former moved north. A number of sedimentary basins formed with the rift, including the Carnarvon basin. The thousands of metres of sedimentary rocks in the basin date from the Paleozoic (beginning 545 million years ago) to the Holocene (present day) (EA 2002a; Veevers 2006).

Uplift along the Western Australian coast has occurred intermittently since the late Cretaceous, producing the anticlinal ranges of the Ningaloo Coast and Exmouth Gulf region. Much of the area that now comprises Western Australia was covered by large shallow epeiric (continental) seas during the Cretaceous, and the rocks that have produced the surface expression of the region are predominantly calcareous, made from the silt and mud and the bodies of billions of marine organisms deposited on the sea bottom over thousands of millennia.

Cape Range itself and its extension in the Muiron Islands are composed of mostly calcareous sedimentary rocks deposited in shallow seas since the Pliocene less than six million years ago, overlain by and interbedded with the alluvial, littoral and shallow marine sediments of the bordering coastal plain as sea

levels rose and fell. Cape Range probably emerged as an island during the Pliocene after which karstification might have extended rapidly down in karst-prone sediments, proceeding laterally as the range emerged from the sea. During sea level lowstands, as at glacial maxima during the Pleistocene, karstification continued into areas that are now offshore, accompanied by incision of the modern drainage (Allen 1993).

During the glacial-interglacial cycles of the Quaternary, Australian landscapes were increasingly subject to cold aridity or 'dust ages' rather than ice ages, as the polar ice sheets, high-altitude tropical glaciers, and mountain and high-latitude glaciers of Europe, Asia and North America expanded. Australia drifted northward into drier climates and dune fields activated across the expanding arid and semi-arid zones, preserving in sediment a record of the prevailing winds of the time. During interglacial periods, sea level rose as the polar ice caps melted, and the arid zone contracted (Bowler 1978; Bowler 1982a). The last phase of glacial aridity, commonly known as the last glacial maximum, began about 25,000 years before present (BP) (Morse 1996). This was a time of intense aridity and colder conditions which peaked between 19,000-17,000 years BP (Morse 1996; O'Connor and Veth 2006). The present interglacial – the Holocene epoch – began around 12,000 years BP.

The last interglacial (lasting from about 135,000-85,000 years ago) featured a period of high water and reef expansion between about 135,000-125,000 years ago, represented at Exmouth Peninsula in the Tantabiddi terrace. At times during the last interglacial, Lake Macleod formed an embayment of the Indian ocean, and might have connected via a channel to Exmouth Gulf, isolating Cape Range as an island once more. The modern Dirk Hartog Island, in the Shark Bay World Heritage Area, is a possible analogue for Exmouth Peninsula at times of higher sea level during the Pleistocene. At the last glacial maximum, the now inundated red Pleistocene dune fields of Exmouth Gulf extended into a low coastal plain which began to be submerged beneath the rising waters of the gulf as the polar ice caps melted during the Holocene.

The western flank of Cape Range is fringed by a striking series of well-defined wave-cut terraces. From 60 metres at their highest point, to around six metres above sea level at their lowest, these terraces record uplift and sea level change from the Pliocene to the last interglacial, and provide a series of reefs and high water stands through time, culminating in the living Ningaloo Reef. Ningaloo Reef dominates the coastal geomorphology in the west of the region. There is currently little data on the growth history of the reef. It was formed from the late Pleistocene to early Holocene, between 60-10,000 years ago (Wyrwoll et al. 1993). The lowest of the terrestrial terraces (the Tantabiddi terrace) represents a previous high water mark and reef-building episode. Dates for the higher, older terraces remain inconclusive. Each of these reefs, in chronological succession, contains progressively fewer coral genera in common with the modern reef (Veeh et al. 1979; Wyrwoll 1993).

Indigenous history

General Archaeology

A rich assemblage of materials preserved in the limestone rock shelters of Exmouth Peninsula show that Indigenous people had a comprehensive and sophisticated knowledge of marine resources between 35,000 and 17,000 years ago (Morse 1993a, 1993c; Przywolnik 2005). The discovery of shell beads at Cape Range dated to more than 32,000 years BP also provides the earliest evidence for personal ornament in Australia (Morse 1993b). At this early time, Cape Range would have overlooked a gently sloping coastal plain stretching some six kilometres to the western shoreline (Morse 1988). Archaeological evidence recovered from rock shelters on the peninsula suggest that Indigenous people were episodically occupying these places, perhaps on a seasonal basis, from 35,000 to 17,000 BP. They utilised a diverse range of edible and non-edible marine fauna including crab, fish, sea urchins, molluscs and bivalves, and included a range of arid plains fauna in their diet. A predominance of sandy bottom mollusc species including baler shell (*Melo sp.*), pearl shell (*Pinctada sp.*), tusk shell (*Dentalium sp*.) and bivalves suggest a reefed or rocky shore was not a dominant coastal feature during this time (Morse 1999, 74).

During the height of the last glacial maximum, sea levels around the world dropped to about 150 metres below their current level as sea water was taken up by enormous ice shelves that blanketed parts of the earth. At this time, the retreat of the shoreline would have been less dramatic at Exmouth Peninsula than elsewhere in Australia, as it is just ten kilometres from the modern shoreline to the 200 metre bathymetric contour of the continental shelf. Even during the height of the last glacial period, rock shelters in the western foothills of Cape Range would never have been more than ten to twelve kilometres from the coast

(Morse 1999). While there appears to be a hiatus in occupation across northwest Australia during the height of the last glacial maximum (O'Connor 1996, 1999, 2007; Veth 1993), archaeological evidence suggests that Pilgonaman Creek rock shelter on Cape Range may have been occupied at this time (Morse 1993a, 1993c).

Following the last glacial maximum, the warming of the atmosphere led to the slow rise of sea levels and the return of people to the Cape Range area. The coastline would have been considerably different to that prior to glaciation. While a broader range of rock shelters are occupied after the last glacial maximum, there appears to be a similar resource use pattern to that found in the Pleistocene, with people exploiting marine and terrestrial resources. At Pilgonaman Creek and Yardie Well rock shelters terrestrial fauna dominate the assemblage, with an increased diversity in marine resources at the end of the Pleistocene and early Holocene, when the coast was only two to three kilometres from the rock shelter. According to Przywolnik (2005, 190) evidence of mangroves appear for the first time on the northern part of the peninsula at around 10,730 BP, when fragments of mud whelk (*Terebralia palustra*) appear in the Jansz rock shelter deposit. With the advancing sea levels, the early Holocene coastline would have provided a variety of marine habitats (mangroves, rocky coasts and sandy bottoms), a rich resource base to sustain human populations.

It is also during this phase that rock art first emerges in the area, and for a few thousand years white ochre motifs are painted on the walls of the C99 rock shelter (Przywolnik 2005). Both Jansz and C99 rock shelters are abandoned for a second time, ca. 8,000 BP, coinciding with the decline of mangrove habitat on the peninsula. Mandu Mandu Creek rock shelter was not occupied at all during this period (Morse 1999). The earliest shell middens in the nominated area date to around the early mid-Holocene on the Warroora coast and nearby Coral Bay. The Warroora midden dated to 7,810 BP and the Mulanda Bluff midden (7,210 BP) both contain remains of *Terebralia* shell (Morse 1996).

Archaeological evidence suggests that an intensification of occupation began ca. 6,000 BP when sea levels stabilised at their current levels. Rock shelters and shell middens show a similar marine faunal assemblage to that of the Pleistocene with the addition of more turtle bone and shell, and an expanded terrestrial faunal assemblage (Morse 1993a). There is also a change in the type of stone used during this period with exotic fine-grained stone being introduced to sites and a new tool assemblage, including tula adzes, burren adzes and backed artefacts and points. Tula adzes and burren adzes were used for woodworking, while backed artefacts and points were used in hunting. New rock art motifs painted in red rather than white ochre also appear, showing stylistic similarities with rock art found in the Pilbara and Murchison regions (Przywolnik 2005, 191 and 200). These late Holocene developments are indicative of growing social and economic networks with groups from outside the peninsula. During the Holocene changes in technology and food preferences conform to the established sequence in the Pilbara and other parts of northern Australia.

Relations between Europeans and Indigenous people
Early ethno-historic descriptions of the original Indigenous people occupying Exmouth Peninsula are few. This is in part attributed to the area's evaluation as offering little early agricultural potential and as hazardous to shipping, resulting in little exploration and visitation.

The first recorded European contact with North West Cape was a sighting by the crew of the Dutch ship Zeewolf in 1618. Later the same year, the first known landing by a European was made by Captain Jacobz of the ship Mauritius (DEWHA 2007b).

An early proposal to establish a northwest colony for the purpose of cultivating cotton was championed by surveyor Francis Thomas Gregory in 1861. He recorded a meeting with local Indigenous people:

On our return to the 'Dolphin' we found that she had been visited by two natives, who had paddled off on logs of wood, shaped like canoes, not hollow, but very buoyant, about seven feet long and one foot thick, which they propelled with their hands only, their legs resting on a little rail made of small sticks driven in on each side (Gregory 1884, 56).

Other early interactions between Europeans and the Indigenous people of Exmouth Peninsula came about as a result of a shipwreck on North West Cape in 1876. The book *The Stefano Castaways* is a translation of an original manuscript recording the experiences of two shipwrecked sailors from the barque *Stefano*. It

describes the *Yinikutira* (*Jinigudira*) and their daily activities, including food gathering and hunting. Marine resources were their staple foods, in particular fish, turtles and dugong (Scurla cited in Przywolnik 2003, 15). Tindale (1974, 243) also notes that the traditional occupants of the peninsula lived amongst the mangroves and were 'coastal people who went out to sea on rafts of sticks'.

There is no one living who claims direct descent from the Yinikutira people (Dench 1998). Details of what happened to the Indigenous people of Cape Range are unknown. In 1865, the Colonial Secretaries Office in London decreed convict labour was not permitted in areas above the 26th parallel, necessitating the use of Indigenous labour in the pastoral and pearling industries. In 1867 the British Government passed the Masters and Servants Act. This meant that Indigenous people could enter into labour agreements with potential employers, however, Indigenous people absconding from service were pursued and imprisoned if they left the stations or pearling fleets. Absconders ended up doing hard labour at the Roebourne Gaol.

By the 1880s, 'black birding' (forcibly detaining and removing Indigenous people from their traditional lands for work) was a common practice along the Pilbara coast (Randolph and Wallam 1991, 53; Weightman, 2005). Suggestions from ethnographic and linguistic research in regions south and east of the peninsula are that European diseases and the practice of 'black birding' decimated the Indigenous population (Przywolnik 2003, 15).

Pastoral leases were taken up across the Cape Range region, and with the aid of free labour, the pastoral industry in the Gascoyne region flourished. The pastoral strike in the Pilbara region during the 1940s and the subsequent introduction of an award pay resulted in an exodus of Indigenous people into regional centres, including Carnarvon and Exmouth.

In 1997 the Indigenous Land Corporation (ILC) purchased Cardabia Station, one of the early pastoral properties located within the boundaries of the nominated area. The station is a pastoral lease of 199,808 hectares that borders the Ningaloo Marine Park and is adjacent to the small tourist town of Coral Bay. The Baiyungu Aboriginal Corporation was established in 1999 primarily to hold title of the station on behalf of Traditional Owners (ILC 2007).

Traditional Owners in the region have formed a group with representatives of several language groups, known as the *Gnulli*, meaning 'all of us'. Members of this group are recognised as being the traditional custodians of the North West Cape area and have ongoing association with many sites within the nominated area. A native title claim for the area was lodged in 1998 on behalf of the Traditional Owners under the application name *Gnulli*. This claim is still active and a determination has not been made (NNTT 2008).

European settlement history

William Dampier, one of many international mariners to traverse the Western Australian coast over the last four centuries, described the Ningaloo Coast in 1699 (Dampier 1703). Matthew Flinders' narrative *A Voyage to Terra Australis* of 1814 is the earliest known published occurrence of the name 'North-West Cape', although the French navigator Nicolas Baudin named the region 'l'extremité nord-ouest' as early as 1801, and his cartographer Louis de Freycinet named Cape or Point Murat at the extremity of the peninsula, and the Muiron Islands during the same voyage (Péron and Freycinet 1807-16; Flinders 1814; Baudin 1974; Marchant 1988). A number of international wrecks are found in close proximity to each other in and around the waters of Ningaloo Marine Park, including the early nineteenth-century wooden ships the American *Rapid* which sank in 1811 and the Portuguese *Correio da Azia* (1816), the Singaporean *Fairy Queen* (1875, wrecked in Exmouth Gulf), the Austro-Hungarian *Stefano* (1875) and *Zvir* (1902), the Scottish *Benan* (1888), and the Norwegian barque *Iona* (1923) (WAM 2007). Their presence points to the hazard presented by Exmouth Peninsula and Ningaloo Reef to navigators, particularly before the advent of reliable chronometers, when too much easting could be disastrous, and the strong winds and tides made navigating small vessels dangerous.

American whalers operated along the Ningaloo Coast as early as the 1790s, initially targeting sperm whales. With improved understanding of whale migrations, they began to hunt humpback whales. While these men most likely went ashore in search of meat and fresh water, they did not establish any infrastructure. Shore-based whaling occurred for brief periods between 1913 and 1955 at several points along the coast. Divers searching for pearls in the region worked mainly in Exmouth Gulf. Many of the

pearling vessels were wrecked travelling between Exmouth Gulf and Fremantle (EA 2002; DEWHA 2007b).

The beginning of the pastoral industry in the region is marked by the establishment of Minilya Station in 1876. The lease covered the whole of Exmouth Peninsula, and was gradually subdivided into the present leases. Thomas Carter acquired 54,600 hectares on the northern and western side of the peninsula which became Yardie Creek Station. After subsequent subdivision from 1907 followed by amalgamation in 1933, the Western Australian Government acquired the remaining Yardie Creek Station in 1959, and it eventually formed part of the Cape Range National Park, gazetted in 1964. The Shire of Exmouth initiated the gazettal and also recommended the southern extension of the park to Yardie Creek, effected in 1969. In 1972 the newly formed Environmental Protection Authority instigated a thorough review of Western Australia's conservation system, eventually recommending the exclusion for conservation purposes of a number of areas of pastoral leases in the Exmouth region (WHCCC 2004; CALM 1987; CALM 2005b; DEWHA 2007b).

The town site of Exmouth grew around the US Naval Wireless Communication Station, established at North West Cape in 1962. When the communications station opened, Exmouth already had a population of 4,000 people. The town was gazetted on 6 December 1963 and the Shire was gazetted as a municipality in 1964. The town soon became the main service centre for trawling and aquaculture in the region. Tourism, recreational fishing and associated infrastructure followed (WHCCC 2004).

The Western Australian Government gazetted the state waters of Ningaloo inland to 40 metres above the high water mark as a Marine Park in 1987. The boundary included about 90 per cent of the reef, extending from about 260 kilometres from North West Cape south to Amherst Point. In 2004 the state government extended the park boundary south another 40 kilometres to Red Bluff, to ensure protection of the entire Ningaloo Reef (DEC 2008c).

In 2000, a proposal to develop the Coral Coast Resort, a $200 million marina resort at Mauds Landing, stimulated community opposition in Perth, Coral Bay and Exmouth, bringing Ningaloo Reef to national prominence. Between 2000 and 2003 Australian novelist Tim Winton campaigned with a number of non-government conservation organisations to prevent the development and Winton became spokesman for the grass roots 'Save the Reef' movement. In December 2002, Winton spoke at a 15,000 strong rally in Fremantle and on 4 July 2003, the Western Australian Premier, Geoff Gallop announced that the resort would not go ahead (Prior 2002; Winton 2002; Winton 2003). In 2004 the state government announced that it would seek World Heritage listing for the area.

Condition:
Except where otherwise stated, this condition report is based on information contained in the state and Commonwealth management plans for the marine management areas and Cape Range National Park (EA 2002a; CALM 1999; CALM 2005a; CALM 2005b).

The area encompassed by Ningaloo Reef Marine Park (state and Commonwealth waters) and the adjoining Cape Range is relatively undisturbed. Low visitation and limited development, coupled with its isolation from large population centres, contributes to the area's naturalness, the uninterrupted views of seascapes and the remote landscapes of the range and coastal plain.

The water and sediment quality of the marine park is good, due not only to the relative lack of onshore development, but also the limited terrestrial run-off in a region of low rainfall. Coral communities are currently in good condition, though with some localised impacts from recreational and commercial vessels, and associated anchoring and mooring activities. Historical impacts include outbreaks of a coral-eating snail (*Drupella spp.*), which killed much of the coral in local areas of reef in the 1970s and 1990s; other areas have been damaged in the past by low oxygen conditions following decomposition of coral spawn in the absence of currents to disperse it sufficiently. These episodes have normally been followed by periods of recruiting and restoration of the coral. The shoreline intertidal reefs are undisturbed in the main, with some localised trampling and historical coral collection.

Known as rainforests of the sea for their rich and diverse marine communities, coral reefs are, like their terrestrial counterparts, threatened by climate change and overexploitation. It is not clear yet how coral

reefs around the world will respond to ongoing warming events. Coral bleaching due to rising global sea-surface temperatures is one of the biggest threats to their survival and structural integrity. A mean summer maximum sea-surface temperature increase of as little as one degree Celsius can appreciably hinder coral growth for six months. Ocean acidification, a result of increased carbon dioxide uptake by ocean waters, also threatens coral reefs around the world by preventing calcification. Coral and algae are in competition for habitat in reef systems. Sea level rise, while potentially providing more reef habitat, also increases sediment and nutrient influx to reefs, allowing algae to thrive at the expense of coral (McCulloch 2007; Pandolfi 2005, Pandolfi 2007).

Studies of ancient reef systems show that coral reefs have survived or recovered from extreme climate events, testifying to their resilience (Hughes 2007). However, the effect on and hardiness of modern reefs is unknown. The ecological response of corals to climate change is determined by a combination of global and local impacts, with feedback. Human activity and increased greenhouse gases might have reduced the resilience of modern reefs, while the rate of temperature, habitat and sea level change may be unprecedented, limiting the ability of reefs to withstand impacts or recover. Studies of past reef responses cannot be used with certainty to predict future reef responses to climate change. However, while it is not possible to shield a reef from global phenomena like climate change or ocean acidification, management and mitigation of local impacts, for example increasing no-take zones, regulating recreation activities, or reducing sediment and nutrient discharge will enhance its resilience (Boesch et al. 2001; Jackson et al. 2001; Anon. 2007; Hughes 2007; McCulloch 2007; Pandolfi 2005; Pandolfi 2007).

Water, sediment and organisms circulate continually between the different environments of the Ningaloo Marine Park and the Muiron Islands Marine Management Area (EA 2002a). Terry Hughes and colleagues wrote in 2007 that 'the recipe for killing a coral reef is simple': If reef, seabed or associated habitats are compromised, either by predation, contamination or climate change, the ecosystems' trophic structure alters dramatically. Predators like *Acanthaster planci* (the introduced crown of thorns starfish) or *Drupella* affect coral survival and reproduction, compromising the balance of adults and juveniles in a reef. Removing a single population from a reef can lead to widespread reductions in biodiversity and loss of reef structure. For instance, if a species of marine megafauna declines significantly, as other vigorous fish, reptiles and mammals will follow selectively and sequentially. Invertebrates then replace smaller vertebrates, and are in turn replaced by algae. The macroalgae previously controlled by larger herbivores begin to rival corals; coral cover decreases and species diversity continues to decline. The ecological shift from a coral-dominated to fleshy macroalgal reef is accompanied by large scale architectural loss. Structural integrity at Ningaloo as in other reefs depends on the balance of trophic levels (Hughes 2007; McCulloch 2007; Pandolfi 2005; Pandolfi 2007).

Although generally undisturbed, the seagrass beds and macroalgal communities of Ningaloo Marine Park are susceptible to inappropriate anchoring and mooring activities, and to environmental impacts such as oil spill or activities leading to increases in nutrient influx. The mangrove communities within the marine park are in good condition, with some localised disturbance in areas of high use associated with recreational activities, including mudcrabbing, and trampling. The sediments in Exmouth Gulf, including a small area of the marine park, have been subject to significant disturbance over several decades due to trawling.

Impacts to marine fauna species include recreational and commercial fishing and by-catch and physical disturbance of important marine habitats. Inappropriate interactive activities, boat noise or collisions may disturb whale sharks, reef sharks, rays, turtles, whales and dolphins.

The Commonwealth waters of Ningaloo Marine Park are relatively undisturbed. The main human activities are recreational and game fishing, boating, and shipping transport. Some commercial fishing has also occurred in the past. Game fishing is an important activity: an increase in hunting billfish, marlin and tuna, has led to localised depletion of key recreational species. Commercial tuna and billfish long-line fishing and deep water trawl fishing operate adjacent to the boundary of the Marine Park.

There are a number of oil exploration wells to the north-west of the marine park. Two petroleum exploration permit areas immediately abut and incise the Commonwealth waters boundary.

Urban development, limestone quarrying, petroleum and mineral exploration, exploitation of the aquifer, waste disposal, pastoral development and increased tourism all disturb or have the potential to disturb the

ecosystems and landscapes of Exmouth Peninsula.

Recreational use (including camping and vehicle access, firewood collection, and the increased occurrence of fire) has contributed significantly to the deterioration of coastal dune communities adjacent to Ningaloo Marine Park. Other impacts include grazing by feral and domestic animals, and the spread of weed species. Boat strikes and vehicle access to the coastal fringe disturb turtle populations and affect nesting activity. Fox predation of turtle eggs continues to threaten turtles, whose populations have been affected in the past by over-hunting. Some hazards, such as entanglement with fishing nets, have diminished, due to the adoption of turtle exclusion devices by the local fishing industry. There are no feral animals in the Muiron Islands, which protect important turtle nesting sites.

The invertebrate cave fauna of Cape Range is vulnerable to disturbance. Populations have highly restricted distribution, and are sensitive to changes in cave environments. Any adjustment to the quantity or quality of water in the caves and wells of Exmouth Peninsula may adversely affect both the aquatic and terrestrial cave fauna. Water extraction from a number of borefields in the Exmouth area has brought about an upward trend in salinity in the aquifer. Urban and industrial developments are proposed for the area, particularly in the eastern part of the peninsula, with attendant construction impacts, waste run off and disposal issues. Pollution may also enter the cave system as a result of spraying of insecticides against mosquitoes. All these activities may unfavourably affect cave faunas.

Overgrazing has been recorded in parts of the range, and is another source of disturbance both on the surface and underground, leading to increased run off, pollutants and sediments entering the underground system. Exotic fish, harmful to native cave fauna, have been found in more recent housing developments south of Exmouth township. The physical characteristics of cave systems change markedly as visitation increases: touching, trampling, collecting, and the unsuitable disposal of litter damages cave ecosystems.

The resource sector has a number of interests in Exmouth Peninsula, particularly in the quantity of high-grade limestone in Cape Range. The national park, including its proposed additions, are subject to a variety of mining tenements and reserves, along with petroleum exploration permits, although there is no active production at present. Mining in the karst environment of Cape Range has a number of impacts, including localised destruction of caves and other karst features, along with disturbance on a broader scale, including to the hydrology of the karst system and to the faunal communities it supports.

Thirty weed species are recorded from the peninsula, most of which occur around Exmouth township. Significant weed invasion has also occurred in the Yardie Creek gorge. On the western coastal plain, buffel grassland has replaced the native *Triodia* grassland. Introduced mammals are well established in the area, including goats and foxes.

Bone accumulations in the cave deposits of Cape Range suggest that more than half the original mammal species of Exmouth Peninsula have become extinct since European colonisation. This reflects a trend across Australia (Baynes and Jones 1993).

Only a handful of the caves and rock shelters of the Cape Range region have been investigated for their archaeological potential (O'Connor 2007). The rock shelters considered in this assessment – Mandu Mandu Creek, Pilgonaman Creek, Jansz and C99 – all have relatively undisturbed living deposits. These dry limestone caves have provided excellent preservation conditions for terrestrial and marine faunal remains.

A number of open midden sites are also located on Exmouth Peninsula. These deposits, generally found in dune blowouts and swales behind the foredunes, vary in size, composition, location and density (Przywolnik 2005). All of these sites have to varying degrees been affected by severe weather in the form of tropical cyclones, contributing to their current appearance and condition (Przywolnik 2002).

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