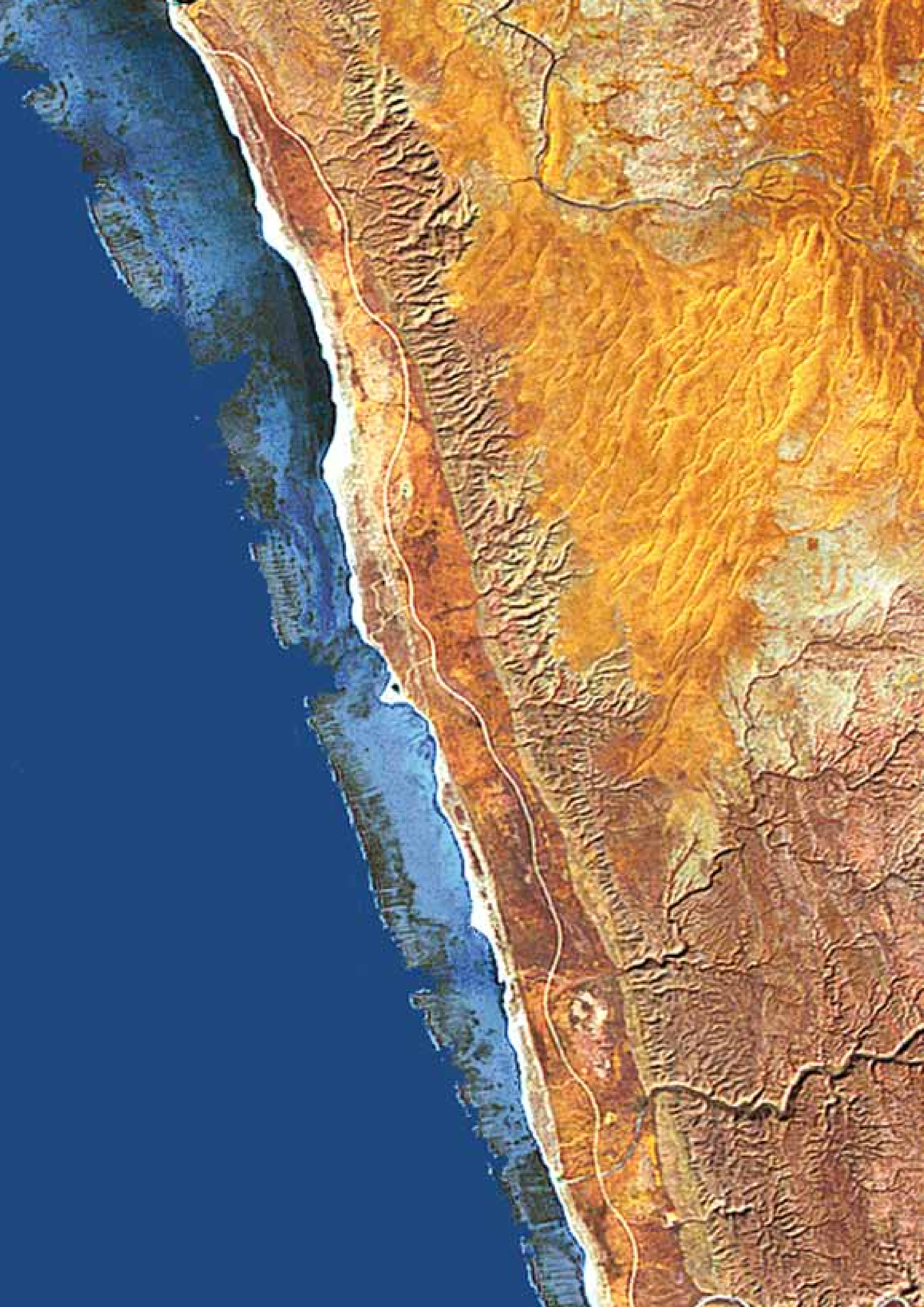
Ningaloo Coast

WORLD HERITAGE NOMINATION



Ningaloo Coast

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Ningaloo Coast: World Heritage nomination

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EXECUTIVE SUMMARY

State Party

Australia

State, Province or Region

Western Australia

Name of Property

Ningaloo Coast

Geographical coordinates to the nearest second

22° 33' 45.4896"S, 113° 48' 37.3176" E

Textual description of the boundary of the nominated property

708,350ha, in the mid-west coast of Western Australia, being: (1) a coastal strip extending from North West Cape about 260km south-south-west to Red Bluff, and (2) adjacent marine areas, reefs and islands. The area generally comprises:

- Ningaloo Marine Park (Commonwealth Waters)
- Ningaloo Marine Park (State Waters)
- Muiron Islands Marine Management Area (including the Muiron Islands)
- Jurabi Coastal Park
- Bundegi Coastal Park
- Cape Range National Park
- Learmonth Air Weapons Range
- Northern and western parts of Vacant Crown Land west of Learmonth town
- North-west part of Exmouth Pastoral Lease
- Northern part and western coastal strip of Ningaloo Pastoral Lease
- Western coastal strips of Cardabia, Warroora and Gnaraloo Pastoral Leases, and
- North-west coastal strip on Quobba Pastoral Lease.

Exclusions:

- North West Cape Area A
- Shire of Exmouth sand pit
- Coral Bay town area, and
- Cardabia, Warroora, Quobba and Gnaraloo Homesteads.

A4 (or "letter") size map of the nominated property, showing boundaries and buffer zone (if present)

See Map 1

Justification: Statement of Outstanding Universal Value

The Ningaloo Coast tells an extraordinary story of biogeography, climate change, the assembling of continents and the opening of oceans, biological richness and environmental conservation. It is one of the best places to encounter the remarkable whale shark, the world's largest fish, which aggregates here in higher numbers than have been recorded anywhere else. Its dramatic setting and rich biology reveal a long record of continental change, isolation and evolution. The property has outstanding biological diversity, and plays an internationally significant role in the protection of marine species. All of these features are extremely well preserved—the management of the Ningaloo Coast demonstrates some of the world's best practice in tropical marine, terrestrial and karst management. The juxtaposition of deep ocean and one of the world's largest nearshore reefs with an arid and ancient continental shore is at the heart of the property's geological, biological and aesthetic value.

Criteria under which property is nominated

The Ningaloo Coast is nominated to the World Heritage List under criteria (vii), (viii) and (x) for containing:

- superlative natural phenomena and areas of exceptional natural beauty and aesthetic importance;
- outstanding examples representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features, and
- the most important and significant natural habitats for in situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

Name and contact information of official local agency

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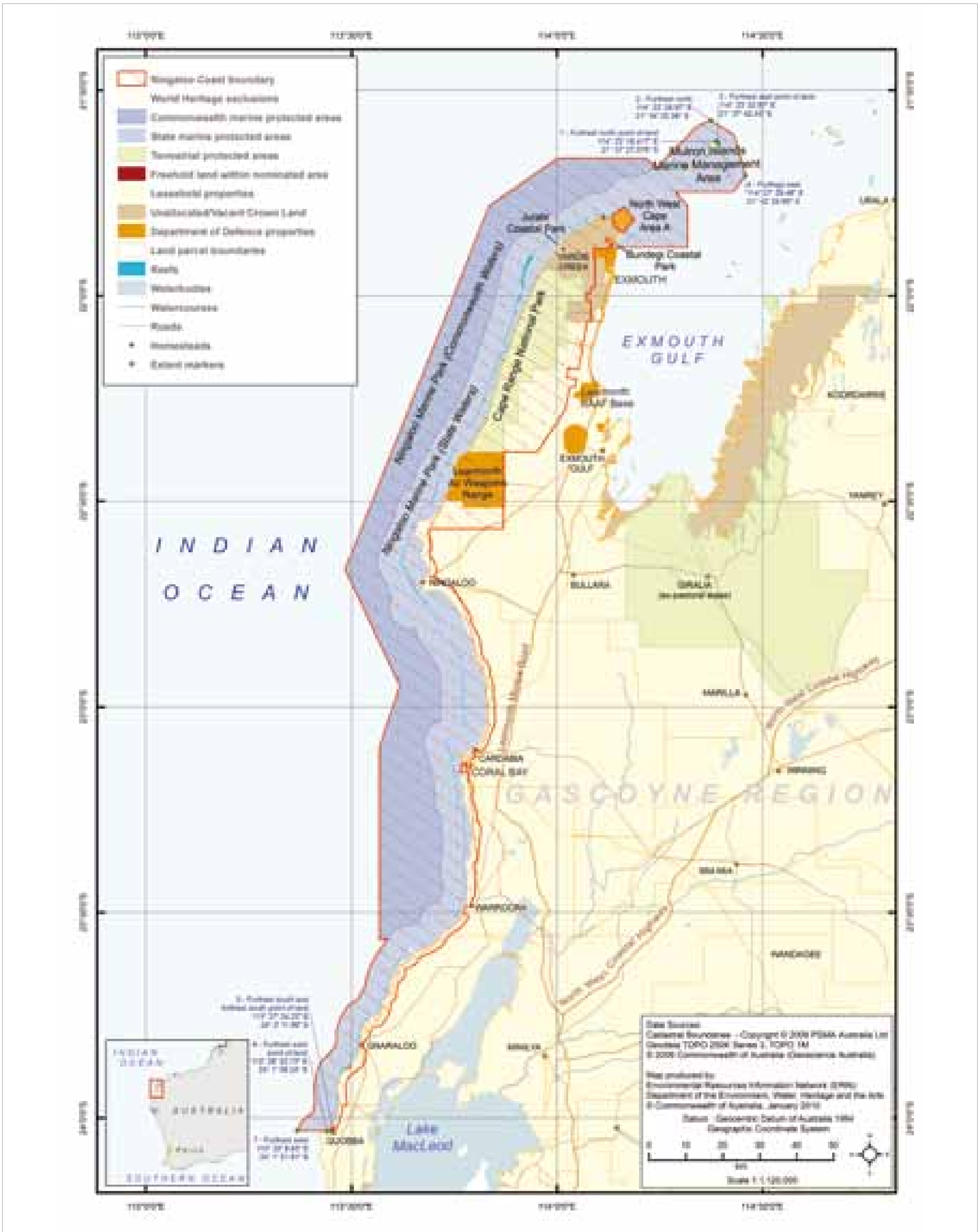
Email: jane.ambrose@environment.gov.au

Web: www.environment.gov.au

Map 1: Boundaries of the nominated property



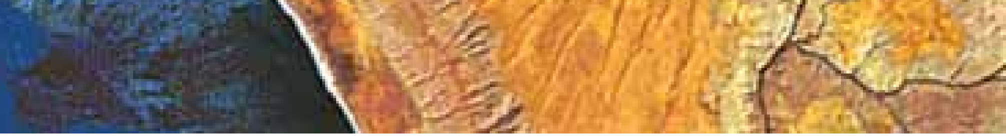
KEY TERMS

Anchialine	a land locked body of water with a subterranean connection to the ocean. The water in an anchialine system is stratified, with fresh or brackish water overlying saline. This intrudes from the coast at depth, or via rainfall, and percolates through the porous rocks, usually of limestone or recently–formed volcanics.
Barrier reef	an organic reef complex roughly parallel to the shore and separated from it by a lagoon of variable depth and width. It may enclose a volcanic island (either wholly or in part), or it may lie a variable distance from a continental coast (such as the Great Barrier Reef off the coast of Queensland, Australia). Generally, barrier reefs follow the coast for long distances, often with short interruptions, termed passes or channels. Large barrier reef complexes like the Great Barrier Reef include fringing reefs, patch and platform reefs, bomboras, atolls and other coral formations.
Biogeography	the study of factors affecting biological distribution over space and time. These include changes in geology, oceanography and climate.
Endemism	natural restriction of a plant or animal to a particular region.
Fringing reef	an organic reef that is attached to or borders the shore of an island or continent, having a rough, tablelike surface that may be exposed at low tide. The width of a fringing reef can vary from a few metres to more than one kilometre. Its seaward edge slopes sharply down to the sea floor. There may be a shallow channel or lagoon between the reef and the adjacent mainland. It may be structurally and biologically identical to a barrier reef, distinguished only by the size or absence of an intervening channel.
Geoecological structure	a landscape feature or system resulting from complex interactions of biotic and abiotic processes through time; for example a living coral reef and limestone karst system.
Gondwana	a Palaeozoic supercontinent comprising South America, southern Africa, Madagascar, India, Australia, New Zealand, New Caledonia and Antarctica. During the late Triassic period, this giant landmass formed part of the supercontinent Pangaea. Gondwana became isolated again when Pangaea broke apart during the Jurassic period. Gondwana itself gradually broke apart during the rest of the Mesozoic era, until Australia finally drifted north from Antarctica in the middle Cenozoic era (Figure 2.2).
Karst	landscape and features formed by the chemical solution of rock, most commonly limestone and other carbonate rich rocks. Karst landscapes are characterised by closed depressions, subterranean drainage, characteristic solution forms and caves.
Pandemism	global or very widespread geographic distribution of a plant or animal.
Phylogeny	the evolutionary history and line of descent of a group of organisms; the study or history of such relationships.
Refugia	areas that have maintained a relatively stable environment over time so that relictual communities of plants and/or animals have survived, and often evolved into taxonomically distinct species.

Remipede	a class of blind, colourless crustacean found in anchialine systems. Remipedes are only known from a handful of sites in the Caribbean Sea and North Atlantic Ocean, and a single species, *Lasionectes exelyi*, found in the Ningaloo Coast's Bundera Sinkhole. The global distribution of remipedes can help explain the movement of continents and the opening of oceans over tens of millions of years.
Rhincodon typus	scientific name for the whale shark, the world's largest fish. The whale shark is the only living member of its genus and of the family Rhincodontidae.
Stygofauna	troglobite fauna that live entirely aquatic lives in caves, aquifers and other groundwater habitats.
Troglobite	fauna living permanently underground and generally beyond the daylight zone of a cave.
Troglofauna	a general term for all cave fauna; any creature having a cave-dwelling mode of life.
Vicariance	the separation of a group of organisms by a geographic barrier, resulting in differentiation of the original group into new varieties or species.

1

IDENTIFICATION OF PROPERTY



1

1A COUNTRY

The nominated property is located within the country of Australia.

1B STATE, PROVINCE OR REGION

The nominated property is located in the state of Western Australia.

1C NAME OF PROPERTY

NAME OF PROPERTY (1.C)	STATE, PROVINCE OR REGION (1.B)	GEOGRAPHICAL CO-ORDINATES (1.D)	AREA	BUFFER ZONE	TOTAL
			(1.F) (TO NEAREST .00 HECTARE)		
Ningaloo Coast	Western Australia	22° 33' 45.4896" S, 113° 48' 37.3176" E	708,350	N/A	708,350

› **TABLE 1.1** Name of site, location details and size of the property.

1D GEOGRAPHICAL COORDINATES

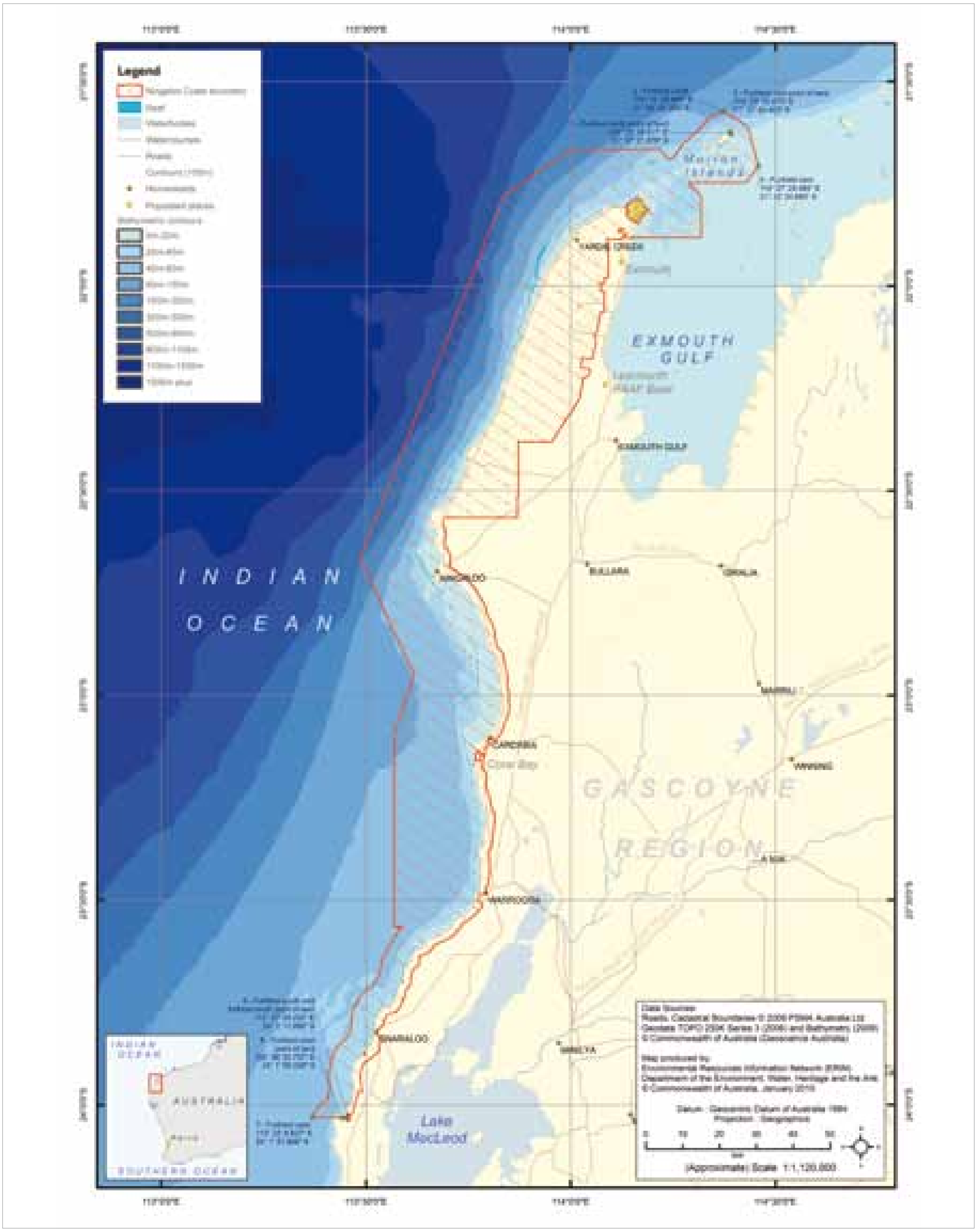
22° 33'45.4896" S, 113° 48'37.3176" E

› **FIGURE 1.1** The dappled pattern of the reef mirrors the scattered vegetation on the range.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

› **PREVIOUS PAGE** Photograph Tony Howard © Western Australian Department of Environment and Conservation

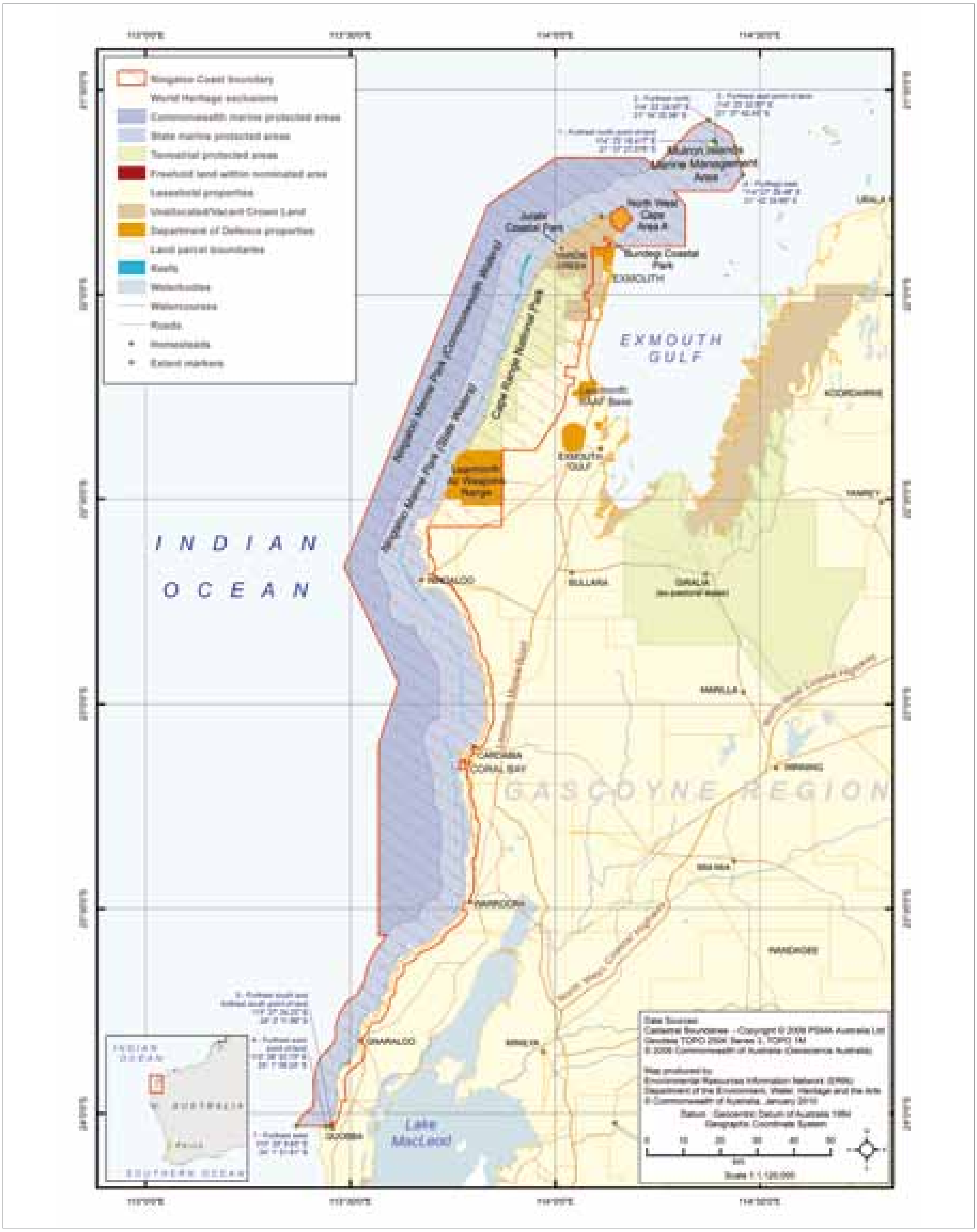
1E MAPS AND PLANS

(i) Maps of the nominated property



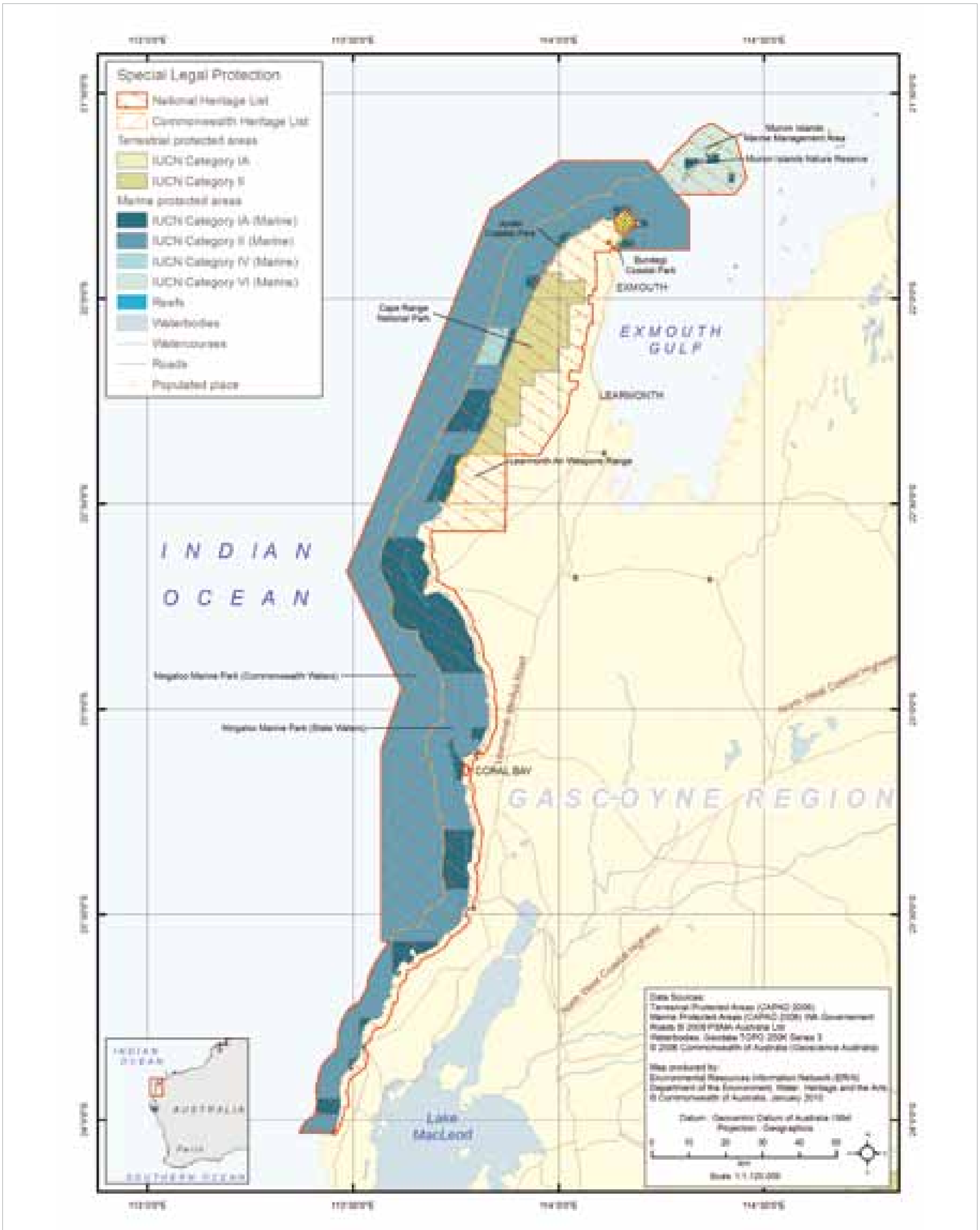
MAP 1.1 Topographic map showing the boundaries of the nominated property.

Maps of the nominated property (continued)

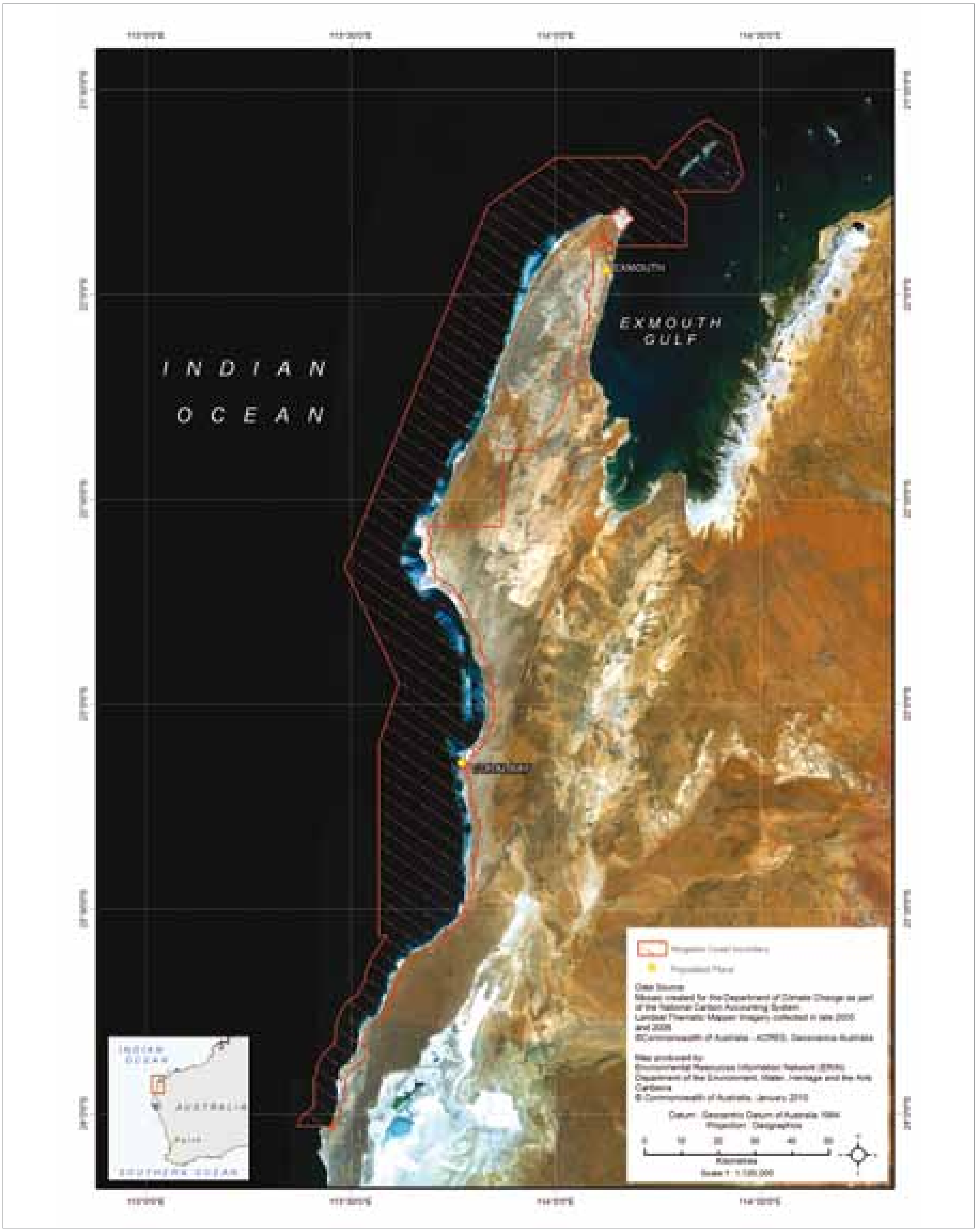


MAP 1.2 Boundaries of the nominated property and associated land tenure.

Maps of the nominated property (continued)



MAP 1.3 Zones of special legal protection.

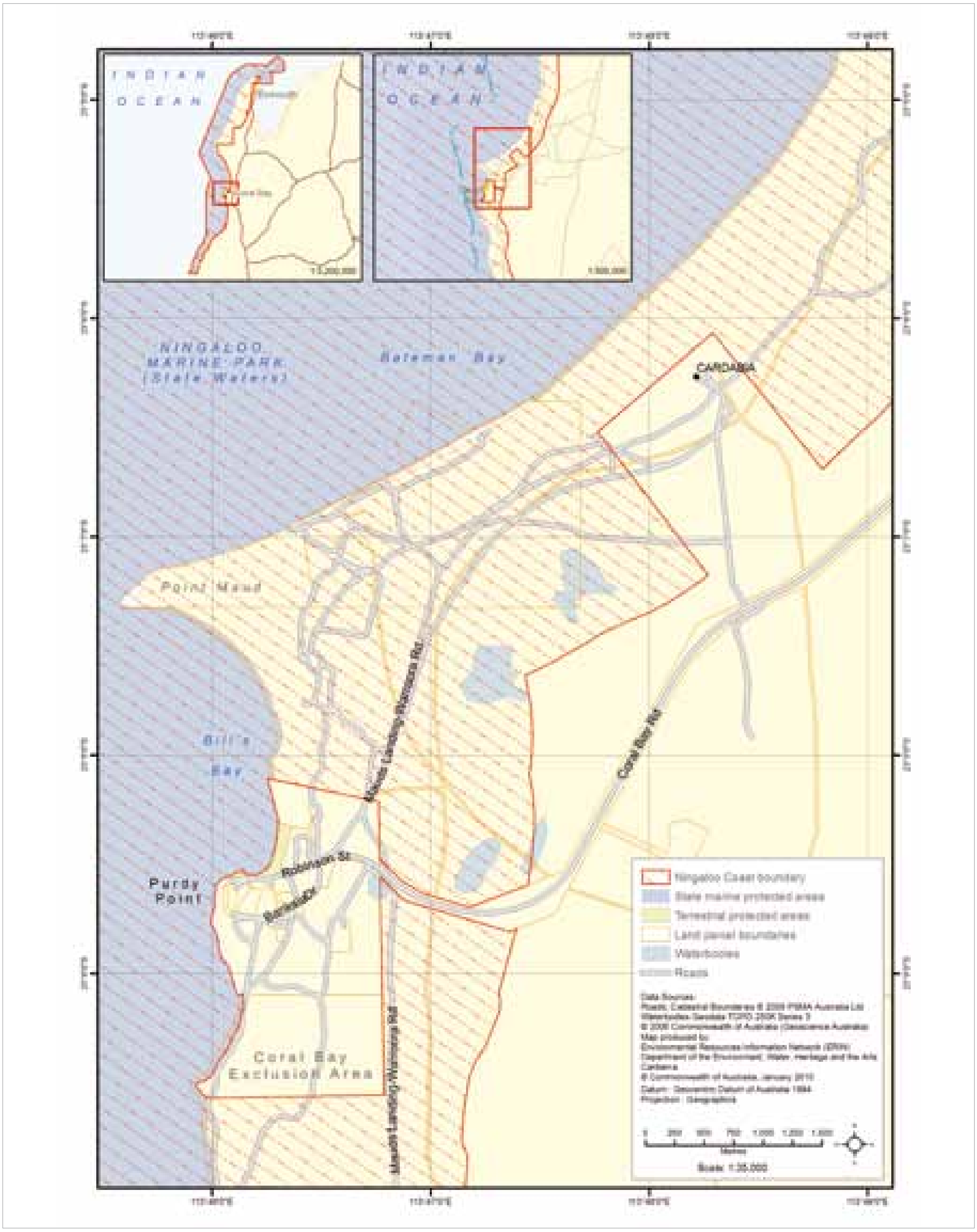


MAP 1.4 Satellite image of the nominated property with graticule overlay.

(ii) Location map

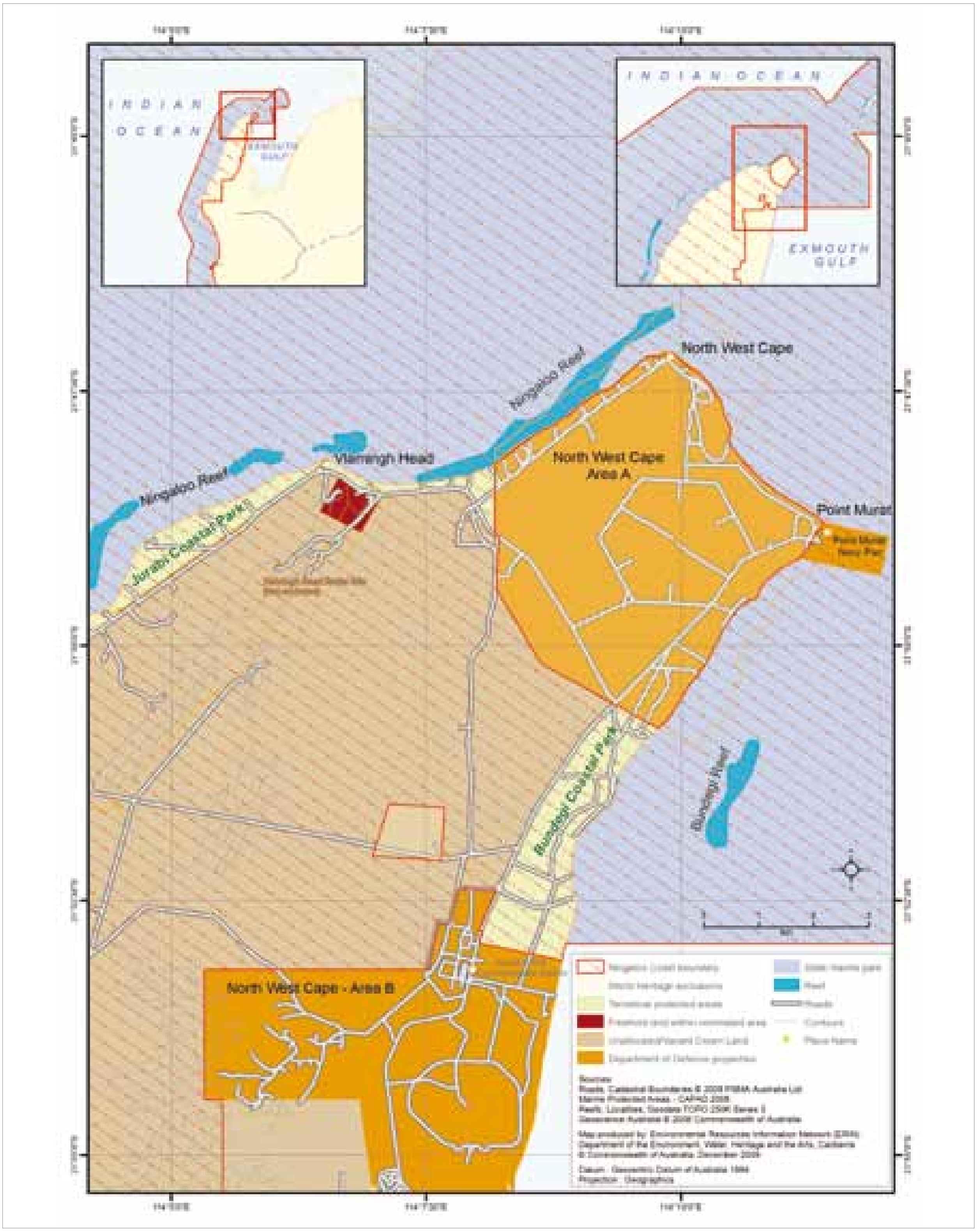
MAP 1.5 Location of the nominated property within Australia.

(iii) Enlargements of excluded areas



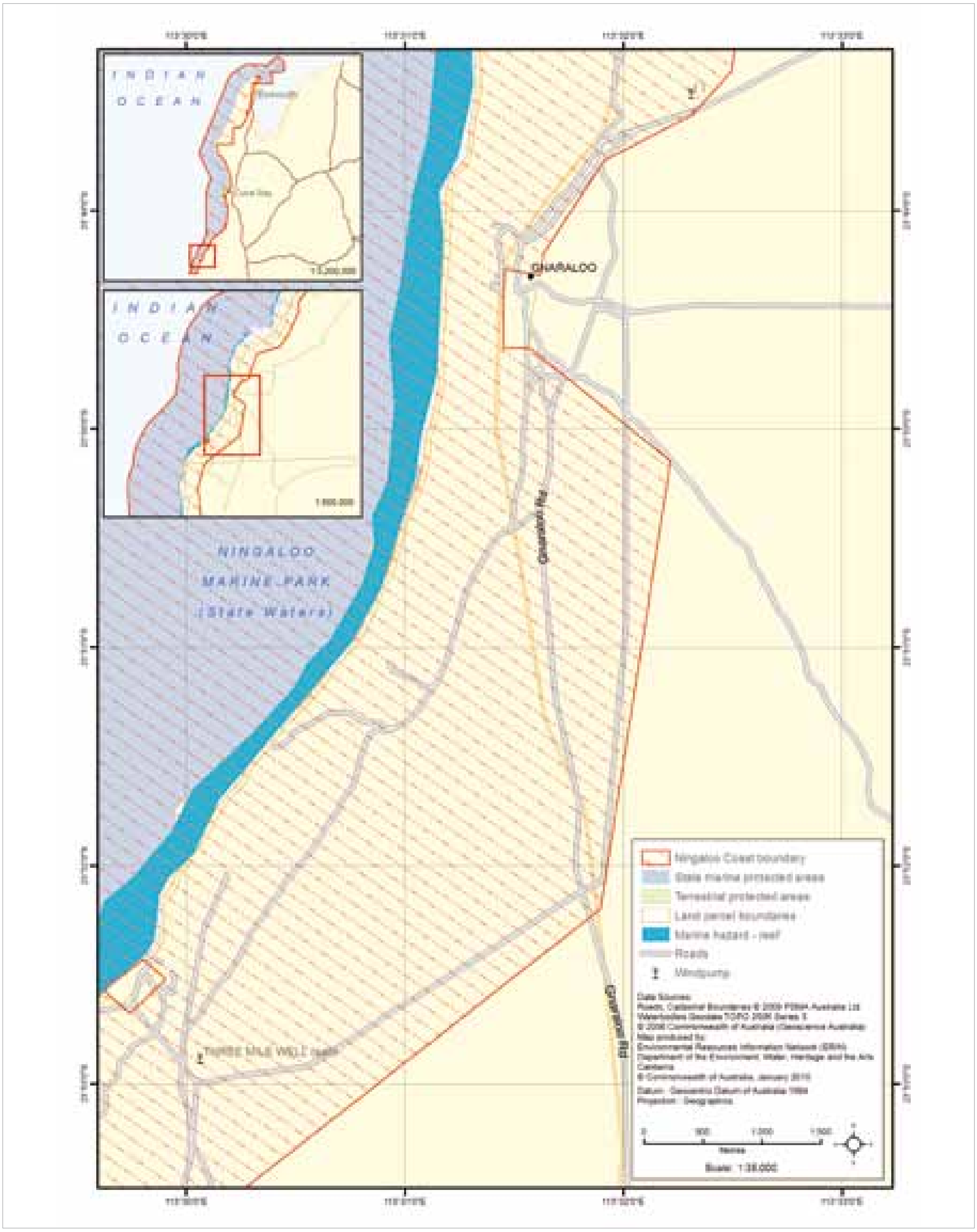
MAP 1.6 Coral Bay enlargement.

Enlargements of excluded areas (continued)



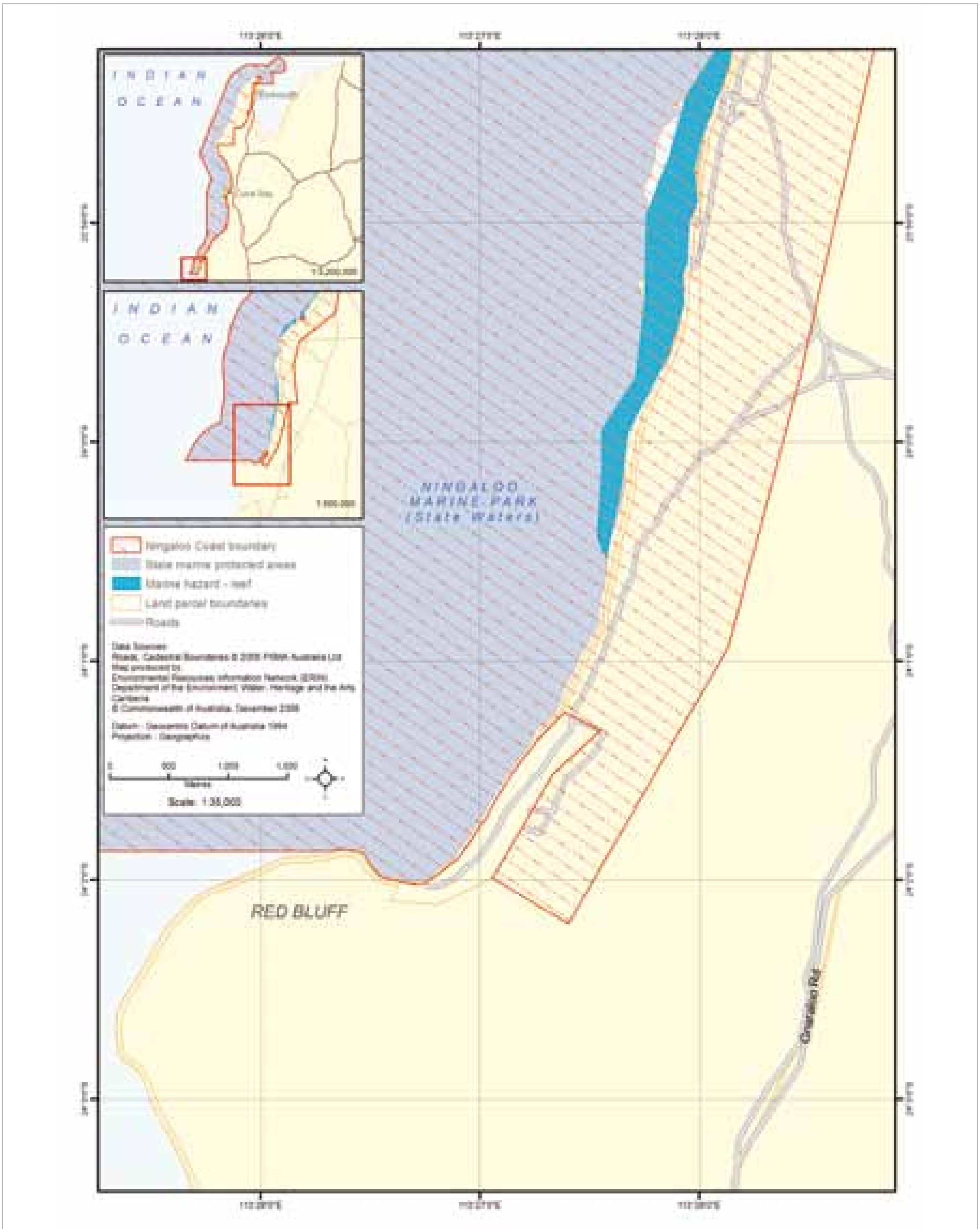
› **MAP 1.7** Australian Government Department of Defence area enlargement.

Enlargements of excluded areas (continued)

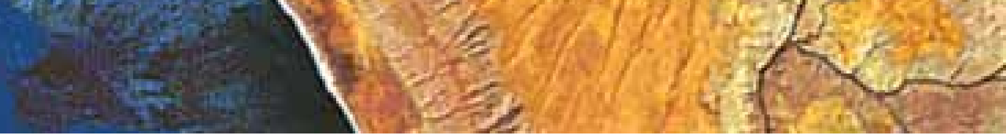


MAP 1.8 Three Mile Camp exclusion enlargement.

Enlargements of excluded areas (continued)



MAP 1.9 Red Bluff enlargement.



1F AREA OF NOMINATED PROPERTY AND PROPOSED BUFFER ZONE

The total area of the nominated property is 708,350 hectares.

A buffer zone is not required for the proper conservation of the nominated property because the nominated values are protected directly by a range of measures. These include management plans at both state and Australian government levels which provide statutory protection. The listed World Heritage values are also protected by the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The EPBC Act, which includes some of the strongest environmental legislation in the world, protects the listed values of Australia's World Heritage properties from significant impact from actions either outside or inside the property.

Any proposed action that may have or is likely to have a significant impact on the heritage values of a declared World Heritage property requires assessment under the EPBC Act and cannot proceed without the approval of the Minister for Environment Protection. This includes not only actions taken within the boundaries of the listed property, but also any actions taken outside the boundaries that may have a significant impact on the listed property's heritage values.

FIGURE 1.2 The Cape Range glows with the setting sun.
Photograph © Bronwyn Collins


2
DESCRIPTION

2

2.A DESCRIPTION OF PROPERTY

The Ningaloo Coast is located on the remote western coast of Australia. Its marine environment is dominated by the spectacular Ningaloo Reef, which is spread out beneath the red limestone ramparts of Cape Range.[1] More than a set of physical, biotic and climatic attributes superimposed over bedrock, the outstanding value of the Ningaloo Coast derives from its functionally integrated reef and karst system lying along an arid coastline. The Ningaloo Coast is also treasured for the rich record it offers of past life and landscapes. Marine biologists, karst specialists, geologists, geomorphologists, palaeontologists, and zoologists can see beneath the surface of the land and sea, to uncover ancestral relationships and explore lost ecosystems.

Encountering the Ningaloo Coast, a traveller can take a journey through the Cenozoic era, moving through a layered history that spans more than 25 million years of change. Beginning on a cliff top looking seaward, the traveller proceeds in geological time from the antique heights above Mandu Mandu Gorge (carved into tropical marine sediments of the Oligo–Miocene epoch), down the escarpment, across Plio–Pleistocene fossil reef terraces incised into the coastal plain, over the Holocene sand dunes and beach, into the shallow lagoon and out over Ningaloo Reef, into the present (Figure 2.2).

FIGURE 2.1 View of Shothole Canyon, Cape Range.
Photograph © BJK Ben Knapinski

PREVIOUS PAGE Photograph Tony Howard © Western Australian Department of Environment and Conservation

GEOLOGICAL TIME				MILLION YEARS BEFORE PRESENT
Phanerozoic eon	Cenozoic era (65–present)	Quaternary period (2.6–present)	Holocene epoch	0.01–present
			Pleistocene	2.6–0.01
		Neogene period (23–2.6)	Pliocene	5.3–2.6
			Miocene	23–5.3
		Palaeogene (65–23)	Oligocene	34–23
			Eocene	56–34
			Paleocene	65–56
	Mesozoic era (250–65)	Cretaceous		144–65
		Jurassic		200–144
		Triassic		251–200
	Palaeozoic era (545–250)	Permian		299–251
		Carboniferous (Mississippian and Pennsylvanian)		359–299
		Devonian		416–359
		Silurian		444–416
		Ordovician		488–444
		Cambrian		542–488

FIGURE 2.2 Geological timescale of the Phanerozoic eon, 542 million years ago to the present (not to scale)

The subterranean environment of the Ningaloo Coast tells even older stories of bygone worlds, reaching hundreds of millions of years back to the Mesozoic era. These histories are represented in communities of terrestrial and aquatic underground fauna that inhabit the Ningaloo Coast today. The ancestors of some of the aquatic invertebrates of the Cape Range aquifer were separated from their free-floating marine relatives in the middle-Mesozoic era, more than 150 million years ago, when tectonic forces broke the supercontinent Pangaea apart (Figure 2.2).

This movement of continents, driven by forces deep beneath the crust, was accompanied by climate change. Since the Miocene, Australia has moved further north away from Antarctica and developed its present arid character. Tropical rainforests, along with their leaf-litter dependent fauna, retreated to the north-east of Australia. Trapped in an increasingly inhospitable surface environment, the invertebrates of Cape Range retreated underground to evolve in isolation, throwing off high-energy adaptations to surface life: growing pale, shedding their wings and losing their eyesight.[2]

The climate, biota, hydrosphere, stratigraphy and landforms, together with the processes that shape them, interact as a unitary whole through time and across spatial scales. The term 'geoecology' usefully describes these links. The marine, terrestrial and underground systems, and flora and fauna of the Ningaloo Coast, can be considered as a perpetually changing, functionally-integrated geoecosystem.[3]

Growth of the modern reef has been shaped by past reef morphologies and sea levels. At the peak of the last interglacial stage, approximately 125,000 years ago, the sea level was up to five metres higher than today. This change is reflected in the fossil reef terraces. Today, Ningaloo Reef grows on a substrate of fossil reefs that formed during the last glacial stage, which peaked approximately 20,000 years ago when sea levels were up to 135 metres lower than modern levels. Several kilometres of the now submerged continental shelf were exposed as coastal plain. As sea levels rose again, corals recolonised the carbonate substrate of the former coastal plain. The modern reef grows in the narrow band of shallow nearshore waters between the western shores of the Cape Range peninsula and deeper ocean waters. Ningaloo Reef forms an unusual nearshore barrier reef that extends for almost 300 kilometres from Red Bluff in the south to the fringing reefs of the Muiron Island group north of the Cape Range peninsula, and around the top of the peninsula to Bundegi Reef in Exmouth Gulf (Map 1.1).[4]

The Cape Range peninsula is characterised by the low, steep karst limestone of Cape Range, built from the skeletons of marine creatures deposited in vanished tropical seas and eroded over millennia into the majestic shapes of the karst terrain. The oranges, pinks and browns of the range contrast with patches of sage green vegetation and vibrant red dune fields. A series of wave-cut terraces stretching for a distance of 90 kilometres sculpts the western side of the range—the legacy of former high sea levels and recent terrestrial uplift. Parched ephemeral river beds wind their way through the rocky gullies, recharged only occasionally by heavy rains from the north.

Below the sunbaked surface lies a hidden network of caves and smaller solutional conduits that are home to a diverse array of cryptic fauna. Their evolutionary histories recall nearly 200 million years of geological and biological change, since the supercontinent Pangaea came together and shortly afterwards began to break apart, foreshadowing the modern distribution of oceans and continents.[5] This cave fauna is found in and around a complex system of groundwater streams, pools and aquifers.

Together Ningaloo Reef and Cape Range, along with a mosaic of related interdependent marine and terrestrial ecosystems, form a functionally integrated limestone structure. The Ningaloo Coast is unusual and important in a number of ways:

- biologically, through the combination of high terrestrial endemism and a rich marine environment
- structurally, as a large nearshore coral reef off a limestone karst system
- climatically, for the juxtaposition of a tropical marine setting and an arid coast
- topographically, as a barrier reef lying alongside a steep limestone range.

Most of the people in the region live in the port town of Exmouth and the smaller community of Coral Bay. The region's permanent human population is around 3,000. Pastoralism is the principal land use—sheep graziers have adopted a form of low-intensity land use suited to the hot, dry environment. Tourism is an increasingly important industry. Visitors from around the world travel vast distances to see the wonders of tropical reef life juxtaposed against the ramparts and gorges of Cape Range. The beauty of the region does not disappoint those who make the long journey of around 13 hours drive from Perth, the nearest state capital city. Visitors and locals experience this beauty walking through the winding gorges of the ancient limestone, swimming alongside majestic whale sharks (*Rhincodon typus*) or simply enjoying the changing colours of the ocean and sky.

FIGURE 2.3 View of Sir Charles Knife Gorge, Cape Range.
Photograph © BJK Ben Knapinski

FIGURE 2.4 Yardie Creek, deeply incised into the arid coastal plains south of Cape Range, flows into the Ningaloo Reef lagoon and through it to the Indian Ocean.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

A GEOLOGICAL HISTORY OF THE NINGALOO COAST REGION

Regional overview

The Ningaloo Coast lies on the western margin of the Australian continent, described as 'one of the classic passive continental margins in the world'.[6] The margin has its origin in the successive break-up of the supercontinents Pangaea and Gondwana, which occurred from around 180 to 50 million years ago. As the Indian and Australian tectonic plates separated and the Indian Ocean opened, the rifting formed a number of sedimentary basins, including the Carnarvon Basin. Thousands of metres of sedimentary rock were laid down in the basin over hundreds of millions of years from the Palaeozoic era to the Holocene period (present day) (Figure 2.2). During the Cretaceous, much of the area that now comprises the western seaboard of Australia was covered by shallow seas. Uplift along the western coast of Australian has occurred intermittently since the late Cretaceous period, producing a series of anticlinal ranges in the region.[7]

Geologically, the Ningaloo region is situated within the Exmouth sub-basin of the Carnarvon Basin and is underlain by 10 kilometres of Permian to Cretaceous marine sedimentary rocks. Overlying the Cretaceous bedrock, the rocks immediately below Cape Range are predominantly carbonate of Palaeogene age (60–20 million years old).[8] These limestone rocks were formed from calcareous silt, mud and the skeletal remains of billions of marine organisms, deposited on the sea bottom over thousands of millennia. Cape Range itself, and its extension in the Muiron Islands, is composed of limestones and other rocks formed since the late Oligocene epoch, from about 26 million years ago. As sea levels rose and fell, the limestones were overlain by and interbedded with a variety of alluvial, littoral and shallow marine sediments.

The mainly carbonate rocks of the Cape Range peninsula consist of three limestone units deposited in different marine environments, dating to the middle Miocene epoch. 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, grading into the calcareous sandstones of the Pilgramunna Formation and the younger Vlaming Sandstone, deposited late in the Miocene epoch. Offshore, carbonate deposition continues on Ningaloo Reef, which maintains close geomorphic and hydrologic relationships with the terrestrial and subterranean parts of the Cape Range peninsula.[9]

For most of its existence, the Cape Range peninsula has been part of the mainland, although it is likely that it was separated from the mainland a number of times by rising seas. Cape Range probably appeared as an island during the mid to late Miocene, after which karstification might have extended rapidly downwards in karst-prone sediments, spreading horizontally as the range emerged from the sea. During the Pleistocene glacial maxima, sea levels were 100 metres or more lower than they are at present, with the consequence that karstification continued into areas that are now some distance offshore, accompanied by incision of the modern drainage.[10] This process created the complex of caves and other karst features that characterise the peninsula today. At times during the last interglacial stage, which lasted from about 135,000 to 85,000 years ago, Lake Macleod, a giant salt lake to the south-east of the Ningaloo Coast, formed a bay of the Indian Ocean and may have connected via a channel to Exmouth Gulf, thus isolating Cape Range as an island once more (Figure 2.2).[11]

The biogeographic history of the region, which includes a chronicle of the movements of supercontinents, is told here in conjunction with a description of the subterranean faunal groups, whose evolutionary histories and distribution help to elaborate an important part of the geological story.

FIGURE 2.5 Dugongs with remoras.
Photograph © Tourism WA

FIGURE 2.6 Orange banksia in full bloom.
Photograph © Tourism WA

AUSTRALIA'S GREAT NEARSHORE REEF

At 290 kilometres long, Ningaloo Reef is one of the longest and best developed nearshore reefs in the world. It is the most structurally complex of the diverse continental reef systems that lie along the western coast of Australia. Stretching north from Red Bluff to the reefs of the Muiron Islands, and from Bundegi Reef around the tip of the peninsula into Exmouth Gulf, Ningaloo Reef forms an almost continuous barrier for 200 kilometres, enclosing an offshore lagoon that varies in width from 200 metres to about seven kilometres. Extensive fringing reefs lie north and south of the barrier, to a total distance of nearly 300 kilometres.[12]

At its northern and southern extremities and surrounding the Muiron Islands, Ningaloo Reef is a simple, flat fringing reef some tens to a couple of hundred metres wide, abutting the beach. Extensive parts of the central region form a barrier reef unusually close to shore, which in places is composed of a near-continuous breakwater, including double barriers, with major navigable back reef and lagoonal habitats —corals, seagrass, algae and sand flat habitats and associated communities.[13] The remarkable development of the back reef is partly due to unusually strong oceanic flushing, which brings in clear water, planktonic food and propagules, shapes beaches, and prevents the smothering of sessile communities by removing fine sediments.[14]

Regional marine setting

The reefs of the tropical carbonate ramp system of the North West Shelf form some of the most important continental tropical reef systems in the world, the longest in the Indian Ocean, and the only significant set of reefs bordering the eastern shores of a major ocean. Sustained by the south-flowing Leeuwin Current, the coral ecosystems of the western coast of Australia are interdependent and mutually sustaining. They are distributed intermittently along the coast for 2,200 kilometres and extend into the east Indian Ocean.[15]

The continental reefs extend from the high latitude reefs of the Houtman Abrolhos Islands 600 kilometres south of the Ningaloo Coast (at latitude 28° 45' S, the most southerly in the Indian Ocean), to the warm water reefs of the Kimberley, which extend as far north as Cape Londonderry (latitude 13° 45' S), 1,600 kilometres east-north-east of the Ningaloo Coast. The oceanic reefs include the reefs of the North West Shelf:

- the emergent Rowley Shoals (15–17°S), 700 kilometres north-east of the Ningaloo Coast
- Scott and Seringapatam Reefs (14°S) 1,200 kilometres north-east of the Ningaloo Coast
- Ashmore Reef and Cartier Reef (12° S), respectively 700 kilometres, 1,200 and 1,400 kilometres north-east of the Ningaloo Coast.[16]

The west coast of Australia, where Ningaloo Reef is located, is exposed to dominant westerly wind systems, which traverse the oceans for considerable distances to drive ocean currents into the reef. The area is oceanographically complex, as the cold north-flowing West Australian Current mixes with the warm Indian Counter Current or Leeuwin Current. The Leeuwin Current brings a flow of tropical water south down the western coast of Australia and is one of the most important biogeographic influences on the regional marine flora and fauna. The current is strongest and closest to the coast during autumn and winter, and its warmth enables the occurrence of tropical species at southern latitudes where such species are not typically found. The western coasts of the other continents lack comparable warm annual currents. Consequently, the growth of modern coral reefs is much reduced at high latitudes in comparison to Australia.[17]

Ningaloo Reef lies between 200 metres and seven kilometres from the modern shoreline. Low average annual rainfall and a lack of run-off are reasons why the reef has developed so close to the shore. The range and the reef are also in close proximity to the edge of the continental shelf. Off the Cape Range peninsula the shelf is very narrow, and between Point Murat and Coral Bay is less than 10 kilometres wide.[18]

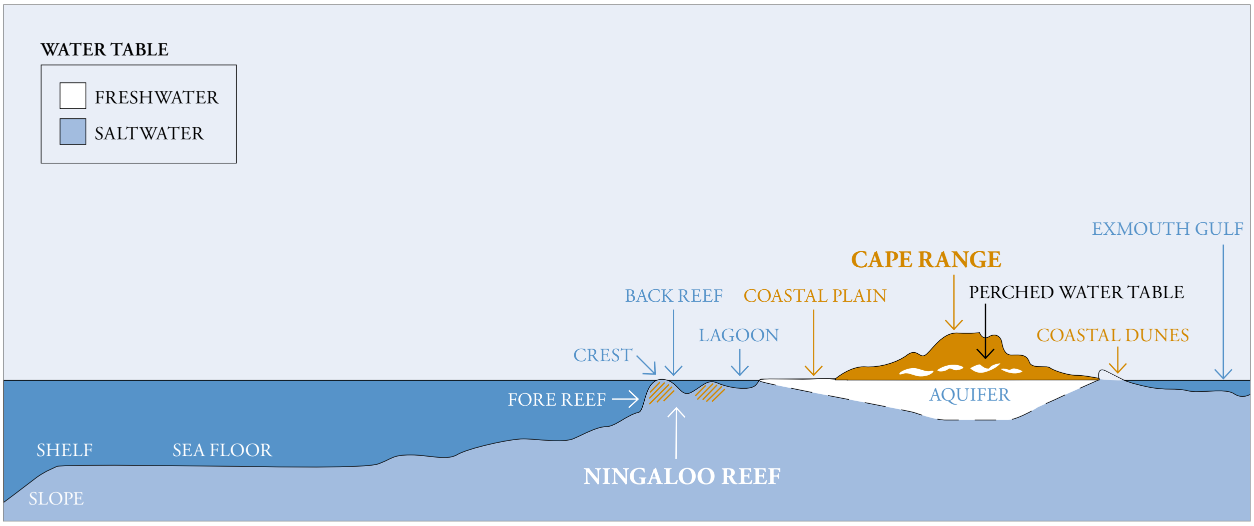
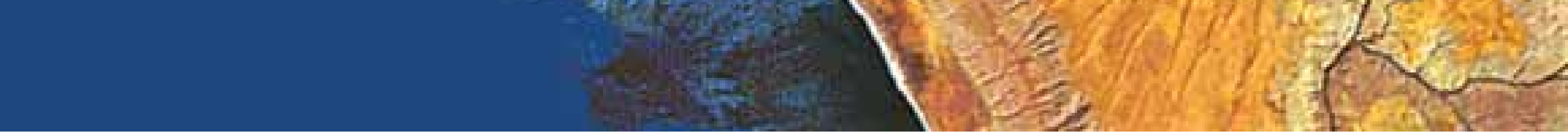


FIGURE 2.7 Cross-section showing the proximity of Ningaloo Reef to Cape Range and to the continental slope.

FIGURE 2.8 The Ningaloo Coast combines one of the world's longest nearshore coral reefs with an arid and remote continental landmass.
Photograph Tony Howard © Western Australian Department of Environment and Conservation



Ningaloo waters

Ningaloo Marine Park and the Muiron Islands Marine Management Area encompass, sustain and protect a series of interconnected habitats, from the continental shelf and slope communities of the open waters, to the barrier reef and coastal ecosystems of Ningaloo and Bundegi reefs and the fringing reefs of the Muiron Islands. The shallower waters include shoreline communities, lagoon, fore-reef and reef flat. Important habitats of the open waters include the waters and seabed of the continental shelf and slope, which extend to 16 kilometres seaward. The open waters support sponge gardens and deepwater corals, and provide habitat for cetaceans, whale sharks (*Rhincodon typus*), billfish and marine reptiles. The deeper waters display a diversity of epibenthic decapod crustaceans, with more species recorded than on any other continental shelf in the world. More than 700 species of reef fish, from a total of more than 1,000 reef and pelagic species, inhabit the waters of the Ningaloo Coast, supported by more than 300 types of coral.[19]

The world's biggest fish

The Ningaloo Coast is one of the best places in the world to encounter the world's largest fish: the whale shark. Little seen during the first 200 years of recorded encounters, the public profile of the whale shark, the colossus of the fish world, has increased since the mid-1980s due to enormous growth in recreational diving and boating, but the animals remain enigmatic.[20] The earliest known whale shark sighting is recorded in the ship's log of the French mariner, Marc-Joseph Marion Dufresne, during his expedition to the Seychelles in 1768. Despite occasional reports over the next 60 years, it was not until 1828 that Andrew Smith, a British doctor and naturalist stationed in Cape Town, provided a scientific description and the name *Rhincodon typus*, from a whale shark killed in Table Bay in South Africa.[21] Until the mid-1980s, there were fewer than 350 confirmed sightings across the globe. Isolated animals have been recorded from nearly 100 locations across a wide range of marine environments at a variety of depths, latitudes and sea surface temperatures, and they are regarded as rare. The International Union for the Conservation of Nature (IUCN) lists whale sharks as vulnerable to extinction in its Red List of threatened species. They are believed to reach sexual maturity at around 30 years and live for more than a century.[22]

Individual tagged whale sharks have been tracked across 13,000 kilometres of Pacific Ocean and for more than 3,000 kilometres in the Indian Ocean. Yet almost nothing is known of their abundance, territory, breeding behaviour or environmental preferences. They appear to be mostly solitary, except for unusual and spectacular aggregations, such as during their annual sojourn on the Ningaloo Coast. These congregations are believed to coincide with a peak in nutrients, for instance during coral spawning, which attracts tropical krill, one of their main food sources.[23] Although their 1.5 metre-wide mouths contain hundreds of teeth, they do not bite or chew, which has contributed to their reputation for placidity—they feed by straining zooplankton and other tiny organisms from the water.[24]

Gentle giants

Whale sharks congregate in numbers around the reef and in the deeper open waters of the Ningaloo Coast in April and June 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.

Increasingly, whale sharks are a focus for ecotourism around the world—swimming with whale sharks is regarded as the signature experience of the Ningaloo Coast. The activity has been called 'swimming with the stars'. Marine biologist Brad Norman describes individual whale sharks as a star-field 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'.

FIGURE 2.9 The magnificent whale shark is the world's largest fish, reaching up to 18 metres in length.
Photograph © Cam Skirving

FIGURE 2.10 Close-up of whale shark with a tracking tag.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

The only representatives of their family, the Rhincodontidae, whale sharks belong to the Orectolobiformes, the order of sharks including nurse sharks, leopard sharks and wobbegongs, but they are closest in their habits to the only other two species of filter-feeding shark, the giants of the Lamniforme order, basking sharks and megamouth sharks. Unlike most orectolobiform sharks, which are benthic (bottom-dwelling in habitat), whale sharks are pelagic (they live in open water).[25] Like their fellow filter-feeding sharks, whale sharks appear to be ovoviviparous: they give birth to live young hatched in utero. This was vividly manifested in a specimen harpooned off Taiwan in 1995—a female shark carrying 300 eggs and a number of foetal sharks that had hatched in her uterus, one of which was reared in an aquarium for 143 days. This is by far the largest number of eggs reported for any shark species.[26]

Other marine vertebrates of the Ningaloo Coast

Eight cetacean species regularly visit the Ningaloo Coast: the humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*), sei whale (*B. borealis*), fin whale (*B. physalis*), blue whale (*B. musculus*), bottle-nosed dolphin (*Tursiops truncatus*), Indo-Pacific humpback dolphin (*Sousa chinensis*) and killer whale (*Orcinus orca*). Sightings of up to 12 other whale and dolphin species have been recorded. Humpback whales move along the reef from June to October in their annual migration to and from breeding grounds further north. Several species of sea turtles aggregate in the area and nest along the beaches of the Ningaloo Coast. Most nesting turtles are green turtles (*Chelonia mydas*) or loggerhead turtles (*Caretta caretta*), but flatback turtles (*Natator depressus*) have been observed nesting on the coast near Jurabi Coastal Park and the Muiron Islands. The Ningaloo Coast is important for sheltering one of the largest hawksbill turtle populations remaining in the Indian Ocean.[27] The endangered dugong (*Dugong dugon*) is found in the waters of the Ningaloo Coast. An unusually large community of about 1,000 dugongs feeds in the waters of the inshore lagoon, grazing the seagrass beds of Norwegian Bay and the lagoon north of Bruboodjoo Point.

A haven for turtles

The Muiron Island group is the northernmost terrestrial part of the Cape Range anticline. These islands are framed by sand beaches, which in turn are protected by a fringing reef (Figure 2.11)*. This combination of features produces ideal conditions for turtle nesting and the beaches of the Muiron group provide internationally important rookeries for rare loggerhead turtles (*Caretta caretta*). Green turtles (*Chelonia mydas*) also nest on these beaches, and hawksbill (*Eretmochelys imbricata bissa*) and flatback (*Natator depressus*) turtles are regularly sighted* (Figure 2.12).

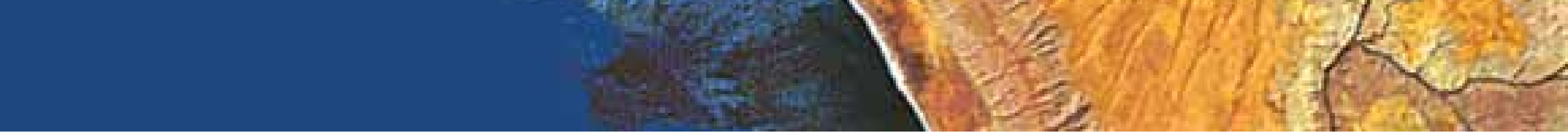


FIGURE 2.11 View of the Muiron Island group.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

FIGURE 2.12 Turtle hatchlings.
Photograph Megan Segers © Western Australian Department of Environment and Conservation

THE LIMESTONE COAST

A harsh dry climate

The Ningaloo Coast experiences the high summer and mild winter temperatures typical of north-western Australia. The mean summer (December–February) maximum and minimum temperatures in Exmouth are approximately 38 and 21 degrees Celsius, respectively. Over the winter months (June–August), mean maximum temperature is about 25 degrees Celsius, and mean minimum temperature is around 12 degrees Celsius.[28]

The region is characterised by an arid to semi-arid climate, with variable summer and winter rainfall. Annual regional rainfall of between 200 and 300 millimetres along the coast is far exceeded by evaporation rates of around 2,000 to 3,000 millimetres. Rainfall is influenced by mid-latitude depressions and cyclonic activity and has been known to vary from 84 millimetres to around 570 millimetres. Cyclones move across the Ningaloo Coast once every three to five years, bringing intense rain. These concentrated rainfall events flood through the desert valleys and bring forth vivid flushes of wildflowers that set seed ready for the next rainfall event. They also play a critical role in recharging underground aquifers with water and organic matter and revitalising cave life.[29] Cyclonic winds may be severe, exceeding speeds of 150 kilometres per hour.[30]

FIGURE 2.13 Arid landscape of Cape Range.
Photograph Dragi Markovic © Department of the Environment, Water, Heritage and the Arts

FIGURE 2.14 Cape Range in the morning light.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

An integrated system

The Ningaloo Coast is characterised by a number of biologically and structurally interconnected landscapes and seascapes. These include the shelf, slope communities and coral reefs of Ningaloo Marine Park and Muiron Islands Marine Management Area; the estuarine habitats of Yardie Creek and Mangrove Bay; the rugged gorges and wave-cut limestone escarpments and platforms of Cape Range; and the karst aquifers within the peninsula. Coastal dunes extend from the southernmost limit of the reef along the shore to the northern tip of the peninsula. Longitudinal dunes, last active during the Pleistocene, occur across the area, over limestone or calcrete with younger deposits closest to the coast, and extend into Exmouth Gulf. Cliffs, wavecut platforms, narrow beaches and mobile sand drifts also feature in the coastal landscape. Because there is little surface run off, groundwater discharge into the lagoon is likely to be prominent along the coast, and submarine springs have been reported from Ningaloo Marine Park.[31]

The eastern slope of the range features a labyrinth of canyons, some of which are up to 120 metres deep. Dry, narrow creek beds on the flanks of the range come to life only briefly after heavy rainfalls associated with large storms or cyclones. The outlets of the larger creeks have radiated across the plains as spectacular alluvial fans, providing a demonstration of the power associated with flooding events. The crest of the range undulates gently, with both external drainage down the deeply dissected flanks and internal drainage into large sinkholes formed along the crest. The south of the range grades into undulating limestone terrain and sand plains. At Mangrove Bay there is a well-developed mangrove community, which is regularly flushed by tidal action; mangroves also occur at Yardie Creek.[32]

Diverse and striking landscapes

The outstanding experiential aesthetic of the Ningaloo Coast is enhanced by dramatically diverse land and seascapes, which offer stark visual contrasts in a relatively compact area of 708,000 hectares. For the last 125,000 years, rising and falling sea levels have carved their imprint in the scarps of Cape Range. Along with shifting sea levels, red dunes—markers of aridity—have advanced and retreated, and been covered by the sea. Geological and climatic history has shaped the Ningaloo Coast into many landscapes, displaying a multitude of hues and textures. This degree of variation in vegetation, ecosystems and topography over a comparatively small area is rare in the arid zone.

FIGURE 2.15 Dawn reflected in the western sky offers its delicate colours to a whaleback dune—view south from Gnaraloo Bay along the Ningaloo Coast.
Photograph © Brett Calcott

FIGURE 2.16 Clear lagoon waters separate Ningaloo Reef from white sand beaches and ancient limestone terraces, Cape Range National Park.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

FIGURE 2.17 The Muiron Islands north of Point Murat, Ningaloo Coast. The islands are contiguous with the Cape Range anticline and share much of its geological history, while the surrounding reefs are integral to the Ningaloo Reef system.
Photograph © BJK Ben Knapinski

FIGURE 2.18 Bundera Sinkhole is the only accessible deep anchialine system in Australia.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

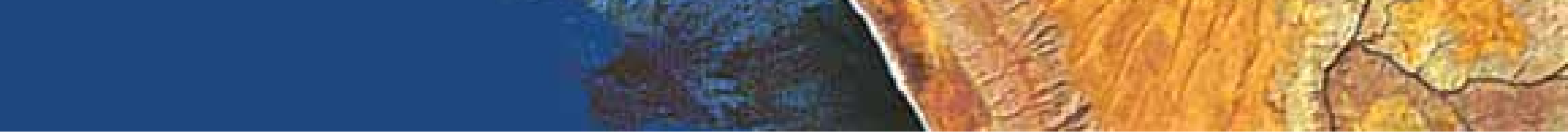
FIGURE 2.19 Ripples on sand dune, Gnaraloo Station.
Photograph © Brett Calcott

An unprepossessing exterior protects the secrets of Bundera Sinkhole; a closer look over its rocky edge reveals aquamarine waters and a wealth of anchialine life (Figure 2.18).

The wind and wildlife etch ornate ephemeral patterns in sand at Gnaraloo Station and Jurabi Coastal Park. On a more majestic scale, Yardie Creek carves its way to the sea in bright shades of blue and green (Figures 2.19 – 2.21).

FIGURE 2.20 Turtle tracks on sand, Jurabi Coastal Park.
Photograph Kirsten Knox © Western Australian Department of Environment and Conservation

FIGURE 2.21 The mouth of Yardie Creek, Cape Range.
Photograph © BJK Ben Knapinski



Cape Range itself presents considerable scenic diversity—it is a heavily dissected limestone range with numerous gorges, rock outcrops and overhangs. The terrestrial wildlife is a visual attraction, particularly rock wallabies, kangaroos, emus, reptiles, osprey and a variety of parrots, finches and other birds. Vegetation also provides high scenic diversity. A shrub steppe is dominated by wattles and eucalypts with a lower storey of small shrubs and spinifex, and varied and colourful seasonal wildflowers.[33]

Vistas large and small bring the changing textures, colours and scales of the region vividly into focus: from the red Pleistocene dune fields of North West Cape to the single blue eye of Bundera Sinkhole, a porthole to biological richness and the plate tectonic history of the world; from the delicate colours and patterns of Gnaraloo Bay and the dramatic white dunes and nearshore reefs of Turquoise Bay to the abundant bird life and tangled mangroves of Mangrove Bay; from the flat orange sand and vivid blue lagoons of the Muiron Island group to the spectacular and varied gorges and canyons of Cape Range; from the tourist brochure spectacle of Coral Bay to the red cliffs and fresh blue waters of Yardie Creek Gorge; and from red termite villages in the plains and foothills to the outer ramparts of Ningaloo Reef. This variety underpins the habitat richness and diversity of the Ningaloo Coast.

Ancestral reefs sculpted by time

Stretching from Vlamingh Head at the northern tip for 90 kilometres south to Point Cloates, Cape Range dominates the terrestrial landscape of the peninsula. Its geological history is one of marine sedimentation, Miocene uplift, and exposure of Palaeogene and Neogene strata. The range is around 20 to 25 kilometres wide and rises abruptly from sea level to over 300 metres. It is a heavily dissected, asymmetric limestone anticline that has eroded into a series of plateaus, lesser hills and ridges, dissected by gorges and steep stony slopes. The Muiron Islands at the northern tip of the peninsula are the partially submerged continuation of the anticline.[34]

The western side of Cape Range features four major wave-cut terraces together forming a staircase of gigantic scale, rising from around six to 60 metres above sea level. Eroded into former beaches and nearshore reef deposits, the terraces provide a dramatic and well-preserved record of past sea levels and uplift events. The coastal plain is between one and five kilometres wide, and is formed by the lowest and youngest of the wave-cut platforms, the Tantabiddi terrace.[35]

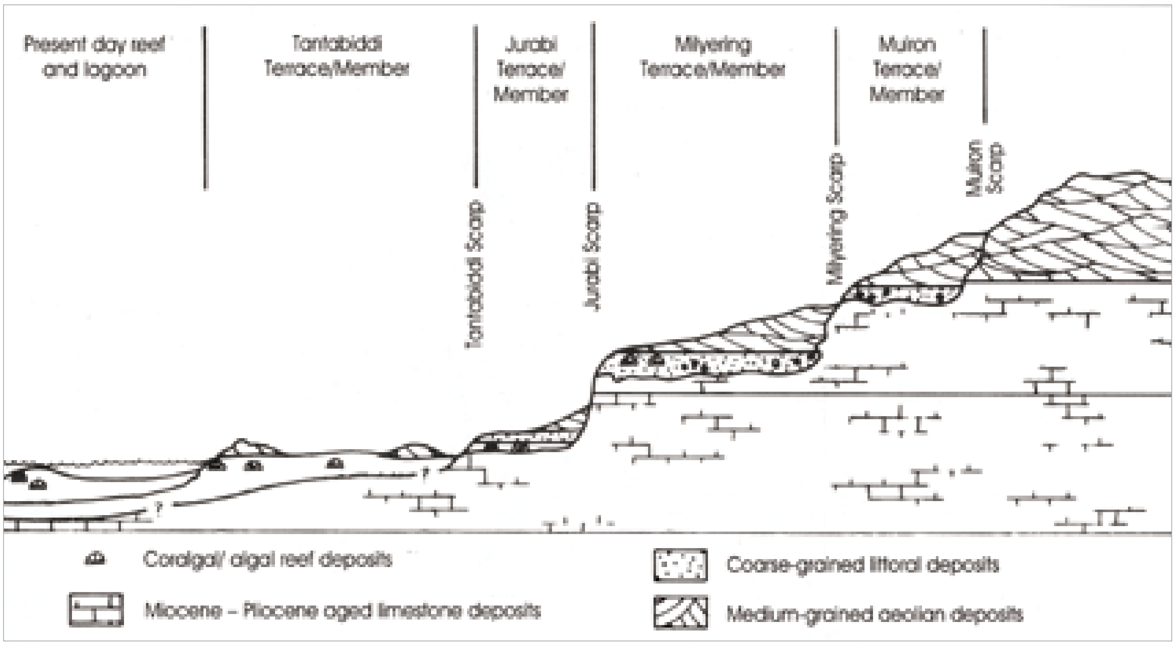


FIGURE 2.22 Diagram of marine terraces (K-H Wyrwoll et al. 1993, after van der Graaff et al. 1976).

The Cape Range limestones, into which the four major wave-cut terraces are carved, were deposited on a warm water carbonate ramp or shelf off the western coast of Australia during the Miocene period. Representing shallow water tropical deposits, they contain coral and fish fossils among largely foraminiferal and other material. The fossil environments that have been preserved are predominantly seagrass banks and open shelves/ramps, exposed in sections of international geomorphological significance in a number of gorges.[36]

The emergent reef complexes of the major terraces 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 or scarp, which is from 800–1,600 metres wide and six metres above sea level) includes fossil reef fauna that has strong species overlap with the adjacent living Ningaloo Reef. The Tantabiddi terrace has been dated to the last interglacial stage, around 125,000 years ago, when the sea was up to five metres higher than today. The older terraces—Jurabi, Milyering and Muiron—are not well dated, but may extend back into the Pleistocene epoch, or may be even older.[37] At up to 55 metres above sea level, the Muiron scarp is the highest and oldest.

The terraces record the uplift, still-stand and eustatic sea-level history of the Cape Range peninsula, and the responses of reef fauna to environmental changes over time (Figure 2.20, Figure 2.21).[38] 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.[39] The Tantabiddi terrace represents a period of stronger Leeuwin current flow and increased reef development, under conditions as much as two degrees Celsius warmer than present.[40] In oceans threatened by rapid climate change, such a clear juxtaposition of differing marine environments over time is important for studying impact and ecosystem response.

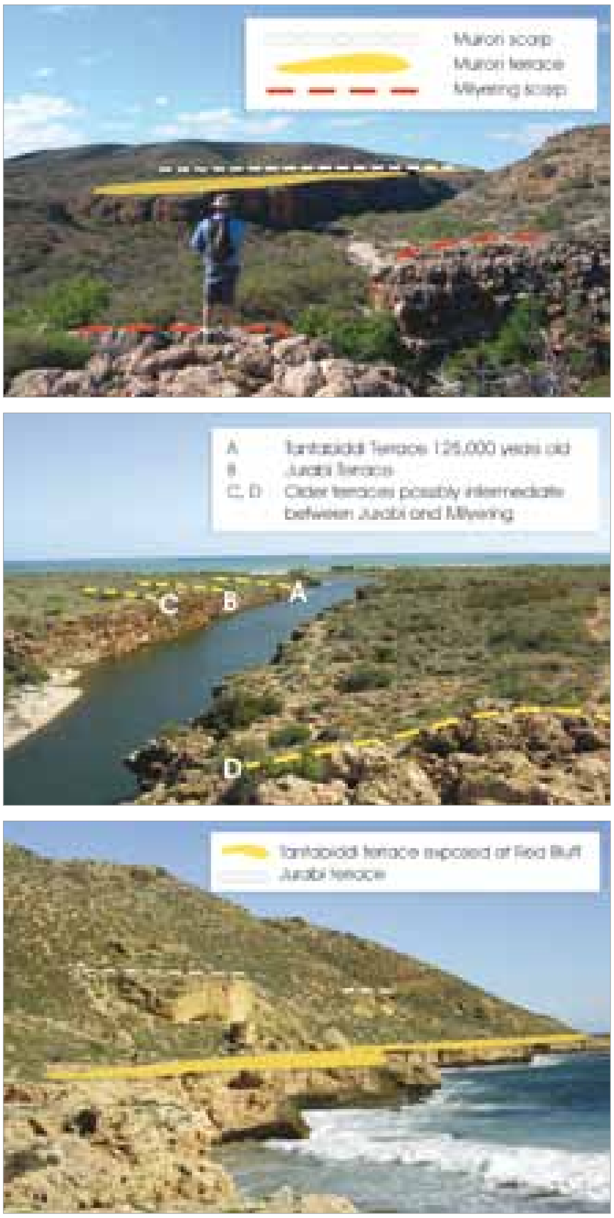


FIGURE 2.23 (a) View of the upper and oldest terrace, the Muiron scarp, from a lower and younger terrace (b) Two terraces at Yardie Creek viewed from a higher, older terrace (c) The best preserved section of the youngest terrace, the Tantabiddi Scarp. Photographs © K-H Wyrwoll, University of Western Australia

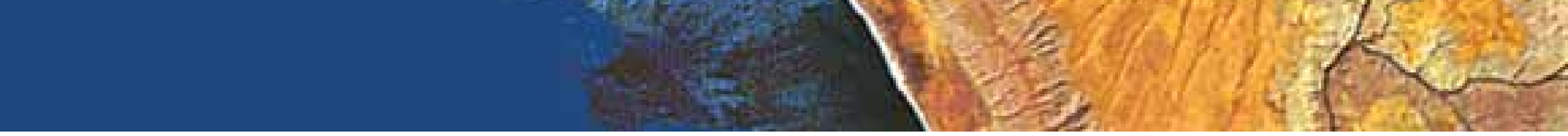


FIGURE 2.24 Fossil coral, bryozoans and shells on wave-cut terrace visible at Yardie Creek.
Photograph © Bronwyn Collins

FIGURE 2.25 Cave interiors, Cape Range.
Photographs Tony Howard © Western Australian Department of Environment and Conservation

Cavernous karst

International scientific interest has focused on the vast network of hidden solutional caves and smaller conduits lying beneath the plateaus, canyons and coastal plain of the Cape Range peninsula. The high relief of Cape Range and lower sea levels in the past have encouraged significant karst development. The hard Tulki Limestone, which dates from the early Miocene, is the main cavernous limestone, but younger Pleistocene to Holocene age limestones also display a range of karst features. Although the full extent of karst development is yet to be revealed, a total of 826 separate features has been recorded to date, including 535 caves, 180 dolines (large, characteristically funnel-shaped, topographically closed depressions), extensive karren (solutional furrows or fissures, runnels, pits and shafts), gorges and springs which pit the surface of the range and fringing plains.[41]

Caves up to 100 metres deep have been found in the Tulki Limestone, which makes them the deepest known caves in mainland Australia. Other caves reach up to six kilometres in lateral extent. One of the most remarkable discoveries has been the presence of permanent standing water bodies in five caves between 110 to 200 metres above sea level along the central plateau of Cape Range. These high cave pools may occur because the caves are located over three isolated perched water tables, and indicate changes in the water table over time.[42]

Aquifers, groundwater and anchialine systems

Around the world, coastal anchialine systems such as at the Ningaloo Coast typically develop in porous limestone or volcanic rocks, which are flooded by seawater following post-glacial sea level rises. The diversity of karst features beneath the Cape Range peninsula is matched by an equally impressive variety of water bodies. The close proximity of ocean waters which can intrude into the karst system has resulted in the complex overlapping of fresh and saline water. The hydrological system of Cape Range is isolated from the surrounding Carnarvon Basin.[43] Fresh water lenses overlying water of marine origin form what is known as a Ghyben–Herzberg groundwater system within parts of the Cape Range aquifer. Measurements of salinity indicate that a thin lens of fresh groundwater overlies brackish groundwater, and that fresh groundwater extends to more than 100 metres below sea level on the eastern flank of the range.[44] The salinity of the groundwater increases with proximity to the coast.[45] (Figure 2.7 and 2.26)

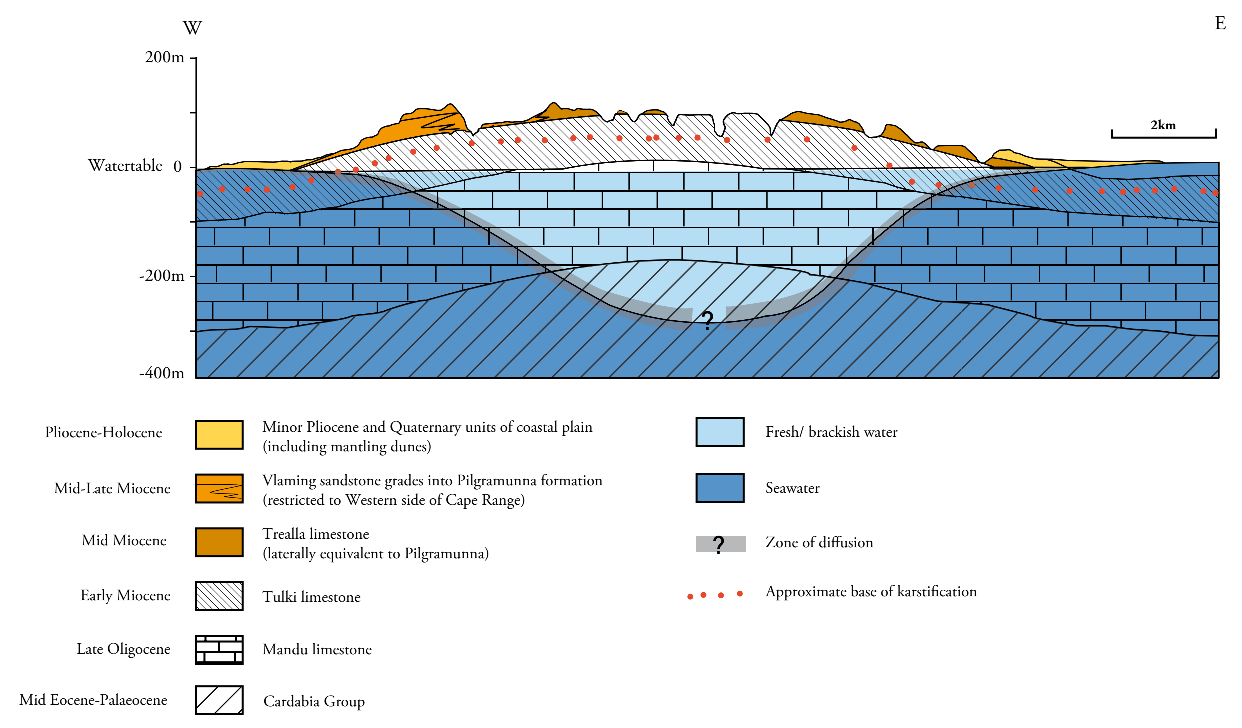


FIGURE 2.26 Hydrogeological cross-section (after Allen 1993).

Rain that falls onto the Cape Range peninsula drains into the limestone through a number of localised sinkholes and minor joints found along the crest of the range. Water makes its way through this internal drainage network until it reaches the boundary of the Tulki and older Mandu Limestone layers where it pools above higher density salt water and is ultimately discharged into the ocean below sea level.[46]

The level of the shallow groundwater table on the coastal plain fluctuates with the ocean tides, reflecting the interconnection between the modern karst hydrological system and the former glacial age karst hydrological network, which is now drowned by the sea. Through the mixing of saline and freshwater, a maze of conduits has developed within the limestone, hastened by increased solution rates caused by the mixing process. Enhanced dissolution at the interface of fresh and salt water is characteristic of coastal karst. In Cape Range, this has created a water-filled network of cave passages in both freshwater and anchialine conditions, and has allowed for the movement over time of marine invertebrates from nearshore marine to karst environments. Limestone anchialine pools and caves of the coastal groundwaters of Cape Range are landlocked at the surface, with subterranean connections to the ocean, via coastal aquifers.[47] (Figure 2.26)

LIFE BELOW THE SURFACE

The network of subterranean caves and waterways beneath the Cape Range peninsula shelters a unique assembly of cave-dwelling animals. More than 80 subterranean taxa have been recorded from the peninsula, of which 75 are solely confined to a subterranean habitat. The taxonomy of the subterranean fauna of the Cape Range peninsula is complex, with species falling into three main groups of widely different origins: the terrestrial troglobites and two groups of aquatic stygofauna. Terrestrial troglobite communities are affiliated with the rainforests of moister climates. This troglobitic fauna includes insects (beetles, crickets, cockroaches, planthoppers), centipedes, millipedes, arachnids (whipscorpions, pseudoscorpions, spiders and mites), and slaters. These unusual creatures have adapted to cave life. Many are eyeless or pale in appearance, having long ago lost exoskeleton pigmentation. Stygofaunal communities consist of specialist subterranean aquatic species, many of which have their ancestry in coastal populations of the ancient supercontinent of Pangaea, while others have freshwater origins.[48]

Obligate subterranean animals, such as the troglobites and anchialine fauna, have a special place in biogeography because, by virtue of their subterranean adaptations, they become trapped underground in the original setting and are unable to disperse widely. Their obligate subterranean life and typically highly restricted distributions, along with the geological persistence of subterranean habitats, make troglofauna excellent subjects for biogeographic study.[49]

Subterranean communities often comprise lineages that have become isolated underground across different geological eras, and therefore have the potential to yield information on geological and climate events over deep time. They potentially provide robust subjects for testing biogeographic hypotheses. An illustrative example is the Bathynellacea, small, worm-like crustaceans largely confined to freshwater subterranean habitats with Pangaean distribution.

Along with taxonomic and molecular work, there has been research addressing key aspects of the ecology of the subterranean systems.[50] The combination of anchialine stygofauna and relictual rainforest fauna within the same cave system is unusual globally. The subterranean fauna of the Cape Range peninsula is accordingly highly diverse, with the highest level of troglomorphic diversity for a single karst area in Australia and one of the highest levels in the world.[51]

FIGURE 2.27 Tanaid blind shrimp, Cape Range. Photograph Clay Bryce © Lochman Transparencies

Swimmers of the underworld

The distribution of the fully aquatic cave fauna (stygofauna) of Cape Range relates directly to the hydrology and geological history of the region. The freshwaters of the Cape Range karst are bounded by marine waters on all sides, except for the hypersaline waters to the south. The freshwater lens, overlying brackish water, has an estimated elevation of about 10 metres along the centre of the range, down to about one metre above sea level around the coastal strip, and is recharged following exceptional rainfall events.[52]

The stygofauna of the coastal plain occurs at the periphery of the freshwater lens and the brackish layer, up to about 1.2 metres above sea level. The fresh to brackish waterways are permanently inundated and show daily tide-induced movements of up to 15 centimetres. There is evidence that the western and eastern coastal systems are connected along the coastal corridors and around the northern limit of Cape Range, rather than across the range. The highly saline groundwater at the neck of the Cape Range peninsula prevents the dispersal of stygofauna along the coast south of Cape Range.[53]

A Tethyan legacy

Over 150 million years ago on the shallow coastal margins of the Tethys Sea, before the break-up of the supercontinent Pangaea, the ancestors of the distinctive stygofauna of Cape Range were free-swimming marine invertebrates. The marine life of the Tethys Sea is thought to have colonised the inland and coastal waters of the continents that once bordered it. Following the final closure of the Tethys seaway due to the movement of continental plates and the reorganisation of ocean currents as the circumglobal Southern Ocean opened, marine connections between various communities of these closely related organisms were broken. Related species became isolated from each other. These are now found at distant localities—a reminder of the former shoreline of the ancient Tethys Sea.[54]

The anchialine system of Cape Range is confined to the part of the coastal aquifer that is underlain by seawater and affected by marine tides. The anchialine system is distinct from the freshwater aquifer and hosts a different fauna.[55] Anchialine habitats like those in the Cape Range are remarkable for their complex, chemically and thermally stratified hydrology. Equally remarkable is the diverse assembly of faunal communities that have been found in these waters. Of special note are communities restricted to the oligoxic (low oxygen) water systems. It is here that most of the biogeographic and phylogenetic relictual fauna can be found. Distinct communities have evolved to depend on the stratification of the water table, suggesting a stable environment that has been maintained over many millennia.[56]

Crustaceans are the richest group of stygofaunal invertebrates. Anchialine crustacean communities characteristically include many different crustacean groups, and can be broadly described by two subgroups: remipede type and procaridid type communities, each defined by the broad composition of species occurring together in any one locality. Bundera Sinkhole, on the coastal plain south of Yardie Creek, is the most studied of the Cape Range anchialine pools (Figure 2.18). The sinkhole contains a wide range of fauna, including fish, amphipods, copepods and ostracods. A single species, *Lasionectes exleyi* (Figure 2.29), is the only southern hemisphere or Indo–Pacific representative of an entire class, Remipedia, and defines the community as a remipede type. There are only a few communities in the world where remipedes are found. The others occur mostly in the central Atlantic–Caribbean region, with one other outlier in the volcanic anchialine system of the island of Lanzarote in the Canary Islands in the eastern Atlantic.[57] (Map 2.1)

The aquifer of the Cape Range peninsula shows particularly high phylogenetic diversity (diversity at higher taxonomic levels, such as class and order), both within Bundera Sinkhole and throughout the subterranean waters of the range. Species include atyid shrimp, members of the Thermosbaenacea (a blind crustacean order), diverse amphipods, and two vertebrate species: the blind cave eel (*Ophisternon candidum*) and the blind gudgeon (*Milyeringa veritas*).[58] (Figure 2.38)

FIGURE 2.28 An unnamed species of atyid shrimp (*Liagoceradocus genus*) endemic to Cape Range.
Photograph Danny Tang © Western Australian Museum

FIGURE 2.29 *Lasionectes exleyi*, a remipede endemic to Cape Range.
Photograph © Western Australian Museum

Cave dwellers of Ningaloo

The terrestrial cave fauna, or troglobites, of the Cape Range peninsula have adapted and flourished in the cool, humid oasis found beneath the arid surface world. These invertebrate communities house a very high diversity of Arachnida and Myriapoda (spiders, pseudoscorpions, schizomids and millipedes), many of which are found nowhere else in the world. The variation of species in the troglobite communities is striking across the peninsula, with distinct communities restricted to the coastal plain, the foothills and Cape Range proper. Within the species' ranges, they are further subdivided, as illustrated by genetic research on millipede, schizomid and amphipod groups.[59]

The rich cave fauna is dependent on organic matter and water entering the caves from intermittent flooding. Major inflows bring energy sources for the cave ecosystem and water to maintain the humidity required by the troglobites. There is evidence that some caves are linked at lower depths by minor cavities, and small populations of the cave animals persist there in dry times. When the caves are wet and re-energised by the influx of organic matter, these populations move upward into the newly habitable areas and breed. Until the next influx of water the caves slowly dry, the organic matter is consumed, and the population retreats to the more persistently moist reaches of the cave system.[60]

Troglobite species found today at Cape Range reflect the larger processes that have shifted climate zones and continents. The movement of continental plates during the last 25 million years, driven by forces deep beneath the crust and accompanied by oceanographic change, led to the region's present arid character. Tropical rainforests retreated to the north-east of the continent, and the Cape Range invertebrates evolved underground in isolation. For example, a number of species of troglobitic molluscs that are endemic to the Cape Range cave system, but whose relatives are confined to humid climates, rely on the caves for refuge from the arid surface conditions.[61] Many of the present day troglobite species have close affinities with species found in rainforest communities of north-eastern Australia, south-east Asia and Madagascar.

FIGURE 2.30 *Glennhuntia glennhunti*, a cave-dwelling harvestman spider.
Photograph Douglas Elford © Western Australian Museum

THE BIOGEOGRAPHIC STORY OF THE NINGALOO COAST

The physical structure and remarkable subterranean biota of the Ningaloo Coast are a record of the global biogeographical, oceanographic and plate tectonic changes that have occurred over more than 150 million years. As Pangaea broke into Gondwana and Laurasia, ocean currents shifted and climates were transformed. The Ningaloo Coast provides striking examples of key biogeographic processes, such as isolation and adaptation leading to change within both populations and species.

Isolation, adaptation and change

Four distinct populations of the subterranean and surface faunal groups, united only in their highly disjunct distribution and degree of endemism, contribute to the biogeographic uniqueness of the Ningaloo Coast.[62] The Cape Range peninsula stygofauna, widely regarded as representing relict Mesozoic populations, may represent two separate groundwater colonisation events of the wider sedimentary basin wherein the peninsula developed:

- The first colonisation event involved the Tethyan-age marine ancestors of modern range-dwelling amphipod crustaceans during the initial uplift of the range.

- The second subterranean invasion occurred much later, when two species of fish (the blind gudgeon and cave eel) and several species of atyid shrimp were washed in from the fresh waters of a precursor of the Ashburton River, which was then much closer to the range than it is now.

Subsequently, during the continued northern drift of Australasia during the Miocene, the rainforests that covered much of continental Australia retreated to the north and east as the continent moved into drier latitudes. This habitat contraction and encroaching aridity drove rainforest-dependent invertebrates underground, where they continued to adapt and evolve to a changing environment. The descendents of these leaf-litter parent communities form the modern terrestrial troglobitic fauna of the Cape Range peninsula.

The surface flora and fauna, such as millstream palms (*Livistona alfredii*), reptiles and native mammals, display a high degree of phylogenetic diversity, contributing to this story of isolation, adaptation and change over time.

The greatest biogeographic significance of the Ningaloo Coast results from its Tethyan and Gondwanan histories. The modern western coast of Australia formed part of the south-eastern margin of the Tethys Ocean during the late Palaeozoic to early Mesozoic eras, when 'Australia' was the south-eastern peninsula of the supercontinent Pangaea.[63] The anchialine system of the Cape Range peninsula houses highly endemic, rare and unusual aquatic species (stygofauna), some of which have Tethyan affiliations. For example, distantly related or unrelated taxa, whose closest relatives are known only from far-flung locations along the former Pangaean shores between 250 and 150 million years ago, coexist in the deeper high-salinity layers of Bundera Sinkhole, a cenote or collapsed doline in the Cape Range peninsula anchialine system (Figure 2.31).[64]

FIGURE 2.31 Bundera Sinkhole, a collapsed doline in the Cape Range peninsula.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

The closest living relatives of several species of crustacean inhabiting this sinkhole are found two oceans away in several localities on the American plate, including Mexico, Cuba and the Bahamas, and in the Canary Islands.[65] 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 a former marine connection between the two places.[66] Other species found in Bundera Sinkhole, sometimes the only Australian representatives of their orders, have congeners in the Balearics in the western Mediterranean, Bermuda and Mexico's Yucatán Peninsula. *Danielopolina kornickeri*, a primitive, cave-dwelling ostrocod (a class of tiny crustacean whose adult form is typically contained in a calcareous bivalved carapace) which occurs in the Bundera Sinkhole, is the only known occurrence of the *Danielopolina* genus in the Southern Hemisphere and the Indo–West Pacific region.[67]

Two types of anchialine faunal community are generally found around the world. Each of these is regarded as containing a characteristic set of taxa that are predictable even to the generic level, however far apart in the world they are found. The first, termed the remipede type, is confined to epicontinental anchialine waters, such as in the Cape Range peninsula, and is characterised by the presence of remipede crustaceans.

The second, termed the procaridid type and characterised by the presence of procaridid crustaceans, is confined to the anchialine waters of seamount islands. This type of anchialine fauna is known from Hawai'i, Bermuda, Ascension Island, and Christmas Island, which are all isolated seamount islands.[68] The presence of a remipede type crustacean community in the waters of the Bundera Sinkhole strongly suggests that the Cape Range stygofaunal community shares a common origin with those in the West Atlantic.[69]

Remipedes are enigmatic and their origins and phylogenetic relationships remain controversial.[70] The first remipede crustaceans were discovered by Jill Yager in 1979 in a marine cave in the Bahamas.[71] In the three decades since then, another 18 species from three families have been discovered, as well as a single Carboniferous fossil, *Tesnusocaris*. However, the mysterious crustaceans have revealed little else. The recent discovery of a larval stage from a community in the Bahamas has shed some light on their phylogeny, demonstrating similarities between the early larval stages of the Remipedia and larvae of some higher Crustacea, the Malacostraca (for example, crabs and lobsters).

Two main hypotheses explaining the distribution of stygal fauna in anchialine habitats around the world have currency: a deep sea hypothesis and a shallow water, or Tethyan hypothesis. According to the former, most anchialine immigrants evolved from deep-sea ancestors. The latter hypothesis supports a shallow, coastal marine origin for most anchialine colonists.[72]

The Tethyan theory proposes that the taxonomic predictability of these assemblages across hemispheres, the modern barriers to their dispersal and the strictly stygobiont conditions in which they live, suggest that their distribution results from the separation of ancestral populations formerly widely distributed along the shallow, warm-water margins of late Palaeozoic and Mesozoic seas (Figures 2.32 and 2.33). These Tethyan lineages may have been divided from each other by the movement of tectonic plates during the Mesozoic era. They have been restricted to subterranean environments since their separation.[73]

FIGURE 2.32 Reconstruction of Early Triassic Earth. (Adapted from Scotese 2003 Paleomap Project, www.scotese.com)

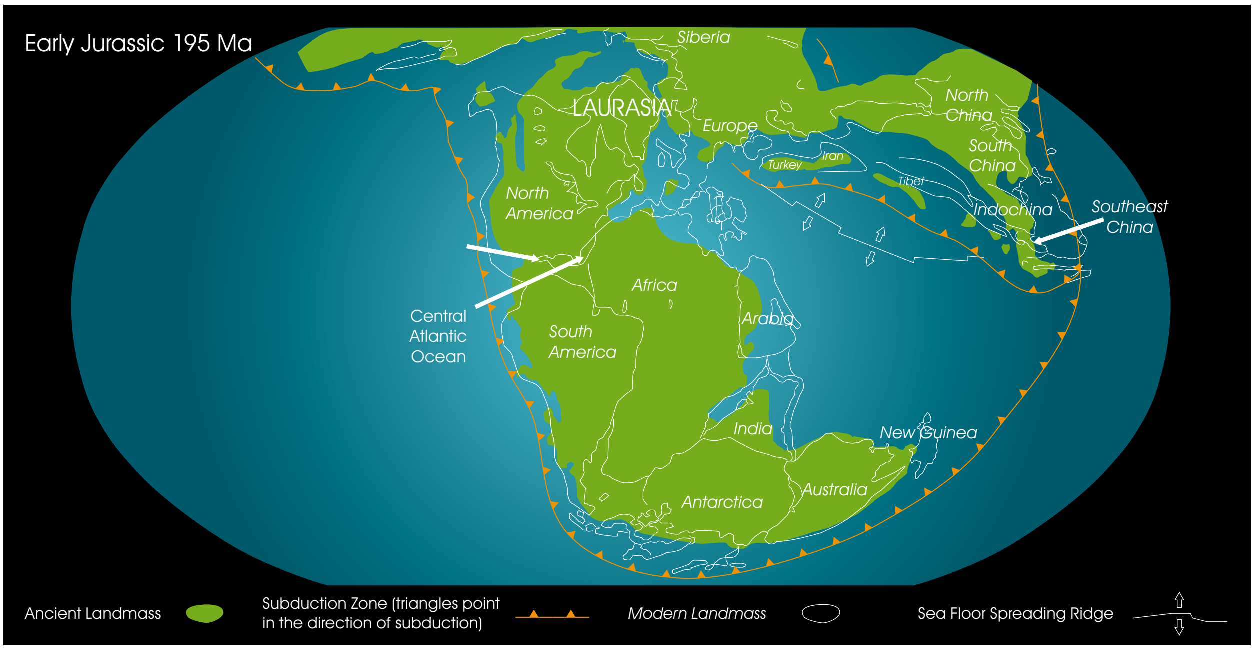


FIGURE 2.33 Reconstruction of Early Jurassic Earth. In this reconstruction, Pangaea has begun to break apart with the opening of the European Epicontinental Sea and the initiation of the Central Atlantic Ocean.
(Adapted from Scotese 2003 Paleomap Project, www.scotese.com)

As described previously, the main distributional range of the class Remipedia extends from Mexico's Yucatán Peninsula to the Bahamas; they are found in greatest diversity in the anchialine caves of the Bahamas Bank (Map 2.1). Two species have been found outside these areas: one on Lanzarote (in the Canary Islands in the Eastern Atlantic); and another in Bundera Sinkhole, on the southern flanks of Cape Range on the Ningaloo Coast. As they have never been found outside a cave habitat, it is not clear how or when they colonised these cave systems that are now separated by two oceans. This markedly disjunct distribution lends weight to theories about a marine corridor—the Hispanic Corridor—which was opening during the Jurassic period. This would have enabled limited faunal exchange between the Panthalassic (Pacific) Ocean and the west Tethys Sea, through the opening 'North Atlantic' and 'Caribbean' seas (Figures 2.32–2.34).[74]

From the latest Palaeozoic to the mid Mesozoic Era (approximately 250–180 million years ago), the Gondwanan continents were part of a huge, roughly crescent-shaped landmass centred on the equator, which covered most of one hemisphere (Pangaea). This landmass was entirely surrounded by an ocean (the Panthalassic Ocean), with an enormous embayment, bight or gulf forming the mouth of the crescent on its eastern margin (the Tethys Sea or Ocean). The western coast of 'Australia' was then on the northern shore of the south-eastern arm of the crescent (Figures 2.32 and 2.33).

Almost as soon as it formed, lithospheric stresses began to break Pangaea apart again. At the beginning of the late Triassic period, it had begun to rift into two large continental bodies, Laurasia and Gondwana, with an epicontinental sea (the European Epicontinental Sea) forming between them (Figure 2.33).[75] Gondwana consisted of the southern Pangaean continents, which became South America, Africa, Antarctica, India/Malagasy and Australasia (including Australia/New Guinea, New Zealand and New Caledonia). By the middle Jurassic, ocean circulation had altered as a consequence of the rifting of 'North America' from 'South America' and 'Africa', and the opening of the central Atlantic and Caribbean Seas between Africa and South America.

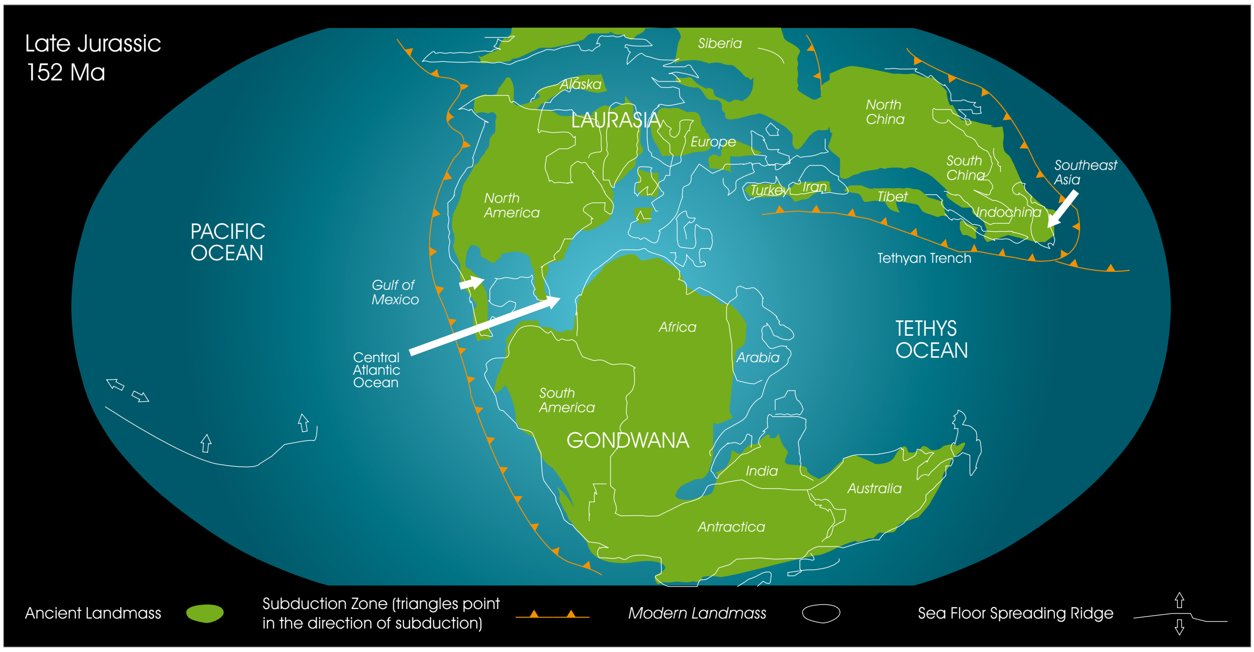
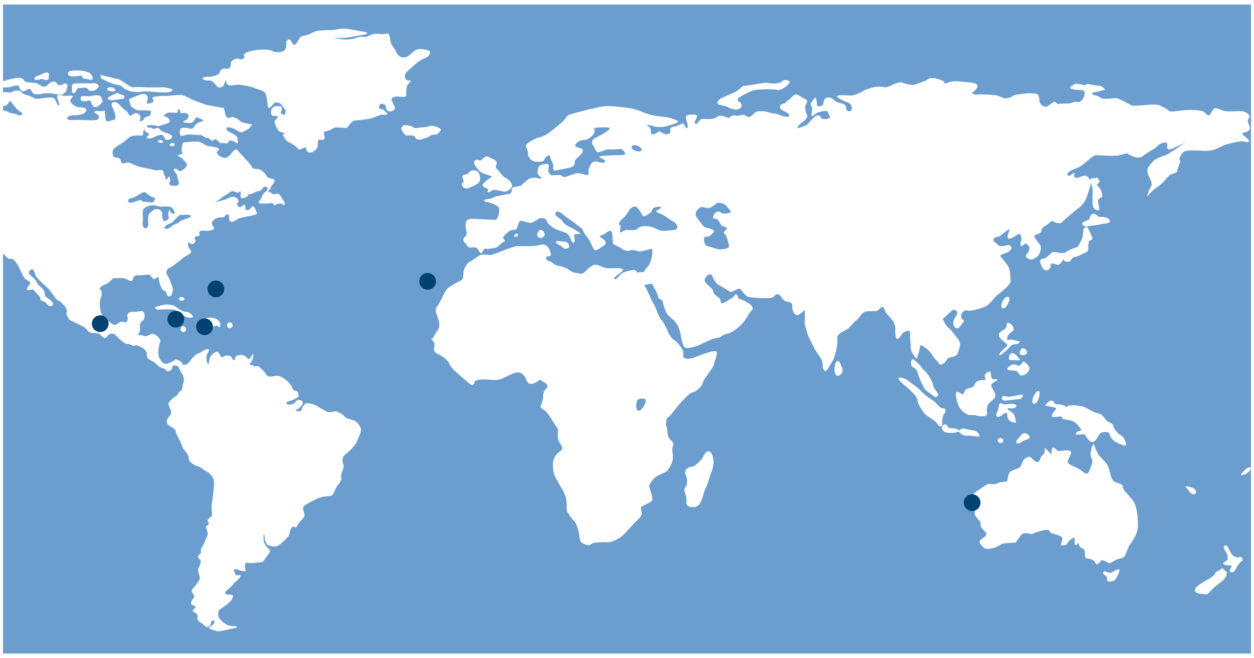


FIGURE 2.34 Reconstruction of Late Jurassic Earth.
(Adapted from Scotese 2003 Paleomap Project, www.scotese.com)

The hypothesised opening of the Hispanic Corridor between North and South America allowed flow west from the Tethys to the Panthalassic (or proto-Pacific) Ocean. This would have enabled extensive exchange of marine biota between the western Tethys and eastern Panthalassic–Pacific. Stratigraphic and palaeontological evidence support this conclusion.[76] Based on studies of Mesozoic molluscs, Smith (1983) and Hallam (1983) suggested that this central American corridor provided a sporadic, intermittent and restricted level of faunal exchange between the eastern Pacific and western Tethys from around 192 million years ago (the early Pliensbachian epoch of the early Jurassic).[77] Such a circumtropical current could have been a means of dispersal of the benthic parent populations of modern remipede-type anchialine communities during the late Jurassic period (Figure 2.34).

The western edge of the Pilbara Craton has been disappearing for the past 60 million years. Over most of this period, it is likely that there have been reef-type environments at the edge of the continent. Therefore, ancient lineages have had nearly continuous opportunities to occupy habitats along the rim of the region, which has been essentially stable over geological timescales. Carbonate environments deposit continuously on the new edge. Progeny of such parent populations would continue to occupy and reoccupy these new types of environments opportunistically, as they develop. Therefore, the Cape Range peninsula is the latest in a long line of now geologically invisible environments, in which ancient fauna have continually occupied more recent environments as they have arisen.[78]

In summary, the coastal plain habitat of the Cape Range peninsula supports a fauna of a type unknown elsewhere in the southern hemisphere. This fauna is characterised by the presence of a species of animal from the class Remipedia, a class that only occurs elsewhere in similar anchialine habitats on either side of the North Atlantic (Yucatán, Mexico, islands of the northern Caribbean, and Lanzarote in the Canary Islands; Map 2.1). Although a proportion of this fauna is endemic to Bundera Sinkhole, the sole accessible deep anchialine system in Australia, elements of the fauna also occur widely in the more superficial waters of the Cape Range coastal plain, including species of *Stygiocaris* (Atyidae), *Halosbaena* (Thermosbaenacea), *Haptolana* (Cirolanidae), various amphipods, and Australia's only subterranean fishes, the blind cave eel and blind gudgeon.[79]



MAP 2.1 Known remipede communities: Mexico, Bermuda, Bahamas and Cuba in the Western Atlantic Ocean, Lanzarote in the Eastern Atlantic Ocean, and the Cape Range peninsula in Australia in the eastern Indian Ocean.

Travelling north

By approximately 80 million years ago (the upper Cretaceous), Australia and Antarctica had split from the other eastern Gondwanan lands (India and Madagascar), to form the south-eastern shore of the opening Indian Ocean. Australia continued to drift north and its separation from Antarctica was effected by 45 million years ago. Rich contemporary coal and bauxite deposits provide evidence demonstrating Australia's cool temperate to subtropical climate during the late Eocene and early Oligocene (Figure 2.35).[80]

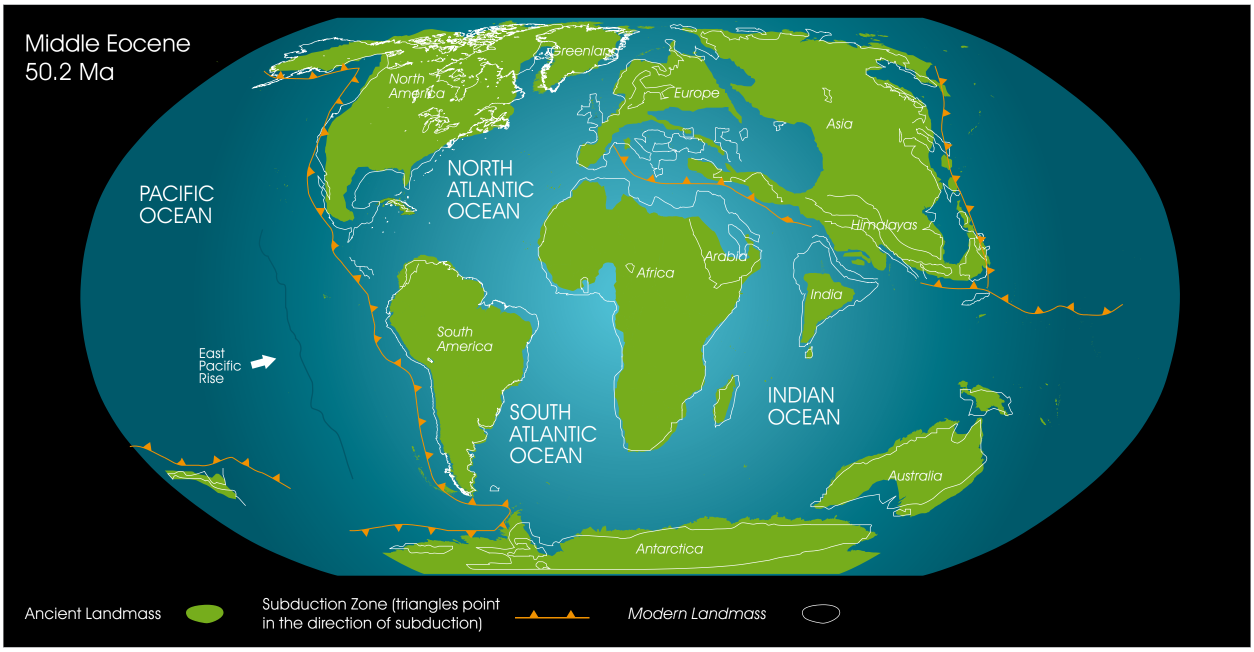


FIGURE 2.35 Reconstruction of Earth during the middle Miocene. This image shows a circumglobal current linking the opening Indian Ocean to the North Atlantic Ocean via the remnants of the Central Atlantic or Tethys seaway, and the former Hispanic Corridor linking the North Atlantic to the Pacific Ocean.
(Adapted from Scotese 2003 Paleomap Project, www.scotese.com)

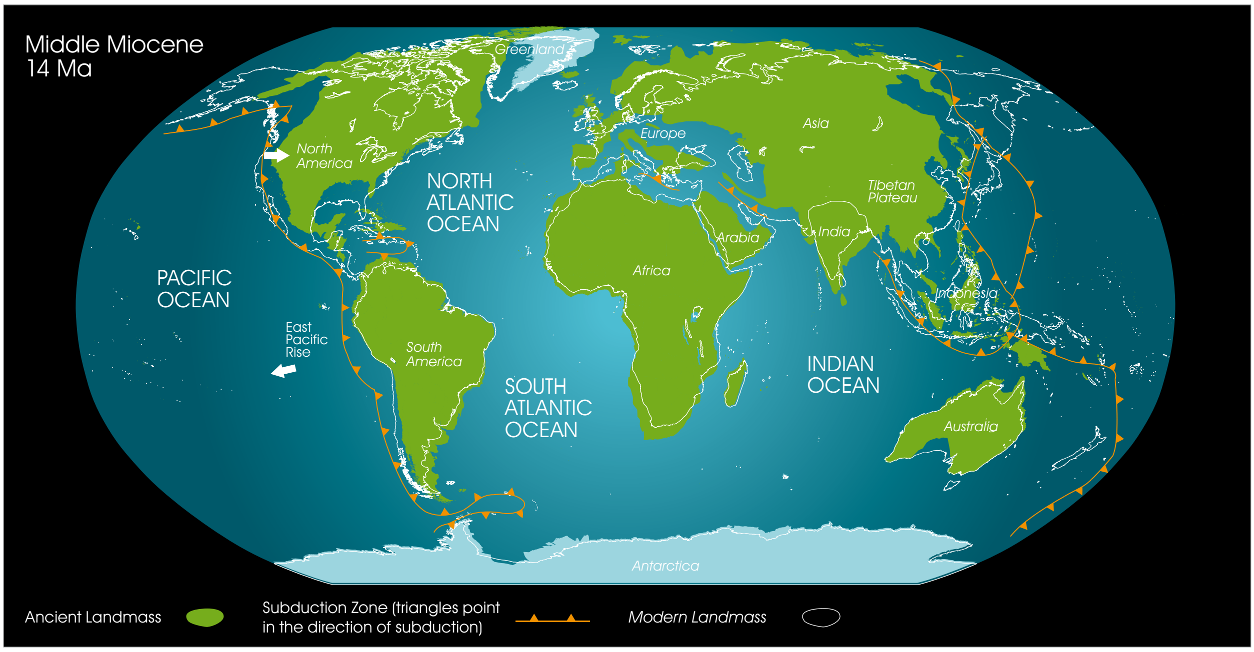


FIGURE 2.36 Reconstruction of Earth during the middle Miocene. This image shows the closure of the Hispanic Corridor as North and South America joined, and the gradual closure of the connection between the Indian and North Atlantic Oceans as Arabia collided with western Asia to form the Mediterranean Sea. Global climates changed as the Southern Ocean widened with Australia's increasing separation from Antarctica and the formation of a circumpolar current.
(Adapted from Scotese 2003 Paleomap Project, www.scotese.com)

This rapid northward movement of Australia towards south-east Asia profoundly shaped the Australian biota, including its subterranean fauna, during the Cenozoic. Ocean currents and winds became reorganised with the closing of the Tethys seaway. The opening of the circumpolar Southern Ocean altered climate patterns significantly in the southern hemisphere, contributing to a gradual drying and cooling of Australia as the Miocene progressed. Distinct fluctuations in climate accompanied the formation of the Antarctic ice cap 15 million years ago, during the middle Miocene (Figure 2.36). Cool, arid, windy glacial periods and warm, humid interglacial periods interleaved, leaving their imprints in the expansion and stabilisation of deserts and dunefields, the deposition of shallow tropical marine sediments, the distribution of flora and fauna, and the fossil record. These rapid and substantial environmental changes affected Australian (and Gondwanan) biota, which was already enduring selection pressure in the form of increasing isolation. The importance of subterranean refugia such as the Cape Range karst system is brought into focus by these cyclic fluctuations, superimposed on a generally drying trend.[81]

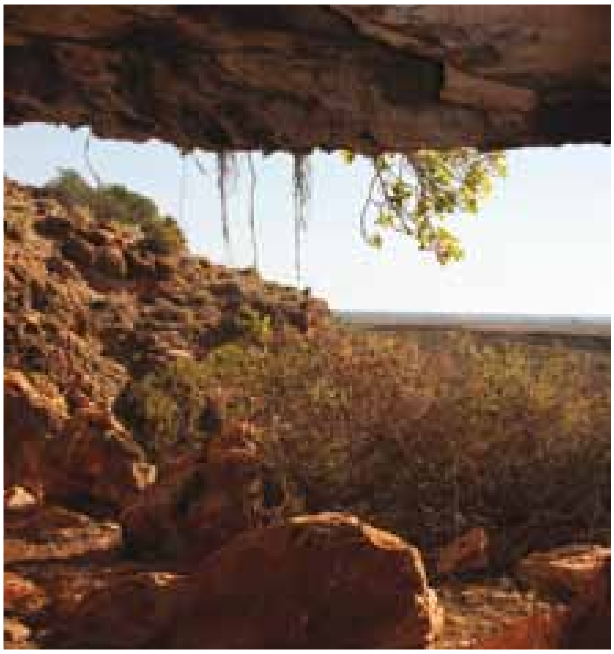


FIGURE 2.37 View from Bunbury Cave, northern part of Cape Range.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

The high density of karst features (which are generally active in humid rather than arid environments) on the Ningaloo Coast, and probable evolutionary relationships between the modern Cape Range terrestrial 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 those that currently prevail.

The terrestrial troglobitic invertebrate fauna of the Cape Range peninsula includes beetles, spiders, cockroaches, slaters, crickets, pseudoscorpions and millipedes. These species, now completely adapted to the deep cave habitat to which they are confined, were once part of an extensive Miocene tropical rainforest leaf litter community (Figure 2.38). The environment most resembling that in which they arose now occurs 1,200 kilometres to the north-east in tropical north Queensland. This widely disjunct pattern is also reflected in the distribution of aquatic stygofauna and is an indication of the major changes in climate that have occurred in Australia during and since the Miocene epoch. As this fauna must have moved vertically many times with the changes in sea level described above, its existence suggests that the Ningaloo Coast subterranean cave and water systems are very extensive vertically as well as geographically.[82]

The richness of the subterranean fauna is testament to the stability of these underground systems over millions of years.

FIGURE 2.38 Subterranean inhabitants of the Cape Range peninsula karst system (a) In rows from top left: 1 *Nocticola flabella*, the world's most cave-adapted cockroach, 2 the millipede, *Stygiochiropus communis*, 3 *Bamazomus vespertinus*, one of seven species of micro-whipscorpion known from Cape Range, 4 the nemobiine cricket, *Ngamarlanguia luisae,* 5 cave pseudoscorpion *Hyella* sp. (*Hyidae*), 6 *Halosbaena tulki*, the only member of the Order Thermosbaenacea known from the southern hemisphere, 7 *Glennhuntia glennhunti*, a harvestmen endemic to the coastal plain, 8 unnamed blind philosciid isopod, 9 *Milyeringa veritas* (Eleotridae), one of two cave fish sympatric on Cape Range.
Photographs Douglas Elford © Western Australian Museum
(b) *Ophisternon candidum*, the blind cave eel and *Milyeringa veritas*, the blind gudgeon.
Photograph © Western Australian Museum[83]

LIFE ON THE SURFACE

In contrast to the life that has evolved in the cool, dark reaches of the subterranean world below the Cape Range peninsula, a wide range of animals and plants have adapted to the hot, arid conditions of the surface. The peninsula is part of the transition zone between the tropical, temperate and central desert regions of Australia. This results in an unusual mixture of species, many of which are at the northern or southern limits of their distribution. The peninsula shelters a large number of species and subspecies that are endemic to the region, including an unusual richness of reptiles.

Sunbaked animals

The geology, geomorphology and climate of the region have directly influenced the surface fauna found in and around the Cape Range peninsula. The Cape Range peninsula is connected southward to the sand ridges and plains of the Gascoyne region. The Giralia anticline, south-east of the nominated area, effectively isolates the sand habitats of the peninsula from those to the north and east. The combination of different sand units, the dissected limestone range, extensive intertidal habitats and a coastally influenced climate suitable to both southern and northern mesic (wetter) zone species, combine to maintain a diverse array of vertebrates on the peninsula.[84] The native vertebrate fauna of the Cape Range peninsula includes seven amphibian, 22 mammal, over 100 reptile, and approximately 200 bird species.

FIGURE 2.39 The fairy tern (Sterna nereis) and the osprey (Pandion haliaetus) are International Union for Conservation of Nature red-listed birds found on the Ningaloo Coast. Photographs (a) Bill Belson © Lochman Transparencies (b) Tony Howard © Western Australian Department of Environment and Conservation

The bird and reptile fauna include species typical of the semi-arid and arid zones, along with species from the wetter south-west of Australia. Some of these species are found in populations that have become isolated from their main centres of distribution, particularly the Pilbara and Kimberley regions and the central deserts. Eleven bird species are at the northern or southern limits of their range, or are otherwise isolated from their main populations. Examples include the spotted bowerbird (*Chlamydera maculata*), rufous-crowned emu-wren (*Stipiturus ruficeps*) and the painted firetail finch (*Emblema picta*). The Cape Range peninsula also has a high degree of reptile endemism, with 15 species restricted to the peninsula or immediate region.

A desert garden

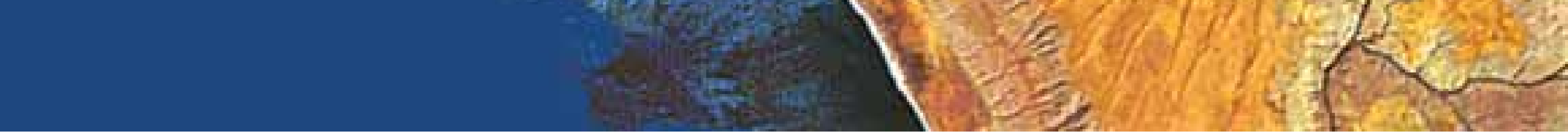
Part of the Carnarvon Xeric Scrub Global Ecoregion, the Cape Range peninsula has a high diversity of plant species, with a total of 630 taxa of vascular plants recorded. The flora is comprised of communities that have adapted to the wide range of generally arid or semi-arid landscapes found across the peninsula, and some relictual taxa. The terrestrial landscapes include a mosaic of rangelands, dune fields, coastal dunes, tidal mud flats, sand flats, alluvial plains and red aeolian dune fields. These landscapes support sparse eucalypt woodlands and acacia shrublands, mixed with more dominant *Triodia* (spinifex) grasslands. The coastal dunes, tidal mud and sand flats, and saline alluvial plains support more specialised samphire and mangrove communities.[85]

The vegetation communities are composed mainly of widespread species, originating from both temperate and tropical regions. This overlap reflects the position of the Cape Range peninsula as a biogeographic transitional zone. A subset of the flora is restricted to the region between Shark Bay and the Cape Range peninsula, such as the spectacular Forrest's featherflower (*Verticordia forrestii*). Another 18 species are confined solely to the peninsula and immediate surrounds. These endemic plants include the Yardie Creek morning glory (*Ipomoea yardiensis*) (Figure 2.41), two grevillea species (*Grevillea calcicola* and *G. variifolia*), a eucalyptus (*Eucalyptus ultima*) and a bottle tree (*Brachychiton obtusilobus*). Many other plants are at the limit of their ranges, including 50 species with southern temperate affinities. Several of these species are unusually disjunct, such as the millstream palm (*Livistona alfredii*), the nearest population of which is approximately 300 kilometres to the north-east, in the Pilbara region.[86]

FIGURE 2.40 Grevillea, Cape Range National Park. Photograph Tony Howard © Western Australian Department of Environment and Conservation

FIGURE 2.41 Yardie Creek morning glory (*Ipomoea yardiensis*). Photograph © Bronwyn Collins

FIGURE 2.42 After rain, flowers flourish in the seemingly inhospitable arid lands. Photograph Dragi Markovic © Department of the Environment, Water, Heritage and the Arts



2B HISTORY AND DEVELOPMENT

Indigenous human habitation

The Cape Range peninsula has a remarkable history of human occupation, stretching back at least 35,000 years. This occupation has been shaped by the region's geological and climatic history. Archaeological evidence suggests that Indigenous people episodically occupied rock shelters on the peninsula, perhaps on a seasonal basis, from 35,000 to 17,000 years before present (BP). They took advantage of the diversity of marine fauna including crabs, fish, sea urchins, molluscs and bivalves, and also incorporated a variety of rangeland fauna in their diet. The region provides the earliest evidence of human ornamentation found in Australia. Shell beads discovered at Mandu Mandu Creek rock shelter at Cape Range have been dated to more than 32,000 BP. Personal ornament has long been recognised as a hallmark of modern human behaviour, and beads and pendants, like those found at Cape Range, are among the oldest unambiguous evidence of this symbolic behaviour.[87]

The limestone geology and steep topography of the Cape Range peninsula provide an excellent environment for the preservation of evidence of human occupation.[88] It is also the nearest point on the continent to the edge of the continental shelf. Even at the height of the last ice age the coast was never more than 10–12 kilometres away. This has facilitated the preservation of evidence of exploitation of marine and coastal resources, which in other places has been covered by the sea.[89] The alkaline environment has preserved a rich assemblage of marine artefacts, including shell beads (Figure 2.43).[90] Similarities between the painted rock art found on Ningaloo rock shelter walls and motifs found hundreds of kilometres away indicate growing social and economic networks between the Yinigudura people of the North West Cape and other Aboriginal groups during the late Holocene.[91] Painted caves such as those found at Cape Range play an important role in documenting the traditional and spiritual stories of the region's Indigenous people over time. Shell middens, created where Indigenous people gathered for meals, are also found in the coastal sand dunes of the peninsula.

The Mandu Mandu necklace

Twenty-two small cone shell beads, recovered from Mandu Mandu Creek rock shelter, show evidence of deliberate modification, including perforations that would have enabled them to be threaded onto string. A high level of standardisation was applied in the manufacture of the Mandu Mandu Creek shell beads. While this is the earliest known example in Australia, such cultural modification of marine shell was practiced by the Yinigudura people of the Cape Range 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. Tusk shell beads are still made in coastal parts of the Kimberley region of western Australia today.[92]

FIGURE 2.43 Mandu Mandu necklace, dated to more than 32,000 years before present. © Western Australian Museum

The Western Australian Government has registered and documented over 140 Aboriginal sites in the nominated area. These include artefact scatters, shell middens, paintings and engravings, ceremonial and mythological areas, grinding patches and grooves, burial sites, and man-made structures. The wide range of sites combines to provide a fascinating insight into the long-running human occupation of the Ningaloo Coast.

A shifting shore

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 became active across the expanding arid and semi-arid zones. During interglacial periods, the sea level rose as the polar ice caps melted, and the arid zone contracted. The waning of the last interglacial stage corresponds to the beginning of human interaction with the region.[93]

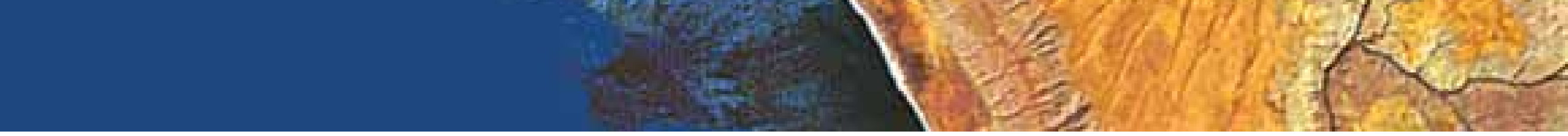
The last phase of intense glacial activity, known as the last glacial maximum, began about 25,000 BP. In Australia, this was a time of intense aridity and cold conditions, which peaked between 19,000–17,000 BP. The now-inundated red Pleistocene dune fields of Exmouth Gulf extended into a low coastal plain, which began to be submerged beneath the rising waters of the gulf as the polar ice caps melted during the present interglacial (the Holocene epoch), beginning around 11,500 BP.[94]

For many years, archaeologists have debated the importance of marine resource use in Pleistocene human economies in Australia and overseas. During the height of the last glacial maximum, sea levels around the world dropped to about 135 metres below their current level, as sea water was frozen into enormous ice sheets that blanketed large areas of the globe, in particular the polar regions. In this context, the Cape Range peninsula occupies an important place in the history of human coastal occupation in Australia. The inundation of the coastal plain with the rise of the sea at the end of the last ice age was less dramatic at the Cape Range peninsula than elsewhere in Australia: it is just 10 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 10–12 kilometres from the coast. Although there appears to be a hiatus in occupation across north-western Australia during the height of the last glacial maximum, archaeological evidence suggests that the Pilgonaman Creek rock shelter on the Cape Range peninsula may have been occupied even at this time.[95]

The rich assemblage of materials recovered from the rock shelters of the Cape Range peninsula, coupled with the probable availability of freshwater even during the arid period, means that Pleistocene archaeological deposits in the region have the potential to provide further insights into early human exploitation of marine resources. Current gaps in the Cape Range chronology may be filled by future archaeological investigations, which would build a detailed chronology of coastal occupation from the Pleistocene into the Holocene—a chronology not likely to be found anywhere else on the continent.[96]

Following the last glacial maximum, the warming of the atmosphere led to gradual sea level rise accompanied by evidence of an increase in human use of the Cape Range area. The early Holocene coastline offered a variety of marine habitats, including mangroves, rocky coasts and sandy bottoms. These habitats provided a rich resource base to sustain human populations. It is during this period that the earliest dated painted rock images emerged in the area, and for a few thousand years white ochre motifs were painted on rock shelter walls. Several rock shelters were abandoned for a second time around 8,000 BP, coinciding with the decline of mangrove habitat on the peninsula.[97]

Intensification of occupation began again around 6,000 BP, when sea levels stabilised at their current levels. There was also a change in the type of stone used during this period. Exotic fine-grained stone was introduced to sites, and a new tool assemblage emerged, which 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 and other activities. New motifs painted in red rather than white ochre also appeared, showing stylistic similarities with rock painting found across the wider region. These late Holocene developments are indicative of increasing social and economic networks involving groups beyond the peninsula. During the Holocene, changes in technology and food preferences conform to the established sequence in the nearby Pilbara and other parts of northern Australia.[98]



Navigating the North West Cape

The first recorded European contact with the Cape Range peninsula was a sighting by the crew of the Dutch ship *Zeewolf* in 1618. Later the same year, Captain Jacobz of the ship *Mauritius* made the first known landing by a European.[99] European exploration of the Indo–Pacific region and the development of extensive trade contacts with north and south-east Asia led to increased ship traffic to Australia's north-west coast by the end of the eighteenth century. American whalers also operated in the area from as early as the 1790s, first targeting sperm whales and later humpbacks. It is likely that these men went ashore in search of meat and fresh water, but they did not establish any infrastructure.

Although detailed charts were available for the waters of the Indonesian archipelago, very little was known of the region to the south. North West Cape, as it was most often referred to by mariners from the early nineteenth century, was easily visible from the sea, and so provided a vital fixed navigational point, enabling ships travelling east to check their bearings. However, the reefs of the peninsula and the islands to its north also proved a significant hazard. The safety of ships navigating these waters was greatly improved by the identification of an accurate position for North West Cape, and a chart of the surrounding waters.[100]

Dangerous waters

The Cape Range peninsula and Ningaloo Reef have long presented a hazard to navigators, particularly before the advent of reliable chronometers. Too much easting could be disastrous, and the strong winds and tides made navigating sailing vessels near coral reefs dangerous. These dangers are reflected in the number of international wrecks in close proximity to each other in and around the waters of the Ningaloo Coast. These include the early nineteenth-century wooden ships the American Rapid, *which sank in 1811, and the Portuguese* Correio d'Asia *(1816); the Singaporean* Fairy Queen *(1875, wrecked in Exmouth Gulf); the Austro-Hungarian* Stefano *(1875) and SS* Zvir *(1902); the Scottish* Benan *(1888); and the Norwegian barque* Iona *(1923).*[101]

In 1801, the French navigator Nicolas Baudin, sailing in the *Géographe*, mapped the region. He returned again briefly in 1803. Among his tasks were to determine the position of North West Cape and the Willem River, earlier reported by Dutch navigators, but never conclusively located. Baudin travelled with a cartographer, Louis de Freycinet, who named Cape or Point Murat at the extremity of the peninsula and the Muiron Islands during the same voyage (Figure 2.44).[102] In charting the coast, Baudin did not venture close to shore, but held the *Géographe* outside the 50-fathom isobath. Baudin observed on 21 July 1803 that

> from North West Cape to the mouth of Willem's River [possibly the modern Yardie Creek] the land looks like an island, the two extremities of which may be distinguished perfectly. This is why those who do not know that there is a river there still think that it is an island.[103]

His survey of the cape was disrupted by a storm, which forced the *Géographe* even further out to sea. When the heavy weather passed, Baudin returned to continue the survey, but he recommenced work from a different position. As a result, and like the charts of the Dutch and English before them, the chart eventually produced of North West Cape based on the work of Baudin and Freycinet was somewhat misleading.[104]

FIGURE 2.44 The Muiron Islands were named and charted in 1803 by Louis de Freycinet, who sailed with Nicolas Baudin in the *Géographe*.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

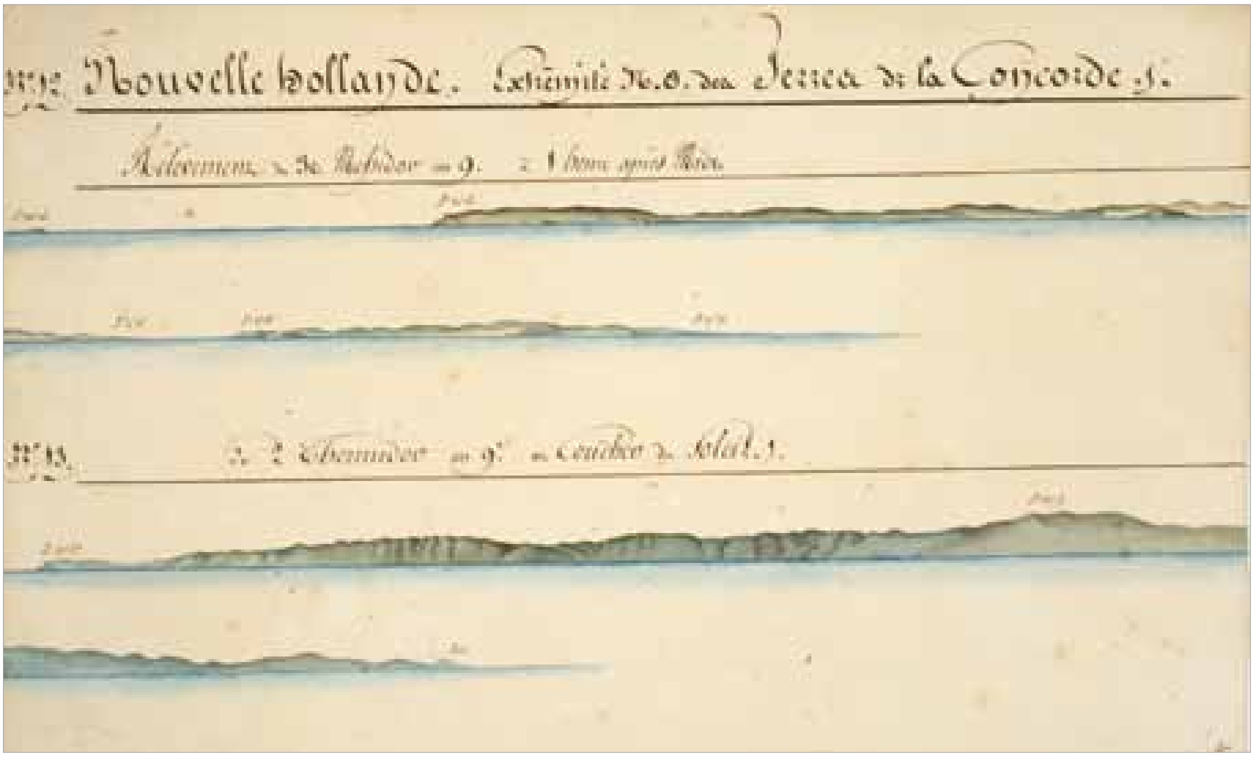


FIGURE 2.45 One of the first European representations of the Ningaloo Coast—a coastal view of 'l'Extremité nord ouest' [North West Cape] by Nicolas-Martin Petit, one of two official artists with Baudin's expedition in 1803. [Document conservé aux Archives Nationales, Paris, MAR/5/JJ/40B. Cliché Atelier photographique des Archives nationales.]
Image © CHAN Paris

In 1817, the British government, concerned at continuing French interest in Australia's north-west coast, commissioned Lieutenant Philip Parker King to chart the northern coastline. King's charting finally established the shape of North West Cape. When King sailed around the Cape Range peninsula in February of 1818, he was impressed by the varied and abundant marine life found in the region's waters, which he described vividly:

> The sea swarmed with turtles, sea snakes and fish of various sorts; and the dolphin was eminently conspicuous for its speed, and the varied beauty of its colours … the sea was abundantly stocked with fish and turtle, though it did not appear to be the season for the latter to lay their eggs. An immense shark was hooked, but it broke the hook and escaped.[105]

The Stefano Castaways

In 1876 the Austro–Hungarian barque Stefano *was wrecked on Ningaloo Reef while on its way from Cardiff to Hong Kong, with a cargo of black coal* (Figure 2.46). *This wreck led to the most extended and widely-described encounter between Aboriginal and European people in the region of the Cape Range peninsula up to that time. Of the 10 men who made it to shore, only two—both teenagers—survived. On the verge of starvation, having resorted to eating the flesh of one of their dead crew mates, they were rescued by local Aboriginal people. Over the next three months, the Yinigudura people nursed the castaways to recovery, then led them to the tip of North West Cape, where they were rescued by a pearling cutter. Their return to Perth caused a sensation. A book,* The Stefano Castaways, *translates the original manuscript recording the experiences of the two shipwrecked sailors. It describes the Yinigudura and their daily activities, including food gathering and hunting. Marine resources were their staple foods, in particular fish, turtles and dugongs.*[106]

FIGURE 2.46 Divers on *Stefano* anchor and windlass, Ningaloo Reef, 8 May 2008.
Photograph © Western Australian Museum

Aboriginal labour and European industry

While European settlement of the Cape Range peninsula did not commence until the late nineteenth century, European industry by then had already had an impact on the Yinigudura, Baiyungu, Ingarda and on other Indigenous groups in the region. In 1865, the Colonial Secretary's Office in London decreed that convict labour was not permitted in areas above the 26th parallel. The use of Indigenous labour in the pastoral and pearling industries followed this decree. 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, the forcible detention and removal of Indigenous people from their traditional lands for work was a common practice along the Pilbara coast.[107]

Pearling, fishing and pastoralism provided the economic mainstay of the region in the early twentieth century. The beginning of the pastoral industry is marked by the establishment of Minilya Station in 1876 by J Brookman. The pastoral lease covered the whole of the Cape Range peninsula, and was gradually subdivided. In 1889, Brookman sold 54,600 hectares of the Minilya leasehold on the northern and western side of the peninsula to Thomas Carter. This became Yardie Creek Station. After further subdivision from 1907, followed by amalgamation in 1933, the Western Australian Government acquired the remainder of Yardie Creek Station in 1959, and it eventually formed the core of the Cape Range National Park, gazetted in 1964.[108]

Thomas Carter: pastoralist and ornithologist

In 1889, Thomas Carter acquired Yardie Creek Station. The house he constructed on the station was built from the nearby wreckage of two ships. During the thirteen years in which he ran sheep at Yardie Station, he was in constant search for permanent water for both his stock and his household. Life was not easy; periods of drought were interspersed with severe tropical cyclones. He lost sheep not just to drought, but also to poisonous plants and dingoes.

While the life of a pastoralist on the Cape Range peninsula was challenging, the location did enable Carter to pursue his other occupation, as a dedicated ornithologist. He explored the range extensively and collected eggs and bird specimens. At times, lack of supplies for his expeditions forced him to eat valuable specimens. He sent numerous specimens to museums, and published articles on the bird life of the region in a number of ornithological journals.

Although his assistant was speared, Carter remained on good terms with the Yinigudura, recording their bird names in 'Birds occurring in the region of the North-West Cape', published in The Emu *on 1 July 1903. He identified 180 birds and secured specimens of 170, two entirely new: the rufous-crowned emu-wren and the spinifex-bird which bears his name,* Eremiornis carteri. *He wrote of the spinifex-bird that 'its flight is feeble, with the short, rounded wings rapidly beating, and tail drooping and expanded … The only note it has been heard to utter is a harsh "chat chat"'* (Figure 2.47).[109]

FIGURE 2.47 Spinifex bird, named *Eremiornis carteri* by Thomas Carter, early pastoralist and ornithologist on Cape Range peninsula.
Photograph © Graeme Chapman

The town of Exmouth

The township of Exmouth was formally established in 1963 as a service facility for the Harold E.Holt Naval Communication Station. When the communication station opened, Exmouth had a population of 4,000 people (its current population is less than 3,000). The town soon became the main service centre for trawling and aquaculture in the region. Tourism, recreational fishing and associated infrastructure also followed.[110]

FIGURE 2.48 The lesser golden plover, described by Thomas Carter in his 'Birds Occurring in the Region of the North-West Cape'.
Photograph Jiri Lochman © Lochman Transparencies

Ningaloo memories

It wasn't only tourists who were astounded by the abundant life of the reef. Duke Wellington, a local who first encountered the reef in the early 1950s, described this first encounter with wonder, almost half a century later:

…when the tide came in the fish came in over the reef as well, and we were fascinated—we just stood on the lumps watching them, and there were great schools of spangled emperor and parrot fish and a lot of sturgeon fish, all up on the reef feeding—and octopus—I've never seen so many. As soon as the tide started to come in they all came out of their holes, and we worked out later what was doing it, it was the colder water coming over the reef—they didn't like the cold water. And oysters! You could sit on one rock and just fill yourself with oysters, which we did.[111]

Tourism is now the most significant source of income for Exmouth. Visitors are attracted by the perfect white beaches, the dramatic Cape Range and the renowned beauty and diversity of marine life on Ningaloo Reef.

Protecting the reef

The Western Australian Government gazetted the state waters of the Ningaloo Coast, inland to 40 metres above the high water mark, as a Marine Park in 1987. The boundary included around 90 per cent of the reef, extending from approximately 260 kilometres from North West Cape south to Amherst Point. Ningaloo Marine Park (Commonwealth Waters) was declared by proclamation under the *National Parks and Wildlife Conservation Act 1975* (NPWC Act) on 7 May 1987.

Gnulli: 'all of us'

In 1997 the Indigenous Land Corporation (ILC) purchased Cardabia Station. The station is a pastoral lease 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 the Traditional Owners.[112]

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 Cape Range area and have ongoing association with many sites within the nomination.

FIGURE 2.49 State and Commonwealth marine parks were declared at the Ningaloo Coast in 1987.
Photograph © Cam Skirving

In 2000, a proposal to develop the Coral Coast Resort, an AU$200 million marina resort north of Coral Bay, stimulated community opposition in Perth, Coral Bay and Exmouth, bringing Ningaloo Reef to national prominence. Between 2000 and 2003, the twice Booker Prize nominated Australian novelist Tim Winton campaigned with a number of non-government conservation organisations to prevent the development. Winton became spokesman for the grass roots 'Save Ningaloo' movement. In December 2002, Winton spoke at a 15,000-strong rally in Fremantle. He described the Ningaloo Coast as:

> …a rugged and beautiful wilderness. People come from all over the world to see it. After all, how many places can you go to where you can swim with a whale shark, a placid animal the size of a bus covered in brilliant dots like an Aboriginal painting. The same day you can be circled by manta rays that roll and swerve like enormous underwater birds. If you're lucky you'll see a dugong, the shy and vulnerable creature of the seagrass meadows. There'll be turtles, of course. I've seen them hatch and waddle down to the water with sky pink as the desert beyond. There'll be more coral than you've ever seen in your life. If you're keen enough you can see the coral spawn like a tropical blizzard. It's an incredible place.[113]

On 4 July 2003, the Western Australian Government announced that the resort would not go ahead.[114]
In 2004, the government extended the park boundary south another 40 kilometres to Red Bluff, to ensure protection of the entire Ningaloo Reef.[115]

From its Indigenous human history to its wreck-scattered coast, from its migratory giants to the seasonal holiday-makers they attract, from the rocky heights of the range, the depths of the continental slope, and the unfolding geotectonic and climate history revealed in its biota, the story of the Ningaloo Coast is the story of the world and of human history: of migration, isolation, adaptability, change, solitude and discovery.

ENDNOTES

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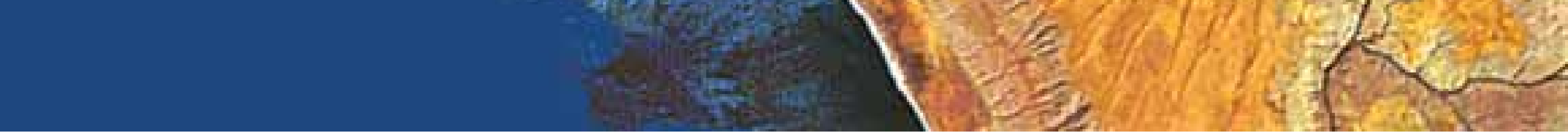
3 JUSTIFICATION FOR INSCRIPTION



3 JUSTIFICATION FOR INSCRIPTION

3.A CRITERIA FOR WHICH INSCRIPTION IS PROPOSED (AND JUSTIFICATION FOR INSCRIPTION UNDER THESE CRITERIA)

The Ningaloo Coast is nominated under criteria (vii), (viii) and (x) for its outstanding universal significance:

Criterion (vii) to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance

- The Ningaloo Coast provides the best opportunity in the world to encounter whale sharks (*Rhincodon typus*), the world's largest fish, together with globally significant populations of iconic marine megafauna—manta rays, dugongs, marine turtles, humpbacks, other cetaceans, rays and sharks.
- The property contains exceptional underwater scenery, including coral reef structures, marine invertebrates and marine megafauna, contrasting with the vivid colours of the arid terrestrial landscape.

Criterion (viii) to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features

- The Ningaloo Coast is an outstanding example representing major biogeographic events in the history of life: increasing biological isolation, shifting continents and the record of climate change over time.

Criterion (x) to contain the most important and significant natural habitats for in situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation

- The Ningaloo Coast is a place of outstanding biological diversity, and has an internationally significant role in the protection of many important species, including the exceptional whale shark, which is a flagship for the health of the oceans.
- The property includes highly significant subterranean and terrestrial ecosystems sheltering unique fauna, which have outstanding universal value from the point of view of science.

Set in limestone land and seascapes of exceptional natural beauty, the land, waters and biota of the Ningaloo Coast have outstanding universal value for demonstrating geological, hydrological and ecological unity over time.

PREVIOUS PAGE Photograph Tony Howard © Western Australian Department of Environment and Conservation

Criterion (vii)

The outstanding aesthetic experience of the Ningaloo Coast is defined by the connections between its terrestrial and underwater landscapes, seascapes, and submarine and subterranean ecologies across time and space. The profusion of life and varied colours and textures of the underwater and terrestrial landscapes inspire and move visitors, be they scientists, divers, tourists or local residents. The principal aesthetic characteristics of the Ningaloo Coast include:

- globally significant aggregations of iconic marine megafauna, including the best opportunity in the world to encounter the internationally celebrated whale shark (*Rhincodon typus*), the world's largest fish
- the exceptional visual contrast of the wave-swept ramparts of Ningaloo Reef stretching for tens of kilometres with the arid limestone coast of the Cape Range peninsula, which is complemented by underwater landscapes of surpassing beauty and intimacy
- the close juxtaposition of open ocean, reef and arid coast, including the region's high water quality and ecosystem intactness.

Criterion (viii)

The Ningaloo Coast has outstanding universal value as an integrated limestone system with features that demonstrate major stages in the record of life and significant ongoing geological changes, including plate tectonic movement and climate modification. Its landforms and biota describe a remarkable biogeographic story about increasing biological isolation, climate change and the shift from pandemism (in which taxa occur widely) to endemism (in which taxa are restricted to particular areas) among marine species, as a result of the rearrangement of continents and ocean currents. Its main features are:

- globally important anchialine ecosystems significant for sheltering unique stygofauna whose distribution demonstrates the effects of continental drift and biological change over 150 million years, since the Jurassic period
- subterranean karst systems providing habitat for rare terrestrial troglomorphic faunas, outstanding for their affiliations with tropical rainforest biota, and reflecting climate change since the Miocene epoch, as the last pieces of Gondwana broke apart and the Australian plate continued its journey north
- a high degree of phylogenetic diversity in subterranean fauna, indicating long isolation
- a series of uplifted marine terraces, which challenge accepted scientific understanding of the development of coasts along passive continental margins
- a rare geoecological structure, which integrates geological and biological elements, from the limestone range through the ancient wave cut terraces to the living marine environments.

Criterion (x)

The Ningaloo Coast has outstanding universal value for its biological diversity, its ecosystem diversity and the presence of rare and threatened species. These elements include:

- a rich, diverse and structurally cohesive tropical coral reef system and associated marine and littoral environments
- the presence of more than 50 per cent of Indian Ocean coral species, with over 300 species in 54 genera
- globally significant aggregations of endangered migratory marine vertebrates
- sixty-nine International Union for Conservation of Nature (IUCN) Red Book-listed species
- seven hundred and thirty-eight species of reef fish, over 1,000 species of marine algae, 600 species of crustaceans, 655 mollusc species and 75 species of true cave invertebrates
- exceptionally rich slope and shelf communities, in particular 155 sponge species, most new to science, and at least 25 new species of echinoderms, with a very strong prospect for the discovery of many more

new species

- key habitat for many of the world's dwindling populations of shark species, resulting in outstanding shark species diversity
- unique subterranean faunas, including many genera that are either endemic to the site, or otherwise known only from localities separated from the Ningaloo Coast by thousands and tens of thousands of kilometres
- an exceptionally diverse arid-zone flora and reptile fauna, with important relictual species and high levels of endemism, from one of the world's megadiverse continents.

CRITERION (vii)

Contains superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance

> *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.*[1]

> *Somehow God or history or something has left it to us to experience, to look after, to pass on to our children and their children. As you can see, I love the place. When you take people to see it they go home completely lit up. Because they've experienced one of the world's last great wild places... Something that stays with them the rest of their life.*[2]

The beauty of the coastal and underwater landscapes of the Ningaloo Coast is recognised around the world in dive, snorkel and popular literature, photography websites, reviews and travel guides.[3] The conceptual and visual juxtaposition of dramatically shifting scales of time and space across diverse and striking underwater landscapes generates wonder and curiosity.

FIGURE 3.1 View of the Cape Range peninsula from the north. Ningaloo Reef is visible from space as a structurally complex, scalloped blue margin fringing the pink, red and grey patterns of the Ningaloo Coast.
Google Earth image.

FIGURE 3.2 Ningaloo Marine Park from the air, looking south—the reef provides a 290 kilometre-long, near-continuous breakwater between the Cape Range peninsula and the Indian Ocean.
Photograph © BJK Ben Knapinski

FIGURE 3.4 A landscape under the sea: a diver films the spectacular coral gardens of Ningaloo Marine Park.
Photograph Suzanne Long © Western Australian Department of Environment and Conservation

FIGURE 3.3 'Astonishment is that state of the soul in which all its motions are suspended' (Edmund Burke, 1844)—aerial view of Shothole Canyon, Cape Range National Park.
Photograph © Ganesh Penfold

FIGURE 3.5 Abundant reef life at the Exmouth Navy Pier.
Photograph © Cathy Zwick

One of the largest biological structures known, Ningaloo Reef is visible from space as a scalloped margin framed in shades of blue along the west coast of Australia. A closer look from a light plane reveals more detail; a striated bulwark extending to the horizon separates the whitecaps of the Indian Ocean from bright-toned lagoon waters that spread out in the shadow of the Cape Range peninsula (Figure 3.1 and Figure 3.2).

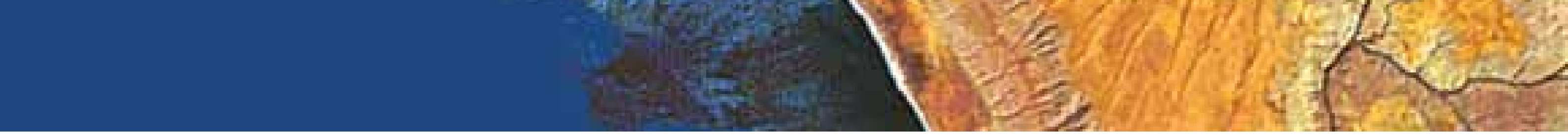
From gorges such as Shothole Canyon, the visitor looks across ancient limestone cliffs, built from sediments deposited in vanished oceans, to the living reef below; and the finer resolution afforded to a diver reveals the spectacular coral gardens, rich colours and abundant life of the reef (Figure 3.3–3.5), frequented by a gentle leviathan, *Rhincodon typus*, the whale shark.

Iconic marine species

A perfect flagship for the health of the oceans.[4]

A whale shark is 'a placid animal the size of a bus covered in brilliant dots like an Aboriginal painting'.[5]

The Ningaloo Coast has outstanding universal value for sheltering a huge seasonal aggregation of *Rhincodon typus,* the world's largest fish (Figure 3.6), among other abundant and diverse marine megafauna. The Ningaloo Coast provides an array of remarkable marine species with permanent shelter or a reliable and plentiful source of sustenance on long journeys north and south.



Among the most diverse and biologically productive environments on Earth, coral reefs are 'oases of biological growth in seas of otherwise low diversity'.[6] Covering just 0.2 per cent of the ocean floor, but containing 25 per cent of known ocean species, they are essential to preserving the biological diversity of the oceans. In turn, as high-level predators and herbivores, marine megafauna are critically important to maintaining the trophic structure and three-dimensional integrity of coral reefs. Large aggregations of these vital components of ocean ecosystems, occurring in protected waters like those of the Ningaloo Coast, are superlative natural phenomena.[7]

Internationally important populations of charismatic marine megafauna feed and shelter in the waters and reefs, including dugongs and several cetacean species.[8] Sharks and rays frequent the marine park in large numbers, including magnificent manta rays, brightly spotted stingrays and at least 19 species of sharks. The Commonwealth Waters of the Ningaloo Marine Park, on the ocean side of the reef, support some of the largest global populations of tuna and several species of billfish.[9]

The waters of the Ningaloo Coast also shelter large numbers of marine reptiles, including seven species of sea snake and internationally significant populations of four species of marine turtle. The beaches of the Cape Range peninsula and the Muiron Islands provide critical rookeries for green and loggerhead turtles, discussed under criterion (x). The Muiron Islands loggerhead turtle rookery is one of the most important breeding grounds in the Indian Ocean for this endangered species.[10]

They look like a star field underwater [11]

From March to June, the Ningaloo Coast plays host to an extraordinary natural phenomenon. A seasonal pulse in nutrients caused by a mass spawning of coral brings 300–500 whale sharks, the largest known aggregation of these animals in the world (Figure 3.7 and Figure 3.8).[12]

FIGURE 3.6 An encounter with *Rhincodon typus* invokes philosopher Edmund Burke's defining interpretation of the sublime in nature as 'the mind … so entirely filled with its object, that it cannot entertain any other'.
Photograph Axel Passeck © Western Australian Department of Environment and Conservation

For their physical characteristics (their extraordinary scale and decoration), mysterious life history and an evolutionary story which has left them taxonomically isolated, whale sharks inspire curiosity and awe. The enigmatic filter-feeders, the largest cold-blooded animals in the world, are beautifully patterned with pale lines and spots on a dark background (Figure 3.6).[13] They are the only living representatives of their family, the Rhincodontidae, with a lineage dating from the Jurassic period (Table 3.1 on page 66).[14]

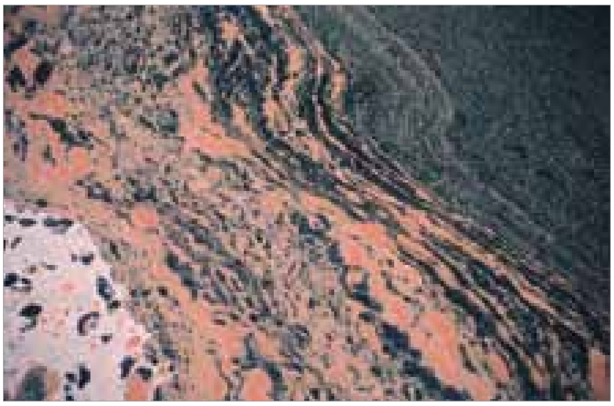


FIGURE 3.7 From the air, coral spawn on water resembles the delicate marbling of an antique endpaper.
Photograph Geoff Taylor © Lochman Transparencies

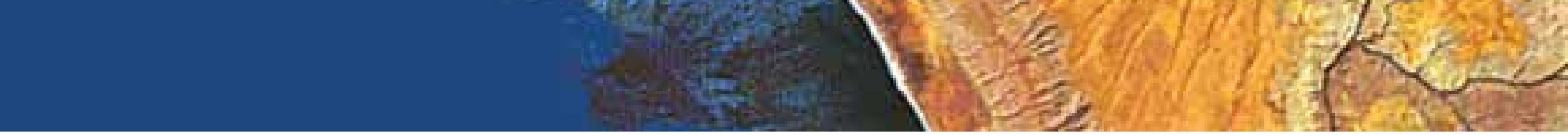
Although migratory and cosmopolitan, whale sharks are found in large concentrations in only a few places on Earth and are internationally venerated. As well as arousing scientific curiosity, whale sharks inspire awe and playful affection around the world (Figure 3.9). Known as *jinbeizame* in Japan, they are widely celebrated and respected as a symbol of good fortune. They are revered by both locals and international visitors at aquariums and festivals.[15] *Antankerana*, a Madagascan dialect, labels them *marokintana* or 'many stars'. Along with whales, they are recognised as a deity in parts of Vietnam, where they are *Ca Ong* or 'Mister Fish'. A search of the online photo-sharing application Flickr reveals over 5,000 photographic records tagged with *jinbeizame*, *butanding* (one of their names in the Philippines) or *whale shark*, including captive and wild whale sharks, toys, figurines and sculptures, demonstrating their global popularity.[16] In Australia, a whale shark is the main character in a popular children's book, *Jinormous Jack*, published in 2005.[17]

Attesting to their iconic status and the almost mystical regard in which they are held, marine biologist Sylvia Earle has written of the placid marine giants that 'as long as whale sharks prosper and coral reefs thrive, there is reason for hope that humankind will achieve an enduring relationship with the ocean, the cornerstone of Earth's life support system'.[18]

Recording the largest known aggregations in the world, the Ningaloo Coast is recognised as the best place on Earth to see this beautiful marine giant.[19] Every May since 2002, more than 1000 visitors flock to the nearby town of Exmouth for the Ningaloo Whaleshark Festival, celebrating the creatures' annual arrival on the reef.[20]

FIGURE 3.8 Whale sharks thrive at the Ningaloo Coast.
Photograph © Conrad Speed

Divers come from around the world to swim with whale sharks, regarded as the signature experience of Ningaloo Reef and described as swimming with a galaxy of stars (Figure 3.6). The whale sharks of the Ningaloo Coast have stirred artists and actors, writers and fishermen, sportsmen and scientists. Two-time Booker Prize nominee Tim Winton, who spearheaded the 'Save Ningaloo' campaign (a high profile popular movement to protect the Ningaloo Coast from a large tourist development early in the millennium), has described being 'moved by a unique place' at Ningaloo, where the awe-struck visitor can swim with whale sharks, those 'beautiful emblems for marine conservation'. Marine biologist Brad Norman, who with his colleagues Zaven Arzoumanian and Jason Holmberg won the 2006 Rolex Award for Enterprise for their work on the giant fish, was inspired by encounters with Ningaloo's whale sharks and has subsequently turned his passionate interest into an award winning example of global participatory science, the ECOCEAN Whaleshark Photo-identification Library.[21]



Whale sharks of the Ningaloo Coast

Inspired by his first encounters with the whale sharks of Ningaloo Reef in 1995, ECOCEAN founder and world-renowned whale shark scientist Brad Norman has devoted his professional life to studying and protecting the magnificent fish. In collaboration with astrophysicist Zaven Arzoumanian and programmer Jason Holmberg, and adapting principles derived from an astronomical pattern-matching algorithm used by NASA to identify galaxies, he developed a technique to identify whale sharks through numerical pattern-matching of their unique patterns of spots.

Norman, Arzoumanian and Holmberg anticipate extending their program for long-term identification of other spotted or patterned animals. This program will provide 'attendant benefits to management and conservation through improved understanding of life histories, population trends and migration routes, as well as ecological factors such as exploitation impact and the effectiveness of wildlife reserves' throughout marine, freshwater and terrestrial ecosystems around the world.[22]

The ECOCEAN Whaleshark Photo-identification Library had its genesis in Norman's work on ecotourism and the whale sharks of the Ningaloo Coast.[23] He founded ECOCEAN to expand the study to include whale sharks around the world. From this local beginning, the organisation has revolutionised whale shark research. The library now contains more than 17,000 images of the elusive marine giants and has identified over 2,000 individual sharks.[24]

Norman and his colleagues have embraced the opportunity for advocacy provided by the charisma and improving profile of 'one of the world's most enigmatic animals', winning a ROLEX Award for Enterprise in 2006 and a Peter Benchley Shark Conservation Award for science in 2007, for their work. In 2008, Norman was named a National Geographic Emerging Explorer. The form of 'citizen science' pioneered in whale shark research at Ningaloo Reef seeks to 'promote shifts away from hunting toward whale shark-based eco-tourism' and 'deliver additional marine conservation messages and resources'.[25]

The enthusiastic participation by citizen scientists and the success of ECOCEAN attests to the widespread popular appeal of whale sharks, and to the particular significance of the Ningaloo Coast as the home of whale shark ecotourism and the best place to experience this colossus of the ocean in its natural environment.

FIGURE 3.9 Children in *butanding* costumes in Donsol, Sorgosan Province in the Philippines, celebrate peak whale shark season and 'God's gift to Donsol'.
Photograph © Ruel Pine/WWF-Phillipines

Whale shark ecotourism was pioneered at the Ningaloo Coast. The Ningaloo model seeks a positive impact on whale shark conservation: all levels of government work with tour operators, marine biologists, the dive community and locals to engage people in the protection of whale sharks, particularly in regions where the majestic animal is under threat.[26] Following the model of the Ningaloo whale shark program, fisherman in Donsol in the Philippines and Gladden Spit off Placencia in Belize have given up hunting sharks to become tour operators, contributing to local economies and increasing protection for the celebrated species (Figure 3.9).[27] The Seychelles has also adopted ecotourism principles that were initiated at Ningaloo Reef.[28]

As the only representative of its family and the largest fish in the world, the whale shark is itself a superlative natural phenomenon: venerated as a good-luck symbol and a deity, inspiring reverence, astonishment and curiosity in human beings (Figure 3.9). The *Operational Guidelines for the Implementation of the World Heritage Convention* state that for the threshold of outstanding universal value to apply under criterion (vii), a superlative natural phenomenon must transcend national boundaries and be of common importance for present and future generations of all humanity.[29]

Whale sharks transcend national boundaries—they are cosmopolitan and migratory, and are venerated around the world. They are of incalculable trophic importance in ocean ecosystems, hence of common importance for future generations, and their global popularity as a marine and conservation emblem confirms their contemporary status as superlative natural phenomena of outstanding universal value. The whale sharks of the Ningaloo Coast are the best-studied in the world, and Ningaloo Marine Park supports the largest known aggregations.

These animals have inspired divers, ecologists, marine biologists, fishermen and tour operators, writers and scientists, as well as the local people of the region. The Ningaloo Coast is nominated to the World Heritage List under criterion (vii) for its outstanding universal significance as the best place to experience the beauty, mystery and inspiration of this charismatic marine giant.

Aesthetic importance

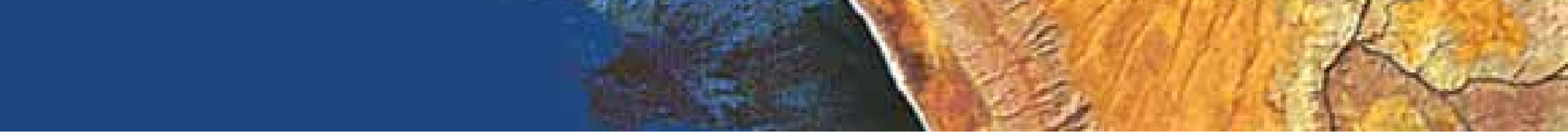
Coral reefs—at their richest in a few remote places—offer wonders in abundance. To snorkel or dive on them is to see shapes, colours and creatures that prefigure and exceed almost anything produced by human imagination.[30]

If you're keen enough you can see the coral spawn like a tropical blizzard. It's an incredible place.[31]

Central to the aesthetic appeal of the Ningaloo Coast is what might be termed its outstanding experiential aesthetic. Its location, unusually close to both the continental shelf and the continental shore, ensures a rare overlap of deep ocean, reef, coast and arid terrestrial environments in a relatively compact area. This juxtaposition provides an attendant contrast in colour, relief and the opportunity to experience the marine environment and the magnificent animals that live there, offering a feast for the eyes and for the mind.[32]

Reefs are celebrated around the world as much for their scenic underwater landscapes as for the vibrancy of the organisms that inhabit them. The quality of the water of the Ningaloo Coast and, critically, the lack of runoff from land-based industry, rivers or high rainfall, ensures its signature panoramic underwater views are among the best in the world. Such scenery is usually only to be found in areas remote from the river-dominated influence of major landmasses, making Ningaloo Reef all the more extraordinary.[33]


FIGURE 3.10 The proximity of the reefs and lagoons to the sparkling white beaches and red-brown range enhances the experiential aesthetic for visitors to the Ningaloo Coast.
Photographs Lorraine Haslem © Department of the Environment, Water, Heritage and the Arts and © Cam Skirving



A megafauna highway

> *The dive quickly turns into a procession of the oversized: the biggest white-tip reef shark I've seen, the biggest lionfish—even the biggest stingray, its 7 ft span revealed as it lifts off from the sand and rockets away.*[34]

Large mammals abound in this marine Serengeti. At least five species of giant baleen whale regularly visit the park, including the three largest of the rorquals (blue, fin and sei whales are the three largest animal species in the world), humpback whales, and northern minke whales. Dolphins, orcas and sea lions play and hunt in waters off the reef. A dugong community of up to 1,000 animals feeds in the seagrass beds.[35]

Perennial inhabitants, among them giant morays, large congregations of reef sharks, giant groupers growing up to three metres, and huge potato cod find shelter in the park and sustenance from the rich reef environments. Vibrant sea snakes and rays add their colour to the lagoon waters.[36] Dive reviews remark on the exceptional size of the Ningaloo marine fauna, especially at the world-renowned Exmouth Navy Pier dive site.[37]

FIGURE 3.11 Like an inverted sky: humpback whales with calf and a manta ray, playing in the Indian Ocean waters of the Ningaloo Marine Park near Turquoise Bay, are captured by a photographer in a light plane.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

Viewed from a light plane, the reef resembles an inverted sky: the majestic capes of manta rays; the glide of turtles floating on invisible wings; the camouflage of stingrays and wobbegongs; sharks and dolphins, like fleets of sleek aeroplanes, in feeding aggregations or gliding in streamlined solitude. The proximity of the reefs to the continental coast, and of the continental shelf and slope to the reefs, ensures the close association of these species to each other, and their accessibility by human beings, reinforcing the powerful experiential aesthetic of the Ningaloo Coast (Figures 3.1, 3.2 and 3.11).[38]

FIGURE 3.12 Green turtles (*Chelonia mydas*) soar like birds in Ningaloo Marine Park.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

Powerful shapes and colours

The Ningaloo Coast is an area of great natural beauty. Images of the reef juxtaposed against Cape Range exhibit striking contrast. At Turquoise Bay, sparkling blue waters in the shallow enclosed lagoon contrast with clean sand beaches. The white surf breaks on the reef as it tops the steeply sloping continental shelf, beyond which lie the deep blue waters of the Indian Ocean. There is a vivid contrast between this seascape and the colours of the ancient and rugged Cape Range, with its deep rocky gorges, light mantle of scattered sage-green acacia scrub, wildflowers and spinifex vegetation (Figures 3.3, 3.10 and 3.13).

Dive spots along the Ningaloo Coast are consistently rated among the best in the world on dive review sites and in books. In particular, the exceptional number of fish, their size and variety, and the wealth of invertebrates and smaller fish found at the Exmouth Navy Pier see it consistently voted one of the top shore dives in the world: 'Divers "who want to see it all", have this dive on their wish list as one of "the special dives to do in a lifetime"'. Elasmodiver.com rates the Navy Pier as the best place in the world to see tasseled wobbegongs, and it has been described as 'the Navy aquarium' for its extraordinary concentration of reef features.[39]

As well as providing an exceptional food resource for migratory marine megafauna, seasonally spawning coral provides a dramatic spectacle (Figures 3.7 and 3.15). The coral gardens of Coral Bay are known around the world for their structural intricacy. Vibrant reef species in the marine park provide a spectacular attraction to swimmers, and passengers in glass-bottomed boats and light planes. The reef's unusual proximity to the shore and its clear waters make it an important site for low-impact human interaction with colourful, attractive reef biota (Figures 3.4, 3.5 and 3.14).[40]

FIGURE 3.13 (a) the red-centred variety of the iconic Sturt desert pea (*Swainsona formosa*) and
(b) the distinctive silhouette of the pandanus palm.
Photographs Tony Howard © Western Australian Department of Environment and Conservation

FIGURE 3.14 Brightly coloured coral reef species such as the nudibranchs above provide a vibrant attraction in the Ningaloo Marine Park. Photographs (a) © Sasha Unger and (b) Tony Howard © Western Australian Department of Environment and Conservation

FIGURE 3.15 'You can see the coral spawn like a tropical blizzard'. (Tim Winton 2002)
Photograph Geoff Taylor © Lochman Transparencies

Colourless crustaceans that look like living crystals swim at the interface of fresh water and tidal layers deep in Bundera Sinkhole, and jewel-like *Nocticola flabella*, the world's most troglobitic cockroach, hides in underground crevices, among other rare and peculiar creatures. In the lagoon and ocean, flamboyant nudibranchs and boldly patterned whale sharks feed on the abundant marine resources. The contrast between these creatures, bright or transparent, hidden or bold, gigantic or microscopic, is at the heart of the outstanding aesthetic value of the Ningaloo Coast under criterion (vii).

In contrast to most tropical reefs around the world, the Ningaloo Coast is located in an arid and remote environment, with low rainfall and minimal runoff from the land to the sea, and a high level of ecosystem intactness. This results in the rich colours and forms of the corals and reef life extending right to the low water mark, producing a spectacular contrast with the desert colours, and providing unusually easy access for observers. While visitors appreciate the visual beauty of coral reefs throughout the Indo–Pacific region, the proximity of Ningaloo Reef to an arid continental coast distinguishes it from most reefs in the world; and the juxtaposition of blue water and white sand, red-brown cliffs and vivid marine life makes a splendid contrast matching any in the world.[41]

Criterion (vii) summary

From its iconic whale sharks to the annual spectacle of coral spawning, or a purple nudibranch brightening a rock, the Ningaloo Coast contains superlative natural phenomena and features of outstanding aesthetic value. Its principal characteristics include:

- globally significant aggregations of iconic marine megafauna, including the best opportunity in the world to experience whale sharks, the world's largest fish
- the exceptional visual effect of the wave-swept ramparts of Ningaloo Reef stretching for tens of kilometres along the arid coast, complementing underwater landscapes of surpassing beauty and intimacy that support colourful and majestic marine life
- the close juxtaposition of open ocean, reef and arid coast, high water quality and ecosystem intactness.

The land and waters of the Ningaloo Coast have outstanding universal value for meeting all aspects of criterion (vii) considered against the characteristics above.

CRITERION (viii):

To be outstanding examples representing major stages of Earth's history, including the record of life, significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features

The Ningaloo Coast is an outstanding representation of major stages in the record of marine life and of significant ongoing geological processes, including the inexorable geographic and climate changes brought about by plate tectonic movement over hundreds of millions of years. Its unity of structure and function through time is at the heart of its value under criterion (viii). Its contemporary form is part of a geological pageant working itself out over thousands of millennia, in increments no longer than the life of a mollusc or the breeding cycle of a subterranean shrimp.[42]

In a 2005 report to the IUCN on geological World Heritage, Paul Dingwall, Tony Weighell and Tim Badman noted that geological and geomorphological features may provide supporting value to other criteria by underpinning biological or cultural diversity.[43] The converse is also true: biological components of the landscape may provide supporting evidence by recording globally significant geological events or processes, as is the case on the Ningaloo Coast.

The IUCN's assessment of outstanding universal value in the context of criterion (viii) takes into account the need to 'encompass the representation of the 4.6 billion years of Earth history, address the evolution of life on Earth as well as the changes in the geography of the planet'.[44] Evolutionary radiations are one of the fundamental patterns in biogeography. These macro-evolutionary phenomena can be studied in extant biota as well as in the fossil record.[45] The outstanding biogeographic and geotectonic significance of the Ningaloo Coast is principally embodied in its outstanding subterranean habitat and fauna and its relationship with other anchialine habitats around the world. Thus their biogeographic importance is represented under criterion (viii) in this nomination. The biological significance of these features is recognised under criterion (x).

Structurally and functionally contiguous with Ningaloo Reef, the Cape Range subterranean karst system supports anchialine and cave faunas that contribute to an extraordinary biogeographic story. The history of the Gondwanan lands and biota during the Cenozoic era (Table 3.1) is a story of increasing isolation and of changing climates. In Australia, this means the expansion of aridity. The subterranean faunas and rangeland communities of the Cape Range peninsula exemplify both these evolutionary drivers, and accentuate the intimate ties between ecology and geological history more vividly than other sites in the former Gondwanan supercontinent.[46]

The anchialine and terrestrial systems of the Cape Range peninsula have outstanding universal value for demonstrating (Table 3.1):

- speciation and adaptation since the break up of the supercontinent Gondwana and the opening of the ancient Tethys Seaway more than 150 million years ago;
- climate change following the opening of the circumpolar Southern Ocean;
- continued biogeographic isolation and the expansion of aridity in the last of the Gondwanan lands during the Quaternary period (the last 2.6 million years); and
- Quaternary warping at a passive continental margin, which has changed geologists' understanding of coastal development in these kinds of tectonic regimes.

FIGURE 3.16 View from Charles Knife Road to karst system of Cape Range.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

GEOLOGICAL TIME				MILLION YEARS BEFORE PRESENT	GLOBAL EVENTS	NINGALOO COAST
Phanerozoic eon	Cenozoic era 'recent life' (65–present)	Quaternary period (2.6–present)	Holocene epoch	0.01–present	Current interglacial stage	Formation of modern Ningaloo Reef on Pleistocene substrate. Modern coastal dunes active
			Pleistocene	2.6–0.01	Glacial/interglacial stages of the Pleistocene affect reef growth worldwide First Australians arrive Glacial cycles expand arid zone in Australia *Homo sapiens* expand across the world	Aboriginal people use marine and terrestrial resources, and create shell beads at the Ningaloo Coast Reefs formed to west of modern reef as coast retreats towards continental shelf during last glacial stage Higher sea level of last interglacial stage creates Tantabiddi terrace (c. 125,000 years ago) Terrestrial flora and fauna find refugia in dissected Cape Range terrain, and the dune fields of the peninsula Jurabi terrace may have been initiated
		Neogene period (26–2.6)	Pliocene	5.3–2.6	Drying trend in Australia Development of the West Pacific Warm Water Pool and Indonesian 'gateway'	Establishment of Leeuwin Current Muiron terrace and Milyering terrace may have been initiated Uplift of the Cape Range peninsula continues
			Miocene	23–5.3	Onset of dry–humid cycles in Australasia. Rainforest begins to retreat across Australia Closure of the Tethys Seaway isolates Atlantic Ocean benthos from Indian/Pacific faunas Southern Ocean continues to open	Ningaloo Coast rainforest retreats; invertebrate fauna retreat into cave system as the region dries Vlaming Sandstone deposited Uplift of Cape Range anticline: Cape Range may have been an island during this period; karstification initiated Trealla Limestones deposited, grading into sandstones of the Pilgramunna Formation Tulki Limestone deposited
		Palaeogene (65–26)	Oligocene	34–23	Circumpolar current and stratified ocean system as the Southern Ocean opens and Australia and Antarctica finally separate	Sediments of Mandu Limestone begin to be deposited in shallow tropical sea on a continental shelf in the late Oligocene
			Eocene	56–34	Australia covered by extensive rainforest Australia continues to drift north Global ocean currents rearrange as Atlantic Ocean continues to open and the Tethys Seaway narrows	Marine crustacean fauna inhabiting coastal fringe move into available carbonate habitat off the west coast of Australia?
			Paleocene	65–56	Late Palaeocene break up of Antarctica and Australia initiated	Cardabia Group carbonates deposited late Palaeocene, Eocene
	Mesozoic era (251–65)	Cretaceous		144–65	Gondwanan and Laurasian flora and fauna evolve independently	Carbonates laid down in shallow sea abutting basement rock of Pilbara craton
		Jurassic		200–144	Crustal instability initiates break up of Pangaea into Laurasia, Gondwana Central Atlantic begins to open Central European seaway	
		Triassic		251–200	Pangaea forms as a crescentic supercontinent surrounding palaeo–Tethys Ocean	'West coast of Australia' is the south eastern peninsula of the Pangaea crescent
	Palaeozoic era (545–251)	Permian		299–251	Gondwana and Laurentia supercontinents begin to come together to form Pangaea	
		Carboniferous (Mississippian-Pennsylvanian)		359–299		
		Devonian		416–359		
		Silurian		444–416		
		Ordovician		488–444		
		Cambrian		542–488		
Precambrian eon (4600–542)						

TABLE 3.1 Geological timeline and table of events (not to scale)

Biogeography, evolution and continental drift

> *The significance of the Cape Range stygofauna rests not only with the species number but also with the kinds of animals represented, their endemicity and zoogeographic origins.*[47]

The outstanding universal value of the Ningaloo Coast karst habitat and associated anchialine ecosystems lies in the contribution of the karst biota to a story that is both global and local. A subterranean system can function similarly to an ocean island or archipelago in terms of preserving biodiversity. The biogeographical associations of the underground fauna of the Ningaloo Coast reveal climate changes over thousands of millennia on a local and regional scale. They also chronicle the geotectonic meandering of Australia across hemispheres and tens of millions of years, contributing to the reconstruction of supercontinents and vanished oceans.

The terrestrial flora and fauna of Cape Range also tell a story of continued botanical and faunal isolation, as the peninsula provided refugia during the expansion and retraction of aridity driven by the glacial and fluvial cycles of the Quaternary period.[48]

Biologically the Ningaloo Coast subterranean fauna is a fundamental part of the complex story of Gondwanan fragmentation, demonstrating the change from marine pandemism to endemism. Populations of marine invertebrates, which were broadly distributed along the shores of the Tethys Sea up to 200 million years ago, dispersed along ocean currents with the opening of circumglobal seaways. They were separated by plate tectonic activity, sea level change and changing ocean currents, in a process known as vicariance, to evolve in isolation.[49] The Ningaloo Coast anchialine system permits a unique understanding of the origins and biogeography of anchialine ecosystems throughout the world.[50]

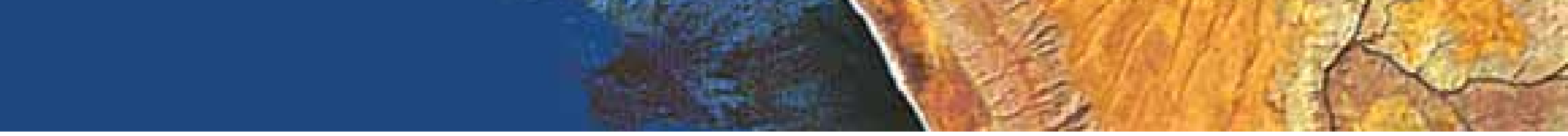
As relicts of a tropical surface world that once existed along the central west coast of Australia, the Cape Range terrestrial troglobites provide a startling reminder of the increasing aridity of the Australian and Gondwanan climates over the last 26 million years.[51] Cape Range supports an extraordinary diversity of troglobite species, many of which represent a relict wet forest fauna with biogeographic affinities to tropical and temperate areas of Australia over 1,200 kilometres away to the south and the north-east, as well as links to sites in other former Gondwanan continents.[52]

Enduring the Cenozoic era

Stygiocaris is a subterranean atyid shrimp genus endemic to the central west coast of Australia. Nuclear and mitochondrial analyses have established that its nearest living relation is the Mexican subterranean atyid genus, *Typhlatya* (whose centres of diversity are the Caribbean, North Atlantic and the Mediterranean), rather than the widely known surface or cave atyids from Australia or the Indo–Pacific.

As with the account of the distribution of remipede crustaceans in Part 2.A, this pattern fits closely with the hypothesis that certain widespread disjunct anchialine genera have descended from marine parent populations from the Tethys Sea. Their vicariant distribution can be explained by sea floor spreading due to plate tectonic movement outlined in Part 2 and summarised in Table 3.1.

FIGURE 3.17 *Stygiocaris stylifera* from Cape Range. Photograph © Danny Tang



As probable Tethyan relicts, surviving initially as opportunists and specialising in their unusual anchialine setting, the stygal communities of the Cape Range peninsula have outstanding universal value for their unique contribution to the understanding of global biogeography and plate tectonics from the end of the Mesozoic era. The Cape Range troglobites represent a relict community of great antiquity. Understanding their ancestries helps build a picture of Australian and Gondwanan climates over the last 26 million years.[53]

The surface flora and fauna of the Cape Range peninsula includes a number of endemics, relict communities of taxa from more humid climates, such as the Millstream palm, *Livistona alfredii* and internationally significant reptile diversity.[54] These flora and fauna found refuge in the surface environments provided by the karst system and foothills of the peninsula, and their study contributes to the important biogeographic story of disjunct populations at the limits of their ranges, expanding upon the biogeographical significance of the range's underground fauna.[55] These communities tell a story of continued botanical and faunal isolation during the Quaternary period, as ice sheets advanced and retreated at high latitudes, influencing patterns of aridity in Australia (Table 3.1).

The troglomorphic communities of the Cape Range peninsula karst system and the endemic, near-endemic or highly disjunct rangeland flora and fauna have outstanding universal value for their unique contribution to the study of global biogeography, climate and ocean circulation. These communities are relics of a tropical surface world long vanished from the central west coast of Australia; they provide a direct link to the last of the Gondwanan continents, which began to break apart at the beginning of the Cenozoic era when Australasia began its long, isolated voyage north to Asia.

FIGURE 3.18 Fossils at Yardie Creek.
Photograph Jacinta Overton © Western Australian Department of Environment and Conservation

Geoecology

Its diverse landscapes are not only habitat for significant Australian vegetation and wildlife, but also beautiful manifestations of the work of geological and ecological processes, climate change, weather and time on an area that was more than once the floor of a shallow ocean.[56]

Perhaps unsurpassed among coral reefs is the clarity with which Ningaloo displays apparent effects on its gross morphology of antecedent geological features.[57]

The Ningaloo Coast is an extraordinary example of a carbonate environment in which present-day biological and geomorphological functions are defined by, reflect and anticipate the region's geological history. This geoecological integrity is at the heart of its outstanding universal value. Themes of increasing biological isolation, palaeoclimate events, geological change and evolution, have culminated in a unique geoecological setting. The main features are:[58]

- arid zone karst terrains that provide the setting for globally important subterranean ecosystems sheltering unique stygofauna and troglomorphic faunas, whose evolutionary relationships contribute to an epic story about the changing planet;
- structural integration of geological and biological elements, so that modern marine fauna will be the future structural components of the limestone system. Their ancient predecessors, preserved as fossils in the limestones of Cape Range, produced the necessary conditions for the survival of the region's extraordinary anchialine fauna over hundreds of millions of years, eroding into the impressive features of the range, while telling the evolutionary story of the reef (Figure 3.18 and Figure 3.19).

The Ningaloo Coast demonstrates an integrated set of geological, hydrological and ecological features reflecting both the region's present ecosystem functions and its evolutionary history. This is expressed today as a time-series of coral reefs and wave-cut terraces, and an evolving karst system and groundwater estuary, sheltering unique subterranean fauna. The physical geology of the place reveals a history of tropical marine life over perhaps the last 20 million years, in evocatively rendered cameos.

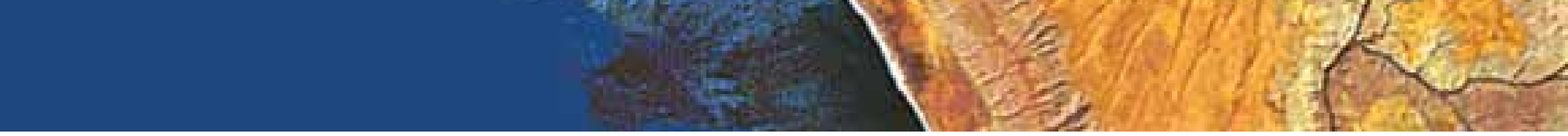
The geoecological importance of the Ningaloo Coast lies in the close geographic, geomorphic and hydrological relationships between the Cape Range peninsula karst system and Ningaloo Reef, and their demonstration of past and ongoing connections between marine and terrestrial environments. As an integrated limestone structure, geology and biology are mutually constituted. Surface features include ramparts, gorges, karren, dolines, and springs. Subterranean features include anastomosing tubes, caves, highly stratified hydrology and perched water tables. The caves provide habitat for an extraordinarily diverse and abundant underground fauna. The limestone of the peninsula and associated wave-cut reef terraces preserve an important record of the evolution of tropical marine environments from the Miocene epoch to the present, which culminates in the living reef and offshore environments. The modern reef and karst system is a contemporary manifestation of marine, coastal and subterranean processes ongoing for tens of millions of years. From Cape Range to the edge of the continental slope, the Ningaloo Coast encompasses habitats demonstrating the principal biological, structural, geomorphological and hydrologic characteristics of a complex limestone structure.[59]

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. Tantabiddi terrace is the youngest and topographically lowest terrace at Cape Range, and is dated to the Last Interglacial (around 125,000 years ago). Cut into the Tantabiddi member of the Bundera Calcarenite, the Tantabiddi terrace 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 (Figure 3.19).[60]

Studies of these uplifted marine terraces are significant for challenging the assumption that vertical (isostatic or tectonic) uplift and subsidence of land along coasts bordering passive continental margins (of which the west coast of Australia is a classic example) 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. Observations of the marine terraces that stretch for long distances along this coast have underpinned calculations of global Pleistocene sea level rise and fall, on the assumption that any uplift would be negligible.[61] Detailed mapping, stratigraphic and isotopic analyses 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 between Shark Bay and the northern end of the Cape Range peninsula are warped and tilted in relation to others. This indicates that significant tectonic activity and uplift along the Western Australian coast continued into the Quaternary. The wave-cut terraces on the western flank of the range and the coastal plain 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.[62]

FIGURE 3.19 View of fossil reef terraces.
Photograph Lorraine Haslem © Department of the Environment, Water, Heritage and the Arts

Studies of these terraces and their relationship to the modern, living reef have contributed considerably to understanding the mechanisms that led to the modern character of the west coast of Australia and have helped change geologists' assumptions about the development of coasts along passive continental margins. Furthermore, in juxtaposition with the living reef and its underwater substrate of Pleistocene shorelines, the terraces help decipher the history of tropical marine environments during the Neogene and Quaternary periods (the last 26 million years), and enable reflections on the fragility, recovery and resilience of coral communities over time. In turn, the modern reef biota holds the promise of a future limestone framework for subterranean habitat or uplifted limestone country.



Ningaloo Reef and the Cape Range peninsula karst, the wave-cut terraces, limestone plains, Pleistocene reef sediments of the peninsula and associated modern terrestrial, marine and subterranean ecosystems, have outstanding universal value under criterion (viii) considered as a complex geologically and biologically integrated limestone system representing significant ongoing geoecological processes and major stages in the record of life.

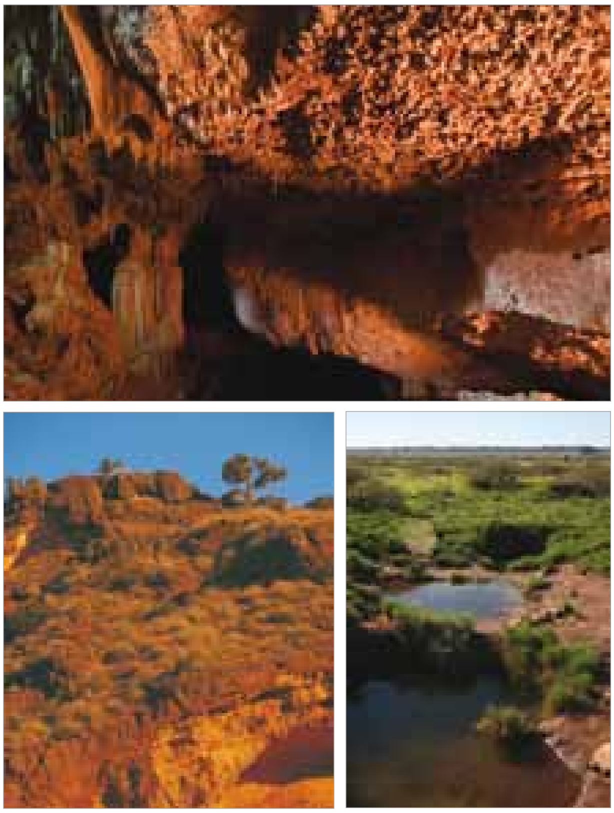


FIGURE 3.20 Karst features of Cape Range at different scales: (a) cave interior showing decoration, (b) view of Cape Range, (c) Tantabiddi Sinkhole.
Photographs Tony Howard and Jacinta Overman © Western Australian Department of Environment and Conservation

Criterion (viii) summary

The Ningaloo Coast is an extraordinary example of an integrated limestone karst system which demonstrates a remarkable biogeographic story about increasing biological isolation, climate change, plate tectonics and evolution. Its main features are:

- globally important anchialine ecosystems sheltering unique stygofauna which illustrate changes to Earth's surface and ocean currents since the Jurassic period
- unique troglomorphic faunas which demonstrate the drying of the last of the Gondwanan continents as Australia drifted away from Antarctica over the last 40 million years
- a high degree of phylogenetic diversity in terrestrial fauna and flora and subterranean fauna, indicating long isolation
- a series of uplifted marine terraces which challenge accepted scientific understanding of the development of coasts along passive continental margins;
- the structural integration of its geological and biological features from the limestone peninsula to the living marine environments.

The living faunas of Ningaloo Marine Park are the future scaffolding of the limestone system. Its unusual subterranean ecosystems and phylogenetically diverse terrestrial flora and fauna underscore the geohistorical coherence of the place. As components of a superlative geoecological carbonate structure, their location, affiliations and ancestry demonstrate:

- the relentless, interrelated action of plate tectonics and climate change
- the local effects of uplift, erosion and sea-level change
- the evolution of marine life
- migration and isolation as biogeographic drivers.

The outstanding universal value of the Ningaloo Coast karst and associated anchialine ecosystems under criterion (viii) lies in the contribution of the karst biota to a story that is both global and local. The biogeographical associations of the underground fauna of the Ningaloo Coast reveal climate changes over thousands of millennia on a local and regional scale, and chronicle the geotectonic meandering of Australia across hemispheres and tens of millions of years, contributing to the reconstruction of supercontinents and vanished oceans. The marine, terrestrial and subterranean environments demonstrate a structural, geological and biological unity rarely expressed with such clarity elsewhere.

The marine and terrestrial environments of the Ningaloo Coast have outstanding universal value for meeting criterion (viii) considered against the categories above.

CRITERION (x):

To contain the most important and significant natural habitats for in situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation

The Ningaloo Reefs are among the most pristine on Earth. With an arid shoreline, very low human population pressures, and conservation enforcement, these reefs have unequalled long-term conservation potential.[63]

The subterranean karst system of the Cape Range supports some of the most diverse and richest aquatic anchialine and terrestrial troglobite cave faunas in the world, without equal in the Indo–Pacific region or the southern hemisphere.[64]

There are few if any places in the world where one of the marine realm's most charismatic species is as closely associated with a particular site as whale sharks (the world's biggest fish) are associated with the Ningaloo coast. This link is due to the seasonal productivity of the reefs, especially the mass production of larvae, and is therefore an integral part of the value of the ecology of the Ningaloo Coast as a whole.[65]

The Ningaloo Coast is one of the most important reef areas in the world for the long-term conservation of both reef and pelagic sharks.[66]

Productive coastal marine systems

Ningaloo Marine Park is one of the world's most biologically diverse shallow water marine ecosystems.[67]

As a productive tropical reef environment located offshore from an arid hinterland with very low run-off and in close proximity to the edge of the continental shelf, the Ningaloo Coast is rare in the world. It has outstanding universal value under criterion (x) as a diverse and healthy reef with one of the best long-term outlooks for conservation in the world.[68]

The Hanoi statement, developed in 2002 at the UNESCO World Heritage Marine Biodiversity Workshop, identifies Ningaloo Reef as one of the priority areas of tropical coastal, marine and small island ecosystems that may merit World Heritage listing.[69] The workshop noted that information available at the meeting was not adequate to discuss Ningaloo Reef in detail. However, since 2002 a considerable body of research has been published by Australian governments and academic institutions and networks, such as the Australian Institute of Marine Studies (AIMS), and the Western Australian Marine Science Institution (WAMSI). This research has identified that the region has outstanding value as a highly productive, high-latitude tropical marine environment off an arid coastline.[70] WAMSI has been engaged in a five-year research program to study the deep water ecologies of the Ningaloo Coast. Preliminary results indicate extraordinarily rich sponge gardens and other shelf and slope communities, and great potential for the discovery of many new species.[71]

Extending about 300 kilometres north from the Tropic of Capricorn, Ningaloo Reef owes its exceptional species richness to the warm Leeuwin Current flowing south from the productive Indo–Pacific region, which facilitates the occurrence of tropical species at temperate latitudes. The marine environment of the Ningaloo Coast is subject to extremely low terrestrial runoff as a result of the porosity of the limestone karst, the arid climate and the low level of industrial or other development. These factors drive the exceptional productivity and quality of the marine environment. As an indicator of its reef biodiversity, Ningaloo Reef is home to more than 50 per cent of Indian Ocean coral species, with over 300 species in 54 genera.[72]

The marine component of the Ningaloo Coast system contains a continuous suite of marine and littoral environments, from continental shelf and slope ecologies, to fringing and barrier reef, lagoon, inshore, island and beach ecologies, and one of the best-developed reefs in the world.[73]

FIGURE 3.21 A Spanish dancer at Ningaloo Reef. Photograph Jiri Lochman © Lochman Transparencies

Ningaloo Reef's position on the mid-west coast of Australia means it is exposed to the dominant westerly wind systems, which have traversed the oceans for a considerable distance to drive ocean currents into the reef. This complements the pumping action that pushes waves over the reef into the onshore lagoon. The area is oceanographically complex, due to the cold, north-flowing West Australian Current mixing with the warm Leeuwin Current as it flows south along the coast.[74]

Because of its unique location close to the edge of a continental shelf, Ningaloo Reef is one of the best-positioned reefs in the world to survive ocean warming and sea-level change. The associated terrestrial environment is arid, with little agriculture or industrial development, which has resulted in virtually no run-off from the land to the reef. These characteristics contribute to the outstanding global importance of the Ningaloo Coast for marine conservation.[75]

Karst ecosystems

> *By their very nature, caves and other subterranean environments are poorly known, and yet they are home to large numbers of endemic species and unique relictual taxa from an earlier age.*[76]
>
> *I have little doubt [these creatures] are 'wrecks of ancient life' or 'living fossils'*[77]

The physical and biological isolation of the heavily dissected limestone peninsula, which has at times been an island, in this arid region, and the adjacent productive marine and subterranean ecosystems close to a continental shelf, combine to produce a complex biological setting. The component species of these systems display a high degree of adaptive radiation and endemism. The nominated property presents an intricate assemblage of limestone features and is noted for the variety of its structures and the processes they represent. This structural complexity is reflected in the flora and fauna.

The subterranean fauna of the Ningaloo Coast is of great biological significance. The fauna of the anchialine and groundwater ecosystems are of considerable scientific interest globally, yielding important information about the evolution of life on Earth, biostratigraphy, geochronology and palaeoclimate. The troglobitic fauna of the karst system gives insights into increasing aridity since the Miocene (up to 23 million years ago), while the stygofauna provides insights into the closure of the Tethys Sea, changing ocean currents and the biogeographical history of the Gondwanan continents.[78]

Cape Range is the only continental deep anchialine system described in the southern hemisphere. It provides vital information about the origins and biogeography of these systems that is otherwise available only from the northern hemisphere. The anchialine fauna at Cape Range has particular scientific significance because most species are not found elsewhere in the Southern Hemisphere; their closest affinities are with species inhabiting anchialine caves of the Caribbean, indicating a 'Tethyan Track' distribution. Furthermore the Cape Range anchialine fauna are unrelated to faunas that occur in other karst regions of Australia.[79]

The stygofauna of the Cape Range peninsula, much of which is represented by crustacean species, is noted for its immense age and zoogeographic origin. This is of great interest to a number of scientific disciplines. Many Cape Range taxa have biogeographic affinities with the North Atlantic Ocean and are considered to be ancient relicts of taxa which evolved from the Tethys Sea, having shared a common origin dating back over 180 million years. For example, *Lasionectes*, the genus of remipede from Bundera Sinkhole, is elsewhere known only from Turks and Caicos Islands in the Caribbean.[80]

With 75 troglobite species, the Cape Range peninsula has the highest level of subterranean faunal diversity for a single karst area in Australia, and one of the highest levels of diversity in the world. This considerable genetic diversity within the subterranean fauna is considered to reflect past isolating events, such as the uplift of the Cape Range anticline and the separation of aquatic habitats (for example, through the lowering of perched water tables under arid conditions). Populations also became separated into northern, central and southern sections of the range, as a result of the penetration of deep gorges into the underlying non-cavernous limestone, forming further barriers to cave fauna dispersal.[81]

The Cape Range peninsula karst contains a wealth of bioclimatic information, both in the cave formations and the Tethyan affinities of the stygofauna. More than 40 publications have addressed the remipede-type anchialine system of Bundera Sinkhole. The rate of discovery of new species on the Ningaloo Coast is rapid and ongoing. Together with the relictual tropical rainforest fauna found in the caves, these characteristics make the peninsula an internationally important scientific research area, contributing to a greater understanding of evolutionary processes and climate changes.[82]

Diverse and rare species

The richness of the troglobitic arachnid and myriapod fauna (at Cape Range) is significant in that it comprises approximately half of the known troglobitic species recorded in the country.[83]

Whale sharks themselves are beautiful emblems for marine conservation. They open debates about the need to protect both the species and the critical habitats that sustain them. The fact that whale sharks cross international boundaries should unite us in our concern and in our efforts.[84]

The ecoregion is…home to a tremendous diversity of endemic reptile species.[85]

To assist its assessment of the outstanding universal value of terrestrial biota under criterion (x), the IUCN uses the WWF Global 200 Ecoregions for Saving Life on Earth. The terrestrial component of the Ningaloo Coast falls within the Carnarvon Xeric Scrub, one of four critically endangered Global 200 Ecoregions within the deserts and xeric shrublands biome. The marine component falls within the Western Australia Marine Ecoregion of the tropical upwelling biome. This is regarded as relatively stable and a hotspot for marine diversity.[86] As an exceptional representative of both these globally important biomes, the Ningaloo Coast has outstanding species diversity in the marine, terrestrial and subterranean realms.

Marine fauna

Internationally, Ningaloo Reef is best known for its coral reef and diverse, vibrant marine life. It is also noted for species of large marine fauna, including seasonal aggregations of the world's largest fish, the whale shark; large pelagic fish including tuna and billfish; whales and dolphins; marine turtles; and dugongs. It is visited regularly by migratory birds listed on international agreements to which Australia is a signatory.

A highly diverse range of marine species may be observed in the open waters and reef areas. For example, more than 300 species of coral, 600 species of crustacean, 1,000 species of marine algae, 738 species of reef fish, and 20 species of whales and dolphins have been recorded. This enormous diversity, which includes a coral diversity greater than any World Heritage site in the Indian Ocean, is in part due to the location of the Ningaloo Coast in a transition zone between tropical northern and temperate southern flora and fauna. A number of tropical species reach their southern limits in the marine park.[87]

FIGURE 3.22 Flock of terns at Coral Bay.
Photograph Darlene Shepherd © Lochman Transparencies

Preliminary work by WAMSI in the non-lagoonal waters of the Ningaloo Coast has identified a high level of endemic fauna and a significant number of new species. Most of the 155 sponge species recorded were previously unknown to science and have not yet had species names assigned. At least 25 new species of echinoderms were also found; including three holothurians that could only be identified to genus, one holothurian that probably belongs to a new genus, and approximately 15 unidentified species of sea stars. One species of holothurian, *Ohshimella ehrenbergi*, has been recorded for the first time in Australia. These early results point to the extraordinary richness of the shelf and slope communities of the Ningaloo Coast. Research is expected to continue to uncover rare, remarkable and so-far unknown organisms.[88]

The Ningaloo Coast is of exceptional importance for whales and dolphins. Thirteen toothed whale and dolphin species, and seven baleen whale species have been recorded.[89] Species that are regularly observed include humpback, minke, fin and blue whales, killer whales and bottle-nosed and Indo–Pacific humpback dolphins.

FIGURE 3.23 Whales swimming alongside dolphins at the Ningaloo Coast.
Photograph © Cam Skirving

Ningaloo Reef and the waters surrounding the Muiron Islands have diverse and abundant shark and ray populations, including more than 19 shark species and five rays. Planktivorous whale sharks (*Rhincodon typus*) are seasonally attracted to Ningaloo Reef due to upwelling of nutrient-rich waters. The marine park's population of between 300 and 500 whale sharks is the world's largest recorded aggregation of this magnificent, threatened species.[90] *Rhincodon typus* was the first shark species to be included in the Convention on International Trade in Endangered Species, in 2002.[91]

The Ningaloo Coast is one of the most important reef areas in the world for the long-term conservation of reef and pelagic sharks. Sharks include the whale shark, hammerhead shark, grey reef shark (*Carcharhinus amblyrhynchos*), white-tip reef shark (*Triaenodon obesus*), black-tip reef shark (*Carcharhinus melanopterus*), tawny nurse shark (*Nebrius ferrugineus*) and several species of tiger shark. Rays include the manta ray (*Manta birostris*), blue spotted maskray, white spotted eagle ray, giant stingray and cowtail stingray (*Pastinachus sephen*). Manta rays aggregate seasonally.

Large aggregations of black-tip reef sharks and grey reef sharks have been reported from several locations. The best known of these is at Bill's Bay, where up to 100 sharks are regularly recorded in water as shallow as 50 centimetres (Figure 3.26). This may be a nursery area. The Ningaloo Coast is the second-most important site in the world after the Great Barrier Reef Marine Park for the long-term maintenance of numerous shark species.[92]

FIGURE 3.24 Manta ray and its attendant sharks and remoras at Ningaloo Marine Park.
Photograph Clay Bryce © Lochman Transparencies

FIGURE 3.25 The magnificent whale shark.
Photograph © Cam Skirving

FIGURE 3.26 Black-tip reef sharks aggregating close to shore at Coral Bay.
Photograph © Conrad Speed

Four of the six marine turtle species that have been recorded at the Ningaloo Coast are regular visitors and breed on the beaches of the Cape Range peninsula and the Muiron Islands: green (*Chelonia mydas*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*) and flatback turtles (*Natator depressus*). Populations of these endangered species are strong here, with between 7,000 and 9,000 individuals recorded in the area. Leatherback (*Dermochelys coriacea*) and olive ridley (*Lepidochelys olivacea*) turtles have also been recorded. All are listed as threatened under Western Australian legislation and five are listed under Australian Government legislation. Australia is one of the few countries in the world that has relatively large turtle populations, and the foreshores of the Ningaloo Coast and Muiron Islands provide important and relatively undisturbed nesting sites for these species.[93] The Muiron Islands loggerhead rookery is one of the most important breeding grounds in the Indian Ocean for this endangered species.[94]

FIGURE 3.27 Loggerhead turtle (*Caretta caretta*) hatchlings at Ningaloo Marine Park.
Photograph Jiri Lochman © Lochman Transparencies

Subterranean fauna

The Cape Range 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 80 subterranean taxa have been recorded from the peninsula, including 75 troglomorphic species, along with a large number of undescribed species (Appendices B and C).[95] There is also a high level of endemism within both the aquatic and terrestrial subterranean species. One hundred per cent of the terrestrial and 95 per cent of the aquatic species are either endemic to the Cape Range peninsula or to the local region. Eighteen per cent of the terrestrial and 15 per cent of the aquatic genera are endemic.[96]

The complex, chemically and thermally stratified hydrology of the coastal plain, along with the distinct freshwater habitats on the plain and the range, provide habitat for a highly diverse aquatic cave fauna. Thirty species in 20 families and 18 orders have been identified so far. The terrestrial cave fauna is similarly diverse, numbering 45 species in 25 families and 12 orders.[97] The Ningaloo Coast is unmatched globally for the number of subterranean families and orders.[98] This unusually high concentration can be attributed to the combination of diverse terrestrial, freshwater and anchialine habitats present on the Cape Range peninsula, and the influence of past and present climatic and environmental conditions, resulting from the region's geological history.[99]

Many of the underground species of the peninsula are listed either under Australian Government or Western Australian threatened species legislation, or both, with 16 species of subterranean fauna listed as threatened, including the blind cave eel (*Ophisternon candidum*) and the blind gudgeon (*Milyeringa veritas*).

Anchialine habitats, including those on the Cape Range peninsula, are characteristically rich in crustaceans, often quite remarkably so, and include copepods, ostracods, atyid shrimps, thermosbaenaceans, hadziid amphipods, cirolanid isopods and remipedes.[100] The diversity of the anchialine fauna reaches its peak at Bundera Sinkhole, which has the highest diversity of anchialine fauna of any single site on the peninsula—13 species, 13 families and 11 orders, together with a complex microbiology.[101] Distinct faunal communities have evolved within different layers of the anchialine systems, indicating both the diverse range of environmental conditions encompassed within these systems, and the remarkable stability of these systems over many thousands of years.[102]

In addition to the obligatory subterranean inhabitants, the terrestrial cave-dwelling fauna of the peninsula is dominated by a wide array of arachnids (pseudoscorpions and spiders), myriapods (centipedes and millipedes), cockroaches, crickets and slaters, including over 40 species, many exhibiting a marked degree of adaptation to subterranean life.[103] At least 20 species exhibit varying degrees of cave dependency, including species that are restricted to caves on the Cape Range peninsula, yet elsewhere in Australia are found above ground.

Some species show either partial modification for subterranean existence or are unmodified and represent surface fauna that occurs opportunistically in caves.[104] Many more taxa await description, especially amongst the isopod crustaceans (Oniscidea), arachnids (Schizomida, Pseudoscorpionida and Araneae) and millipedes (Diplopoda), and it is likely that the known diversity of the terrestrial cave fauna will increase significantly.[105]

Not only is there a great diversity of species within the subterranean habitats of the Cape Range peninsula, but considerable intra-species genetic diversity has been identified.[106] These differences are associated with the deeper gorges that cut through the cavernous Tulki Limestone into the less cavernous underlying Mandu Limestone. For example, the millipede genus, *Stygiochiropus,* has considerable genetic diversity within a single species at the Cape Range peninsula.[107] There is also significant genetic diversity within the subterranean system as a whole, and the Cape Range peninsula exhibits one of the highest numbers of families and orders in a single system in the world. This is owing to the juxtaposition of anchialine, freshwater and terrestrial subterranean habitats, and a prolonged and complex geological history.[108]

Preliminary investigations suggest that the Ningaloo Coast has one of the most diverse cave faunas known in the world, even when compared to sites that have had a far greater level of survey effort, and over a longer time period, such as the Dinaric karst area in Europe.[109] As there has been a relatively low level of research into subterranean environments of the Cape Range peninsula, it is highly likely that new species will be discovered, given more study.[110]

Terrestrial flora and fauna

The Carnarvon Xeric Scrub, of which the Ningaloo Coast is a part, is one of the most biologically diverse and important terrestrial habitats on Earth. Its importance is recognised in its status as one of the Global 200 Ecoregions. The WWF defines the Global 200 as a collection of the most biologically diverse and representative terrestrial, freshwater, and marine habitats on Earth. These are areas where Earth's natural wealth is most distinctive and rich, and where its loss will be most severely felt.[111] The richness and diversity of the biota of the Cape Range peninsula, and of its reptiles and vascular plants in particular, is exceptionally high even in comparison with the rest of this Global 200 Ecoregion.[112] Australia is the most megadiverse continent in the world for reptiles; and the Ningaloo Coast is among the five places in Australia with the highest terrestrial reptile endemism.[113]

The rich terrestrial biota of the Cape Range peninsula mirrors the exceptional diversity of the marine and subterranean systems of the Ningaloo Coast. The peninsula is distinguished by a diverse and highly endemic vertebrate (particularly reptile) fauna, along with a rich flora, which includes important relictual species and high phylogenetic diversity. The richness of this internationally significant biota can be partly attributed to the range of habitats (for example, mangroves, sandy ridges, subterranean wetlands, alluvial plains, rocky ranges, caves), and to its transitional setting where species occur at the limits of their geographical range or as geographically isolated populations.[114]

The Ningaloo Coast is part of a transition zone between the tropical and temperate flora of Western Australia. It contains a number of taxa with either tropical or temperate affinities. A high number of plant and vertebrate species are locally or regionally endemic, or otherwise of biogeographic importance.

The flora of the Cape Range peninsula is particularly rich for an arid limestone environment, with 630 taxa recorded. This represents close to half the 1,348 taxa known for the Carnarvon Botanical District, and includes 12 taxa endemic to the range itself, along with another six taxa largely confined to the peninsula. The composition of the flora is predominantly arid, although a number of tropical and temperate species occur as relictual populations.[115]

The terrestrial reptile and amphibian fauna of the Ningaloo Coast is exceptionally diverse. More than 100 species have been recorded from the Cape Range peninsula alone.[116] Australia is the most megadiverse continent in the world for reptiles, and the peninsula is one of the richest regions in the arid zone.[117] The wealth of restricted and highly restricted endemic species in the nominated area attests to the international importance of the Ningaloo Coast for an entire vertebrate class.[118]

Survey work within the nominated area, to the north and south of the existing Cape Range National Park, confirms the occurrence of a number of lizard species new to science. Several of these are endemic to the nominated area or to the wider Exmouth region. Ninety-nine terrestrial reptile species have been assigned scientific names and many more await taxonomic description.[119]

Fifteen snake and lizard species in the nominated area are endemic, either to the Cape Range peninsula, or to the immediately surrounding area. Of these, a legless lizard and two skinks (*Aprasia fusca, Ctenotus rufescens* and *C. iapetus*) occur predominantly on the peninsula, and are also occasionally found in the dune and sand plain country immediately to the east.[120] The area is particularly important for legless lizards, skinks and geckos. The region from Shark Bay to North West Cape is one of two Australian centres of endemism for Pygopodidae, the legless lizard family. The other is on the other side of the continent more than 4,000 kilometres away, south of Cairns in tropical north-east Queensland.

A gecko, *Strophurus rankini,* occurs only in the coastal dunes of the west coast of the Cape Range peninsula and for a short distance to the south.[121] *Lerista allochira* and an as-yet undescribed species of legless lizard (*Delma* genus) are endemic to the Cape Range peninsula, and four other skinks are restricted to the dissected limestone country of the Cape Range peninsula.[122] The legless lizard, *A. rostrata,* was formerly thought to be restricted to the Montebello Islands until it was recently recorded on the Cape Range peninsula, its first record since the 1950s. An elapid and two species of *Ramphotyphlops* (blind snakes) are regionally endemic, including the Cape Range blind snake, which has only ever been found in the Cape Range.[123]

FIGURE 3.28 The thorny devil lizard (*Moloch horridus*), western netted dragon (*Ctenophorus reticulatus*), and west coast banded snake (*Simoselaps littoralis*), three of the more than 100 reptile species found on the Ningaloo Coast.
Photographs Brett Dennis and Jiri Lochman © Lochman Transparencies

Criterion (x) summary

The Ningaloo Coast provides an outstanding demonstration of biological richness at the interface of marine and terrestrial ecosystems. For an arid region, it shows extraordinary ecosystem productivity, largely influenced by the presence of the south-flowing Leeuwin Current (which allows tropical reef growth at high latitudes), the lack of terrestrial runoff, the moist underground refugia and rugged terrain provided by the karst system, and the mantling dune systems and foothills. Falling within two Global 200 Ecoregions, it demonstrates:

- one of the best long-term prospects in the world for reef conservation, with its combination of arid climate and low sedimentation and runoff, coupled with proximity to deep waters adjacent to the continental shelf;
- globally important subterranean ecosystems and fauna of the arid zone karst;
- an exceptional diversity of marine, terrestrial and subterranean species, many of which are rare globally, endemic to the Cape Range region, or have highly disjunct distributions.

The Ningaloo Coast is of outstanding value for its highly productive marine ecosystems. Compared to other tropical marine systems, it has one of the best chances for long-term conservation on Earth, not only of the reef system, but for all the fauna that depends upon it. It is noted for its rich marine fauna, including the biggest aggregations of the world's largest fish, the whale shark. It is second in the world to the Great Barrier Reef for importance in the long-term conservation of reef and pelagic shark species. Other evidence of exceptional marine diversity includes 20 recorded species of whales and dolphins; large and healthy populations of dugong and six of the world's seven species of marine turtle.

The subterranean fauna of the Cape Range peninsula is rare and taxonomically highly diverse, with the highest number of families recorded anywhere in the world.

As a Global 200 Ecoregion, the Carnarvon Xeric Scrub (of which the Ningaloo Coast is a part) is one of the most biologically diverse and important terrestrial habitats on Earth. The richness and diversity of the biota of the Cape Range peninsula, particularly of its reptiles and vascular plants, is exceptionally high.[124]

The Ningaloo Coast has outstanding universal value under criterion (x) for the diversity and rarity of its species and ecosystems, and for their importance from the point of view of science and conservation.

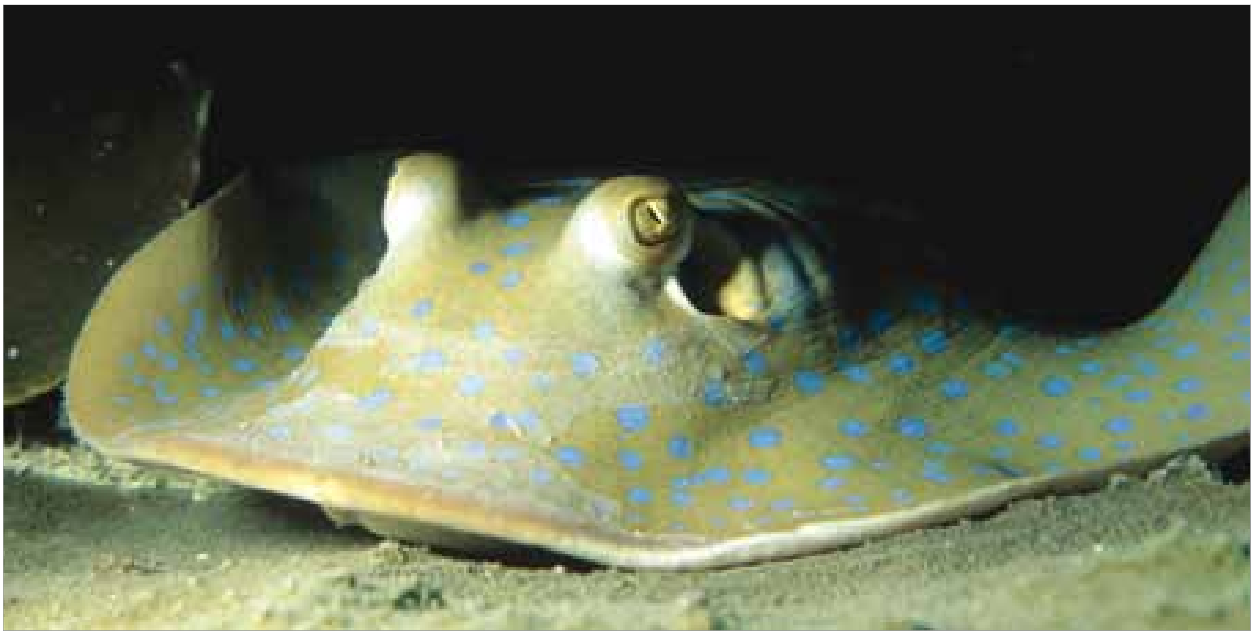


FIGURE 3.29 Blue-spotted fantail stingray at Ningaloo Marine Park.
Photograph Eva Boogaard © Lochman Transparencies

3.B PROPOSED STATEMENT OF OUTSTANDING UNIVERSAL VALUE

The enduring value of the Ningaloo Coast as an integrated system is underpinned by the functional connections between its biota, landscapes, seascapes, submarine and subterranean ecologies, across time, space and species. These components tell globally significant stories about the assembly and disassembly of continents over time, the changing climates of the Cenozoic era and the evolution of life, in a setting of great biological richness.

The physical landscape of the Ningaloo Coast, as a repository of information about the past, is an international resource. Plate tectonics, climate change, cycles of glaciation and aridity, erosion, sedimentation and marine incursion, have combined over the last 150 million years to produce a living, unfinished panorama. Their legacies are visible in flora, fauna, ecosystems, landforms and stratigraphy.

The structural and functional unity of the Ningaloo Coast system through time is at the heart of its outstanding universal value. These patterns in Earth's history have produced rich and diverse marine, subterranean and terrestrial habitats supporting important biological communities which are unique to the region or critically endangered elsewhere in the world. The isolation and low terrestrial run-off from the arid coast have ensured that the ecosystems of the Ningaloo Coast remain in excellent condition.

Set in an unspoiled limestone land and seascape of exceptional natural beauty, the land, waters and biota of the Ningaloo Coast have outstanding universal scientific, aesthetic and conservation value.

The Ningaloo Coast is nominated under criteria (vii), (viii) and (x) for its outstanding universal significance as:

Criterion (vii)

- the best opportunity in the world to encounter and study whale sharks (*Rhincodon typus*), the world's largest fish, together with globally significant populations of iconic marine megafauna, including dugongs, marine turtles, humpback whales, other cetaceans, rays and sharks
- a superlative setting showcasing dramatic contrasts between an arid coast and one of the longest, most spectacular, tropical coral reef systems in the world

Criterion (viii)

- an illustration of an extraordinary biogeographic story about increasing biological isolation, evolution, shifting continents and the record of climate change over time

Criterion (x)

- a place of outstanding biological diversity, with an internationally significant role in the protection of many important species, including the exceptional whale shark, which is a flagship for the health of the oceans
- an area supporting highly significant subterranean and terrestrial ecosystems, which shelter unique fauna with outstanding universal value from the point of view of science

FIGURE 3.30 The Ningaloo Coast: an unspoiled land and seascape of exceptional natural beauty. Photograph © Cam Skirving

3.C COMPARATIVE ANALYSIS (INCLUDING STATE OF CONSERVATION OF SIMILAR PROPERTIES)

Claims referring to World Heritage properties in Part 3.C where unreferenced are taken from IUCN Advisory Body reports (see http://whc.unesco.org/en/list).

Part 3.C compares the Ningaloo Coast to important sites that demonstrate the key elements of an integrated geoecological system or an arid-zone coastal ecosystem. This analysis is based on extensive studies of comparable places around the world, undertaken by international experts between 2004 and 2008. Table 3.2 lists the properties appearing in the following analysis, their World Heritage status and the criteria against which they are compared to the Ningaloo Coast.

Ningaloo Reef is among the best-managed reefs in the world, with globally significant populations of marine turtles, dugongs, whales and sharks, including whale sharks. With its combination of an extremely low human population, an arid coastline with low runoff and adjacent deep waters, as well as world-class adaptive management regimes, Ningaloo Reef has one of the best long-term outlooks in the world for reef conservation. This is in a world where reefs with good long-term conservation prospects are becoming rarer.[125] Ecologically and geologically, the Cape Range peninsula is an integral part of the Ningaloo Coast. It houses an exceptional fauna of great antiquity that has persisted through eons of isolation, and tectonic and climate change.

The Ningaloo Coast is an outstanding example of two categories of place that have been identified as under-represented on the World Heritage List in recent IUCN studies: arid zone karst and coral reefs.

1. There are only 16 properties on the World Heritage List featuring tropical coral reefs. Of these, the only Indian Ocean coral reef property currently on the World Heritage List is Aldabra Atoll in the Seychelles, which is recognised for its terrestrial biological values rather than its reef fauna. Although the World Heritage listed Socotra Archipelago has important coral communities, there are no reefs, and the species complement is more similar to the Red Sea than to the wider Indian Ocean. The eastern Indian Ocean, of which Ningaloo Reef is emblematic, is unrepresented.

2. A recent IUCN thematic report into caves and karst identified Australasia among regions of the world which are poorly represented for karst on the World Heritage List. Furthermore, arid zone karst systems are poorly represented. The report's authors recommend that 'future nominations for World Heritage listing should give particular attention to outstanding karst areas in these regions and/or environmental settings'.[126]

The identification of these two categories of place accentuates the unparalleled value of the Ningaloo Coast, which demonstrates the primary characteristics of an integrated limestone structure against criteria (vii), (viii) and (x).

FIGURE 3.31 Diving with the whale sharks on the Ningaloo Coast. Photograph © Cam Skirving

REGION	SITE	CRITERIA FOR WHICH THE WORLD HERITAGE PROPERTY IS LISTED	CRITERIA FOR COMPARISON IN THIS ANALYSIS
Australasia	*Shark Bay (Australia)*	(vii), (viii), (ix), (x)	(vii), (viii), (x)
	Great Barrier Reef (Australia)	(vii), (viii), (ix), (x)	(vii), (x)
	Tasmanian Wilderness (Australia)	(iii), (iv), (vi), (vii), (viii), (ix), (x)	(viii), (x)
	Willandra Lakes Region (Australia)	(iii), (viii)	(viii)
	Australian Fossil Mammal Sites (Riversleigh/ Naracoorte)	(viii)	(viii)
	Kimberley limestone ranges (Australia)	not listed	(x)
	Nullarbor Plain (Australia)	not listed	(x)
	Spencer Gulf (Australia)	not listed	(vii)
	Huon Peninsula (Papua New Guinea)	not listed	(viii)
	Te Wahipounamu (New Zealand)	(vii), (viii), (ix), (x)	(viii)
Indian Ocean & Red Sea	*Aldabra Atoll (Seychelles)*	(vii), (ix), (x)	(vii), (viii), (x)
	Mahé Island (Seychelles)	not listed	(vii)
	Socotra (Yemen)	(x)	(x)
	Horn of Africa natural areas	not listed (apart from Socotra)	(x)
	Maldive Atolls (Maldives)	not listed	(x)
	iSimangaliso Wetland Park (South Africa)	(vii), (ix), (x)	(vii), (x)
	Richtersveld and the Succulent Karoo (South Africa, Namibia)	Richtersveld listed in part for cultural values (iv), (v)	(x)
	Red Sea reefs of the Saudi Arabian coast	not listed	(vii), (x)
	Tuléar Reef (Madagascar)	not listed	(vii), (x)
	Christmas Island (Australia)	not listed	(vii)
Atlantic Ocean	*Belize Barrier Reef Reserve System (Belize)*	(vii), (ix), (x)	(vii), (x)
	Banc d'Arguin (Mauritania)	(ix), (x)	(x)
	Desembarco del Granma National Park (Cuba)	(vii), (viii)	(vii), (viii), (x)
	Brazilian Atlantic Islands (Brazil)	(vii), (ix), (x)	(vii), (x)
	Lanzarote, Canary Islands (Spain)	not listed	(viii), (x)
	Isla Holbox (Mexico)	not listed	(vii)
	Remipede-type communities of the Caribbean/ West Atlantic	not listed	(viii), (x)
Indo–Pacific & Pacific Ocean	*Tubbataha Reef Marine Park (Philippines)*	(vii), (ix), (x)	(vii), (x)
	Komodo National Park (Indonesia)	(vii), (x)	(vii)
	Lorentz National Park (Indonesia)	(viii), (ix), (x)	(viii)
	Lagoons of New Caledonia (France)	(vii), (ix), (x)	(vii), (x)
	New Caledonia Gondwana forests (France)	not listed	(viii)
	Coiba Island (Panama)	(ix), (x)	(x)
	Whale Sanctuary of El Vizcaíno (Mexico)	(x)	(x)
	Islands and Protected Areas of the Gulf of California (Mexico)	(vii), (ix), (x)	(vii), (x)

TABLE 3.2 Properties appearing in the comparative analysis

REGION	SITE	CRITERIA FOR WHICH THE WORLD HERITAGE PROPERTY IS LISTED	CRITERIA FOR COMPARISON IN THIS ANALYSIS
	Sonoran Desert (United States of America)	not listed	(x)
	Malpelo Flora and Fauna Sanctuary (Colombia)	(vii), (ix)	(vii), (x)
	Galapagos Islands (Ecuador)	(vii), (viii), (ix), (x)	(vii), (viii), (x)
	Los Glaciares (Argentina)	(vii), (viii)	(viii)
	Donsol (Philippines)	not listed	(vii)
	Phoenix Islands Protected Area PIPA (Kiribati)	nominated under (vii), (ix), (x)	(vii), (x)
	Papahānaumokuākea Marine National Monument (United States of America)	nominated under (iii), (vi), (viii), (ix), (x)	(viii), (x)
	Raja Ampat (Indonesia)	not listed	(x)
Other sites	*Mammoth Cave National Park (United States of America)*	(vii), (viii), (x)	(x)
	Sichuan Giant Panda Sanctuary (China)	(x)	(x)
	Monarch Butterfly Biosphere Reserve (Mexico)	(vii), (x)	(vii), (x)
	Serengeti National Park (Tanzania)	(vii), (x)	(vii)
	West Norwegian Fjords (Norway)	(vii), (viii)	(vii)
	Dinaric karst and other karst sites in Europe	not listed	(x)
	Limestone sites of the Mediterranean coast	not listed	(viii)

TABLE 3.2 Properties appearing in the comparative analysis (continued)

CRITERION (vii)

In a 2006 draft strategy paper on future priorities for identifying sites of outstanding universal value for the World Heritage List, the IUCN observed that two discrete ideas are represented in criterion (vii). The first of these, *superlative natural phenomena*, is measurable (as highest, oldest, deepest, largest, etc). The second idea, *exceptional natural beauty and aesthetic importance*, is harder to quantify.[127] In many cases, the superlative natural phenomenon will produce a feeling of awe or a sense of beauty, which corresponds to aesthetic appreciation, uniting the two ideas.

Some of the properties regarded as containing superlative natural phenomena may stand on the superlative degree alone—this aspect can describe a process, a structure, or a concentration of features. These include such places as the Grand Canyon (United States), Lake Baikal (Russia), Shark Bay (Australia), Yellowstone National Park (United States), Lagoons of New Caledonia (France), Teide National Park (Spain), and the High Coast/Kvarken Archipelago (Sweden/Finland). Respectively, these are the deepest canyon, the oldest, deepest lake, the most extensive sea-grass meadows, the densest concentration of geysers, the second-largest reef, the third tallest volcano, and the highest measurable glacio-isostatic rebound.

Other properties, such as Uluṟu-Kata Tjuṯa National Park (Australia), Victoria Falls (Zambia/Zimbabwe) and Kilimanjaro National Park (Tanzania), contain outstanding features with a degree of aesthetic importance or topographic isolation which may elevate their significance above those properties containing taller, larger, more numerous features. These properties encompass a huge monolith towering above a desert plain, a spectacular waterfall and an isolated massif. The superlative degree itself or the context of isolation, relief or relative scale may be the source of an aesthetic response.

As with a number of properties listed under criterion (vii), the Ningaloo Coast contains quantifiable superlative natural phenomena and features of outstanding aesthetic significance. The two ideas expressed in the criterion are compared separately, against the features addressed in 3.A.

CRITERION (VII)	SUPERLATIVE NATURAL PHENOMENA OR AREAS OF EXCEPTIONAL NATURAL BEAUTY AND AESTHETIC IMPORTANCE				
Region	*Site*	*Aggregations of iconic fauna* *Marine species (incl. whale sharks)*	*Other*	*Tropical reef or marine off arid, semiarid or savannah coast*	*Other exceptional aesthetic features*
Australia	*Ningaloo Coast*	✓ aggregations of 300–500 whale sharks;[128] many other large marine fauna including sharks, cetaceans, dugongs, turtles; the nearshore continental setting is unique		✓	✓
	Shark Bay	✓ dugongs and dolphins; not known for whale sharks		✓	
	Great Barrier Reef	✓ whale sharks are present, but are widely dispersed; internationally significant aggregations of marine mammals and sharks			✓
	Spencer Gulf	✓ mass spawning of giant Australian cuttlefish			
Indo–Pacific triangle and west Pacific Ocean	*Komodo National Park*		✓ komodo dragons	✓	
	Donsol	✓ whale shark aggregations offshore			
	Tubbataha Reef Marine Park				✓
	Lagoons of New Caledonia	✓ dugongs			✓
	Phoenix Islands Protected Area	while a number of cetacean species migrate through the region Phoenix Islands Proetected Area is not renowned for concentrated aggregations of single species			
West Indian Ocean and Red Sea	*Aldabra Atoll*		✓ giant tortoises		
	Mahé Island	✓ seasonal whale shark aggregation			
	Christmas Island	✓ mass migrations of red crabs			
	Red Sea reefs of the Saudi Arabian coast	presence of whale sharks recorded but not known to aggregate		✓	✓
	Tuleár Reefs	whale sharks seasonally present; little studied		✓	
	iSimangaliso Wetland Park	✓ dolphins and whales, marine turtles; whale sharks migrate offshore, but do not aggregate in numbers equivalent to the Ningaloo Coast			
Atlantic Ocean	*Isla Holbox*	✓ whale sharks aggregate offshore seasonally; large numbers of gamefish			
	Belize Barrier Reef Reserve System	✓ (Gladden Spit) main whale shark congregations occur outside the World Heritage area, offshore			✓
	Brazilian Atlantic Islands	✓ large aggregations of spinner dolphins			✓
	Desembarco del Granma National Park			✓	
East Pacific Ocean	*Galapagos Islands*	✓ whale sharks present offshore; large numbers of marine mammals and reptiles in the marine park			
	Malpelo Flora and Fauna Sanctuary	✓ major aggregations of large predator fish (especially hammerhead and silky sharks); not noted for whale shark aggregations though individuals have been recorded			✓
	Cocos Islands	✓ major aggregations of large fish, especially hammerhead sharks and dolphins			
	Islands and Protected Areas of the Gulf of California	large numbers of marine species enhance dive aesthetic experience, but the area is not renowned for aggregations		✓	✓
Other	*Monarch Butterfly Biosphere Reserve*		✓monarch butterfly		
	West Norwegian Fjords	✓ marine mammals			✓
	Serengeti National Park		✓terrestrial herbivores and their predators		

TABLE 3.3 Properties compared against criterion (vii)

Iconic marine species

> *There are few if any places in the world where one of the marine realm's most charismatic species is as closely associated with a particular site as whale sharks (the world's biggest fish) are associated with the Ningaloo coast.*[129]

Since the World Heritage criteria were updated in 2002, four natural properties have been inscribed on the World Heritage List under criterion (vii) at least in part for containing significant faunal aggregations. One of these—the Monarch Butterfly Biosphere Reserve (Mexico, inscribed 2008)—has massed intercontinental migrations of a single terrestrial species, the monarch butterfly. The other three—the Islands and Protected Areas of the Gulf of California (Mexico, 2005, 2007), the West Norwegian Fjords (Norway, 2005) and the Malpelo Fauna and Flora Sanctuary (Colombia, 2006)—have aggregations of marine mammals or fish, recognised either for numbers of single species (impressive numbers of hammerhead and silky sharks in the case of Malpelo) or for many different species, whose presence, while not a superlative phenomenon in itself, enhances the aesthetic experience of the underwater environment (cetacean species in the Gulf of California, marine mammals in the West Norwegian Fjords). Other recent World Heritage marine listings recognising aggregating fauna as superlative natural phenomena or as aesthetically important include South Africa's iSimangaliso Wetland Park (1999) and Baía dos Golfinhos, part of the Brazilian Atlantic Islands Fernando de Noronha and Atol das Rocas Reserves (2001). The South African property is celebrated for the spectacle of large numbers of nesting turtles on the beaches of iSimangaliso Wetland Park and offshore migratory megafauna. Baía dos Golfinhos was listed under criterion (vii) because it contains superlative natural phenomena in the form of the largest known population of spinner dolphins in the world. Although present in large numbers at these localities, and celebrated for their ecological and symbolic importance, none of these marine animals has the iconic conservation significance of whale sharks, as the only living representative of the family Rhincodontidae and the largest known cold-blooded animal.[130]

The World Heritage Committee and advisory bodies have long recognised that individual species like the whale shark or aggregations of several species (for example, suites of migratory marine megafauna), can be superlative natural phenomena that provide outstanding associative value to a particular place. Komodo National Park was included on the World Heritage List in 1991 as the best place in the world for komodo dragons, the world's largest reptile. The advisory body report noted the conservation awareness value of promoting (via World Heritage recognition) a 'dramatic or symbolic lifeform' for which there is already significant local pride and sympathy.[131]

Similarly, the Monarch Butterfly Biosphere Reserve is recognised as universally outstanding for the spectacle provided by the sheer numbers of monarch butterflies that overwinter in its forests, and for the butterflies' unusual trans-generation migration.[132] Notable invertebrate migrations in places that have not been nominated to the World Heritage List include the mass spawning of the giant Australian cuttlefish (*Sepia apama*) in South Australia's Spencer Gulf and the spectacular annual forest-to-coast breeding migrations of red crabs on Christmas Island.[133] The terrestrial migrations of herbivorous mammals from Kenya to the Serengeti (Tanzania) are collectively recognised by UNESCO as a superlative natural phenomenon for the huge numbers of animals involved (wildebeest, gazelles, zebras and predator species). In comparison, the iconic vertebrate fauna of marine environments are recognised less for the geographical scale of their migrations and the thousands of numbers involved than for their magnificent size and their trophic importance to the maintenance of ecosystem integrity. They are, therefore, a different category of phenomenon from migratory terrestrial animals or spawning aggregations.

For their importance to the trophic structure of marine ecosystems, marine megafauna like *Rhincodon typus* are considered flagships for the health of the ocean. The whale shark is comparable to iconic cetacean species like the blue whale (*Balaenoptera musculus,* the largest animal ever known) or terrestrial species like the giant panda, Javan rhinoceros or Komodo dragon. It is the biggest fish on Earth and one of the biggest vertebrates ever to exist, and is a superlative natural phenomenon. Unlike the blue whale or the Komodo dragon (but akin to the giant panda), the whale shark is the only living representative of its family, with a lineage that has been dated to the mid-Mesozoic era, when dinosaurs roamed Earth. It is unique among the orectolobiform sharks for its size and its filter-feeding habit, the largest of only three known filter-feeding shark species in the world. It inspires reverence in human beings who encounter it and it is venerated and celebrated in many coastal communities, including the Ningaloo Coast, as has been demonstrated in 3.A.

A migratory species, whale sharks are known from widely dispersed sites in the Indian, Pacific and Atlantic oceans, the Red Sea, the Sea of Cortez, the Gulf of Mexico and the Caribbean Sea. Whale sharks are regarded as cosmopolitan and have been observed in a variety of environments. They appear to be mostly solitary and their occurrence is patchy and unpredictable, except at a few sites where they aggregate regularly.[134]

The most celebrated of these sites include the Ningaloo Coast, the Seychelles, Donsol in Sorsogon Province in the Philippines, Isla Holbox in the Gulf of Mexico, and Gladden Spit in Belize.[135] It is difficult to obtain data on numbers and concentrations of animals aggregated at these sites, apart from Ningaloo Marine Park, where nearly two decades of study has produced estimates of 300–500 individual sharks in reliable annual aggregations from April to July.[136]

Other sites like the Cocos Islands in Costa Rica, the Islands and Protected Areas of the Gulf of California and the Galapagos Islands Marine Park are recognised under criterion (vii) for aggregations of other large marine fauna, either endemic or migratory and cosmopolitan species, but are not renowned for whale shark aggregations. When whale sharks occur in these locations, they are not found in large numbers. Whale sharks occur in the Great Barrier Reef Marine Park, but have never been recorded in concentrations equivalent to the Ningaloo Coast, nor have they been recorded in nearshore environments.[137]

Whale sharks are known from a few places in the Caribbean–West Atlantic Ocean region. Gladden Spit, about 40 kilometres off the coast of Placencia in Belize, is outside the Belize Barrier Reef World Heritage Area, although it has been a conservation reserve since 2000. Whale sharks are regularly observed in the waters of Gladden Spit between April and May, and ecotourist operators have adapted methods that were pioneered on the Ningaloo Coast.[138] No scientific reports are available that estimate total numbers of aggregated whale sharks. A claim by the dive and shark enthusiast website, elasmodiver.com, for the largest single observed aggregation (of 150 whale sharks off Isla Holbox in the Gulf of Mexico) is half the minimum estimate for the Ningaloo Coast aggregation, and is unconfirmed in scientific literature.[139] There is no comparable nearshore aggregation of whale sharks or other shark species as observed off Ningaloo Reef.

The Brazilian Atlantic Islands were listed as superlative natural phenomena in 1991 in part for the aggregations of spinner dolphins that frequent the World Heritage area, but whale sharks are not recorded from this property.

A famous destination for divers, the World Heritage listed Cocos Island National Park (Costa Rica) is recognised for its extensive numbers of large fish (especially hammerhead sharks) and dolphins. However, shark numbers have declined in recent years. Humpback whales, pilot whales, bottlenose dolphins, sea lions and three species of turtle are more common.

The waters of the eastern tropical Pacific surrounding Malpelo Island is recognised on the World Heritage List for supporting large populations of fish, marine mammals and sea turtles. It is best known for aggregations of more than 200 hammerhead sharks (*Sphyrna lewini*) and more than 1,000 silky sharks (*Carcharhinus falciformis*). Whale sharks have been observed in the area, but not in large numbers. Non-reef marine life has similarly distinctive megafauna at both localities, but whale sharks are rare visitors and have never been observed in numbers comparable to the Ningaloo Coast.

The Galapagos Islands are recognised as containing superlative natural phenomena in the form of diverse and abundant marine fauna—these animals readily accompany divers. Whale sharks have been observed, but in neither the numbers nor the nearshore environment of the Ningaloo Coast aggregations.

Donsol in Sorsogon Province (Philippines) has been called the ‘whale shark capital of the world’ by local tour operators and the Sorsogon regional tourist board, and anecdotally has been identified as supporting the ‘highest concentrations’ of the enigmatic giants.[140] However, recorded numbers are in the order of 60 individual sharks, not approaching the numbers that aggregate at the Ningaloo Coast (300–500 individuals). Furthermore, the Donsol aggregations are some distance offshore and are less accessible than the Ningaloo aggregations.[141] In turn, Ningaloo has been described as 'the best place in the world to see the world's largest fish'.[142]

Small numbers of whale sharks are visible all year in the Seychelles, particularly off the island of Mahé; however, during their peak season (from August to October), they appear to number no more than 50 animals, which is considerably fewer than the Ningaloo Coast. The World Heritage listed Aldabra Atoll in the Seychelles is recognised under criterion (vii) for its pristine environment and large population of giant tortoises, but large aggregations of whale sharks do not occur there. To date there has been very little research into the whale sharks off Madagascar—they are not recorded from nearshore environments there.[143]

The Ningaloo Coast protects superlative natural phenomena in the form of large aggregations of charismatic marine megafauna in an unusual nearshore environment. It is particularly noted for large aggregations of whale sharks—*Rhincodon typus*—the world's largest fish. Divers, marine ecologists and other visitors flock to the Ningaloo Coast every year from April to July to witness the rare phenomenon, as well as to enjoy the region's other marine spectacles. The Ningaloo Whaleshark Festival helps educate thousands of locals and visitors about the enigmatic giant. Ningaloo Marine Park protects other marine migratory species that are threatened in many other parts of the Indian Ocean and the world. Large aggregations of other marine vertebrates have been recorded; for example, manta rays, humpback whales and black-tip reef sharks (more than 100 individuals at some locations).[144]

A major marine science research hub, the Ningaloo Coast has long been regarded as the home of whale shark research and conservation. Three hundred to 500 individual whale sharks (mostly juvenile males) congregate off the reef for four months of every year, attracted by a pulse of productivity accompanying coral spawning.[145] The area is distinguished from other well-known whale shark localities by the numbers recorded and by the relatively close approach of whale sharks to the shore. This accessibility, in a location that is subject to a world-class adaptive management regime, adds immeasurably to visitors' experiences and is central to the Ningaloo Coast's outstanding heritage value. Providing an iconic visitor experience, the place is sensitively regulated to ensure minimal disturbance of marine fauna. Ecotourism models developed at the Ningaloo Coast include shark identification and tracking programs, conservation work, and collaboration and self-regulation between the dive industry and marine scientists. These best practice models are being exported to the world.[146]

Aesthetic importance

Since the World Heritage criteria were updated in 2002, four properties have been added to the World Heritage List under criterion (vii) in recognition of their outstanding underwater scenery:

- Islands and Protected Areas of the Gulf of California (Mexico)
- West Norwegian Fjords (Norway)
- Malpelo Fauna and Flora Sanctuary (Colombia)
- the Lagoons of New Caledonia (France).

The area of the World Heritage listed Tubbataha Reefs Natural Park (Philippines), also listed under criterion (vii), was increased threefold in 2009. The Brazilian Atlantic Islands, listed in 2001, are another recent example. Marine fauna have been recognised in IUCN assessment reports and by the World Heritage Committee as an integral part of the aesthetic experience of these underwater landscapes.[147]

Comparable to these properties, the Ningaloo Coast is recognised by divers as one of the premier diving locations on Earth for its superlative underwater scenery. The underwater experience is enhanced by the presence of large numbers of marine fauna, from brightly coloured reef invertebrates to majestic megafauna, made accessible by the unique nearshore setting and proximity to the deeper waters of the continental slope at Ningaloo Reef.[148]

In contrast to the underwater scenery of Malpelo, the West Norwegian Fjords and the Gulf of California, all of which lack extensive tropical coral reefs, Ningaloo Reef, Tubbataha Reefs Natural Park, the Brazilian Islands and the Lagoons of New Caledonia are renowned for their extensive and spectacular coral reef structures. Indeed, the IUCN has recognised New Caledonia for a number of features which also characterise the Ningaloo Coast:

- some of the most beautiful reef systems in the world
- the wide variety of shapes and forms that occur within a comparatively small area
- landscapes and coastal backdrops that are rich and diverse
- richness and diversity that continues below the surface to magnificent reef structures.
- colourful, charismatic fauna which enhances the scene.[149]

Furthermore, the nearshore location and excellent water quality of the reefs of Ningaloo ensure they are easily visible from the beach at low tide, and are more easily accessible than the New Caledonia barrier reefs.

Tubbataha is known for its spectacular, 100-metre near-perpendicular coral 'walls', where the shallow coral reef ends abruptly.[150] The proximity of Ningaloo Reef to deeper waters also makes for dramatic underwater contrast between the reef crest and the Indian Ocean. Much like the Ningaloo Coast, Atoll das Rocas (Brazilian Islands) is internationally recognised for its 'spectacular seascape at low tide' and the natural aquarium formed by its lagoon. In addition, in comparison to tropical coral reefs off these humid coasts, on the Ningaloo Coast the colours of the arid zone terrestrial landscape produce a vivid contrast with tropical waters.[151]

Reefs provide the drama of shifting scales like no other biological structure—the largest organic features known, they are visible from outer space. Close up, their spectacular and detailed beauty and abundant life are revealed. Aesthetically significant coastal and marine sites feature coral reefs in the Pacific region, the Indian Ocean and Red Sea, and the Caribbean/Atlantic Ocean. These include the World Heritage listed Great Barrier Reef, the Lagoons of New Caledonia, Indonesia's Komodo National Park, Tubbataha Reefs Natural Park, Desembarco del Granma in Cuba and the Belize Barrier Reef, as well as the renowned Red Sea fringing reefs and the extensive fringing reefs of Madagascar which are not on the World Heritage List, and the reefs of the Phoenix Islands Protected Area of Kiribati (which has been nominated to the World Heritage List). All but the Ningaloo Coast, the Red Sea reefs, Belize Barrier Reef and Madagascar are in the Pacific Ocean. Most occur in oceanic settings or off wet tropical terrestrial areas with lush and spectacular rainforest flora. This is in sharp contrast to the arid karst range in a continental coastal setting of the Ningaloo Coast, with its sparsely vegetated, pink, brown and red limestone crags overshadowing a turquoise sea.

Like Ningaloo Reef, the Red Sea, Malagasy, Komodo and Cuban reefs and the coral communities of Shark Bay all fringe arid to semi-arid coastlines. However, the west coast of Madagascar receives more than twice the rainfall of the Ningaloo Coast, and many of its reefs are classic fringing reefs, lacking the range of structures of the nearshore barrier reefs, fringing reefs and bommies of the Ningaloo Coast. The Malagasy coast is also subject to much more runoff and sedimentation than the Ningaloo Coast, so its waters lack the clarity of Ningaloo Reef. Shark Bay shows a similarly dramatic contrast between turquoise waters and arid terrestrial environment, but lacks the impressive karst topography of the Cape Range peninsula and the underwater ramparts and vivid colours of Ningaloo Reef. The reefs of Desembarco del Granma are small and lack Ningaloo Reef's visually striking reef ramparts and underwater landscape—it is listed under criterion (vii) for its towering terraces and cliffs, rather than the underwater environment.[152]

Although 70 per cent of the terrestrial area of Komodo National Park is dry savannah, it cannot really be described as semi-arid as the island has substantial patches of tropical vegetation and pockets of cloud forest, and the coast receives up to four times the average annual rainfall of the Ningaloo Coast. While it is recognised on the World Heritage List for the 'stark' contrast its green vegetation offers to 'the brilliant white sandy beaches and blue waters surging over coral',[153] there is no equivalent to the contrast offered by the vivid marine environment of Ningaloo Coast beneath the dusty red spine of Cape Range and its fringing coastal plain.

The fringing reefs of the Red Sea share the dramatic arid setting of Ningaloo Reef, but take a completely different form. Discontinuously spanning the coasts of the Red Sea for hundreds of kilometres, the fringing reefs lack the range of reef structures and contrasting land and seascapes that occur over the comparatively small area of the Ningaloo Coast. Furthermore, the underwater landscapes of the Ningaloo Coast are recognised as much for their dramatic structures as for the colour of the corals, unlike the Red Sea corals.[154]

Summary of criterion (vii)

The outstanding aesthetic experience of the Ningaloo Coast is underpinned by:

- the presence in large annual aggregations of an exceptional fish, the whale shark, as well as other charismatic marine megafauna; and
- the accessibility and dramatic juxtaposition of the arid limestone coast of Cape Range with the powerful shapes and colours, and vivid reef life that makes Ningaloo Reef beloved of visitors.

None of the other places referred to above contain all these elements that make the Ningaloo Coast an outstanding natural property. It contains superlative natural phenomena in an arid setting along a tropical coast of dramatic contrast and great natural beauty.

FIGURE 3.32 Seen from the air, the reef and range of the Ningaloo Coast form a sweeping harmony.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

CRITERION (viii)

Criterion (viii) addresses the major stages of Earth's history. This is divided into three categories: (a) *record of life*, (b) *significant ongoing geological processes in the development of landforms*, and (c) *significant geomorphic or physiographic features*. Taking Earth's history as a fourth subset of criterion (viii), Paul Dingwall, Tony Weighell and Tim Badman produced a framework of 13 features for the assessment of properties in a 2005 IUCN thematic report. The recognition of the criterion as comprising 'four distinct, although closely linked, natural elements relevant to geological and geomorphological science' was formalised by the IUCN in 2008 in an evaluation of standards for assessing the outstanding universal value of natural places.[155]

Under the subset Earth's history, the authors identified phenomena that record important events in the development of the planet, including elements of global-scale crustal dynamics like continental drift and seafloor spreading. Furthermore, the IUCN's assessment of outstanding universal value in the context of criterion (viii) takes into account the need to 'encompass the representation of the 4.6 billion years of Earth history, address the evolution of life on Earth as well as the changes in the geography of the planet'.[156] Accordingly, the Ningaloo Coast has been compared to important coastal, island and inland sites under the two categories that capture this requirement:

- biogeography, plate tectonics and climate change; and
- geoecology.

The break-up of Pangaea during the Mesozoic era, and the global implications of the oceanographic and climate shifts accompanying the gradual isolation of Australia and Antarctica during the Cenozoic era, are among the most significant events of the last 200 million years. This is in terms of their scale and their effect on the modern distribution of land, oceans and biota. There are few places in the world that illustrate these episodes as vividly as the Ningaloo Coast.

CRITERION (VIII)	MAJOR STAGES OF EARTH'S HISTORY INCLUDING THE RECORD OF LIFE, SIGNIFICANT ONGOING GEOLOGICAL PROCESSES IN THE DEVELOPMENT OF LANDFORMS AND SIGNIFICANT GEOMORPHIC OR PHYSIOGRAPHIC FEATURES		
Region	*Site*	*Biogeography, plate tectonics and climate change*	*Geoecological integration and significant landforms*
Australasia	*Ningaloo Coast*	✓ anchialine systems sheltering rare and relictual fauna, demonstrating the effects of continental drift and climate change since the Jurassic	✓ undisturbed functionally integrated karst and reef system
	Shark Bay	✓ stromatolites of Hamelin Pool	
	Australian Fossil Mammal Sites (Naracoorte and Riversleigh)	✓ mammal evolution	✓ the karst system that trapped living fauna at Naracoorte over millennia is also the means of their preservation as fossils, a process that continues today
	Tasmanian Wilderness	✓ relictual flora describes former links to New Zealand and Patagonia; some fauna has Tethyan affinities	✓glacial and periglacial processes
	Willanda Lakes Region	✓Pleistocene lakes, dune systems and the archaeological record of human activity indicating changing climates of the last glacial and interglacial cycles	
	Te Wahipounamu (New Zealand)	✓ relictual flora describes former links to Tasmania and Patagonia	✓ glaciers and fjords; plate tectonics
	Huon Peninsula (Papua New Guinea)		✓ marine terraces
West Indian Ocean	*Aldabra Atoll (Seychelles)*		✓ example of Darwin's theory of atoll formation
Atlantic Ocean and Mediterranean Sea	*Yucatán Peninsula and the remipede–type communities of the Caribbean–West Atlantic (includes Sian Ka'an Biosphere and Bahamas Bank)*	✓ centre of distribution for remipede crustaceans	✓ submerged karst system and offshore reefs
	Desembarco del Granma (Cuba)		✓ uplifted marine terraces and associated ongoing development of karst topography
	Lanzarote (Spain)	✓ presence of remipede-type anchialine community; the only known remipedes in the east Atlantic	
	Coastal karsts of the Mediterranean region		✓ history of alpine uplift, Miocene Messinian Event, glacio-eustatic changes of the Pleistocene epoch[157]
Indo–Pacific triangle and Pacific Ocean	*Lorentz National Park (Indonesia)*	✓ a central cordillera showing ecological diversity as the product of uplift	
	Los Glaciares (Argentina)	✓ relictual flora illustrates former links to New Zealand and Tasmania	✓ glacier landforms
	Papahānaumokuākea Marine National Monument (United States)		✓ hotspot island formation and subsidence demonstrates the movement of tectonic plates; landforms describe the stages of atoll evolution from high island to submerged sea mount
	New Caledonia's Gondwana forests (France)	✓ floristic links to Australia, New Zealand and South America describe former Gondwanan connection and long isolation since New Caledonia and New Zealand separated about 55 million years ago	
	Galapagos Islands (Ecuador)	✓ island biogeography	✓ volcanic island archipelago whose physical evolution is recalled in its modern form

TABLE 3.4 Places compared to the Ningaloo Coast against criterion (viii)

Biogeography, climate change and evolution

Biological components of the Ningaloo Coast, in the form of living species with ancient lineages that have outstanding universal value in their own right (see criterion (x), also record mechanisms for the 'evolution of life on Earth as well as changes in the geography of the planet'.[158] These biological components illustrate that the Ningaloo Coast is:

- a key member of a trio of Australian properties including the Australian Fossil Mammal Sites World Heritage Area and the Tasmanian Wilderness World Heritage Area, which together narrate the defining story of the final break-up of Gondwana: the northward drift of Australasia away from Antarctica, biological isolation, and the rearrangement of global climate systems and ocean currents following the opening of the circumpolar Southern Ocean;
- the unique southern hemisphere and Indo–Pacific member of a group of anchialine systems concentrated in the west Atlantic–Caribbean region, which provides an outstanding illustration of increasing biological isolation, continental movement, continuity and change in the biological and geological records.

A number of places on the World Heritage List that can also be considered representative of chapters in the evolution of life and the distribution of continents and oceans are considered below.

The World Heritage listed Australian Fossil Mammal Sites of Naracoorte and Riversleigh describe a story of climate change and increasing aridity in Australia. This complements the biogeographic history of the Cape Range peninsula subterranean system. Unlike Cape Range, the evolutionary value of these sites is reflected not in the vicariant relationships of living biota with communities elsewhere in the world, but in the rich palaeontological record they provide of terrestrial vertebrates now vanished. As Australia drifted north and the climate gradually dried, its inhabitants evolved and diversified in isolation. The Riversleigh site preserves 25 million years of this remarkable history, as the setting was transformed from a lush rainforest to modern savannah. This mirrors the history told by the genetic affiliations of the modern Cape Range terrestrial troglobites, whose ancestors retreated underground as their rainforest habitat vanished.

The Tasmanian Wilderness World Heritage Area is one of the most significant centres of survival for the monogeneric tree and shrub family Nothofagaceae (or southern beech). Like the faunal elements of the Cape Range peninsula anchialine system, the 35 species of *Nothofagus* known globally show a highly disjunct distribution across widely dispersed areas. This suggests that these lands were connected as part of the supercontinent Gondwana. The modern range of the genus encompasses New Zealand, New Guinea, New Caledonia and Argentina; its fossil range includes Antarctica. The relictual flora of the Tasmanian Wilderness World Heritage Area tells a story of biogeographic isolation and refugia over geological timescales, shifting climates and the break-up of Gondwana.

As well as the Tasmanian Wilderness World Heritage Area, a suite of sites in the Pacific have similarly strong floristic affinities pre-dating the breakup of Gondwana. The outstanding universal significance of the presence of *Nothofagus*, as an iconic representative of the Gondwanan flora, has been recognised in the World Heritage listing under criterion (viii) for Te Wahipounamu in south-west New Zealand and Los Glaciares in Argentina.

Te Wahipounamu provides a striking modern representation of Gondwanan flora and fauna. As well as species of southern beech, the site contains some 14 species of podocarp, flightless kiwis, 'bush' moas and carnivorous *Powelliphanta* land snails. The forests of Los Glaciares in southern Argentina are dominated by *Nothofagus* species, making it another link in the global chain of Gondwanan heritage. The Gondwanan forests of New Caledonia are not currently World Heritage listed. They represent evolution over more than 60 million years of isolation, since the main island of New Caledonia split off from the remainder of Gondwana. These forests exhibit a remarkable level of floral endemism at higher taxonomic levels, with ancestral links to the forests of Gondwana.

The Ningaloo Coast provides an example that complements the story told by these four sites; in contrast, it represents Indian and Atlantic ocean, rather than Pacific and Southern ocean biogeography. As a faunal site, it adds important new evidence to those locations already listed primarily for floristic affinities. Its subterranean fauna provide living evidence of the effects of Pleistocene drying on the Australian continent, as plate tectonic activity continued to move the last of the Gondwanan lands further apart and into new climates.

The Willandra Lakes Region is recognised under criterion (viii) for its Pleistocene geomorphology, which reveals a history of ice age Australia and climate change during the period of human occupation. The story told in the sediments of its dry lakes and lunettes (crescent-shaped dunes bordering the leeward shores of lakes) draws attention to the adaptive pressures to which Australian biota were subject during the glacial and interglacial cycles of the Quaternary sub-era. The troglobitic fauna of the Ningaloo Coast and their subterranean limestone home extends this narrative of a drying continent into the Palaeogene period.

Shark Bay is recognised under criterion (viii) on the World Heritage List for the presence of stromatolites, one of the world's oldest life forms, in a variety of structures. The Hamelin Pool stromatolites demonstrate an important evolutionary case study, linked to fossil stromatolites elsewhere in the continent. However, this case study covers the period in Earth's history before the development of multicellular animal life. It does not reflect plate tectonic processes and it lacks the epic biogeographic focus of the Cape Range peninsula story.

The Galapagos Islands are recognised as archetypal examples of island biogeography. They are the evolutionary laboratories that helped provide Charles Darwin with the conceptual breakthrough that led to his articulation of the theory of natural selection. The geographical isolation of the Cape Range peninsula subterranean environments presents a suitable analogue for ocean island biodiversity (and indeed, Cape Range may have been an island at times during the Neogene period) and tells a biogeographic history that harmonises with the evolution of the Galapagos. However, the story of island biogeography is a different narrative from that of the global rearrangement of continents represented by the Cape Range faunas.

The geology and geomorphology of the main mountain range of Lorentz National Park in West Papua, Indonesia, provides striking physical evidence of the collision of the leading edge of the Australian tectonic plate with the Pacific plate. The uplift is ongoing and is also a vivid manifestation of the northward drift of the last of the Gondwanan continents as the leading edge of the Indo–Australian plate collides with the western edge of the Philippine plate. The ecological diversity of Lorentz National Park is directly referable to its complex tectonic and glaciological history. The Ningaloo Coast tells a complementary biogeographic story of refugia and vicariance, embodied in its relictual terrestrial karst fauna, which have been separated from their rainforest congeners by the encroaching aridity that accompanied this inexorable journey north. Similarly, the geological setting of the Ningaloo Coast cannot be decoupled from the rich diversity of subterranean and marine life it supports.

The remipede-type communities of the Atlantic Ocean bring the biogeographic and plate tectonic significance of the Ningaloo Coast into sharp focus. The flooded karst of the Yucatán Peninsula, including the World Heritage listed Sian Ka'an Biosphere Reserve, contains at least two species of remipede, while the Bahamas Bank is the centre for remipede diversity. A number of other places in the Caribbean–Western Atlantic region, such as Cuba, also contain species of remipedes. A single species of remipede has been found at Lanzarote, one of the Canary Islands off the west coast of Africa. The Ningaloo Coast is the only other site in the world where remipedes have been found. They occur in association with a range of predictable subterranean crustacean taxa. Located in the Southern Hemisphere and the Indo–Pacific region, the Ningaloo Coast is separated from the Caribbean–Atlantic centre of remipede diversity by two oceans and more than 10,000 kilometres. The presence of a remipede (*Lasionectes exleyi*) endemic to the Cape Range aquifer enhances the biogeographic significance of each of these places, and provides a global perspective which is lacking without the contribution offered by the Ningaloo Coast.[159]

The unique and diverse ecosystems and landforms of the Ningaloo Coast have outstanding universal value for their unusual biogeographic history. This history gains even greater resonance when juxtaposed with the above properties. In turn, the geological and biogeographical significance of the properties described here is enhanced and extended with the recognition of the unfolding evolutionary laboratory of the Cape Range peninsula.

Geoecology

Places included in this section are comparable to the Ningaloo Coast in that the processes of physical evolution of their landforms are recalled in their modern form and function. The genesis of limestone coasts and tropical marine environments around the world are often closely linked. However, this reciprocity is nowhere more evident than in the geobiological entity that comprises the Ningaloo Coast. A lucid record of marine life of the late Cenozoic era, including the history of reefs since the Pliocene epoch, is documented in the sediments and scarps of the Cape Range peninsula. The future of the karst system and its constituent limestone is foretold in the reef and tropical marine shelf below. The colourless, crystal-like life forms concealed in the fossiliferous passages, caves and crevices of the range replicate the extraordinary diversity of modern coral reefs. They are a haunting reminder of a geological past of tropical rainforest edging an ancient humid shore, where now there is rangeland and desert.

Like the Ningaloo Coast, the extensive karsts around the Mediterranean Sea have experienced plate tectonic forces (alpine uplift in this case) and sea level change, especially during the Messinian salinity crisis of the late Miocene. Approximately five and a half million years ago, sea levels dropped to the point that Atlantic and Indian ocean waters were not entering the Mediterranean Sea—this resulted in a drastically reduced water level and hypersaline conditions. These karst landscapes also reflect Pleistocene glacio-eustatic sea level fluctuations; their subterranean ecosystems have been influenced by major environmental and hydrological changes. What distinguishes the Ningaloo Coast from the Mediterranean karst systems is the demonstrable antiquity of its rich subterranean fauna. Furthermore the Ningaloo Coast is on a passive plate margin in an arid region, which is a structural and biogeographical environment that is very different from the karsts of the Mediterranean Coast.[160]

The superb series of uplifted marine terraces at the Papua New Guinean Huon Peninsula present a record of the evolution of Quaternary reefs from 300,000 to 30,000 years ago, culminating in the modern fringing reefs of the region. The sequence spans the last glacial cycle and is a primary source of knowledge of reef evolution and of sea-level change during that cycle. The whole area is tectonically active. The Ningaloo Coast by comparison is one of the most stable coastlines in the world; this is attested to by its series of four principal wave-cut reef terraces, which culminate in the modern Ningaloo Reef. The terraces of the Ningaloo Coast, while fewer in number than the Huon Peninsula terraces, occur in a very different tectonic and climatic setting and span a broader stretch of time (from the late Pleistocene, back to the Pliocene and possibly earlier). Studies of the terraces have changed assumptions about the development of coasts along passive continental margins—they reveal a very different history of uplift and sea level change, and relate modern Indian Ocean reef faunas to those of the Pleistocene and possibly Pliocene epochs.[161]

The uplifted marine terraces and associated karst geomorphology of Desembarco del Granma National Park in Cuba are among the best examples in the world of significant ongoing geological processes in the development of limestone landforms. They are significant geomorphic and physiographic features in their own right. However, the modern reefs of the area are somewhat depauperate and do not reflect the evolutionary history of the terraces with the clarity of the Ningaloo Coast and Huon Peninsula systems.[162]

The Naracoorte Caves, part of the Australian Fossil Mammal Sites, is situated in southeastern Australia on a series of limestone ridges that show significant karst development. This karst system, which trapped living fauna at Naracoorte over millennia, is also the means of their preservation as fossils. The process continues today as animals fall into sinkholes and become trapped in caves to become subfossils, demonstrating the geoecological integration of the karst system, fossil deposits and modern fauna.[163] The Ningaloo Coast demonstrates a different sort of geoecological integration. Its modern karst habitat is built from sediments formed from the bodies of marine creatures—a process that is ongoing in a modern tropical coral reef setting.

FIGURE 3.33 The physical structures of the Ningaloo Coast reveal a remarkable story of biological isolation, climate change, plate tectonic movement and evolution.
Photograph © Cam Skirving

The Galapagos Islands are on a mantle hotspot where the Nazca, Pacific and Cocos tectonic plates meet. The islands were formed by volcanoes rising out of a submarine platform at a depth of 1,300 metres. The volcanism, like that of other oceanic islands such as Hawai'i and the Azores, is thought to be the product of a mantle plume, a column of hot igneous rock that rises from deep in the planet. Geologists use hotspots to help track the movement of Earth's plates, so the location, age and evolution of each of the islands records the tectonic history of the area as oceanic crust moves over the plume, and islands form, grow and sink below the waves.

This geological history is fundamental to the high levels of endemism for which the Galapagos Islands are renowned. Similarly, the islands and atolls of the World Heritage nominated Papahānaumokuākea Marine National Monument illustrate gradual movement of the Pacific plate to the north-west. Emerging islands move slowly away from the hotspot, which causes the volcanoes, creating a chain of volcanic islands grading into atolls and eventually underwater sea mounts that in their gross morphology and geographic relations reflect and record the history of their formation, in an excellent example of Charles Darwin's 1842 theory of atoll formation.

Like Papahānaumokuākea, Aldabra Atoll in the Seychelles owes its existence to the drowning of a volcanic island. Similar to the Ningaloo Coast, its morphology reflects and explains its history, although this is on a smaller geological and geographic scale. Darwin proposed that atolls like Aldabra form in areas where the sea floor subsides. As a mountain top becomes inundated, it may develop fringing reefs. When the mountain is totally submerged, some reefs may form atolls, reflecting the shape and size of the original mountain. The Ningaloo Coast, being tectonically stable, is much older than any atoll in existence today. Not enough is known about the anchialine pools of Aldabra to make comparisons with those of the Ningaloo Coast. It does not appear on the World Heritage List for its geological and structural value.[164]

As a carbonate formation on the passive margin of a continent, sometimes an offshore island and sometimes a peninsula, the Ningaloo Coast provides an entirely different geoecological record. Its wave-cut terraces have contributed to the understanding of a very different tectonic regime from the mid-Pacific setting of the Galapagos Islands and Papahānaumokuākea, or the Seychelles' western Indian Ocean setting.

The World Heritage listing of the Tasmanian Wilderness, Los Glaciares and Te Wahipounamu is in part due to the striking way in which these properties reveal the effects of glaciation and, for Te Wahipounamu, plate tectonic activity. The geomorphology of the Tasmanian Wilderness reflects glacial and periglacial processes of the last ice age at the southern edge of a continent that did not experience extensive Pleistocene glaciation. The landforms of Los Glaciares are exceptional for demonstrating the ongoing effects of both advancing and retreating glaciers, as well as providing numerous modern examples of glacier erosion. Te Wahipounamu offers evidence of the intertwined geological and biological consequences of Pleistocene glacial and inter-glacial periods, through the site's deeply incised mountainous landscape and disjunct species distribution. These are very different climate effects and geological processes from those that shaped the modern Ningaloo Coast, which is instead a product of the 'dust age' or interfluvial that characterised much of Pleistocene Australia during the last glacial stage.

As one of only three of the world's major modern tectonic plate boundaries found on land, Te Wahipounamu records in spectacular style the effects of uplift caused by the Pacific plate rising over the Indo–Australian plate. However, Te Wahipounamu lies on an active fault and the processes it displays are relatively well understood. In contrast, the western coast of Australia occupies a very different geological setting. The Ningaloo Coast offers new evidence which contradicts earlier scientific models for geological processes occurring on a passive continental margin.

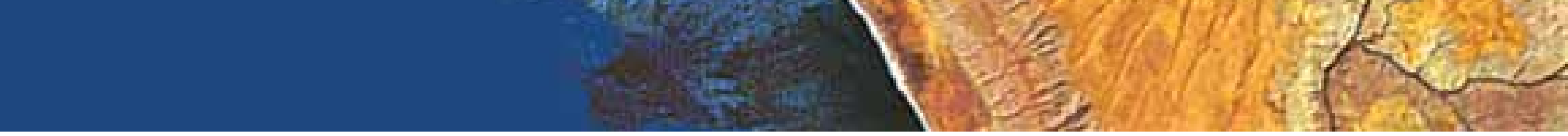
Summary of criterion (viii)

The sites outlined above tell important stories about the evolution of life, biogeography, continental drift and the reorganisation of global climate systems. However, unlike the Ningaloo Coast, none of them is characterised by the broad representation of all elements of an integrated limestone system. Furthermore, the extra context provided by the biogeographic and tectonic history of the Ningaloo Coast enriches properties already recognised on the World Heritage List under criterion (viii).

The Ningaloo Coast is an integrated limestone system of global importance. Its features demonstrate major stages in the record of life and significant ongoing geological changes, including plate tectonics and climate modification. Its karst habitat, biota and uplifted terraces reveal a remarkable tectonic and biogeographic story, which describes increasing biological isolation, climate change, plate tectonic movement and evolution. Its main features are:

- globally important anchialine systems sheltering unique stygofauna, which reveal geographic and biological change over 150 million years;
- subterranean karst systems providing habitat for rare terrestrial troglomorphic faunas affiliated with tropical rainforest biota, which demonstrates climate change since the Miocene epoch as the Australian plate continued its journey north;
- a rare geoecological structure, which includes a functionally integrated karst and reef system, and a magnificently preserved time series of fossil and living coral reefs.

Other places in the world contain some of these elements, but the Ningaloo Coast is the only place where they combine to record and elucidate three of the defining components of biogeographic change in a continental limestone setting: plate tectonics at a passive margin, climate change and isolation. No other location demonstrates the effects of geological and biological coevolution so vividly and intimately.



CRITERION x

The Ningaloo Coast offers an outstanding illustration of coastal, inshore marine and subterranean ecosystems along an arid limestone coast. These ecosystems reveal a wealth of life apparently at odds with their modern terrestrial arid setting. The abundant, well-developed tropical coral reef and associated environments, and the diverse and unusual subterranean wetland of the Cape Range karst are of outstanding universal value from the point of view of science and conservation.

CRITERION (X) COMPARISON SITES	PLACES COMPARED	PRODUCTIVE COASTAL MARINE ECOSYSTEM	KARST ECOSYSTEMS	DIVERSE AND RARE SPECIES	WORLD HERITAGE PROPERTY
Australia	*Ningaloo Coast*	✓	✓	✓	
	Great Barrier Reef	✓		✓	✓
	Shark Bay	✓		✓	✓
	Tasmanian Wilderness		✓		✓
	Nullarbor Plain		✓		
	Kimberley limestone ranges		✓		
Indian Ocean	*Red Sea*	✓		✓	
	Socotra and other Horn of Africa sites	✓	✓	✓	✓
	Aldabra	✓		✓	✓
	Tuléar Reef	✓		✓	
	iSimangaliso Wetland Park	✓		✓	✓
	Maldives			✓	
	Richtersveld and the Succulent Karoo			✓	In part
Atlantic sites	*Desembarco del Granma*	✓		✓	✓
	Brazilian Atlantic Islands	✓		✓	✓
	Lanzarote, Canary Islands		✓		
	Bermuda, and the Bahamas		✓		
	Sian Ka'an Biosphere Reserve		✓	✓	✓
	Yucatán Peninsula		✓	✓	
	Banc d'Arguin	✓		✓	✓
Indo–Pacific and Pacific sites	*Whale Sanctuary of Vizcaino*	✓		✓	✓
	Gulf of California	✓		✓	✓
	Lagoons of New Caledonia	✓		✓	✓
	Tubbataha Reef	✓		✓	
	Coiba Island	✓		✓	✓
	Malpelo Fauna and Flora Sanctuary	✓		✓	✓
	Komodo National Park			✓	✓
	Raja Ampat Islands			✓	
	Papahānaumokuākea			✓	
	Phoenix Islands Protected Area			✓	
	Sonoran Desert (United States)			✓	
Continental sites	*Mammoth Cave, Kentucky; also Texas and Alabama (United States)*		✓		
	Dinaric karst and other karst sites in Europe		✓		
	Sichuan Giant Panda Sanctuary			✓	✓

Note: Aldabra Atoll and the islands of Socotra contain areas of karst, but these have not been sufficiently well studied for fruitful comparison with the Ningaloo Coast.

TABLE 3.5 Properties compared against criterion (x)

Productive coastal marine systems

With its high-production marine and estuarine environments off a low-nutrient arid coast, the Ningaloo Coast shares some elements with the following properties: Shark Bay (Australia), Banc d'Arguin National Park (Mauritania), Reserva del Vizcaino (Mexico), Desembarco del Granma National Park (Cuba), the Islands and Protected Areas of the Gulf of California (United States) and the Socotra Archipelago (Yemen). One non-World Heritage area is compared here: the Red Sea ecosystems.

Among Australia's marine World Heritage sites, the Great Barrier Reef and Shark Bay have individual features that are similar to the Ningaloo Coast. However, neither of these sites has the co-occurrence of fringing or barrier reefs and an arid coastline. The Ningaloo Coast is also atypical among tropical coral reefs for its location on a narrow continental shelf. In the case of the Great Barrier Reef, there is no arid coastline; consequently, the reef is subject to higher levels of runoff and turbidity, as a result of the higher rainfall and greater human population along much of the length of the adjoining coast. In the case of Shark Bay, there are small coral communities, but no coral reefs, and a carbonate landscape with no known karst.

The eastern Indian Ocean reefs are unrepresented on the World Heritage List, including Australia's important west coast system. Containing 67 per cent of the reef and pelagic fish species of the west coast of Australia, the Ningaloo Coast protects the most diverse of the western Australian reefs.[165] Although other stretches of reef in the western Australian system contain significant features, Ningaloo Reef is exceptional for its dramatic scale, structural integrity, scientific significance, biogeography, species richness and for its relationship to the unique Cape Range peninsula subterranean wetland.[166]

The Ningaloo Coast marine system can be compared to the Socotra archipelago in the Indian Ocean and the reefs of the Red Sea. The marine life of the Socotra archipelago is subject to many converging ocean currents. It lies between the major endemic populations of the Red and Arabian seas. The archipelago itself is a major centre of dispersal and replenishment for the surrounding seas. Marine areas in Socotra are less degraded than most Indian Ocean reefs; however, threats are increasing.[167] Although there is a diversity of coral species at Socotra, the coral habitats are not classified as reefs, and are of a different composition and structure to true reefs, such as Ningaloo Reef.

The coral reefs of the Red Sea are not inscribed on the World Heritage List, but are recognised as globally important. The reefs of the Red Sea are structurally very different from Ningaloo Reef's continuous series of reef platforms, and contain fewer reef species. The fringing reefs of the Red Sea are generally narrow and steep, directly adjoining the shore with little or no lagoon. They provide no equivalent to the more than 290-kilometre near-contiguous series of fringing and barrier reefs skirting the Ningaloo Coast. The physical environments of the Red Sea and Ningaloo reefs are also markedly different. The enclosed reef waters of the Red Sea are highly saline due to the absence of rivers and the high evaporation rates associated with the dry desert climate. By contrast, Ningaloo Reef is not highly saline as it is flushed each day by ocean waters.[168]

Several other sites with an arid or semi-arid coastline are inscribed on the World Heritage List, including the Gulf of California (United States), the Vizcaíno Whale Sanctuary (Mexico), Desembarco del Granma (Cuba) and Banc d'Arguin (Mauritania), yet none combine terrestrial and marine components with equivalent richness in reef and karst faunal groups, as at the Ningaloo Coast.

Although Desembarco del Granma has relatively well developed coral formations, they are much less well developed and more subject to pollution and sediment run-off than the reefs of the Ningaloo Coast. They are in an area of greater pressure from human settlement. Banc d'Arguin is situated on the coast of Mauritania in a transition zone where the Sahara desert meets the Atlantic Ocean. The terrestrial environment is very arid and human impacts are low. Although the park is important for marine fauna, there are no reefs within this area.[169] Similarly, although the Vizcaíno Whale Sanctuary and the Islands and Protected Areas of the Gulf of California both support important concentrations of marine mammals and other marine vertebrate species, there are no substantial reefs in the region.

The long-term integrity of Ningaloo Reef is among the best in the world. It has among the highest conservation potential of any reef site on Earth, due to the extraordinarily low human population by world standards, the arid coastline and negligible amounts of sediment carried on to the reef. The presence of deep ocean in close proximity means that the reefs are flushed with open ocean water, 'leaving them in a condition that is rarely seen elsewhere'.[170] The importance of Ningaloo Reef is magnified in a climate of rising and severe pressures on reefs around the world, due to increasing anthropogenic impacts.

Karst ecosystems

Although deep continental anchialine systems are relatively common in the northern hemisphere, the Cape Range peninsula system is the only one known in the southern hemisphere. The biogeographic importance of the Cape Range karst habitat is exemplified by *Lasionectes exleyi,* the single Southern Hemisphere representative of the Remipedia, a class of aquatic stygofaunal crustacean. All species of the class are found on the American plate, with two exceptions: Lanzarote, a volcanic anchialine island in the Canary Islands off the west coast of Africa; and Bundera Sinkhole on the Cape Range peninsula. Other remipede-type communities of the Atlantic Ocean include the flooded karst of the Yucatán Peninsula, including the Sian Ka'an Biosphere Reserve. A number of other places in the Caribbean region (such as Cuba and the Bahamas) also contain species of remipedes and associated species within anchialine habitats.

The absence of anchialine communities characterised by remipedes outside the Central American region underscores the importance of Lanzarote and Cape Range in biogeographic terms. The Ningaloo Coast, as a carbonate landscape on the edge of a continent, has added relevance compared to Lanzarote (which is a volcanic island) for understanding the evolution of carbonate coastal environments since the mid-Mesozoic era, and as the sole example of a remipede-type community outside the Atlantic Ocean.[171] In combination, Lanzarote and Cape Range are pivotal in elucidating the story of the opening and closing of the Tethys Sea and the break-up of Pangaea and Gondwana, based on the living evidence in the form of these small crustaceans.

The Ningaloo Coast karst system is in the arid zone, which is a category of environment that was identified as under-represented on the World Heritage List in a recent IUCN thematic report on karst.[172] None of the sites of the Caribbean or the Yucatán Peninsula approaches the Ningaloo Coast for aridity. The Yucatán is a flooded karst in a humid, subtropical climate. Lanzarote is arid, but is a volcanic anchialine system that does not contain karst.

Similar arid zone karst settings include the Socotra archipelago and the Nullarbor Plain in Australia. However, the karst of Socotra is poorly studied and is predominantly located away from the arid coast in the more humid coastal hinterland and montane regions. The Nullarbor Plain karst system, while arid, does not have the species richness of the Ningaloo Coast. The author of the thematic report on karst, Paul Williams, also noted that Australasian karst is poorly represented. The World Heritage listed Tasmanian Wilderness contains karst, but is in a cool-temperate climate. The Kimberley limestone range karst occurs in a monsoonal setting. These places are discussed in the next section in more detail.

Diverse and rare species

Diverse marine fauna

A 2002 study published in the journal *Science* identified 18 global coral reef biodiversity hotspots.[173] The western coast of Australia, from Ningaloo Reef at the Tropic of Capricorn to Rottnest Island in the south, ranked second in the numbers of species that have a restricted distribution across the globe and seventh in total diversity. With the inclusion of the magnificent New Caledonian reef system in 2008, Pacific Ocean coral reefs are reasonably well represented on the World Heritage List. However, Indian Ocean reefs remain under-represented. Those properties that contain reefs in the western Indian Ocean (Aldabra Atoll, Seychelles, and Socotra Archipelago, Yemen) are primarily listed for terrestrial biodiversity, and do not include substantial areas of reef. No coral reefs in the eastern Indian Ocean have been inscribed on the list.[174]

Preliminary research has recently begun on the benthic communities of the Ningaloo Coast by the Western Australian Marine Science Institute. Researchers have already discovered a multitude of species either previously undescribed, unknown from the region, or unrecorded from Australian waters. There are extraordinarily rich communities living on the continental shelf and slopes off the Ningaloo Coast, and many new discoveries are anticipated as survey work in the region continues.[175]

Due to the size of Ningaloo Reef, the arid coastline, low human population, good water circulation with deep waters adjacent to the reef, and a sound management regime, the Ningaloo Coast has one of the highest long-term conservation prospects of any reef in the world. Only one other region in the world shares similar environmental conditions: the Saudi coast of the northern Red Sea.[176] Other sites around the world that are in relatively good condition and have long-term integrity, but with different conditions to those described above, include the islands of Socotra, the Phoenix Islands Protected Area, the iSimangaliso (Greater St Lucia) Wetland in South Africa, the Lagoons of New Caledonia, the Gulf of California, the remote Aldabra Atoll in the Seychelles, and the equally remote Brazilian Atlantic Islands, along with several sites around Australia, including the Great Barrier Reef and Shark Bay.

Sites in the Indo–Pacific or 'coral triangle', including countries such as Indonesia, the Philippines, northern New Guinea and the Solomon Islands, house the greatest diversity of coral species and associated reef fish and other species in the world. For example, Tubbataha Reef has had nearly 400 coral species recorded, while the site with the highest coral diversity in the world is at Raja Ampat Islands in West Papua, with 533 species. Reef fish numbers are similarly high in this region, with over 400 species at Tubbataha, and a huge diversity of 1,500 species at Komodo National Park in Indonesia.[177]

However, many reefs are subject to severe pressures, including intensive fishing, destructive fishing practices including blasting and poisoning, and land degradation, leading to sedimentation and eutrophication.[178] Although the species diversity is exceptional at reefs in the coral triangle, such as Komodo National Park and Tubbataha, there are fewer top predators, including sharks and other large fish, than at the Ningaloo Coast. An exception to this within the coral triangle is the Raja Ampat Islands, which have the highest biodiversity in the world for corals, and for reef fish, with over 1,600 species in a relatively small area.[179] However, many other reefs in the central and western Pacific are very vulnerable to natural predation and to damage.[180]

In 1996 the Belize Barrier Reef Reserve System was World Heritage listed on the basis of it being the largest, most diverse reef complex in the Atlantic–Caribbean area, despite the IUCN noting that marine biodiversity in the Caribbean is significantly lower than in the Indo–Pacific region. On this basis, two comparisons are set out here: a comparison of Indian Ocean reef diversity, being the region that contains the highest diversity reefs globally; and also a comparison of all marine sites of importance for marine fauna.[181]

Comparison of Indian Ocean reef faunal diversity.

Generally, the diversity of reef fauna is known in detail only for corals and reef fish. Corals are a particularly good indicator of the diversity of reef life as they are responsible for building the habitats on which other taxa depend. The diversities of corals is thus a good indicator of reef biodiversity in general.[182]

The number of marine mammal species at the Ningaloo Coast is comparable with the number at Shark Bay—approximately 20 species have been recorded at both places. There are 323 fish species at Shark Bay, compared with 738 reef fish at Ningaloo. Shark Bay is not rich in coral species, with around 80 species, compared with over 300 species at Ningaloo—this represents one of the richest concentrations of this group in the Indian Ocean.[183] Shark Bay is an important stronghold for dugong (*Dugong dugon*) supporting an estimated 10,000 animals, while the Ningaloo Coast also supports an important population of around 1,000 animals.[184] Two marine turtle species breed at Shark Bay: the green turtle and loggerhead.[185] Of the six species of marine turtle found at the Ningaloo Coast, four are recorded as breeding there.

The Socotran archipelago is subject to several converging ocean currents and lies between the major endemic marine species populations of the Red and Arabian seas. Marine life is very diverse and includes 251 species of coral, which is higher than most other sites in the Red Sea, approximately 400 species of coastal fish and 300 species of crab, lobster and shrimp.[186] However, the coral formation is different to that at Ningaloo Reef. There are few or no reefs developed on biogenic calcium carbonate, rather coral communities have developed directly on non-reef substrates or relict reef deposits. These have less diversity of structure compared to true reefs, and therefore less resilience to climate change.[187]

Marine habitats in the Socotran archipelago are generally in good condition, although threats are increasing. The region is a transition zone where related but distinct communities overlap. The marine communities of the Socotra archipelago include local and regional endemics, and rare species with restricted global distributions. Marine areas in Socotra are less degraded than most Indian Ocean reefs, and the archipelago itself is a major centre of dispersal and replenishment for the surrounding seas.[188]

In contrast to the Ningaloo Coast, Socotra is not known to support significant populations of marine megafauna, such as whale sharks, whales, dolphins and dugongs, nor are as many fish species found there.[189]

Aldabra Atoll is a refuge for the famous giant tortoise and flightless bird populations of the western Indian Ocean, as well substantial marine turtle breeding populations and large seabird colonies.[190] The diversity of corals in the Seychelles as a whole is unknown, but is predicted to be in the order of 290 species. The diversity of reef fish across the entire archipelago is relatively high at 676 species. A 2005 study identified between 200 and 244 fish species from the Aldabra waters.[191] The Aldabra reefs are less diverse and are much smaller than those at the Ningaloo Coast, with a circumference of approximately 31 kilometres. The reefs occur patchily in shallow water of less than 10-metre depth. Shark populations may be stable here due to the remoteness of the island, but this is unconfirmed.[192]

The coral reefs of the Red Sea are structurally very different from Ningaloo Reef's continuous series of reef platforms. The Red Sea also contains fewer reef species (260) for the entire stretch of coastline, measuring almost 2,000 kilometres, compared to Ningaloo Reef, with over 300 species in just under 300 kilometres of coast.[193] However, the Red Sea region is characterised by a high level of endemic species (a product of its unusual recent geological history), high salinity and isolation from the rest of the Indian Ocean. Thus many species of fish, crayfish, mollusc, and other invertebrates are endemic to the Red Sea, and overall, 30 per cent of species are unique to the system, with an even higher percentage of endemism in some fish families.

The Maldives comprise a series of coral atolls that run for 800 kilometres in the central Indian Ocean. They constitute an important stepping stone between the reefs of the eastern and western Indian Ocean, and have a high coral diversity, with 209 scleractinian corals. They are also in relatively good condition. However, the species numbers do not rival those of Ningaloo Reef, despite covering a much greater area.

The iSimangaliso Wetland Park supports a very high terrestrial and marine diversity. Thirty two marine mammals and nearly 400 reef fish have been recorded in the park. The park also provides important nesting sites for leatherback and loggerhead turtles. The diversity of corals, however, is relatively low, with 129 species, and there is no true coral reef. The marine waters support significant whale populations and the park is in the migratory path of the humpback and southern right whales.[194] There are three species of dolphin (bottlenose, humpback and spinner dolphins), and a small dugong population. Whale sharks are sighted occasionally but not in large numbers.[195]

The Tuléar Reef is located on the central western coast of Madagascar, which is the fourth largest island in the world, with a total marine area of around 5,500 square kilometres. Most of the western side of the island is severely erosional. There is little difference between the coral reef fauna of the Tuléar region and that of northern Madagascar where the reefs are less affected by terrestrial erosion. Both the Ningaloo Coast and Tuléar regions have substantial near-shore reefs bordering straight dry coasts on one side and deep ocean on the other. Water clarity is good in both regions and marine diversity is broadly similar. Although both regions are arid, the Tuléar terrestrial environment is eroded due principally to anthropogenic pressures resulting in a reduction of the species richness, density, and the size of the coral fish populations. These pressures are not present at Ningaloo Reef. The recognised World Heritage values of Madagascan sites under criterion (x) relate primarily to terrestrial endemic mammals and reptiles, rather than the marine realm.

	CORAL DIVERSITY	REEF FISH DIVERSITY
Ningaloo Reef	311	738 (out of an approx. total of 1,000 reef and pelagic species)
Shark Bay	80	323 (unspecified whether this includes pelagic species)
Aldabra	244	676 (unspecified whether this includes pelagic species)
Socotra	251	Approx. 400 (unspecified whether this includes pelagic species)
Red Sea	260	Possibly 508 reef (out of a total of 1248 reef and pelagic species)
Tuléar Reef	130	700 (reef and pelagic species)
iSimangaliso Wetland	129	399 (unspecified whether this includes pelagic species)
Maldives	209	1,000 (reef and pelagic species; the diversity of reef fish alone is not available)

TABLE 3.6 Comparison of coral and reef fish diversity in Indian Ocean and Red Sea sites[196]

Of the sites in the Indian Ocean, only the entire region of the Red Sea rivals the Ningaloo Coast for numbers of coral and reef fish species, despite the Red Sea encompassing a far larger area. Ningaloo Reef stands out as the most diverse of the Indian Ocean reefs, based on the combined numbers of coral and fish species, which in turn is indicative of the diversity of reef systems. The Ningaloo Coast also rivals other marine sites around the world for the health and diversity of its marine species, and as having one of the best long-term conservation outlooks for marine species globally.[197]

Comparison of all World Heritage marine sites noted as being of importance for marine fauna

The following analysis compares important marine sites primarily on the basis of the numbers of marine mammals, reptiles and sharks, as these are comparatively well recorded across the globe. Sharks are in decline around the world and, as top predators, play a significant role in maintaining ecosystem health. The relative importance of each population of marine mammals, reptiles and sharks, where documented, along with known aggregations, is also noted. For other faunal groups, such as the molluscs and crustaceans, a comparison has not been attempted due to the patchy knowledge of these groups across the world (although they are abundant and diverse along the Ningaloo Coast).[198] An important consideration for World Heritage listing is the integrity of each property, and the long-term viability of populations and ecosystems.

The Ningaloo Coast is the best place in the world to view and study the whale shark. During the mass spawning of coral, whale sharks aggregate in numbers that are unmatched anywhere else in the world.[199] Vital research that uses individual identification, pioneered at the Ningaloo Coast, enables demographic details of whale sharks to be determined with a high degree of accuracy.[200] Whale shark numbers are sharply declining in a number of countries, and the Ningaloo Coast is one of the most important strongholds for the species.

The global conservation significance of whale sharks is brought into focus by consideration of a terrestrial species, the giant panda. The Sichuan Giant Panda Sanctuary was inscribed on the World Heritage List under criterion (x) as the main habitat of the giant panda, a species described as a flagship for global conservation efforts. Similar to the whale shark, the giant panda is phylogenetically distinct, as the only species of its family.[201] Like giant pandas, whale sharks have been described as a flagship for global conservation. They have added ecological significance because of the trophic importance of marine megafauna to tropical marine environments.[202] Furthermore, the whale shark is the largest cold-blooded animal known.

The Ningaloo Coast, along with the Great Barrier Reef and the iSimangaliso Wetland in South Africa, is of major conservation importance to several baleen whale species, and is also one of the best places in the world to observe them.[203] Australia is one of the few remaining countries in the world to support large populations of marine turtles and the Ningaloo Coast provides important nesting sites, particularly for green, loggerhead, flatback and hawksbill turtles.[204]

The Great Barrier Reef is the world's largest reef system, at 2,600 kilometres in length, and is outstanding in a number of respects, although the reef's biodiversity is not as high as that for sites within the coral triangle. The Great Barrier Reef supports exceptional megafauna populations, notably sharks, dolphins, dugong and turtles. Absolute numbers of whale sharks at the Great Barrier Reef are comparable to those at the Ningaloo Coast, however, whale sharks are seen in greater concentrations at Ningaloo where resident populations of 300–500 individual sharks have been recorded.[205] At the Great Barrier Reef, whale sharks are widely dispersed in inaccessible offshore waters. Approximately 30 species of whales and dolphins have been recorded within the marine park, and the area is an important breeding ground for many species. The park also has a high diversity of sharks, with 27 species of whaler sharks and three hammerheads, many of which also occur along the entire northern coast of Australia.[206] Taken on species numbers alone, the Great Barrier Reef has higher diversity than Ningaloo Reef. However, given its arid climate and exceptionally low population, Ningaloo Reef is not subject to the same anthropogenic pressures as the Great Barrier Reef.

Sites in the Atlantic Ocean with important populations of marine mammals and/or reptiles include the waters off the island of Desembarco del Granma in Cuba, the Brazilian Atlantic Islands off Brazil, and Coiba National Park in Panama.

Desembarco del Granma is visited by endangered marine species including loggerhead turtles (*Caretta caretta*), green turtles (*Chelonia mydas*), olive ridley turtles (*Lepidochelys olivaceas*) and the critically endangered hawksbill turtles (*Eretmochelys imbricata*).[207] However, the reefs of Desembarco del Granma are less well preserved and much less species rich than those of the Ningaloo Coast; the island is principally recognised for its outstanding karst formations, including uplifted terraces.[208]

The Fernando de Noronha Archipelago and Rocas Atoll of the Brazilian Atlantic Islands off the coast of Brazil are important for the breeding and feeding of tuna, shark, turtle and marine mammals. Baia de Golfinhos has an exceptional population of resident dolphins. It provides a critical stronghold for the Atlantic spinner dolphin (*Stenella longirostris*). The islands are a key site for the protection of biodiversity and endangered species in the southern Atlantic Ocean. They are important for the conservation of threatened species of marine turtles, particularly the hawksbill turtle. The site may be important for the maintenance of shark populations, but this has not been confirmed. Although the Rocas Atoll is recognised for its spectacular coral scenery, there are no reefs on the scale of the Ningaloo Coast.[209]

The marine ecosystems of Coiba National Park and its Special Zone of Marine Protection (Panama), support extraordinary biodiversity as a result of the Gulf of Chiriquí buffering against temperature extremes associated with the El Niño and Southern Oscillation phenomena. The property includes 760 fish species, with 33 species of sharks, including whale sharks, and 20 cetaceans. However, the reefs have a low diversity of coral species.[210]

Comparable World Heritage sites in the Pacific Ocean include the Whale Sanctuary of Vizcaino and the Islands and Protected Areas of the Gulf of California. Located in the central part of the peninsula of Baja California, the coastal lagoons of the Vizcaino Reserve are important reproduction and wintering sites for the grey whale (*Eschrichtius robustus*), harbour seal (*Phoca vitulina*), California sea lion (*Zalophus californianus*), northern elephant-seal (*Mirounga angustirostris*) and blue whale, and are home to four species of marine turtles.[211] However, there are no coral reefs so total biomass is not as high as that for the Ningaloo Coast.[212]

Similarly, the Islands and Protected Areas of the Gulf of California, off Mexico in the eastern Pacific Ocean, is highly diverse for both marine fauna and terrestrial life. This property is an important ecoregion of high priority for biodiversity conservation. The total number of species of fish (891) is highest compared to other marine and insular World Heritage properties, with the number of marine mammals reported to be between 30 and 35 species.[213] However, there are no coral reefs in the Gulf of California, so total biomass is not as high as at the Ningaloo Coast.[214]

The Lagoons of New Caledonia are listed under criterion (x) as a marine site of exceptional diversity, with a continuum of habitats from mangroves to seagrasses and a wide range of reef forms. The barrier reefs and atolls in New Caledonia form one of the three most extensive reef systems in the world, together with the Great Barrier Reef and the Meso-American barrier reef (of which the 96,000 hectare World Heritage listed Belize Barrier Reef is a portion). The property provides habitat for a number of threatened fish, turtles, and marine mammals, including a large dugong population. The ecosystems are in good condition, with healthy populations of large predators and a great number and diversity of big fish.[215] There is no arid coastline.

The waters of the eastern Pacific Ocean surrounding the World Heritage listed Malpelo Island (Colombia) provide a complex and rich ecosystem, influenced as they are by several marine currents and varied bathymetry. This property supports important populations of pelagic bony fishes, sharks, marine mammals and sea turtles, including huge aggregations of hammerhead and silky sharks. However, with 394 fish species, it does not compare to the Ningaloo Coast for numbers of fish species. Although Malpelo Island has some luxuriant coral growth, it has no reefs.[216]

Two Pacific Ocean sites have recently been nominated under criterion (x) for their outstanding biological diversity: the Phoenix Islands Protected Area and Papahānaumokuākea Marine National Monument. However, both of these sites, as volcanic-formed coral atolls, are quite different to the Ningaloo Coast.

The Phoenix Islands Protected Area comprises a series of coral atolls located mid-ocean in the central Pacific between Australia and Hawai'i, close to the equator. It is home to more than 200 coral species and 518 shallow reef fish species, including large shoals of threatened bumphead parrotfish (*Bulbometopon muricatum*). Its coral diversity is less than that of the Ningaloo Coast; however, which records over 300 coral species. The Phoenix Islands Protected Area also provides critical habitat for important seabird populations that are of global significance, including several endangered species, and nesting beaches for threatened green turtles and possibly for hawksbill turtles.

Papahānaumokuākea Marine National Monument encompasses the northernmost three-quarters of the Hawai'ian Archipelago. Central to its nomination to the World Heritage List is the site's importance as critical habitat for vulnerable and endangered seabirds: Papahānaumokuākea is described as the largest tropical seabird rookery in the world. It is also notable as a top-predator-dominated system.[217] Reef fish endemism rates vary through the island chain, from 20 per cent up to 63 per cent. The site provides critical habitat for breeding populations of Hawai'ian monk seals (*Monachus schauinslandi*) and significant nesting habitat for the threatened Hawai'ian green turtle *(Chelonia mydas)*. The property supports hawksbill, leatherback, olive ridley and loggerhead turtles, and more than 20 cetacean species. However, Papahānaumokuākea, unlike the Ningaloo Coast, incorporates only a very small terrestrial area (1,400 hectares) and does not have an arid coastline.

Diverse subterranean fauna

In their analysis of the large number of karst landscapes that are already entered on the World Heritage List, the authors of a recent IUCN thematic study on World Heritage and karst note that southern hemisphere karst, including Australasian karst, is under-represented on the list. Furthermore, there is poor representation of karst landscapes in arid and semi-arid environments. The authors also note that it is desirable for nominations to have karst as just one of a range of outstanding values. The Ningaloo Coast meets all of these criteria.[218]

FIGURE 3.34 The thermosbaenacean crustacean *Halosbaena tulki*.
Photograph © WF Humphreys

❱ **FIGURE 3.35** *Nocticola flabella*, a troglobitic cockroach. Photograph Bill Humphreys © Western Australian Museum

The list of sites chosen for comparison is based on information presented in Paul Williams' 2008 karst thematic study for the IUCN, with additional sites noted as having important subterranean biota by biospeleologist Boris Sket. Of the World Heritage properties listed in Williams' study, only a small number are recorded as being important for subterranean fauna; the same applies to his proposed Tentative List karst sites.[219] Sites in Australia with high levels of recorded cave fauna include the Tasmanian Wilderness World Heritage Area, the limestone ranges of the Kimberley, and the vast and arid Nullarbor Plain. World Heritage properties outside Australia that are known to harbour important subterranean fauna are Sian Ka'an Biosphere Reserve, which is part of the Yucatán Peninsula in Mexico, and Mammoth Cave in the United States.

The Tasmanian Wilderness World Heritage Area is listed for high levels of richness and endemism of terrestrial flora and fauna. The site datasheet from the IUCN's World Conservation Monitoring Centre (WCMC) notes the presence and outstanding importance of cave fauna within the region, and the high level of species richness and numbers of endemics. The Mole Creek karst contains a diverse invertebrate cave fauna, with over 80 species recorded. However, of these only 12 are troglobites, or true cave fauna, compared with 75 troglobitic species at the Ningaloo Coast. Three cave invertebrate species are endemic to the area: *Tasmanotrechus cockerilli* (cave beetle), *Hickmanoxyomma gibbergunyar* (cave harvestman) and *Pseudotyrannochthonius typhlus* (cave pseudoscorpion).[220]

Subterranean habitats and the presence of subterranean fauna are not known in the Shark Bay World Heritage Area.

Two comparable sites in Australia that are not inscribed on the World Heritage List are the Nullarbor Plain and the Kimberley Limestone Ranges. The Nullarbor Plain is an area of extensive karst in southern Australia, covering approximately 200,000 square kilometres. More than 100 invertebrate species had been recorded from the Nullarbor caves by the early 1990s, including 14 troglobites, ranging from spiders to isopod crustaceans, insects and a stygobitic amphipod. These are all endemic. [221] The troglobites are a small sample of late Neogene/Pleistocene surface fauna, now absent from the region. Despite the considerable progress already made in documenting the cave invertebrate biota, it is clear that a thorough survey of the distribution and taxonomic relationships of the Nullarbor subterranean fauna is not yet complete.[222]

There is little systematic information on the flora and fauna of the caves of the Kimberley limestone ranges in Australia's tropical north-west, but this is more of an indication of lack of research than that the caves are unimportant biologically. Work by Bill Humphreys and others has found significant terrestrial and aquatic cave invertebrate communities with many troglobites present.[223] Overall, the karst of the Devonian reef system of both the west and east Kimberley limestone ranges contain numerous troglobitic and epigean (surface) taxa that are endemic at the specific, generic or family level. Some of these have been described by taxonomists, but most await formal description.[224]

In the context of Australia, the subterranean biodiversity of the Cape Range peninsula is outstanding. No other karst area in Australia has as rich a fauna. Bayliss Cave in North Queensland has been noted as a global hotspot for subterranean diversity, but only contains 24 troglobites.[225] Barrow Island, approximately 160 kilometres north of the Ningaloo Coast, supports a subsample of the values of the Cape Range peninsula, but Barrow Island is biologically much less diverse, both on the surface and subsurface.[226] Likewise, subterranean faunal diversity in the Kimberley limestone ranges and the Nullarbor Plain do not match those at the Cape Range peninsula, although the known diversity of the Kimberley limestone ranges in particular is likely to increase with further field research and taxonomic work.

Sian Ka'an Biosphere Reserve, on the Yucatán Peninsula in Mexico, protects a great variety of habitats and vegetation types: from rainforests, wetlands and mangroves, to lagoons and coral reefs. The area of well-developed coastal low plateau or swamp karst has characteristic elements, like sinkholes or cenotes, cays, lagoons and water holes, forming a unique and complex hydrological system that sustains a high diversity of species and habitats. Anchialine habitats and communities have also been described for Sian Ka'an. The WCMC natural site datasheet notes that a total of 550 terrestrial and 843 aquatic invertebrate species have been observed there, although how many of these are cave dependent is unspecified.[227] There are approximately 500 named troglobitic species recorded for the whole Yucatán Peninsula, of which perhaps 25 per cent are aquatic. More than 40 stygobitic species have been recorded, including 39 crustaceans and two fish.[228]

Of the sites in the United States, the UNESCO website notes that Mammoth Cave National Park has the world's largest network of natural caves and underground passageways. The park and its underground network of more than 560 kilometres of surveyed passageways are home to a varied flora and fauna, including a number of endangered species. The park has a rich troglobitic fauna. There are more than 130 species that regularly inhabit the Mammoth Cave System: troglobites (species confined to caves); troglophiles (that complete one part of their life cycle in the cave) and trogloxenes (species that use caves opportunistically). The cave fauna of the South-Central Kentucky Karst is claimed to be among the most diverse in the world.[229] Of 130 species, 41 are documented as being obligate cave fauna, considerably fewer than the 75 species recorded at the Cape Range peninsula.[230]

In an important paper on hotspots of subterranean diversity, Culver and Sket documented 20 sites around the world that have 20 or more species of obligate cave fauna.[231] Fourteen of the 20 sites are in Europe, mainly in France, Slovenia and Italy; three are in North America; one is in Australia (north Queensland); one is in Indonesia; and one is in Bermuda. Only six of the 20 sites were recorded as having more than 40 obligate cave species (see also Table 3.7 below). These are Mammoth Cave in the United States (41 species); three sites in Slovenia (including the Postojna–Planina system with 84 species, by far the highest number of species for one system); one site in Bosnia–Herzegovina (60 species); and another in Romania (47 species). The Cape Range peninsula has 75 species. The Dinaric karst, which includes parts of Slovenia, Croatia and Bosnia–Herzegovina, incorporates the richest sites found so far in the world, with a total of 388 cave-dependent fauna. Sket points out that the Dinaric Karst in general, and the Slovenia karst in particular, covers a very large area, measuring around 117,000 square kilometres (58 times larger than the Cape Range karst). The latest unpublished data from Slovenia from Sket revise the richness estimates within Slovenia and point to an area in south-west Slovenia as having 120 confirmed species, in an area roughly equivalent in size to the Cape Range karst.[232] Nevertheless, the number of orders in the whole of the Slovenian system is 33, barely more than the 30 orders recorded at the Cape Range peninsula, despite the former being an order of magnitude larger.

Other sites with a known high diversity of subterranean fauna in the Caribbean include the Bahamas and the Yucatán Peninsula. The United States has a number of sites with high subterranean diversity in the southern and eastern states, including two cave systems of roughly similar extent to the Cape Range system—one in Alabama, (52 species of troglobites) and one in Texas (46 troglobites). In comparison, the Cape Range peninsula has 75 troglobites.

In Central America, Hamilton-Smith and Williamson report that the Yucatán karst region has a complex and diverse system of subterranean caverns and subterranean fauna (including troglobitic, stygobitic and anchialine species).[233] They also note that Iliffe reported that '41 stygobitic species have been identified from Yucatán caves including 39 crustaceans and two fish. Most have marine origins and many belong to the same genera as cave species from Cuba and the Bahamas'.[234] The Yucatán encompasses an area of 150,000 square kilometres, around 22 times larger than the Cape Range karst, yet the numbers found here are rivalled by those at Cape Range, which has a number of genera in common.

In summary, the diversity of the Cape Range peninsula subterranean fauna compares very favourably on both a national and a global scale.[235] In comparison to other known areas of high cave fauna diversity, the Cape Range peninsula has a high number of orders for terrestrial and aquatic species combined, with 30 orders represented (see Table 3.7 below). With one exception (the entire karst system in Slovenia), this high number of orders is not matched at any other site in the world. This reflects exceptional taxonomic diversity within a limited area. The number of orders is mirrored in the number of families, with 45 families represented. This outstanding taxonomic diversity is only matched by sites in Bermuda and the Bahamas, although the data are inconclusive for these two countries as only figures for aquatic families were available at the time of preparation of this nomination.

At a global level, the Cape Range peninsula is unusual because of the juxtaposition of relictual rainforest faunas and anchialine faunas within the same karst system—this is reflected in the high species numbers. It is also an outstanding example globally of anchialine fauna in Neogene orogenic karst.[236] The Cape Range peninsula has a considerably higher diversity of families and orders, reflecting the unusual complexity of the fauna and associated subterranean habitats.

The composition and phylogeny (evolutionary development and history) of the higher order crustaceans of the anchialine communities have few direct comparisons in the world, other than sites on either side of the Atlantic Ocean. In the context of Australasia, many higher order crustaceans are found only at the Cape Range peninsula (that is, orders and suborders).[237] The Cape Range peninsula karst habitat is of outstanding universal value for the exceptional number and taxonomic diversity of cave fauna found there, and for the biogeographical story that it tells.

Table 3.7 sets out the sites that have the highest known obligate cave fauna diversity around the world.[238]

PLACE	ORDERS (WHERE DATA ARE AVAILABLE)	FAMILIES (WHERE DATA ARE AVAILABLE)	AQUATIC CAVE FAUNA	TERRESTRIAL TROGLOBITES SPECIES	TOTAL OBLIGATE FAUNA	APPROX. SIZE OF AREA IN KM^2 (WHERE KNOWN)
Whole of Slovenia	33	76	242	189	430	20,000
Bahamas (aquatic only)	21	39	114		114	~11,400
Postojna–Planina cave system (Slovenia)	22		61	37	98	
Canary Islands	12		15	70	85	~2,000
Bermuda (aquatic only)	20	43	81		81	39
Cape Range peninsula (Australia)	30	45	30	45	75	~2,000
Vjetrenica Jama (Bosnia–Herzegovina)			39	21	60	
Alabama (United States of America)	17	17	16	35	51	~2,800
Pestera de la Movile (Romania)			18	29	47	
Texas (United States of America)	16	25	26	20	46	
Mammoth Cave (United States of America)	~16		15	26	41	
Yucatán (including Sian Ka'an; aquatic only) (Mexico)	10	19	41		41	150,000

TABLE 3.7 Comparison of subterranean invertebrate diversity around the world

Diverse terrestrial flora and fauna

The richness of terrestrial species at the Ningaloo Coast is comparable with other arid zone coastal regions that demonstrate high biodiversity, including World Heritage-listed Shark Bay (Australia), the Socotra Archipelago (Yemen) within the Horn of Africa, the arid terrestrial components of the Islands and Protected Areas of the Gulf of California, and the adjacent whale sanctuary at the Reserva del Vizcaino (both Mexico). Comparable regions that are not on the World Heritage List include South Africa's Richtersveld (an area of the Succulent Karoo) and parts of the Horn of Africa. Although part of the Richtersveld was nominated to the World Heritage List for natural and cultural values in 2007, and it was listed under two cultural criteria, the World Heritage Committee deferred assessment of natural values. The Succulent Karoo and the Horn of Africa are two entirely arid regions in the world that are recognised by Conservation International as terrestrial Biodiversity Hotspots.[239]

Australia is among the top 17 countries for biological diversity (defined by the number of species and the degree of endemism). Australia has the highest number of endemic reptile species in the world—around 600 species. The country with the next highest recorded level of reptile endemism is Mexico, which has around 400 species.[240]

The Ningaloo Coast is one of the five most outstanding places in Australia for terrestrial reptile endemism, and is the only region in the top ten that is in the arid zone. Compared to other World Heritage sites in Australia, only Shark Bay (also part of the Carnarvon Xeric Scrub) approaches the Ningaloo Coast for reptile diversity. Nearly 100 species of reptiles have been recorded at Shark Bay, compared with more than 100 species so far identified at the Ningaloo Coast.[241] The extraordinary terrestrial reptile diversity of the Ningaloo Coast is highlighted by the respective area of these two sites: at over 600,000 hectares, the terrestrial component of the Shark Bay World Heritage Area is more than three times the terrestrial area of the Ningaloo Coast.[242]

The mega-diverse Horn of Africa is another arid region that is particularly important for reptile endemism; 93 endemic species have been recorded there.[243] However, these species occur in a discontinuous area of around 83,000 square kilometres of remaining natural habitat, which is equivalent to more than 40 times the area of the terrestrial component of the Ningaloo Coast. Furthermore, the region only contains about five per cent of its original habitat.[244]

Within the Horn of Africa, the World Heritage-listed Socotra archipelago houses more reptiles than any other equivalent-sized region in Africa. The Socotra archipelago is comparable in size to the Ningaloo Coast. It has 26 endemic reptile species, while the Ningaloo Coast has 15 endemic species of snakes and lizards.[245] Although the Socotra archipelago has more endemic reptiles than the Ningaloo Coast, the total diversity of reptiles is lower, with Socotra supporting 34 species overall, whereas the Ningaloo Coast is home to more than 100 recorded reptile species—almost three times as many.[246] Furthermore, it would be surprising if Socotra, an archipelago that has long been isolated, did not contain a high proportion of endemic species. In contrast, the Cape Range peninsula has been connected to mainland Australia for thousands of years. The high terrestrial endemism found at the Ningaloo Coast is thus all the more unexpected and significant.

For an arid zone region, the Succulent Karoo biome of South Africa and Namibia has exceptional plant endemism, particularly for succulent plants. The region includes nearly 5,000 vascular plant species in an area of 112,212 square kilometres, and up to 40 per cent of these are endemic.[247] Namaqualand, a winter-rainfall desert of around 50,000 square kilometres located in north-western South Africa, is defined botanically as the part of the Succulent Karoo with plant assemblages strongly influenced by winter rainfall and fog. The Richtersveld, in South Africa's Northern Cape province, is in the north-east of the wider Namaqualand region, and contains the richest collection of succulent plants in the world.[248] In the southern Richtersveld, the Richtersveld Cultural and Botanical Landscape (also known as the Richtersveld Community Conservancy) was World Heritage listed in 2007 for cultural values, but also has some of the most intact ecosystems of the Succulent Karoo.[249] It is roughly equivalent in area to the Ningaloo Coast and receives comparable rainfall. Absolute plant species numbers are not available for the World Heritage area, but 33 endemics have been recorded, compared to around 12 on the Ningaloo Coast.[250]

The Succulent Karoo shows relatively high levels of reptile endemism, but it is lower per unit area than the Ningaloo Coast. Although the terrestrial component of the Ningaloo Coast is less than two per cent of the area of the Karoo, it protects almost as many endemic lizard species, with 15 species endemic to the Cape Range peninsula and the immediate region, compared with 16 species restricted to the entire Succulent Karoo.

The Sonoran Desert, considered one of the richest regions in the world for desert biodiversity, covers parts of Arizona, California and north-western Mexico. Its 560 plant species are grouped into a number of different vegetation communities, and the United States portion contains 58 reptile species.[251] At around 220,000 square kilometres, it is 120 times larger than Ningaloo Coast. It is also considerably more densely settled, with a population of around seven million people. Mexico's Reserva del Vizcaino covers an area of more than 25,000 square kilometres of the Sonoran Desert. Like the Ningaloo Coast, Reserva del Vizcaino is celebrated for its outstanding marine biota. However, the Ningaloo Coast combines outstanding marine biota with a considerably greater diversity of terrestrial flora: 635 plant species are found at the Ningaloo Coast, compared with 469 vascular plant species at Reserva del Vizcaino.[252] The Ningaloo Coast is home to more than 100 terrestrial reptile species.

The terrestrial areas of the Islands and Protected Areas of the Gulf of California (Mexico) support 115 reptile species. Although discontinuous, the total area is considerably larger than the Ningaloo Coast. The number of species of vascular plants (695) present in this serial property is higher than the number of species reported in other marine and insular properties included in the World Heritage List, but the Ningaloo Coast has comparable numbers (635).[253]

In summary, the Ningaloo Coast is clearly of outstanding significance for its terrestrial species, particularly plants and reptiles, when compared to other highly diverse arid ecosystems around the world. The only comparable arid-zone region with greater plant diversity than the Ningaloo Coast is South Africa's Richtersveld, which is part of the Succulent Karoo biome, the most species diverse arid-zone biome in the world for flora. The Succulent Karoo biome, however, has considerably lower reptile diversity than the Ningaloo Coast. The only Australian property that approaches the Ningaloo Coast for richness of plants or of reptiles is the Shark Bay World Heritage Area. However, the species complement of Shark Bay is quite different and is contained in an area three times the size of the Ningaloo Coast. As a vital component of the internationally important and critically endangered Carnarvon Xeric Scrub Ecoregion, the Ningaloo Coast shows globally exceptional plant richness and reptile diversity.

Criterion (x) summary

The WWF has delineated 238 Global Ecoregions that are the highest priority for conservation, comprising 142 terrestrial, 53 freshwater and 43 marine regions. The Ningaloo Coast falls within two Global Ecoregions: the Carnarvon Xeric Scrub Global Ecoregion and the Western Australian Marine Global Ecoregion. The IUCN has recently identified the WWF Global Ecoregions as a tool to assist in assessing criterion (x).[254]

Internationally, the Ningaloo Coast stands out from other World Heritage marine sites that have karst features, for the coherence and structural integrity of its coral reef and limestone system, its marine biodiversity, and for its arid climate. The Western Australian Marine Global Ecoregion encompasses the largest area of tropical coral reefs in the Indian Ocean. Coral reefs extend for over 3,000 kilometres along the west coast of Australia and north-west into the Indian Ocean. They compromise numerous reef systems and reef structural types, ranging from open ocean atolls to fringing and barrier reefs.[255] Ningaloo Reef, at 290 kilometres long, encompasses all of these reef types, with the exception of ocean atolls.

The western reefs of Australia contain a great diversity of fish, corals and invertebrates.[256] Ningaloo Reef is an outstanding example of this diversity. It is the site of the largest known aggregations in the world of the iconic and threatened whale shark, with gatherings of 300–500 animals recorded. It is a stronghold for a rich diversity of marine species that rely on the Leeuwin Current and on the coral that grows in profusion. Six of the world's seven marine turtles abound here, in numbers rivalled by only a handful of places around the globe. Twenty of the world's cetacean species are found here. The place provides an important migratory stopover for blue, minke, fin and humpback whales. There are more than 20 species of sharks, with populations that are large and healthy—a feature that is now becoming considerably rarer in other parts of the world.

The Carnarvon Xeric Scrub Global Ecoregion has high levels of species richness and endemism. Australian deserts support the richest reptile faunas in the world and the Carnarvon Xeric Scrub is a centre for endemism for a wide range of taxa. As a subset of this globally important and endangered ecoregion, the Ningaloo Coast is a centre for endemism with high levels of terrestrial and subterranean endemic species when compared to other areas of Australia and the rest of the world.[257]

3.D INTEGRITY

In accordance with the *Operational guidelines for the implementation of the World Heritage Convention* (2008), the Ningaloo Coast meets the following conditions for integrity against criteria (vii), (viii) and (x):

Criterion (vii)

At almost 300 kilometres in length, the Ningaloo Coast encompasses an exceptional setting, showcasing contrasts between an arid landscape and one of the longest tropical coral reef systems in the world. The nomination includes all the wave-swept ramparts of Ningaloo Reef, which stretch for hundreds of kilometres along the arid coast, as well as the fringing reefs of the Muiron Islands, Bundegi Reef and Gnaraloo Bay. It encompasses sweeping terrestrial vistas that complement the underwater landscapes in some of the clearest waters in the world.

Criterion (viii)

The Ningaloo Coast is exceptional in that it contains all the key interdependent elements of an integrated limestone structure preserved in its natural relationships. The place is an example of a rare geoecological structure that includes a functionally-integrated karst and reef system, and an excellently preserved time series of coral reefs. The Cape Range peninsula includes globally important anchialine ecosystems that support species that illustrate tectonic and climatic changes since the middle Jurassic, along with terrestrial subterranean species that are affiliated with tropical rainforest species found in the far north of Australia and at other former Gondwanan sites.

Criterion (x)

The Ningaloo Coast constitutes the most important site for the conservation of biological diversity in Indian Ocean coral reefs, the subterranean faunas of the Cape Range peninsula (one of the richest in the world), and the critically important vascular plant and reptile species of the Carnarvon Xeric Scrub Ecoregion. It is the only Southern Hemisphere locality for many globally important subterranean faunal groups.

The nominated property is of adequate size to ensure the complete representation of features that convey the property's significance. The boundary encompasses the entire Ningaloo Reef, including the Muiron Islands to the north, a substantial proportion (approx. 90 per cent) of the Cape Range peninsula and its associated terrestrial habitats, and all the associated coastal plains on the western side of the peninsula.

The Ningaloo Coast falls within two Global 200 Ecoregions (as delineated by the WWF), considered to be of the highest priority for conservation across the world. These include the Carnarvon Xeric Scrub Ecoregion and the Western Australian Marine Global Ecoregion.

The Ningaloo Coast protects an important area of Carnarvon Xeric Scrub, one of four critically endangered Global 200 Ecoregions within the deserts and xeric shrublands biome, which is recognised for its significant arid-zone biodiversity.

The Western Australian Marine Global Ecoregion includes the largest barrier reefs in the Indian Ocean. Coral reefs extend for more than 2,400 kilometres along the western coast of Australia. These comprise numerous reef systems and structures, ranging from open ocean atolls to patch, fringing and barrier reefs. Ningaloo Reef, at 290 kilometres long, encompasses all these reef types, with the exception of ocean atolls. The area includes the largest barrier and fringing reefs of the region.

The 2008 edition of the Global Coral Reef Monitoring Network *Status of Coral Reefs of the World* reported that almost 20 per cent of the world's coral reefs have been destroyed and a further 35 per cent are under threat from global warming and over-fishing. In their report on the worldwide status of coral reefs, the authors stated that the coral reefs of Australia and Papua New Guinea cover nearly 20 per cent of the world's total reef area and contain high levels of biological diversity. The authors also noted that human pressures on these reefs are lower than in other parts of the world. The report emphasised the importance of effective management to ensure the conservation of reef ecosystems, and state that best practise management in Australia has set the benchmark around the world, citing as prime examples the Great Barrier Reef and the western Australian reefs. The Ningaloo Coast is a particularly good example, as highly effective partnerships have been established between coral reef scientists and the reef managers.[258]

Australia's human population is relatively low. The small population of Australia's west coast is concentrated in the south, leaving a vast tropical coastline barely inhabited. Much of the coastline is arid and borders deep water. This has enormous beneficial consequences for coral reefs: there is very little sediment transport from the land to the ocean and the reefs are flushed daily with open ocean water, leaving them in a condition that is rarely seen elsewhere. With groundbreaking adaptive management regimes, the extension of the marine park boundary and the inclusion of the Muiron Islands into the conservation estate in 2004, Ningaloo Reef in its entirety and the surrounding marine waters, are managed predominantly for their conservation values.[259]

Climate change and ocean acidification will endanger every reef in the world. Because of the resilience of the reefs of the Ningaloo Coast to the local stressors that afflict most other reefs, and because of their unique climatic and geographical setting, they are also likely to be better placed to weather these global impacts. On this basis alone, the Ningaloo Coast has exceptional merit in terms of both World Heritage and conservation potential.[260]

The Ningaloo Coast contains one of the most important reef areas in the world for the long-term conservation of marine species. Top predators, especially large sharks, have been so drastically reduced that they are now rarely seen in coastal reefs of Asia, Africa and tropical America. The few large sharks still seen in these locations are usually oceanic species not normally associated with coral reefs. Sharks, especially reef sharks, are common at Ningaloo and their numbers have not been greatly diminished through fishing: there are 19 confirmed, and potentially up to 21, species of whaler sharks (including tiger sharks) and two hammerhead sharks found in the area. It is realistic to liken the role sharks play in the

FIGURE 3.36 The intricate featherstar.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

world's oceans to the role high-level carnivores play in Africa.[261] As with big cats in the Serengeti, the presence of a healthy diversity of sharks at the Ningaloo Coast is of paramount importance to maintaining this prime example of an ecosystem with a species structure that is relatively intact, including its carnivores.

Whale sharks are an outstanding aspect of the Ningaloo Coast. They occur here in dense, predictable aggregations, which can be monitored more effectively than anywhere else in the world. Their annual migration is linked to the seasonal productivity of the reefs, and is therefore an integral part of the value of the ecology of the Ningaloo Coast as a whole.[262]

The Ningaloo Coast plays a pivotal role in the protection of habitat for critical populations of dolphins and dugongs. Most of the major populations and major conservation sites are in Australian waters. The Ningaloo Coast provides important habitat for the protection of this species. It also provides important breeding habitat for threatened species of marine turtles—several large rookeries occur along the length of the coastline. This nomination encompasses a large proportion of the migration routes for a number of species of whales, and part of a whale and calf resting area between the Muiron Islands and North West Cape.[263]

The nominated area encompasses habitats and ecosystems that regulate nutrient and sediment input into the reef, including stands of mangroves and intertidal mud flats at Mangrove Bay and Yardie Creek, along with over 2,000 hectares of macroalgal communities on the shallow limestone lagoonal platforms.[264]

Ningaloo Reef has been assessed as in a good state of health by global standards. It has escaped the widespread impacts of coral bleaching or crown-of-thorns seastars seen elsewhere in the Indo–Pacific in the 1990s and since 2000. In the past, sites along the reef have suffered coral mortality episodes, notably from natural events (localised coral deaths due to the decay of mass coral spawn) and one recorded outbreak of a coral-eating gastropod. Sanctuary zones that place strict limits on recreational fishing have been increased in the past few years, while commercial fishing is limited and restricted to the general use zones, thereby ensuring the ongoing conservation of reef species and populations in the marine zone.[265]

The Ningaloo Coast encompasses unique subterranean faunas, including taxa that are either endemic to the site, or that have highly disjunct distributions across Australia and the world. The Cape Range peninsula supports the only accessible deep anchialine system known in the Southern Hemisphere. The integrity of caves and subterranean waterways (and the associated hydrological system) of Cape Range and the surrounding coastal plains are of critical importance in maintaining the habitats, populations and gene flow of the cave fauna of the peninsula. Due to the sparse human population, most of the 400 known karst features in Cape Range and the coastal plain remain relatively undisturbed. For most of the subterranean species, either the entire population, or a substantial proportion of the range of the population, is encompassed within the nominated area.

Populations of terrestrial and aquatic species that are restricted to the underground habitats are vulnerable to adverse impacts, such as land clearance, water abstraction, pollution and impacts from cavers. Therefore, the integrity of the surface of the Cape Range peninsula is important in maintaining the integrity of the subterranean systems.[266] There has been some disturbance associated with the development of the town of Exmouth and associated infrastructure on the eastern coastal plain, along with a limestone quarry on the Cape Range karst on the eastern flanks of the range. However, these impacts are generally localised and management prescriptions are in place to ensure protection of the karst system and associated fauna, as detailed in Part 5.[267]

The karst features of the coastline and their associated anchialine and subterranean ecosystems, the healthy protected populations of sharks, dolphins, dugongs and whales, the biodiversity of the reefs and ocean ecosystems and the vast expanse of spectacular arid landforms are among the most unspoiled in the world, and are all worthy attributes of a World Heritage site.

The nominated property includes all the necessary elements to express its outstanding universal value and to encompass all the values claimed under criteria (vii), (viii) and (x).

(ENDNOTES)

1 Norman 2007a.

2 Winton 2002.

3 A sample of the available electronic and published literature praising the Ningaloo Coast experience includes Carter & Dunston 2007, pp. 201–210; Wilson 2008; Knapinski 2007; Bright 2005; Zell & Bedford 2005; Murphy & Whitehead 2008; Elasmodiver 2008a; Fodor's Travel 2008.

4 Norman 2007a.

5 Winton 2002.

6 Wood 1999, p. v; Pandolfi 2007.

7 Jackson et al. 2001; McCulloch 2007; Pandolfi et al. 2005; Hughes et al. 2006.

8 Boyle et al. 2008; Gales et al. 2004; Preen et al. 1997; Aw 1996, p. 16; LeProvost et al. 2000.

9 CALM 2005a.

10 Storrie & Morrison (1998); CALM 2005a; CALM 2005b; Kendrick & Mau 2002; LeProvost et al. 2000.

11 Brad Norman quoted in Rolex Awards 2007.

12 Bradshaw et al. 2007; Corey et al. 2008; Boyle et al.2008, pp. 35–36.

13 Rowat 2007; Colman 1997; Davis et al. 1997.

14 Colman 1997, pp. 1221–1226; Stevens 2007.

15 Images of whale shark sculpture searchable on Flickr (www.flickr.com/photos) and Getty Images (www.gettyimages.com/Home.aspx).

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17 Barrymore & Dance 2005.

18 Earle 2008.

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20 DEC 2007c.

21 ABC Television 2007; Rolex Awards 2007; DEWHA 2008; Winton 2002; Winton 2008.

22 Arzoumanian et al. 2005; Holmberg et al. 2008.; Cribb 2006, pp. 22–34.

23 Norman 1999.

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26 Porteous 2007; Rowat 2007; Colman 1997.

27 Quiros 2005; Black 2005; Porteous 2007; Rowat 2007.

28 Rowat & Engelhardt 2007.

29 UNESCO 2008a. (Section II.A. Paragraph 49)

30 Henderson 2007.

31 Winton 2002.

32 For example, Wilson 2008; Knapinski 2007; Jackson 1997.

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34 Wilson 2008.

35 Kendrick & Mau 2002; CALM 2005a; LeProvost et al. 2000.

36 CALM 2005a.

37 For example, Dukes & Dukes 2008; Elasmodiver 2008.

38 For example, Wilson 2008.

39 Jackson 1997; SCUBA Travel 2009; Diversion Dive Travel 2008; Elasmodiver 2008; Fodor's Travel 2008; Dukes & Dukes 2008.

40 Knapinski 2007; Murphy & Whitehead 2008; Veron 2008a; Fodor's Travel 2008; Bright 2005; Dukes & Dukes 2008.

41 Wilson 2008; Fodor's Travel 2008; Bright 2005; G Kelleher pers. comm. 10 August 2008. For examples, see Knapinski 2007; Murphy & Whitehead 2008.

42 CALM 2005a.

43 Dingwall et al. 2005.

44 Dingwall et al. 2005, p. 41.

45 Abe & Lieberman 2009.

46 Lieberman et al. 2007.

47 Knott 1993, p. 112.

48 Kendrick 1993, pp. 193–206.

49 Russell 2004.

50 Humphreys & Spate 2006; Hamilton-Smith et al. 1998.

51 Humphreys & Spate 2006; Humphreys & Collis 1990.

52 Humphreys 1993; Humphreys 2000a; Harvey et al. 1993, pp. 129–144; Edward & Harvey 2008.

53 Humphreys & Spate 2006; Hamilton-Smith et al. 1998; Russell 2004; Humphreys & Collis 1990.

54 Keighery & Gibson 1993, pp. 51–86.

55 Keighery & Gibson 1993, pp. 51 and 54; Rodd 1998; Kendrick 1993, p. 192. Terrestrial species richness and diversity were calculated using the Australian Natural Heritage Assessment Tool (ANHAT), a national database of Australian flora and fauna species that allows comparison across the continent.

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60 van de Graaff et al. 1976, pp. 62–69; Denman & van de Graaff 1977; Veeh et al. 1979; Kendrick et al. 1991; Lambeck & Nakada 1992; Stirling et al. 1998.

61 Veeh et al. 1979, pp. 285–292; Lambeck & Nakada 1992, pp. 125–128.

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64 Humphreys 2000a.

65 Veron 2008a.

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67 AIMS 2008.

68 Veron 2008a.

69 In February and March 2002, 62 coastal and marine scientists attended the *World Heritage marine biodiversity workshop: Filling critical gaps and promoting multi-site approaches to new nominations of tropical coastal, marine and small island ecosystems* in Hanoi, Vietnam.

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72 Veron 2008a.

73 CALM 2005a.

74 Hamilton-Smith & Williamson 2008, p. 2; Cassata & Collins 2008.

75 Waples 2008.

76 Boulton et al. 2003.

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80 Humphreys 1999a; Humphreys 2000a; Humphreys 2008a.

81 Humphreys 1993; Humphreys 2000a; Edward & Harvey 2008. Humphreys & Adams 2001.

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84 Winton 2008.

85 WWF 2009, Carnarvon Xeric Scrub Global Ecoregion (www.panda.org/about_our_earth/ecoregions/carnavon_xeric_shrub.cfm).

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88 Fromont et al. 2008.

89 CALM 2005a.

90 Bradshaw et al. 2007; Bradshaw et al. 2008, p. 1894; Boyle et al. 2008, pp. 35–36.

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94 Storrie & Morrison 1998, p. 93; CALM 2005a; Kendrick & Mau 2002; LeProvost et al. 2000.

95 Humphreys 2000b.

96 Humphreys 1993; Humphreys 2000ab; CALM 2005b.

97 Based on species list in Appendix C and D and figures from B Sket, pers. comm. 27 October 2008.

98 Humphreys 1993; Humphreys 2000ab; CALM 2005b.

99 Humphreys & Spate 2006; Hamilton-Smith et al. 1998.

100 Iliffe 2000.

101 Wilson & Humphreys 2001; Seymour et al. 2007.

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104 Harvey et al. 1993; Edward & Harvey 2008.

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106 Adams & Humphreys 1993; Humphreys 2000a.

107 Humphreys & Shear 1993; Humphreys 2000a.

108 Based on species list in Appendices B and C, and data provided by B Sket, pers. comm. 27 October 2008.

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111 WWF 2009; National Geographic 2009, Wild World (www.nationalgeographic.com/wildworld/profiles/g200_index.html); Olson & Dinerstein 2002.

112 CALM 2005b; terrestrial species richness and diversity were calculated using ANHAT, a national database of Australian flora and fauna species that allows comparison across the continent.

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128 Bradshaw et al. 2007, p. 486; Bradshaw et al. 2008, p. 1894.

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4

STATE OF CONSERVATION AND FACTORS AFFECTING THE PROPERTY

4

STATE OF CONSERVATION AND FACTORS AFFECTING THE PROPERTY

The nominated property is in excellent condition, particularly when compared to reefs and coastlines in other parts of the world. The nominated World Heritage values are not currently threatened by any major risks. Marine biologist Clive Wilkinson stated recently that for the reefs of Australia:

> Management continues to set the benchmark for best practice, both in eastern Australia on the Great Barrier Reef and, more recently, off Western Australia. Particular features are the effective partnerships between coral reef science and management.[1]

The Ningaloo Coast is located in a remote region in Australia, where there are comparatively low levels of development. Consequently, human modification of and impacts on the terrestrial and marine ecosystems have been minimal. Comprehensive legislative and management frameworks are in place across three levels of government—national, state and local—to ensure the property is maintained to an exceptional standard and conserved for future generations. The Ningaloo Coast has been included in the Australian Government's National Heritage List, and parts in the Commonwealth Heritage List.

Visitor pressures are currently low, and visitor management and education programs are well developed. Planning provisions exist to limit the increase in visitor numbers over time. Environmental monitoring programs with strong volunteer involvement provide information for adaptive management, and promote greater understanding and interaction with the natural environment. Threats posed by wider regional and global issues, such as climate change, are being monitored and will be addressed by local, state and national management actions wherever possible. The full suite of legislation, management and monitoring initiatives are detailed in Parts 5 and 6.

FIGURE 4.1 Bushwalking is a popular activity at the Cape Range National Park.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

4.A PRESENT STATE OF CONSERVATION

The nominated area is in an excellent state of conservation and is not subject to any major risks, except climate change pressures. Minor threats are being managed effectively through a comprehensive management framework. The Ningaloo Coast is situated in an isolated location with a small regional population and insignificant urban development, so direct threats from human activities are low. The arid climate results in extremely low levels of runoff. In addition, the *Ningaloo Coast Regional Strategy Carnarvon to Exmouth*, a 30-year strategic land-use plan, limits significant development to the towns of Exmouth and Carnarvon, both of which are outside the nominated area.[2] Fishing activities and associated impacts are regulated and effectively controlled by a systematic compliance and enforcement regime. Although cyclones occur occasionally in this part of Australia, they are sporadic, passing through the region every three to five years. Natural disturbance through severe storm and cyclone events is important in maintaining coral species diversity in the world's coral reefs: disturbance destroys the faster-growing branching corals, and allows

PREVIOUS PAGE Photograph Marie Lochman © Lochman Transparencies

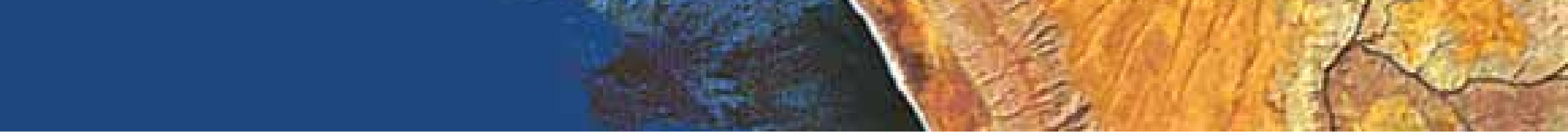
slower-growing massive corals to survive.[3] Occasional cyclone events are unlikely to destroy the nominated World Heritage values. Risk preparedness strategies are addressed under Sections 4.B (II) on environmental pressures and 4.B (III) on natural disasters.

The overall conditions of low rainfall and minimal runoff contribute to the excellent water quality of Ningaloo Reef, which supports its abundant and thriving flora and fauna. Coral reef communities, sponge gardens, shoreline intertidal reef communities, macroalgal and seagrass communities, and mangroves are generally in excellent condition along the Ningaloo Coast. The most accessible and largest aggregation of migratory whale sharks known in the world occurs at Ningaloo Reef.[4] Other unusual and endangered flora and fauna flourish in the largely undisturbed waters. The population of humpback whales has been increasing steadily over recent years. The current estimated recovery rate is approximately 10 per cent per year.[5] On the land, Cape Range provides diverse habitats for an outstanding array of flora and fauna, including remarkable and rare subterranean fauna, which provide insights into biogeography and evolution. Pressures to the property are detailed below, and are managed under the relevant management plans and legislative regimes (see Part 5).

Baseline habitat mapping

The largest hyperspectral coral reef survey in the world mapped the whole of Ningaloo Marine Park—an area of more than 3,400 kilometres.[6] This survey method provides images at a spatial resolution of 3.5 metres, allowing detailed habitat and bathymetry mapping, particularly when coupled with biodiversity field surveys of the area. This is important baseline information against which future changes can be measured.

FIGURE 4.2 Gorgonian coral glowing in the clear waters of Ningaloo Reef. Photograph Geoff Taylor © Lochman Transparencies



4.B FACTORS AFFECTING THE PROPERTY

	POTENTIAL IMPACT	CURRENT LEVEL OF RISK	OUTLOOK (5/25 YEARS)	CURRENT MANAGEMENT
DEVELOPMENT PRESSURES				
Pastoralism	Minor	Low	Decreasing	Managed on a sustainable basis under the Pastoral Lands Board
Fishing	Minor–moderate	Low	Stable	Strictly regulated; includes a zoning system that incorporates no-take sanctuary zones
Water abstraction	Major	Low	Stable; possible decrease	Strictly managed; alternatives under investigation
Resource extraction	Major	Low	Stable	Proposed activities that have a significant impact on values subject to assessment process
Accidental discharge of oil or other polluting substance	Major	Low	Stable	Integrated national plan, including stockpiling of equipment at Exmouth
ENVIRONMENTAL PRESSURES				
Climate change	Major	Relatively low to moderate	Increasing	Strategies to increase resilience of ecosystems
Pollution	Minor	Low	Stable	Restrictions; ongoing monitoring and education
Feral animals and invasive plant species	Minor	Low	Decreasing	Management regime that has resulted in large reduction in pest numbers
NATURAL DISASTERS				
Cyclones	Moderate	Moderate	Possible decrease	Part of local ecology; extensive monitoring and strategies to ensure resilience of plant and animal communities
Fire	Moderate	Low	Stable	Cape Range National Park management plan details the fire management regime
VISITOR / TOURISM PRESSURES				
Tourism	Moderate	Low	Steady increase	Comprehensive management programs, including an overall development strategy for the region
Boating	Minor	Low	Stable	Restricted facilities; regulation and education strategies

TABLE 4.1 Pressures on the potential World Heritage values of the Ningaloo Coast

Each of the factors is discussed under the five main headings below.

DEVELOPMENT PRESSURES

The Ningaloo Coast is not subject to major development pressures such as urban encroachment or large-scale resource extraction. Settlements in the area are small in scale and existing land uses have a low impact. Development proposals that could affect the nominated property are managed under the *Western Australian Planning and Development Act 2005* and the Ningaloo Coast statement of planning policy 6.3. Proposals that could have a significant impact on the nominated property are subject to the comprehensive assessment and approval requirements of the *Western Australian Environmental Protection Act 1986*. Development proposals are also subject to the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), if the proposals are likely to have a significant impact on listed World Heritage, National Heritage or Commonwealth Heritage List values, or on threatened or migratory species listed under the EPBC Act (see Part 5.B).

Minor development pressures are outlined below. The impacts of these activities are managed through a comprehensive legal and management framework (see Part 5). Pastoralism, fishing, water abstraction and mining pressures are regulated under stringent management systems and according to legislative requirements.

Pastoralism

Development pressure associated with pastoralism is low and is decreasing for the Ningaloo Coast. Pastoralism is the historical and prevailing land use in the surrounding region—it occurs in some parts of the nominated property. Sustainable land management practices have been integrated into pastoral grazing activities for decades. Areas of six pastoral leases within the property have been identified as 'proposed conservation and recreation areas' and are expected to be managed consistent with the formal conservation reserve system of Western Australia by 2015.

Fishing

Fishing is a minor threat to the nominated property as it can affect the biodiversity and ecosystem functioning of Ningaloo Reef. Small-scale commercial and recreational fishing occurs within parts of the nominated property and the surrounding region. Both commercial and recreational fishing are comprehensively regulated under Western Australia's *Fish Resources Management Act 1994*, and are subject to a range of management requirements as outlined in Section 5.B. These include provisions regarding the bag and size limits, gear restrictions, seasonal restrictions and licensing. Within the nominated property, 34 per cent of Ningaloo Marine Park (State Waters) and seven per cent of Muiron Islands Marine Management Area are zoned as 'no-take' areas. Recent research shows that the current zoning scheme, which was introduced in 2005, protects a more comprehensive and representative set of fish assemblages than the previous scheme.[7]

FIGURE 4.3 Ningaloo Station shearing sheds.
Photograph Geoff Taylor © Lochman Transparencies

Baseline data on fish populations

An extensive project surveyed more than 900 sites in 2006–07 to collect data on fish populations in Ningaloo Marine Park (State Waters). A particular emphasis of the project was to assess the effect of sanctuary 'no-take' zones on fish populations.[8] The findings indicated that well-established sanctuary zones can have a positive effect on maintaining populations of fished species, which in turn influences the abundance and diversity of associated fish assemblages. However, the variation in the abundance of many species in sanctuary and other zones is relatively small. This may be the outcome of a number of factors: high rates of cross-boundary movement, relatively low overall fishing pressure, or the need for increased compliance within the sanctuary zone.[9] The results of these surveys are being used to evaluate the current management of Ningaloo Marine Park, and will be integral to future research and monitoring.

Recreational and some commercial fishing under Western Australia jurisdiction are allowed in other zones in accordance with the management plan. Ningaloo Marine Park (Commonwealth Waters) is managed as an International Union for Conservation of Nature (IUCN) Category II reserve, and recreational fishing is currently managed in accordance with an approval under the EPBC Act. The approval provides conditions that are consistent with the rules that apply in the state component of Ningaloo Marine Park. Capture of vulnerable species is prohibited, including turtles, dugong and whale sharks, as well as other fish species such as the potato cod.

Management arrangements allow Indigenous people to exercise customary hunting and fishing rights. Limited hunting of dugong and turtles occurs on an occasional basis, and is managed through liaison with the Coral Coast Park Council (see Part 5.A). Ongoing research in Ningaloo Marine Park will establish baseline data on fish populations. Regulations are responsive to the impact of fishing on target species and their associated ecological assemblages. If monitoring indicates that fishing is causing significant biodiversity impacts, management arrangements provide for the introduction of further measures, including appropriate restrictions.

The current level of commercial fishing within the nominated property is minimal. Commercial fishing is not permitted in Ningaloo Marine Park (Commonwealth Waters) and a limited amount is permitted in State Waters. Additionally, the area between Tantabiddi Well (21° 56' S) and Point Maud (23° 07' S) extending out to the limits of the Australian Exclusive Economic Zone (200 kilometres) is closed to commercial fishing.[10] This covers nearly 60 per cent of the Ningaloo Marine Park (State Waters).

In addition to the prohibited species listed above, commercial shark fishing is not permitted in the region. The main commercial fishery in the area is the Exmouth Gulf Prawn Managed Fishery, which mostly occurs outside the property. Extensive closures to trawling activity were introduced in Exmouth Gulf in the 1960s to protect areas of particular significance as prawn nursery areas.[11] Additionally, a small number of wetline vessels (under 10) operate out of Coral Bay and Exmouth. No aquaculture enterprises are located within the nominated property. Proposals for additional commercial fishing operations are subject to assessment under the *Fish Resources Management Act 1994*, the *Pearling Act 1990* (if appropriate) and the Commonwealth EPBC Act (see Part 5.B).

The Ningaloo Coast plays annual host to large aggregations of whale sharks. The Ningaloo whale shark population is impacted by activities that occur elsewhere in its range, outside of Australian Waters. Evidence indicates that the whale shark populations of the world may be under increasing threat and could be declining.[12] Fishing of the species is illegal in Australia, but markets for whale shark meat, fins and oil exist in some south-east Asian countries. In light of these threats, the Ningaloo Coast is an important refuge.

Australian governments have undertaken various measures to protect whale sharks at the Ningaloo Coast. The whale shark is protected as a listed threatened and migratory species under the EPBC Act. Human interactions with whale sharks at the Ningaloo Coast are regulated by a code of conduct, and have become a model for successful nature-based tourism around the world.[13] The full suite of government and community initiatives in relation to the protection of whale sharks is outlined in Part 5. Australia also seeks to work collaboratively with the international conservation community, and promotes the need for additional efforts, including research into the life cycle and ecology of the whale shark.

FIGURE 4.4 A balance of sanctuary zone and recreation zone areas allows management of fish stocks and recreational fishing.
Photographs Tony Howard © Western Australian Department of Environment and Conservation

FIGURE 4.5 The well-managed marine areas of the Ningaloo Coast have become an important international refuge for whale sharks.
Photograph Cam Skirving © Western Australian Department of Environment and Conservation

Water abstraction

Visitation is a potential pressure on groundwater-dependent ecosystems sheltering stygofauna species within the nominated property. Increased visitation to the area is expected to lead to increased demand for potable water. Groundwater abstraction is regulated and set within sustainable yields, and is licensed under the *Rights in Water and Irrigation Act 1914*. To avoid unacceptable impacts on groundwater-dependent ecosystems, investigations into major future water requirements are currently underway.

The *Ningaloo Coast Regional Strategy Carnarvon to Exmouth* sets out guidelines for water availability. For example, the strategy requires development proposals to incorporate water conservation strategies, such as composting toilets, greywater and stormwater re-use and low-flow shower heads, and to endeavour to obtain water from a variety of sources including rainwater.[14] In addition, the strategy requires that the location and scale of development and future expansion should be consistent with the availability and sustainability of safe and reliable water sources.[15] Guidelines for sewage are also provided in the strategy.[16]

Resource extraction

Resource extraction is a minor risk to the Ningaloo Coast. Exploration and extraction of natural resources does not take place within the nominated property. Significant offshore oil and gas reserves currently being surveyed and extracted are located outside the property, within Commonwealth Waters. There are no pipelines, processing plants or shipping facilities within the property boundaries. Quarrying occurs on high grade limestone deposits near the eastern boundary of the property, some ten kilometres south-west of Exmouth. These activities have not had a significant impact on the World Heritage values of the property. An area of high value limestone resource of strategic importance, where quarrying may occur in the future, is located on the eastern boundary of the property, some 30 kilometres south of Exmouth. Quarrying at this site will only be approved if it does not have a significant impact on the World Heritage values of the property.

The resource industries that operate in the vicinity of the nominated property are tightly controlled under both Western Australian and Commonwealth legislation. Mining and petroleum proposals are administered under the *Mining Act 1978* (Cwlth), the *Petroleum Act 1967* (Cwlth), the *Petroleum (Submerged Lands) Act 1982* (WA) and/or the *Petroleum (Submerged Lands) Act 1967* (Cwlth). Proposals that could have a significant impact on the nominated property are subject to the *Environmental Protection Act 1986* (WA). Proposals are also subject to the Australian Government's EPBC Act. The full range of legislative protection is outlined in Part 5.B.

The Learmonth Air Weapons Range (see Section 1.E (i) Maps of the nominated property) was acquired by the Australian Government Department of Defence in the mid 1970s and became one of the most active ranges in Australia until bombing ceased in the early 1990s. Use of the range since that time has been limited to ground-based training exercises, primarily by the Australian Army, and has been confined to a relatively small impact area surrounded by firebreaks. The Royal Australian Air Force has responsibility for the range. A 2009 review of Department of Defence ranges recommended the continued use of LearmonthAir Weapons Range, concluding that it is of strategic importance for work-up training in support of the forward operating base, and a significant risk mitigator to potential loss of the current ranges in the south-west of Western Australia. The Department of Defence provides a high level of management commitment and resources to ensure that Australian Government, National Heritage and potential World Heritage values are managed and protected.

Accidental discharge of oil or other polluting substances

A severe natural disaster, piracy, terrorism incident, or major maritime accident could potentially impact on human infrastructure in the region and pose a risk to the nominated property. Damage to shipping and offshore petroleum facilities could result in the release of petroleum, gas or other substances, with consequences for the marine life and ecosystems of the Ningaloo Coast. Depending on its size, location and composition, an accidental discharge could result in damage to Ningaloo Reef and other habitats, and could impact on the health, viability and diversity of the property's marine ecosystems. To date, there has been no major spill of oil or any other polluting substance in the region. Australia has a comprehensive management system in place to avoid, and mitigate the impacts of, accidental discharges. The *National Plan to Combat Pollution of the Sea by Oil and Other Noxious and Hazardous Substances* is an integrated government and industry framework for the prevention of, and effective response to, marine pollution incidents.[17]

The Commonwealth Australian Maritime Safety Authority manages the national plan, and provides response equipment in all major ports, as well as personnel, training and funding. For any oil spills in Western Australia, WestPlan Marine Oil Pollution (WestPlan MOP) comes into effect. WestPlan MOP sits under the national plan and identifies key response agencies in Western Australia. WestPlan MOP provides scope for effective response, including training and equipment, outlines operational plans and develops teamwork and cooperation between agencies.[18] In Western Australian State Waters, the plan is implemented by the Western Australian Department of Transport and the Western Australia Department of Environment and Conservation is the lead agency responsible for oiled wildlife response.[19] Moreover, the industry-funded Australian Marine Oil Spill Centre (AMOSC) can provide additional personnel and equipment to combat an oil spill anywhere in Australia within 24 hours.[20]

A range of equipment has been pre-deployed to Exmouth by the Department of Transport and AMOSC. The *National Maritime Emergency Response Arrangement* provides further support for management of any maritime incidents that have the potential to produce significant pollution.[21] All offshore facilities in the area have contingency plans. These management arrangements are backed by robust legislation. Australia is a signatory to the International Convention for the Prevention of Pollution from Ships. The Convention is implemented in Commonwealth Waters by the *Protection of the Sea (Prevention from Pollution from Ships) Act 1983* and in state waters by the *Pollution of Waters by Oil and Noxious Substances Act 1987* (WA).

FIGURE 4.6 A rigorous framework exists to manage threats to the marine life of the Ningaloo Coast.
Photograph Peter and Margy Nicholas © Lochman Transparencies

ENVIRONMENTAL PRESSURES

The Ningaloo Coast is not subject to the major environmental pressures commonly affecting coral reefs and karst environments elsewhere in the world, due to its isolation, aridity and low level of population and development. These factors, together with the unique oceanographic situation of Ningaloo Reef, are likely to give the Ningaloo Coast ecosystems greater natural resilience to climate change than can be expected of coral reef and karst environments that are already suffering multiple environmental pressures. Pollution and other impacts from oil and gas exploration in the region, commercial shipping and recreational boating have had a minimal impact on water quality at Ningaloo Reef. Feral animals and invasive weed species are effectively controlled or managed. The management system for the Ningaloo Coast is described in Part 5.E.

Climate change

The world's coral reefs and associated ecosystems are all potentially under threat from climate change. Authors of a report on global climate change and ocean acidification, appearing in the 2008 edition of *Status of Coral Reefs of the World*, recommended that the best way to increase resilience to climate change is by ensuring that the health of individual reefs is maintained through the effective management of other threats.[22]

Climate change poses a lesser threat to the nominated property than it does to many other reefs in the world (see Part 3.C). This is due to the comprehensive, best practice management of the Ningaloo Coast, and its latitudinal and oceanographic setting. With an extensive conservation reserve system already in place and minimal impacts occurring from high-density development or other catchment land uses, the Ningaloo Coast is considered to have a high natural resilience to impacts of climate change.

For example, sea level rise associated with climate change is anticipated to be between 0.5 and 1.4 metres above 1990 levels by 2100.[23] This represents a small risk to the ecological values of the coral reef system, which may be mitigated with adaptive management processes already in place. Recent studies have shown that under strong

FIGURE 4.7 Hermit crab on Ningaloo Reef.
Photograph Clay Bryce © Lochman Transparencies

southerly winds, especially during summer, localised cool water upwelling occurs along the continental shelf region adjacent to Ningaloo Reef. These events typically lower the water temperatures adjacent to the reef by two to three degrees Celsius which helps to protect the reef from higher temperatures.[24]

Extensive coral bleaching has not been observed at Ningaloo Reef. A bleaching event occurred at Coral Bay in 2006, but this was a low-temperature occurrence. This event has been attributed to cold air temperatures, a high pressure system and aerial exposure of corals due to a low spring tide. The bleaching had a minor impact on coral communities, but the reef made a full recovery.[25] Research in recent years has documented the likelihood 'that Ningaloo Reef may be less likely to be affected by bleaching than reefs elsewhere in the world, whether through intrinsic factors, or because local oceanography buffers the reef from extreme temperature changes'. This highlights the significance of Ningaloo Reef as a coral reef refuge and a reference site of local, regional and international importance.[26]

Terrestrial ecosystems are also being managed for adaptation to the possible impacts of climate change. The *Cape Range National Park Management Plan* (revised plan in preparation) includes strategies to decrease the vulnerability of species and ecosystems to climate change, including through protection of groundwater quality and quantity, creation of conservation reserves, pest animal and weed control, fire management, and programs to reintroduce vulnerable or endangered native species.

Pollution

The release of chemicals and sediment into the water system has the potential to have a large impact on Ningaloo Reef and the aquatic fauna of Cape Range. However, the current level of risk is low due to the relative isolation and particular hydrology of the Ningaloo Coast. The generally low rainfall and high evaporation that occurs in the area limit the amount of run off and therefore the amount of land-based pollutants that enter the marine and karst environments.

To protect the quality of water sources in regional Western Australia, water reserves are proclaimed under the *Country Areas Water Supply Act 1947* (WA) and managed under relevant plans such as the *Carnarvon Water Reserve Water Source Protection Plan, Exmouth Groundwater Allocation Plan* and *Exmouth Water Reserve Water Source Protection Plan*.[27] The *Country Areas Water Supply Act 1947* also allows for the control of potentially polluting activities, regulation of land use and prevention or clean up of pollution in public drinking water source catchments or reserves.[28] Development proposals are subject to the Australian Government's EPBC Act.

The input of excessive nitrogen into the groundwater system or marine environment has the potential to affect the low-nutrient ecosystems of the reef. Input can be caused by the discharge of nutrient-rich effluent or the runoff of agricultural fertilisers, but neither of these occurs at significant levels at the Ningaloo Coast. Sewage output is minimal. The *Ningaloo Coast Regional Strategy* stipulates that there is to be no discharge of wastewater to the groundwater system or the sea.[29] Coral Bay, the only township adjacent to the reef, has a pond-based evaporative wastewater treatment plant, which is securely lined to prevent leaching. The major land use in the region is pastoralism, which does not use significant amounts of fertiliser.

Commercial shipping and recreational boating in Ningaloo Marine Park and surrounding area also have the potential to release pollutants, sewage and other wastes and debris. Commercial shipping in the area is at a low level, with approximately 4,000 voyages made in and around Ningaloo Marine Park (Commonwealth Waters) from 1999 to 2004.[30] Strategies to address maritime pollution include education and information programs, as well as comprehensive plans for combating oil and chemical spills (detailed above). The water quality of the Cape Range aquifer and Ningaloo Reef is monitored on an ongoing basis, and management arrangements allow for the introduction of further measures if any significant decline in water quality is detected.

Protecting Bundera Sinkhole remipedes

The remipede community in Bundera Sinkhole would be particularly vulnerable to groundwater contamination. The coastal strip in which Bundera Sinkhole is located has been designated an area of environmental management priority by the Australian Government Department of Defence and the Western Australian Planning Commission. In 2007, the Department of Defence provided funding to the Western Australian Museum for the drilling of groundwater monitoring wells around the sinkhole. Strategies are in place to ensure the quality of the groundwater in this area. Observations to date have found that the water in the sinkhole and surrounding karst system is not contaminated. The Department of Defence has also undertaken significant work to reduce the possibility of contamination, including the removal of rubbish from the nearby South Yardie Well, and installation of a secure cover.

Feral and pest animals and invasive plant species

Feral and pest animals and invasive plant species are threats that are managed and monitored under a comprehensive management system. Crown of thorns starfish, which have caused large-scale damage at other reefs, are only found in small numbers at Ningaloo Reef, and there have been no major outbreaks of this pest to date. The coral-eating snail, *Drupella cornus*, damaged parts of Ningaloo Reef in the mid-1980s and 1990s, but coral communities have now recovered as a result of management intervention.[31] Goats and foxes have had the greatest impact on the terrestrial area of the property. Goats compete with native animals for food, water and shelter, and cause erosion by the action of their hooves and through overgrazing. Control measures include periodic culling programs and supplementary culls as required, to keep goat numbers below a level of acceptable impact. Further information regarding the feral goat control program is outlined in Part 6.C. Foxes were once more common throughout the area and threatened native fauna by predation: turtle eggs, turtle hatchlings and rock wallabies were particularly vulnerable. Foxes are now effectively controlled by a baiting program. The baiting program uses 1080 poison that is fatal to introduced species. Native species have an adapted tolerance to 1080 as the substance is derived from a native Western Australian plant.

Weed invasion is also a threatening process that affects the property; however, weeds do not constitute a major threat to flora and fauna populations.[32] Weed species of particular concern on the peninsula include buffel grass (*Cenchrus ciliaris*), kapok (*Aerva javanica*), stinking passion flower (*Passiflora foetida*) and great broom (*Bromus diandrus*). Weed control programs are implemented under the *Environmental Weed Strategy for Western Australia*.[33] Neither feral animals nor weed species pose a significant threat to the potential World Heritage values of the property.

NATURAL DISASTERS AND RISK PREPAREDNESS

Overall, the risk of major natural disasters is relatively low due to Australia's stable geology and climate. Although the nominated property is located in a region that is susceptible to cyclones, floods, storm surges, seiches, tsunamis and fire, these climatic conditions are natural processes that have shaped the landscape and seascape of the Ningaloo Coast over many millennia. Risk management strategies are contained in management plans and regional strategy documents.

Cyclones

Cyclones are a potential threat to the Ningaloo Coast and rigorous measures are in place to address this risk. It is estimated that a cyclone impact causing wind gusts in excess of 90 kilometres per hour in the vicinity of Exmouth occurs about once every two to three years on average, and once every five years on average in the southern part of the Ningaloo Coast near Carnarvon.[34] The Intergovernmental Panel on Climate Change has indicated that 'there is some evidence that regional frequencies of tropical cyclones may change…and that the peak intensity may increase by 5 per cent to 10 per cent and precipitation rates may increase by 20 per cent to 30 per cent'.[35]

Recent modelling by the Commonwealth Scientific and Industry Research Organisation (CSIRO) indicates a significant drop in cyclone frequency along the north-west coast of Australia by 2070, as well as a decrease in the number of long-lived cyclones, although an increase in severity is expected.[36] The *State Tropical Cyclone Emergency Management Plan* details the emergency management arrangements for the risk of tropical cyclones, and associated flooding and storm surges.[37] A comprehensive monitoring and warning system is in place.

Fire

For millennia, fire has been a natural phenomenon in the Australian arid zone through lightning strikes. It does not threaten the National Heritage and potential World Heritage values of the Ningaloo Coast. Indigenous people have also used fire regularly and purposefully across the landscape for a variety of reasons. Fire regimes are likely to have changed following European settlement.

Most plant species along the Ningaloo Coast possess characteristics that allow them to survive regular fire, although some species in the western gorges and valleys of Cape Range, and on the western limestone ridges, are likely to be fire sensitive. Fire management in the area requires consideration of karst and associated values, as well as the interaction of fire with ecological pressures such as predation, over-grazing and weed invasion. The *Cape Range National Park Management Plan* identifies a number of strategies for managing fire and improving knowledge on fire impacts and ecology.

VISITOR/TOURISM PRESSURES

Tourism

Visitors and tourism present a relatively minor pressure to the nominated property. Visitors are attracted to the area for its natural beauty and for the unique wildlife experiences it offers. Visitor numbers have increased steadily since the late 1990s and some areas have experienced more rapid increases than others.[38] The Ningaloo Coast attracts an estimated 180,000 visitors annually, who either stay in the property itself or in the adjacent towns of Exmouth, Coral Bay and Carnarvon.[39] Most visitors to the Ningaloo Coast visit Cape Range National Park at least once, and the park is also popular with locals. The park receives approximately 220,000 visits each year, mainly between April and October.[40]

FIGURE 4.8 Visitors to the Ningaloo Coast cite 'appreciating nature' as a primary reason for coming to the region. Photograph Tony Howard © Western Australian Department of Environment and Conservation

Pressures associated with increased visitors include demand for groundwater, degradation of vegetation, erosion, sewage and waste disposal, rubbish dumping, disturbance to marine and terrestrial wildlife and illegal fishing. Management plans, policies and programs (such as compliance, communication and education programs) address these pressures, as well as future projected increases in visitation levels, including increases that may occur if the property is inscribed on the World Heritage List. These arrangements are detailed in Part 5.

Figure 4.9 shows the camp sites recorded along the Ningaloo Coast during the Western Australian April and July school holidays from 1995 to 2008. Data from 1995 to 2005 cover the Cape Range National Park to the Warroora pastoral lease. From 2006 onwards, surveys were expanded to cover the Cape Range National Park to Quobba pastoral lease (to align with the extension to Ningaloo Marine Park boundaries).

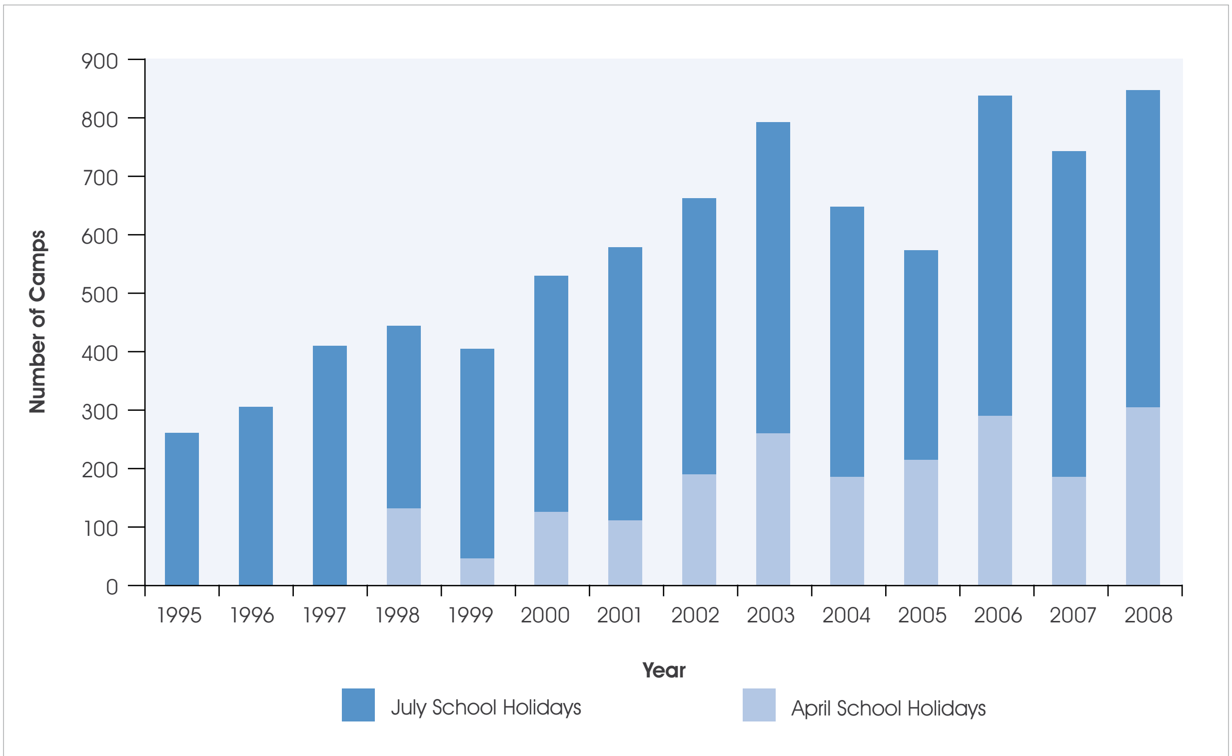


FIGURE 4.9 Total number of camp sites recorded along the Ningaloo Coast during April and July school holidays in Western Australia.

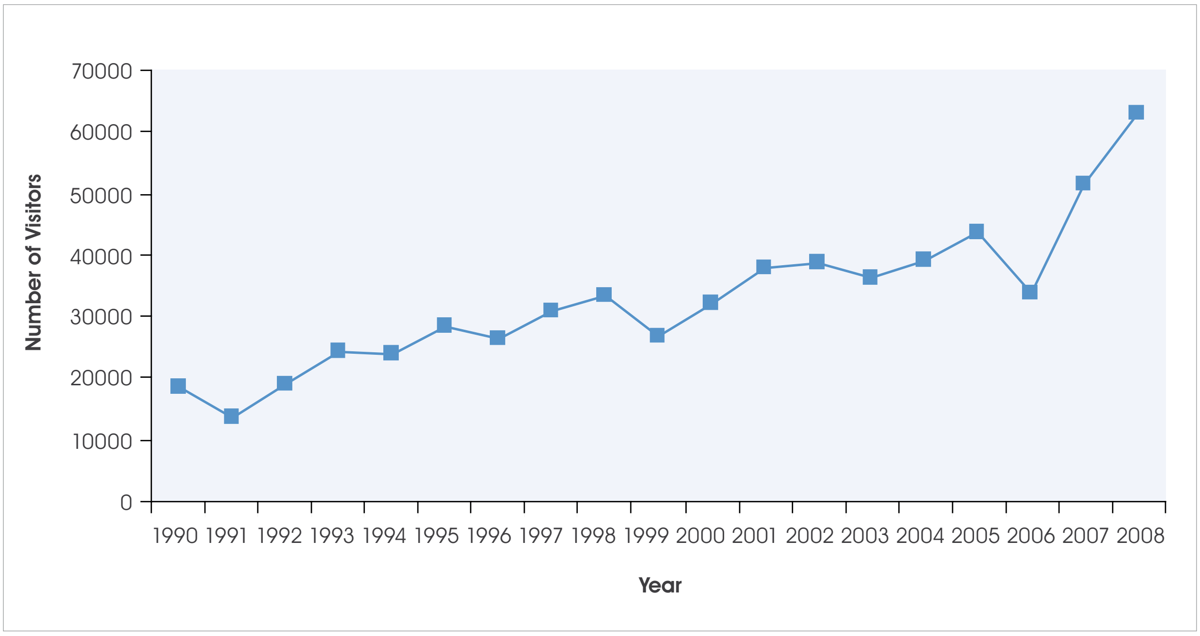


FIGURE 4.10 Milyering Visitor Centre statistics for Cape Range National Park.[41]

Strategic planning on a regional basis guides visitor growth and limits tourist development to sustainable levels. Visitor accommodation, camping activity and associated infrastructure and development in the property are guided by the *Ningaloo Coast Regional Strategy Carnarvon to Exmouth*.[42] This 30-year land-use planning strategy establishes Exmouth and Carnarvon as the locations for higher-order and higher-impact development, infrastructure and tourism facilities.

The strategy also defines the location of camping and small-scale ecotourism development along the coast, to ensure that continuous, large-scale and unmanaged development does not occur. The strategy sets maximum development levels in identified tourism localities to ensure that overnight accommodation does not exceed a sustainable level appropriate to the location.

Development proposals are assessed against guiding principles that focus on sustainable development, community aspirations, Aboriginal heritage protection, interdependence with natural ecological processes, limits of acceptable change, the precautionary principle, cumulative impacts and protection of values.[43] For example, the strategy requires development proposals to include waste management programs that minimise waste production and maximise recycling.[44] Key aspects of the strategy are that it provides for staged development, and is subject to review by the Western Australian Planning Commission at least every five years.

FIGURE 4.11 Accommodation along the Ningaloo Coast remains small scale; management plans identify areas that are appropriate for overnight accommodation and place limits on their capacity to increase.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

A series of complementary management plans and policies for lands and waters set out measures for managing the impact of visitors on the Ningaloo Coast (see Part 5). Management plans identify appropriate day visit and recreation sites to ensure visitors have enjoyable experiences without creating unacceptable impacts on the property. Camping is managed effectively under management plans in prescribed areas (see Part 5.E) and previous campsites (that were located in inappropriate areas) are being rehabilitated. The establishment of public moorings at key dive sites reduces the risk that coral will be damaged by anchors from small boats.

Management plans also guide appropriate activities within identified management zones, such as recreational activities like fishing, and commercial operations including boat and four wheel drive tours. Tour operators within the conservation reserve system are managed under the Western Australia Conservation and Land Management Regulations 2002 and Wildlife Conservation Regulations 1970. Licence conditions for tour operators require them to demonstrate that their activities contribute positively to the conservation of the area. Tours provide an opportunity for visitors to experience the Ningaloo Coast in a managed and informed way, and for the potential World Heritage values of the property to be meaningfully presented.

FIGURE 4.12 Visitors to the Cape Range National Park are able to view birds from this fauna hide at Mangrove Bay. Photograph Tony Howard © Western Australian Department of Environment and Conservation

World class collaborative model—business and visitors working together for conservation

The Ningaloo Coast offers the world's most accessible high-quality whale shark experience from March to June each year, with a nature-based tourism industry focused on snorkelling with whale sharks in the waters off Ningaloo Reef. Whale shark tour operator licences are allocated by the Western Australian Department of Environment and Conservation through an application process that assesses the applicant's skills, qualifications and their commitment to best practice sustainable operations. Operators must meet strict licence conditions and operate within an industry code of conduct. Fourteen tour licences have been approved for a five-year period (2009–2013). Licence holders are audited to ensure that they comply with the required standards and to encourage continual improvement.

The impact of this nature-based tourism industry on the whale sharks is managed by the whale shark interaction management program.[45] As detailed in Part 5, the program includes a major focus on education, research and monitoring, and involves collaboration between management agencies and commercial operators to measure the impact of the tourism industry on the whale shark population. This is a key part of the world-class management and protection regime that is in place to protect and conserve whale sharks at the Ningaloo Coast. The whale shark tour operator licence allocation process and training program were presented at the second International Whale Shark Conference in Mexico in July 2008, where they were recognised as comprising the leading management program in the world. Wilson et al. 2007

A 2002 survey found that the most popular activities for visitors to Cape Range National Park were appreciating nature, relaxing, swimming, snorkelling, viewing marine wildlife, viewing terrestrial wildlife, walking, taking photographs and fishing.[46] Interpretive information aims to build on visitors' appreciation of the environment by increasing visitors' understanding of its heritage significance and encouraging them to behave responsibly during their visit. (See Part 5.H and 5.I for details on other visitor services to manage the impact of visitors on the nominated property.)

FIGURE 4.13 Interpretive information incorporated into the facilities at Turquoise Bay help to manage visitor impacts.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

Boating

Recreational boating has the potential to impact on the ecological value of the nominated property if it results in the inappropriate disposal of effluent and rubbish, disturbance of wildlife, or the anchoring and movement of vessels in sensitive habitats. The number of visitors to the property pursuing non-extractive nature-based marine recreational activities has increased over the last 20 years.[47] These activities are managed under legislation and in accordance with relevant management plans. Management is on a flexible basis, to allow for the growing and changing range of water-based activities.

A variety of strategies are in place to minimise the threat posed by recreational boating, including the education of visitors and the introduction of codes of conduct for interacting with some species. Management controls include restrictions on boating access, with boat launching facilities only available at three locations within the nominated property: Bundegi, Tantabiddi and Coral Bay.

FIGURE 4.14 One of only three sites for launching recreational boats used in the nominated property.
Photograph Darlene Shepherd © Lochman Transparencies

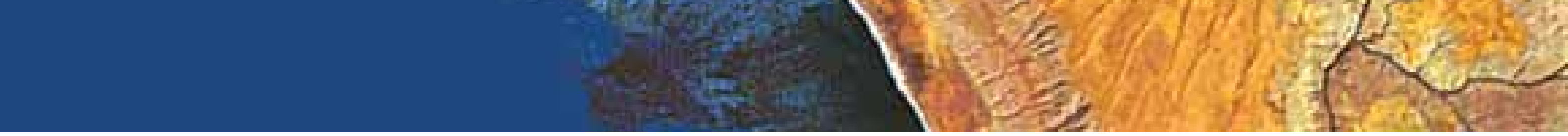
NUMBER OF INHABITANTS

There are fewer than 37 permanent inhabitants within the nominated property. The adjacent townships of Exmouth and Coral Bay have permanent populations of 1,844 and 190 people, respectively, and nearby Carnarvon has a population of 5,283.[48]

The total area of nominated property is 708,350 hectares with no buffer zone. The estimated population within the nominated property is 35 in 2008.

AREA	PERMANENT
Cape Range National Park	2
Learmonth Air Weapons Range	0
Freehold and leasehold properties	~35
TOTAL	~37

TABLE 4.2 Ningaloo Coast inhabitants by area and status
Source: Western Australian Department of Environment and Conservation, and Australian Department of Defence.



(ENDNOTES)

1 Wilkinson 2008, p. 17.

2 WAPC 2004b, p. 24.

3 WAPC 2004b, p. 33.

4 Boyle et al. 2008, pp. 35–36; Bradshaw et al. 2008, pp. 1894–1905, especially p. 1894.

5 Jenner et al. 2008, pp. 38–41.

6 Waples 2008.

7 Babcock 2009.

8 Waples & Hollander 2008.

9 Waples & Hollander 2008.

10 DoF 2008.

11 DoF 2008.

12 Bradshaw et al. 2007; Stevens 2007.

13 Quiros 2005; Waples & Hollander 2008.

14 WAPC 2004b.

15 WAPC 2004b.

16 WAPC 2004b.

17 AMSA 2008a.

18 DoT 2009.

19 DPI 2008.

20 AMOSC 2002.

21 AMSA 2008b.

22 Eakin et al. 2008, pp. 29–34.

23 ACECRC 2008, p. 11.

24 Pattiaratchi et al., 2008.

25 Waples & Hollander 2008.

26 Waples & Hollander 2008.

27 WRC 2000.

28 WRC 2000, p. iii.

29 WAPC 2004b.

30 Ceccarelli & Kospartov 2006, p. 1.

31 Chin et al. 2008, pp. 159–176, particularly p. 168.

32 CALM 1999; Dixon et al. 2001, pp. 92–101.

33 CALM 1999.

34 Australian BoM 2008.

35 Houghton et al. 2001.

36 CSIRO 2007.

37 FESA 2007.

38 Western Australian Department of Environment and Conservation Visitor Information and Statistics corporate database (VISTAT) [2009]

39 TWA 2008.

40 VISTAT [2009]

41 VISTAT [2009]

42 WAPC 2004b.

43 WAPC 2004c.

44 WAPC 2004b.

45 CALM 1997.

46 Polley 2002.

47 CALM 2005a.

48 ABS 2006.

5 PROTECTION & MANAGEMENT OF THE PROPERTY

5. PROTECTION AND MANAGEMENT OF THE PROPERTY

The nominated area is comprehensively protected and managed under a management system comprising legislation, management plans and associated policies and programs. Linking these components is the *Ningaloo Coast Strategic Management Framework* (the framework), which is a cooperative document, endorsed by the Australian Government and the Government of Western Australia. The framework outlines the suite of legislative and other measures that are in place across all levels of government, including management plans and a range of strategies to ensure the highest level of protection for the Ningaloo Coast.

The numerous management plans that have been developed for areas within the nominated property acknowledge the importance of integrated and complementary approaches. The *Cape Range National Park Management Plan* and the management plan for Ningaloo Marine Park and Muiron Islands Marine Management Area also ensure the involvement of the Indigenous custodians in the management of the site. In addition, the local community and visitors contribute to the ongoing management and preservation of the heritage values of the property. The aim of the framework is to ensure a consistent and integrated management approach across all parts of the property. The Ningaloo Coast Advisory Committee will ensure that heritage has a function in the life of the community, and that the best scientific and technical studies are used to protect the values of the property. The framework is provided as supporting documentation for the nomination (see Part 7).

FIGURE 5.1 A stately perentie, (*Varanus giganteus*). The perentie is the largest lizard found in Australia, and the fourth largest anywhere on Earth.
Photograph Jiri Lochman © Lochman Transparencies

PREVIOUS PAGE Photograph Jiri Lochman © Lochman Transparencies

5.A OWNERSHIP

NAME	OWNERSHIP
Bundegi Coastal Park	Western Australian Government
Learmonth Air Weapons Range	Australian Government
Cape Range National Park	Western Australian Government
Proposed conservation and recreation areas	Western Australian Government
Jurabi Coastal Park	Western Australian Government
Muiron Islands	Western Australian Government
Muiron Islands Marine Management Area	Western Australian Government
Ningaloo Marine Park (Commonwealth Waters)	Australian Government
Ningaloo Marine Park (State Waters)	Western Australian Government
Unallocated Crown land, Cape Range peninsula	Western Australian Government
Vlamingh Head Lot 1	Shire of Exmouth
Lighthouse Caravan Park, Vlamingh Head Lot 2	Private owner
Vlamingh Head Lot 4	Shire of Exmouth
Vlamingh Head Lot 6	Private owner
Proposed conservation and recreation areas *	Western Australian Government, privately leased

* These areas may be transferred to the management responsibility of DEC pending negotiations with pastoral leaseholders.

TABLE 5.1 Ownership of the nomination area

FIGURE 5.2 A black-flanked rock wallaby (*Petrogale lateralis*), listed as vulnerable under the EPBC Act.
Photograph © Grant O'Grady

FIGURE 5.3 The dramatic lionfish.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

NATIVE TITLE CLAIM

In 1997, the Gnulli Native Title Claim Working Group lodged a Native Title claim over an area that includes the Ningaloo Coast under the *Native Title Act 1993* (Cwlth). The Gnulli Native Title Claim Working Group represents the Indigenous custodians of the area and includes members of the Yinigudura, Baiyungu and Ingarda language groups. The Native Title claim is currently in mediation with the National Native Title Tribunal. Rights and interest granted under the *Native Title Act* may include rights to:

- live on the area;
- access the area for traditional purposes, like camping or ceremonies;
- visit and protect important sites;
- hunt, fish and gather food or traditional resources like water, wood and ochre; and
- teach law and custom on country.

The right to possess and occupy an area to the exclusion of all others can also be granted over unallocated Crown land. The Australian Government Department of the Environment, Water, Heritage and the Arts (DEWHA) and the Western Australian Department of the Environment and Conservation (DEC) have consulted the representatives of the Indigenous custodians of the Ningaloo Coast area. Indigenous involvement in the management arrangements for the property are detailed below in Sections 5.C and 5.E.

5.B PROTECTIVE DESIGNATION

Comprehensive legislation is in place across three levels of government in Australia to ensure the protection of the nominated property. These Acts of Parliament can only be amended or revoked by further legislation. Map 1.3 indicates areas of special legal protection declared under this legislation. Commonwealth legislation applies to Ningaloo Marine Park (Commonwealth Waters) and Learmonth Air Weapons Range. State legislation covers all other areas of the nominated property. Additionally, the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) protects the National Heritage and potential World Heritage values of the entire nominated area, along with matters of national environmental significance inside and outside of the property.

FIGURE 5.4 Gould's Wattled Bat (*Chalinolobus gouldii*). Photograph Jiri Lochman © Lochman Transparencies

<table>
<tr><th colspan="11">LEGISLATIVE CONTEXT</th></tr>
<tr><th>The Ningaloo Coast</th><th>Ningaloo Marine Park (Commonwealth waters)</th><th>Ningaloo Marine Park (State Waters)</th><th>Muiron Islands Marine Management Area</th><th>Cape Range National Park</th><th>Muiron Islands Nature Reserve</th><th>Bundegi and Jurabi Coastal Parks</th><th>Unallocated Crown land</th><th>Proposed conservation and recreation areas *</th><th>Leasehold & freehold land incl. pastoral leases</th><th>Learmonth Air Weapons Range</th></tr>
<tr><td></td><td>Marine Park Established 1987</td><td>Established 1987 Expanded 2004</td><td>Established 2004</td><td>Established 1964 Expanded 1969</td><td>Established 1973</td><td>Established 1988</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">National legislation</td><td colspan="10">Environment Protection and Biodiversity Conservation Act 1999</td></tr>
<tr><td colspan="9"></td><td>Defence Act 1903</td></tr>
<tr><td rowspan="10">State of Western Australia

(provincial) legislation</td><td></td><td colspan="8">Wildlife Conservation Act 1950</td><td></td></tr>
<tr><td colspan="4"></td><td colspan="5">Planning and Development Act 2005</td><td></td></tr>
<tr><td></td><td colspan="8">Environmental Protection Act 1986</td><td></td></tr>
<tr><td></td><td colspan="8">Land Administration Act 1997</td><td></td></tr>
<tr><td></td><td colspan="8">Heritage of Western Australia Act 1990</td><td></td></tr>
<tr><td></td><td colspan="8">Aboriginal Heritage Act 1972</td><td></td></tr>
<tr><td colspan="3"></td><td colspan="6">Rights in Water and Irrigation Act 1914</td><td></td></tr>
<tr><td></td><td colspan="5">Conservation and Land Management Act (CALM) 1984</td><td>CALM Act[1]</td><td>CALM Act (proposed)[2]</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Western Australian Marine Act 1982</td><td colspan="7"></td></tr>
<tr><td colspan="3">Fish Resources Management Act 1994</td><td colspan="7"></td></tr>
<tr><td>Local legislation</td><td></td><td></td><td></td><td>Local Government Act 1995</td><td></td><td colspan="4">Local Government Act 1995</td><td></td></tr>
</table>

* The proposed conservation and recreation areas do not include homestead and other improvement areas which are negotiated to remain in or associated with ongoing pastoral leases.

TABLE 5.2 Australian, state and local legislation for the Ningaloo Coast

Environment Protection and Biodiversity Conservation Act 1999

Australia's obligations under the World Heritage Convention are reflected in the provisions of the EPBC Act to promote a best practice, nationally consistent standard for the management and protection of Australia's World Heritage properties. The legislative protection of the EPBC Act for World Heritage properties is exceptional among State Parties to the World Heritage Convention.

The EPBC Act also established the Australian 'National Heritage List' to recognise and protect places of outstanding heritage value to the nation. The legislation provides comprehensive protection for National Heritage and World Heritage places, including protection that extends beyond the property boundary. The Ningaloo Coast was included in Australia's National Heritage List in 2010. In the event the area is inscribed on the World Heritage List, the Ningaloo Coast will become a declared World Heritage property protected under the EPBC Act.

Any proposed action that may have or is likely to have a significant impact on the heritage values of a National Heritage place or a declared World Heritage property requires assessment under the EPBC Act. This includes not only actions taken within the boundaries of the listed property, but also any actions taken outside the boundaries that may have a significant impact on the listed property's heritage values. This means, in effect, that the EPBC Act provides a legislative buffer zone for Australia's National Heritage and World Heritage places. The Minister for the Environment, Heritage and the Arts makes the final decision on whether the proposal may proceed or not. Under a bilateral agreement between the Australian and Western Australian governments, the Western Australian Environmental Protection Authority may undertake the environmental impact assessment process for the Australian Government.

One of the Act's requirements is that it is reviewed every 10 years. The first of these reviews took place in 2009, and the Australian Government expects that the review will result in legislated amendments to the EPBC Act aimed at improving its functionality. More broadly, the EPBC Act applies to any actions that will have, or are likely to have, a significant impact on a matter of 'national environmental significance'. These matters are defined as declared World Heritage properties; gazetted National Heritage Listed properties; wetlands of international importance (Ramsar wetlands); Commonwealth marine areas; listed threatened species and communities; listed migratory species; and nuclear actions. In the case of World Heritage and National Heritage List properties, the Act protects the listed heritage values. Any action inside or outside the property (including the airspace above it) which has the potential to significantly impact the values, triggers the legislation's assessment and approval provisions.

The EPBC Act also has other provisions that are relevant to the nominated property. For example, the EPBC Act protects the environment from significant impacts if a proposed action takes place in Commonwealth marine areas, on Commonwealth land or by a Commonwealth agency. The EPBC Act also contains provisions that prohibit and regulate actions in relation to threatened species, migratory species, cetaceans (whales and dolphins) and other (listed) marine species. Appendix A of this document lists some of the species that are found at the Ningaloo Coast that are protected under the Act. Substantial civil and criminal penalties may be imposed for breaches of the EPBC Act.

Ningaloo Marine Park (Commonwealth Waters)

Ningaloo Marine Park (Commonwealth Waters) is a declared Commonwealth reserve under the EPBC Act. The EPBC Act requires that Commonwealth reserves be assigned to an International Union for Conservation of Nature (IUCN) category, and managed in accordance with the Australian IUCN reserve management principles for that category. Ningaloo Marine Park (Commonwealth Waters) is managed as an IUCN Category II National Park, which means that it is a protected area managed mainly for ecosystem conservation and recreation.

The EPBC Act prohibits certain actions from being carried out in a Commonwealth reserve, except in accordance with a management plan or, in the absence of a management plan, with approval from the Director of National Parks. It is an offence to kill, injure, take, trade, keep or move a member of a native species; to damage heritage; to carry on an excavation; to erect a building or other structure; to carry out works; or to take an action for commercial purposes. Mining operations and commercial fishing are prohibited in Ningaloo Marine Park (Commonwealth Waters). Recreational fishing consistent with the conservation of the listed values is permitted and is managed through education, and compliance and enforcement programs.

A large proportion of this area is also inscribed on the Commonwealth Heritage List. The listing is titled 'Ningaloo Marine Area—Commonwealth Waters' and the listed values are protected by the EPBC Act. This means that an agency must not take an action that is likely to have an adverse impact on the Commonwealth Heritage values of the area, unless there is no feasible and prudent alternative, in which case all reasonable measures must be taken to mitigate the impact of the action.

The listed values include whales (a number of species), whale sharks, turtles, sharks, dugong, dolphins, birds including wader and migratory species, and billfish. A full list can be found in the Australian Heritage Database.[5]

Not all of the Commonwealth Heritage listed place is covered by the Ningaloo Marine Park, because the threshold for inscription on the Commonwealth Heritage List is lower than that the threshold for a Commonwealth marine park. The boundary of the World Heritage nomination follows that of the Commonwealth marine park, rather than the Commonwealth Heritage List place, to reflect the outstanding universal value of the property. The values of the Commonwealth Heritage List place continue to be protected by the relevant provisions of the EPBC Act.

Defence Act 1903

The *Defence Act 1903* (Cwlth) contains provisions that empower the Australian Government Department of Defence to manage and protect Learmonth Air Weapons Range in regard to public use. The Department of Defence is preparing to apply to parliament for the range to be gazetted as a 'public area' under the relevant provisions of this Act. This would give Defence the authority to curtail access and to appoint rangers to oversee management. As a Commonwealth Heritage listed property, the Range is also subject to the provisions of the EPBC Act.

WESTERN AUSTRALIAN GOVERNMENT LEGISLATION

Conservation and Land Management Act 1984

The Western Australian *Conservation and Land Management Act 1984* (CALM Act) is the principal legislation for establishing and managing conservation reserves in Western Australia. Conservation reserves are areas of the natural environment that are formally reserved for public purposes, including for the conservation of native species, biodiversity, ecosystems and recreation. The CALM Act provides for the use, protection and management of certain public lands (including waters) and for establishing the authorities responsible for that land. Under the CALM Act, the Marine Parks and Reserves Authority has responsibility for the care, control and management of Ningaloo Marine Park (State Waters) and the Muiron Islands Marine Management Area. The Conservation Commission of Western Australia is the vested authority for Cape Range National Park. The Muiron Islands are jointly vested with the Conservation Commission of Western Australia and the Shire of Exmouth. DEC manages conservation reserves on behalf of these bodies. The CALM Act also allows DEC to issue leases and licenses to operators conducting commercial activities on land and/or waters to preserve these reserves and parks. DEC is guided by government and departmental policies, management plans and strategic planning documents (including the *Ningaloo Coast Regional Strategy Carnarvon to Exmouth*) in determining whether leases or licenses are appropriate.[6]

FIGURE 5.5 Recreational activities within the Cape Range National Park are carefully managed under the *Conservation and Land Management Act 1984.*
Photograph Tony Howard © Western Australian Department of Conservation and Environment

Ningaloo Marine Park (State Waters), Muiron Islands Marine Management Area and Cape Range National Park have been established as reserves under the CALM Act to ensure the protection of their natural environments. In Ningaloo Marine Park (State Waters), only recreational and commercial activities that are consistent with the conservation and restoration of the natural environment are permitted. A zoning scheme has been developed under the CALM Act that includes sanctuary zones representative of the marine habitats of the park. Ningaloo Marine Park is a 'Class A' reserve under the CALM Act, which affords it extra protection by requiring that any amendment, cancellation or change to the boundary must occur by an Act of Parliament. Muiron Islands Marine Management Area is managed and protected under the Act to ensure that it can be used for conservation, recreation, scientific and commercial purposes. Three conservation areas have been set aside within this reserve. Cape Range National Park is managed to ensure the maintenance and restoration of the natural environment, protection of flora and fauna and the preservation of the archaeological, historic and scientific interest of the area. Recreational activities that are consistent with these objectives are permitted within the park.

Areas within six pastoral leases are identified as 'proposed conservation and recreation areas' and are expected to be managed consistent with the formal conservation reserve system of Western Australia by 2015. The pastoral stations are currently managed by pastoral leaseholders who are issued a lease by the Pastoral Lands Board. The areas proposed for inclusion in the conservation reserve system will be designated an appropriate reserve type and purpose for management under the CALM Act.

Environmental Protection Act 1986

The Western Australian *Environmental Protection Act 1986* (EP Act) is the principal and guiding legislation for environmental impact assessment in Western Australia. The EP Act provides for the prevention, control and abatement of pollution and environmental harm and for the conservation, preservation, protection, enhancement and management of the environment. The EP Act establishes the Environmental Protection Authority of Western Australia, which assesses development proposals likely to have a significant impact on the environment. The Environmental Protection Authority provides recommendations to the Western Australian Minister for the Environment, who determines whether the proposal

FIGURE 5.6 Iconic animals such as the echidna (*Tachyglossus aculeatus*) are protected under the *Wildlife Conservation Act 1950*. Photograph Keely Markovina © Western Australian Department of Conservation and Environment

may proceed with or without conditions, or may not proceed.[7] DEC assists the Environmental Protection Authority in the process of assessing development proposals and administers pollution control legislation. The EP Act provides for a review of the operation and effectiveness of the Act five years after the Act commenced. Significant amendments to the Act were passed in 2003 following a review of the Act.

Wildlife Conservation Act 1950

The Western Australian *Wildlife Conservation Act 1950* (WC Act) is the principal legislation for the conservation and protection of native wildlife in Western Australia. The WC Act provides for the protection of flora and fauna throughout Western Australia, including the coastal sea. Specific protection declarations made under the WC Act apply to many species at the Ningaloo Coast, such as the Wildlife Conservation (Fauna of Ningaloo Marine Park) Notice 1992; the Wildlife Conservation (Close Season for Whale Sharks) Notice 1996; and the Wildlife Conservation (Close Season for Marine Mammals) Notice 1998. The WC Act is enforced by wildlife officers appointed by DEC.

Planning and Development Act 2005

The Western Australian *Planning and Development Act 2005* (P&D Act) is the principal and guiding legislation for planning in Western Australia. The P&D Act sets out the requirements for planning and development of land and establishes the Western Australian Planning Commission, which has responsibility for urban, rural and regional land use planning and land development matters. The Western Australian Planning Commission (or its delegate) has statutory planning and development powers under this Act for the Ningaloo Coast. Decisions on development applications are guided by several planning documents and policies. These include: the *Ningaloo Coast Regional Strategy Carnarvon to Exmouth*; *Ningaloo Coast Statement of Planning Policy 6.3*; *Statement of Planning Policy 2.6—State Coastal Planning*; *Management Plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area*; and *Cape Range National Park Management Plan*.

The *Ningaloo Coast Regional Strategy Carnarvon to Exmouth*, released in 2004, is a strategic land use plan that establishes a framework for land use and sustainable tourism for the Ningaloo Coast over 30 years. The strategy has legal backing from the *Ningaloo Coast Statement of Planning Policy 6.3* under the P&D Act. Developed with extensive community consultation, the *Ningaloo Coast Regional Strategy Carnarvon to Exmouth* provides a clear vision for sustainable development embedded in the desire to conserve the natural values of the area. The strategy identifies Carnarvon and Exmouth as the main centres for significant development, both of which are outside the nominated property boundary. A development application may only be approved if the proposal is consistent with the regional land use plan, the coastal tourism framework, the planning and environmental guidelines for sustainable tourism on the Ningaloo Coast and the Coral Bay settlement plan or Exmouth or Carnarvon structure plans contained within the *Ningaloo Coast Regional Strategy Carnarvon to Exmouth*. Additionally, proposals are referred for environmental impact assessment where there is likely to be a significant impact on the environment under the EP Act, and, if appropriate, the EPBC Act.

Land Administration Act 1997

The Western Australian *Land Administration Act 1997* (LA Act) is the principal and guiding legislation for the administration of Crown land, land acquisitions on behalf of the Western Australian Government, leases, licenses and easements and the establishment of reserves and land for roads and public access. Pastoral leases are also established and managed under the LA Act. Land conservation reserves are afforded special protection under this Act when they are created as 'Class A' reserves. Amendments to 'Class A' reserves in terms of purpose or boundary require approval from the two houses of the Western Australian Parliament. Cape Range National Park and the Muiron Islands Reserve are both 'Class A' reserves under this Act.

FIGURE 5.7 Sanctuary zones within the Ningaloo Marine Park provide safe havens for marine species such as convict surgeons. Photographs Tony Howard © Western Australian Department of Conservation and Environment

Fish Resources Management Act 1994

The Western Australian *Fish Resources Management Act 1994* (FRM Act) provides overarching legislation for the protection of fish and fish habitat, and for the management of fish resources in Western Australian waters. The objectives of the FRM Act include: conservation of fish and fish habitats; development of fish resources for the benefit of present and future generations (including commercial and recreational fishing); the development and management of sustainable aquaculture; and management of extractive aquatic ecotourism. Under the FRM Act, recreational fishing restrictions apply within established marine conservation reserves, including Ningaloo Marine Park (State Waters) and the Muiron Islands Marine Management Area. The FRM Act is serviced by the Western Australian Department of Fisheries.

Rights in Water and Irrigation Act 1914 and Country Areas Water Supply Act 1947

The quality of groundwater within and beyond the nominated property is comprehensively regulated through legislation. The Western Australian *Rights in Water and Irrigation Act 1914* is the principal legislation for the regulation, use and protection of water resources in Western Australia. The Western Australian Minister for Water must take sustainable management of water resources into account when making a decision to grant a water abstraction licence.[8] Some of the key objects of this Act are provision for sustainable use of development of water resources to meet users' needs; protection of ecosystems and the environment in which water resources are situated; and integration of water resource management with management of other natural resources.[9] This Act is important in ensuring high-quality ground water, which plays a key role in protecting the potential World Heritage values of the nominated property.

The Western Australian *Country Areas Water Supply Act 1947* allows for the creation of water reserves for the protection of public drinking water sources, and by-laws to ensure the control of potentially polluting activities, regulation of land use and prevention or clean up of pollution in water source protection reserves. Development activity may be restricted in water source protection reserves to protect the water source from degradation. The Exmouth Water Reserve extends into the nominated property and is protected under these acts.

Local Government Act 1995

The Western Australian *Local Government Act 1995* (LG Act) provides for a system of local government in Western Australia including the ability for local governments to create by-laws to manage certain activities. Local governments may issue notices under the LG Act in relation to water run-off, unsightly land, overgrown vegetation, rubbish or disused material, minimising sand drifts, controlling artificial lighting and public safety.

Western Australian Marine Act 1982

The *Western Australian Marine Act 1982* (WAM Act) regulates boating in Western Australian waters, including in marine conservation reserves. The WAM Act allows the Western Australian Department of Transport to place speed restrictions on vessels and put in place measures for safe vessel navigation and equipment. These provisions contribute to visitor safety and the protection of marine mammals and coral reefs from inappropriate vessel activity.

5.C MEANS OF IMPLEMENTING PROTECTIVE MEASURES

Australia provides a high level of legal protection to its World Heritage and National Heritage properties. Legislative protection applies across three levels of government: the national, state and municipal levels. The heritage values of the Ningaloo Coast are also safeguarded through a robust protective management system. The Ningaloo Coast *Strategic Management Framework*, endorsed by the Australian Government and the Western Australian Government, documents a wide range of measures provided under planning and heritage legislation, and plans and policies of the Australian Government and of the Western Australian Government. This legislation provides protection beyond the nominated area as outlined below. An overview of the legislative context is provided at Table 5.3.

Several Western Australian Government agencies have responsibility for managing most of the nominated property to meet the requirements of the relevant statutory management plans. DEC manages the conservation reserves system on behalf of the Conservation Commission of Western Australia and the Marine Parks and Reserves Authority under the CALM Act (WA). DEC also manages Ningaloo Marine Park (State Waters), Muiron Islands Marine Management Area and Cape Range National Park in accordance with management plans prepared under the CALM Act. In addition, DEC undertakes the day-to-day management of Ningaloo Marine Park (Commonwealth Waters) under agreement with DEWHA (the responsible authority for this area). DEC has management responsibilities within the area of unallocated Crown land within the nominated property in accordance with a memorandum of understanding with the former Western Australian Department for Planning and Infrastructure and a management agreement put into effect under the CALM Act.[10] DEC and the Shire of Exmouth jointly manage Jurabi Coastal Park, Bundegi Coastal Park and the Muiron Islands in accordance with the *Jurabi and Bundegi Coastal Parks and Muiron Islands Management Plan 1999–2009*.[11] DEC also administers the *Wildlife Conservation Act 1950* and the *Environmental Protection Act 1986*, which are relevant to protecting the heritage values of the property, as described in Section 5.B.

Community participation is a key principle of the management arrangements for the Ningaloo Coast property. DEC undertakes community consultation during the development of management plans and provides ongoing opportunities for community involvement in management activities. The Jurabi and Bundegi Coastal Parks and Muiron Islands Advisory Committee (made up of representatives from the Shire of Exmouth, Exmouth Shire Council and DEC) provides advice on the management of these reserves.

<table>
<tr><th colspan="10">GOVERNANCE ARRANGEMENTS</th></tr>
<tr><th>Ningaloo Coast</th><th>Ningaloo Marine Park and Commonwealth Waters</th><th>Ningaloo Marine Park (State Waters)</th><th>Cape Range National Park</th><th>Muiron Islands, Bundegi and Jurabi</th><th>Muiron Islands Marine Management Area</th><th>WA unallocated Crown land</th><th>Proposed conservation and recreation areas *</th><th>Freehold owners and leaseholders incl. pastoral lessees</th><th>Learmonth Air Weapons Range</th></tr>
<tr><td rowspan="2">National governance</td><td colspan="9">Environment Protection and Heritage Council & Australian World Heritage Advisory Committee</td></tr>
<tr><td colspan="9">Ningaloo Coast World Heritage Advisory Committee</td></tr>
<tr><td>Australian Government agencies</td><td>Department of the Environment, Water, Heritage and the Arts</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>Department of Defence</td></tr>
<tr><td>Western Australia

(provincial) agencies</td><td>Department of Environment and Conservation

&

Department of Fisheries</td><td>Department of Environment and Conservation

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Department of Fisheries</td><td>Department of Environment and Conservation</td><td>Department of Environment and Conservation</td><td>Department of Environment and Conservation</td><td>Department of Regional Development and Lands

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Department of Environment and Conservation</td><td>Department of Environment and Conservation</td><td>Department of Regional Development and Lands

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Department of Environment and Conservation</td><td></td></tr>
<tr><td>Local agencies</td><td></td><td colspan="5">Shire of Exmouth</td><td>Shire of Exmouth

&

Shire of Carnarvon</td><td>Shire of Exmouth</td><td></td></tr>
</table>

* These areas may be transferred to the management responsibility of the Department of Environment and Conservation pending negotiations with pastoral leaseholders.

TABLE 5.3 Governance arrangements for the Ningaloo Coast

The Indigenous custodians of the area are also involved in management arrangements for the Ningaloo Coast. Strategies for ensuring the participation of local Indigenous people in management arrangements for the property are specified in the Ningaloo *Marine Park and Muiron Island Marine Management Area 2005–2015 Management Plan No. 52*, the *Ningaloo Marine Park (Commonwealth Waters) Management Plan 2002–2009* and the *Cape Range National Park Draft Management Plan*.[12]

The Coral Coast Park Council has been convened by DEC since 2004. The Council comprises representatives of the Gnulli Native Title Claim Working Group and DEC, and facilitates Indigenous involvement in the management of Cape Range National Park, Ningaloo Marine Park, and Jurabi and Bundegi Coastal Parks. Additionally, the Cardabia pastoral station is leased by the Baiyungu Aboriginal Corporation. In 2006, the Baiyungu entered into a joint management agreement with the Western Australian Government which includes provisions for joint management of the area of Cardabia Station proposed as a conservation reserve, as well as for cultural tourism initiatives.

The Western Australian Department of Fisheries manages and regulates commercial and recreational fishing, aquaculture and pearling activities under the *Fish Resources Management Act 1994* (WA) and *Pearling Act 1990* (WA). The Department of Fisheries has responsibility for enforcement of these Acts, and oversees a compliance and community education program for recreational and commercial fishing within and beyond the nominated property. The department has a range of management mechanisms for commercial fishing, including fishery specific management plans; spatial, temporal or gear restriction management arrangements; effort controls; and size limits. These management arrangements are regularly monitored and reviewed with input from stakeholder and community groups.

The Department of Fisheries has working arrangements with DEC, through which the two departments share joint responsibilities for marine reserves. For example, cross authorisation arrangements have been developed so that authorised officers in both departments can enforce legislation administered by either agency. Both Ningaloo Marine Park (State Waters) and Ningaloo Marine Park (Commonwealth Waters) are managed as an IUCN Category II—National Park: Protected Area Managed Mainly for Ecosystem Conservation and Recreation.

DEWHA manages recreational fishing within Ningaloo Marine Park (Commonwealth Waters). Commercial fishing is not permitted in Ningaloo Marine Park (Commonwealth Waters) under the EPBC Act. DEWHA has working arrangements with the Western Australian Department of Fisheries and with DEC, which work together to undertake compliance activities in Ningaloo Marine Park (Commonwealth Waters).

FIGURE 5.8 Strict guidelines exist to promote sustainable development and protect the biodiversity of terrestrial habitats. Photograph Tony Howard © Western Australian Department of Environment and Conservation

The Western Australian Department of Water is responsible for managing Western Australia's water needs and ensuring these needs are met now and in the future. Part of the role of this department in managing water resources involves licensing groundwater and surface water users within the nomination area under the *Rights in Water and Irrigation Act 1914* (WA). The Department develops management plans and policies for the allocation of water, management of environmental water requirements and monitoring of water resources. Routine site inspections of water users at the Ningaloo Coast are undertaken by the Department of Water. An annual monitoring program of private users is conducted in Exmouth.

Small portions of six pastoral stations are located within the nominated property, to the south and east of Cape Range National Park: Exmouth Gulf Station, Ningaloo Station, Cardabia Station, Warroora Station, Gnaraloo Station and Quobba Station. All are managed by individual leaseholders. The Western Australian Pastoral Lands Board, established under the *Land Administration Act 1997* (WA), administers pastoral leases, including these stations, to ensure they are managed on an ecologically sustainable basis. Areas within the pastoral leases that have been identified as 'proposed conservation and recreation areas' are expected to be managed consistent within the formal conservation reserve system of Western Australia by 2015.

› **FIGURE 5.9** Yardie Creek.
Photograph Jane Ambrose © Department of the Environment, Water, Heritage and the Arts

The Western Australian Planning Commission, or its delegate, makes determinations on development applications and master plans. The *Ningaloo Coast Regional Strategy Carnarvon to Exmouth* sets out strict planning and environmental guidelines that are used in determining development applications and defining master plans along the Ningaloo Coast. The strategy also provides a high degree of environmental and sustainable development control for planned activities.

The Australian Department of Defence is responsible for the management of the Learmonth Air Weapons Range. The Department is formally committed to responsible and sustainable environmental management under its Environmental Management System (EMS), adopted in 2001. The EMS is consistent with the *International Standards Organisation Standard on Environmental Management Systems* (ISO 14001: 2004). Environmental planning, management and monitoring activities in the Range are carried out in accordance with the EMS and the EPBC Act to protect the National Heritage and potential World Heritage values of the site. When management of public access to the range is achieved through declaration of the coastal strip as a public area, the Department of Defence will either employ rangers with expertise in managing public recreational access to conservation areas, or establish arrangements to delegate this responsibility to DEC.

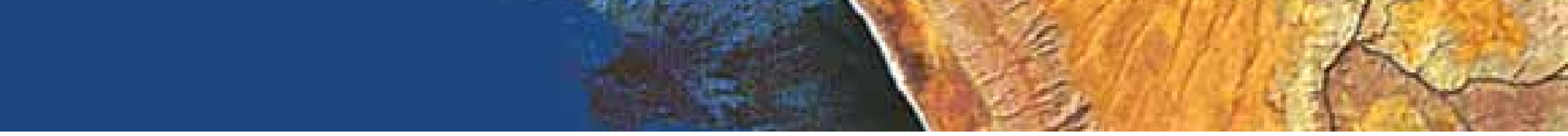
Should the property be inscribed on the World Heritage List, a Ningaloo Coast World Heritage advisory committee will immediately be established by the Australian Government and the Western Australian Government to advise agencies and assist in the management of issues affecting the World Heritage values of the property. The advisory committee will be made up of scientific experts and local community members. Scientific members will have expertise on World Heritage values. Community members will represent social and cultural interests of the community, which may include Aboriginal interests, fishing, tourism, pastoralism and conservation. The advisory committee will be an important forum for discussion and will facilitate the involvement of the community in the management of the property. The advisory committee will ensure that the best scientific and technical measures are used to identify and protect the values of the area.

5.D EXISTING PLANS RELATED TO MUNICIPALITY AND REGION

A number of local, regional and state strategies and plans recognise the outstanding natural heritage of the Ningaloo Coast. These documents contain policies and programs to protect the outstanding natural values of the property. Table 5.4 outlines local, regional and state strategies that contribute to the protection of the Ningaloo Coast.

PLANS AND STRATEGIES	NAME OF PLAN	DATE ADOPTED	AGENCY RESPONSIBLE FOR PREPARATION OF THE PLAN
Regional plans	*Ningaloo Coast Regional Strategy Carnarvon to Exmouth*	2004	Western Australian Planning Commission
	Exmouth Water Reserve Water Source Protection Plan	2000	Western Australian Department of Water (formerly Water and Rivers Commission)
	Exmouth Groundwater Allocation Plan: Exmouth Groundwater Sub-area	1999 (due for review in 2009)	Western Australian Department of Water (formerly Water and Rivers Commission)
	State Sustainability Strategy	2003	Western Australian Government
Plans to protect marine and terrestrial species	*Cape Range Remipede Community (Bundera Sinkhole) and Cape Range Remipede Interim Recovery Plan 2000–2003 (currently under review)*	2000	Western Australian Department of Environment and Conservation
	Whale Shark Interaction Management with Particular Reference to Ningaloo Marine Park: Western Australian Wildlife Management Program No. 27	1997	Western Australian Department of Environment and Conservation
	Whale Shark (Rhincodon typus) *Recovery Plan 2005–2010*	2005	Australian Government Department of the Environment, Water, Heritage and the Arts
	Recovery Plan for Marine Turtles in Australia 2003	2003	Australian Government Department of the Environment, Water, Heritage and the Arts (formerly Environment Australia)
	White Shark (Carcharodon carcharias) *Recovery Plan*	2002	Australian Government Department of the Environment, Water, Heritage and the Arts
	Dugong (Dugong dugon) *Management Plan for Western Australia 2007–2016*	2007	Western Australian Department of Environment and Conservation
	Marine Turtle Recovery Plan for Western Australia (final in preparation)	2009	Western Australian Department of Environment and Conservation
	Wildlife Conservation Plan for Dugongs in Australia	in preparation	Australian Government Department of the Environment, Water, Heritage and the Arts

TABLE 5.4 Local, regional, state and national strategies and plans for the Ningaloo Coast



REGIONAL PLANS

Ningaloo Coast Regional Strategy Carnarvon to Exmouth (2004)

The *Ningaloo Coast Regional Strategy Carnarvon to Exmouth* is a 30-year strategic land use plan that sets the framework for land use and sustainable tourism for the entire area. Development of the strategy was guided by input from a community advisory group, a technical advisory group and the local community. The strategy is subject to review at least every five years, allowing for adaptive management responses to changing uses and issues. This plan sets the framework for statutory planning decisions through the Ningaloo Coast Regional Interim Development Order. The accompanying *Ningaloo Coast Statement of Planning Policy 6.3* provides the legal framework for key elements of the strategy under the *Planning and Development Act 2005* (WA).

Exmouth Water Reserve water source protection plan (2000)

The Exmouth Water Reserve has been declared under the *Country Areas Water Supply Act 1947* to protect the public water supply source from contamination. The protection of the area's unique subterranean fauna is also an explicit concern of the plan. The Water Reserve includes areas of land in and adjacent to the nominated property. Development in the Water Reserve is limited under the plan, with compatible land uses including the maintenance of native vegetation and continuation of low intensity pastoral activities.

FIGURE 5.10 Forrest's Featherflower—*Verticorida forresti*. Photograph Jiri Lochman © Lochman Transparencies

Exmouth Groundwater Allocation Plan: Exmouth Groundwater Sub-area (1999)

The *Groundwater Subarea Allocation Plan: Exmouth Groundwater Sub-area* establishes policies and principles for the sustainable allocation of groundwater resources in the Exmouth Groundwater Subarea.[13] The plan was developed in response to concerns over rising groundwater salinities in the town of Exmouth and the impact of increased development in the area. Groundwater, the major water resource in the Exmouth Groundwater Sub-area, is carefully managed to meet the water supply requirements of the area on a sustainable basis. Under the plan, all wells in the Cape Range Group Aquifer, including all domestic wells, must be licensed. The plan is scheduled for review in 2009–2010.

PLANS TO PROTECT MARINE, SUBTERRANEAN AND TERRESTRIAL SPECIES

Cape Range Remipede Community (Bundera Sinkhole) and Cape Range Remipede Interim Recovery Plan 2000–2003

The Cape Range remipede community (at Bundera Sinkhole) is a threatened ecological community and has been assessed as critically endangered by the Western Australian Threatened Ecological Communities Scientific Committee. The Cape Range remipede (*Lasionectes exleyi*) and blind gudgeon fish (*Milyeringa veritas*) are both part of the community and have been listed as vulnerable under the Commonwealth EPBC Act.[14] The interim recovery plan is produced under policy statements 44 and 50 developed by DEC.[15] The plan details recovery actions, such as setting up a recovery team, access, exclusion of pastoral stock, identifying threatening processes, monitoring, goat control, land use planning and liaison with relevant authorities and land users. This plan is currently being reviewed.

Whale Shark Interaction Management with Particular Reference to Ningaloo Marine Park: Western Australian Wildlife Management Program No. 27 (1997)

A whale shark interaction management program was established by DEC in 1997.[16] The program aims to improve management of whale shark interactions with people and provide the scientific basis to determine if management strategies need to be modified. After every whale shark season, a progress report is prepared by DEC to assess monitoring results, make recommendations on further research and monitoring, evaluate whether management objectives were met and evaluate the cost-effectiveness of the management program. The report is made available to stakeholders, including whale shark tour operators.

Dugong (*Dugong dugon*) Management Plan for Western Australia (final in preparation)

The aim of the *Dugong* (Dugong dugon) *Management Plan for Western Australia 2007–2016* is to maintain viable dugong populations throughout the dugong range in Western Australia, including at the Ningaloo Coast. The IUCN lists the dugong as vulnerable. In Australia, the dugong is protected at both the state and national levels of government (see Appendix A).[17] The plan contains strategies to address population data; habitat information; impacts of climate change; impacts from marine vessel activity, fishing bycatch and debris, developments and traditional hunting; and provision of the educational materials.

Wildlife Conservation Plan for Dugongs in Australia (in preparation)

The Australian Government is developing a Wildlife Conservation Plan for Dugongs in Australia. The Dugong Wildlife Conservation Plan is being prepared in consultation with scientists, managers and Indigenous communities and other who have responsibilities for and an interest in dugongs. It is due to be completed in 2010.

FIGURE 5.11 People who take part in whale shark interaction tours pay a levy that contributes to the management of the activity. Photograph © Cam Skirving

Recovery Plan for Marine Turtles in Australia (2003)

The *Recovery Plan for Marine Turtles in Australia* was developed in 2003 as required under the EPBC Act for threatened species.[18] Six species of marine turtles found in Australia are listed as threatened under the Act, of which three (green, loggerhead and flatback) have significant rookeries in the nominated property. The plan aims to identify and address anthropogenic impacts on marine turtles to reduce mortality; protect critical foraging and nesting habitats; enhance education and awareness; monitor key populations; strengthen international collaborations; and engage Indigenous people in the recovery and management of marine turtles. The plan is currently being revised. The 2003 plan outlines actions for the protection, conservation and management of marine turtle populations in Australia.

Marine Turtle Recovery Plan for Western Australia (final in preparation)

The *Marine Turtle Recovery Plan for Western Australia* aims to stop further decline of marine turtle populations and to facilitate their recovery throughout their range in Western Australia. The IUCN lists the green turtle and loggerhead turtle as endangered, and the hawksbill turtle as critically endangered. The plan identifies the Ningaloo Coast as containing important populations of these turtles and habitats critical for their survival. The plan also contains strategies to address community awareness; predation on turtle nests; population data; habitat information; guidance to developers and industry; planning for tourism and recreation; management of harvesting by Indigenous peoples; research; fishing bycatch; guidance to vessel operators; and climate change.

FIGURE 5.12 Baby turtle. Photograph © Tristan Simpson

Whale Shark (*Rhincodon typus*) Recovery Plan 2005–2010 [19]

The *Whale Shark* (Rhincodon typus) *Recovery Plan 2005–2010* is a national plan that addresses the management of threats to whale sharks. Whale sharks enter Australian waters seasonally and frequent the coastal waters adjacent to Ningaloo Reef. The species is listed as vulnerable under the EPBC Act and the *Convention for Migratory Species* and the *Convention for International Trade in Endangered Species,* which require development and implementation of a recovery plan.[20] The main threat to whale sharks is commercial harvesting outside the jurisdiction of the Australian Government.

The recovery plan promotes increased international cooperation to reduce fishing pressure, to halt the decline of the species. Within Australian waters, the recovery plan focuses on anthropogenic threats by actively managing the impact of tourism on whale sharks. It is an offence to kill, injure, take, trade, keep or move a whale shark in Commonwealth Waters without a permit. Whale sharks are similarly protected in Western Australian (State) Waters through the *Wildlife Conservation Act 1950* and the *Conservation and Land Management Act 1984*. The recovery plan will remain in place, with five-year reviews, until the number of whale sharks visiting Australian waters has improved and the species is no longer listed as vulnerable.

White Shark (*Carcharodon carcharias*) Recovery Plan (2002) [21]

The white shark is listed as vulnerable under the EPBC Act and is a protected species under Western Australian legislation. A recovery plan for the species was made in 2002 under the EPBC Act. The overall recovery objective of the *White Shark* (Carcharodon carcharias) *Recovery Plan* is 'to recover white shark numbers in Australian waters to a level that will see the species removed from the schedules of the *Environment Protection and Biodiversity Conservation Act 1999*'. The plan focuses on managing primary threats to the species. These threats include being caught as bycatch in commercial fisheries; being caught accidentally or illegally by recreational fishers; mortality related to shark control activities; impacts from ecotourism and cage divers; and the illegal trade in body parts.

Community partnerships to protect whale sharks

FIGURE 5.13 Divers' photographs allow individual whale sharks to be identified by their distinctive patterns of spots.
Photograph © Tourism WA

An important collaborative project has been established to protect whale sharks at the Ningaloo Coast and to promote the conservation of whale sharks around the world.[22] ECOCEAN Inc, whose pioneering whale shark identification work was outlined in Part 3, collaborates with other nongovernment organisations such as Earthwatch, individual volunteers in the community, and DEC in Australia, as well as scientists in the United States. These partnerships, focused on the whale sharks of the Ningaloo Coast, are an excellent example of a community working together for the conservation of a globally significant species.

Activities undertaken by the partners include data collection and analysis, and the creation of the ECOCEAN Whale Shark Photo-identification Library. During the whale shark season, spotter planes are employed by whale shark tour operators to spot whale sharks from the air. Spotter plane businesses provide their search and sighting data to DEC. The data is used by DEC to compare whale shark search efforts and occurrences over the seasons. This may indicate trends in whale shark numbers.

Whale shark industry videographers have the capability to photograph nearly every whale shark encountered at the Ningaloo Coast. Videographers can enter into an agreement with DEC, in conjunction with their commercial filming permit, to provide whale shark footage to DEC for the purpose of photo identification. Volunteers assist DEC by taking still photographs from the video footage, cataloguing images and collecting other information to assist whale shark conservation.

DEC forwards these images to the Australian Institute of Marine Science and ECOCEAN. People from around the world can also contribute images to the ECOCEAN Whale Shark Photo-identification Library. By identifying individual whale sharks from all over the world, scientists are able to estimate population numbers, identify trends in whale shark numbers and monitor the movement of whale sharks. Photographic identification monitoring programs are being implemented in various known whale shark hot spots, so that trends in whale shark numbers can be determined at a global scale.

5.E PROPERTY MANAGEMENT PLAN OR OTHER MANAGEMENT SYSTEM

A comprehensive management system has been developed to ensure the full protection of all parts of the nominated property. The *Ningaloo Coast Strategic Management Framework* (2009) has been developed and has been endorsed by the relevant Australian Government and Western Australian Government ministers. Management plans have been developed to meet the requirements of Australian Government and Western Australian Government legislation.

The framework will ensure that there is effective integration of approaches across the various management plans to ensure consistent and holistic management of all areas within the nominated property. Indigenous people and the wider community play an important role in contributing to the implementation of the plans and protection of the nominated property. The development of all management plans has included community consultation, and, for a number of plans, direct consultation with Indigenous representatives has occurred.

FIGURE 5.14 Mandu-Mandu Gorge.
Photograph Jiri Lochman © Lochman Transparencies

MANAGEMENT SYSTEM									
	Ningaloo Marine Park and (Commonwealth Waters)	**Ningaloo Marine Park (State Waters)**	**Muiron Islands Marine Management Area**	**Cape Range National Park**	**Muiron Islands, Bundegi and Jurabi**	**WA unallocated Crown land**	**Proposed conservation and recreation areas**	**Freehold owners and leaseholders**	**Learmonth Air Weapons Range Facility**
National planning	*Ningaloo Coast World Heritage Strategic Management Framework* (2009)								
WA regional planning	*Ningaloo Coast regional strategy Carnarvon to Exmouth* (2004)								
Common-wealth planning	*Ningaloo Marine Park (Commonwealth Waters) interim management arrangements*								*Learmonth Air Weapons Range Management Plan* (in preparation 2010)
WA State Government (provincial) planning		*Management plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area 2005–2015* (2005)	*Management Plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area 2005–2015* (2005)	*Cape Range National Park Draft Management Plan* (final in preparation)	*Jurabi and Bundegi Coastal Parks and Muiron Islands management plan* (1999)	*Ningaloo Coast Unallocated Crown Land management framework* (2009)	*Management consistent with the objectives and underlying principles of the Cape Range National Park Management Plan conducted by the Department of Environment and Conservation*	*Management by pastoral lessees under the Pastoral Lands Board, other lessees and freehold owners, consistent with the Ningaloo Coast Regional Strategy Carnarvon to Exmouth.*	

TABLE 5.5 Management system for the Ningaloo Coast

NINGALOO COAST WORLD HERITAGE STRATEGIC MANAGEMENT FRAMEWORK (2009)

The nominated area is comprehensively managed under a management system entitled the *Ningaloo Coast Strategic Management Framework* to ensure the highest level of protection. The framework is endorsed by the Australian Government and the Western Australian Government.

The framework comprises legislative and planning regimes across three levels of government, conservation management plans for all parts of the nominated area, and a range of strategies to integrate and promote best practice in protection, conservation, presentation and community engagement. These strategies include: sharing historical, scientific and technical research and other materials; continuous improvement in conservation and management practices; common interpretative resources; and risk management approaches. The Ningaloo Coast World Heritage Advisory Committee will oversee the implementation of the framework, which is provided as part of the supporting documentation for this nomination (see Part 7).

MANAGEMENT PLAN FOR NINGALOO MARINE PARK AND MUIRON ISLANDS MARINE MANAGEMENT AREA (2005)

The *Management Plan for Ningaloo Marine Park and Muiron Islands Marine Management Area* has been prepared under the Western Australian *Conservation and Land Management Act 1984* for the Marine Parks and Reserves Authority. The plan applies to Ningaloo Marine Park (State Waters) and Muiron Islands Marine Management Area. It outlines a suite of management strategies to protect the natural and cultural heritage values of the area, and to ensure that there is opportunity for sustainable recreational and commercial uses. The key aspects of management include:

- implementation of a zoning scheme that includes sanctuary zones;
- implementation of comprehensive research and monitoring programs to improve the understanding of the natural environment and the impacts of human activities;
- implementation of community education and information programs to support the management of the reserves;
- development and implementation of recreation management plans to facilitate the sustainable management of recreation activities;
- management integration with the adjacent terrestrial reserves; and
- cooperation with relevant agencies, organisations and the community in managing the marine environment, including the involvement of the local Indigenous community in the management of the reserves.

Objectives, strategies, performance measures and management targets outlined in the plan reflect an outcome-based approach from which the effectiveness of management can be assessed. This model is consistent with national standards and has been adopted by the Marine Parks and Reserves Authority to facilitate better conservation and management outcomes, and a more objective and effective approach to auditing management by DEC. The Marine Parks and Reserves Authority has a statutory responsibility to assess the implementation of the plan periodically. The Marine Parks and Reserves Authority assesses annual reviews prepared by DEC and prepares an annual audit report. It also assesses implementation of the plan on a periodic basis (e.g. mid-term) and prior to the statutory 10-year review of the plan. These assessments are based on the preceding annual reviews and on input from stakeholders regarding management of the marine park.

The plan guides management of the marine park for a period of 10 years, or until such time as a statutory revision is undertaken and a new management plan prepared. The CALM Act specifies that in the event of such a revision not occurring by the end of the plan's specified lifespan of the plan, it will remain in force in its original form unless it is revoked by the Western Australian Minister for Environment or a new plan is approved. Full public consultation will occur at the time of a revision and prior to a new plan being submitted to the Marine Parks and Reserves Authority and the Minister for Environment for approval.

Ningaloo Marine Park (Commonwealth Waters) interim management arrangements

The second management plan for the reserve, the Ningaloo Marine Park (Commonwealth Waters) management plan (2002), expired in July 2009. The reserve is currently managed under interim management arrangements and will continue to be managed under these arrangements until a new management plan is in place. It is anticipated a new plan will be developed pending the outcomes of bioregional planning processes in 2010. The *Ningaloo Marine Park (Commonwealth Waters) Information for Visitors* document outlines the interim management arrangements.[23]

The document provides for the Commonwealth Waters to continue to be managed as an IUCN Category II Reserve (National Park) in accordance with the Australian IUCN reserve management principles set out in the Environment Protection and Biodiversity Conservation Regulations 2000.[24]

Management responsibility for Ningaloo Marine Park (Commonwealth Waters) rests with the Australian Government through the Director of National Parks. The Director has delegated authority under the EPBC Act and EPBC Regulations to specific members of the Marine Division of DEWHA.

The reserve is protected and managed to preserve its natural condition according to the following objectives:

- provide for the preservation of the marine environment and key ecological processes of the reserve;
- manage scientific, educational, recreational and tourism activities to maintain the natural state of the reserve; and
- encourage and regulate the appropriate use of the reserve.

Management of the Ningaloo Marine Park (Commonwealth Waters) component of the reserve is undertaken in partnership with the Western Australian Department of Environment and Conservation and the Western Australian Department of Fisheries. Management is consistent with the adjoining Ningaloo Marine Park (State Waters).

Jurabi and Bundegi Coastal Parks and Muiron Islands Management Plan (1999)[25]

The *Jurabi and Bundegi Coastal Parks and Muiron Islands Management Plan* is consistent with the requirements of the Western Australian CALM Act. The plan identifies management strategies relating to the conservation of biological, physical, cultural and landscape values; provision of public recreation in a manner that is consistent with conservation; promotion of awareness and understanding of cultural and natural heritage values; management of commercial uses in a manner that minimises their impacts; and research and monitoring to increase knowledge and understanding of the environment.

Cape Range National Park Draft Management Plan 2005

The Cape Range National Park management plan is being reviewed and revised under the Western Australian CALM Act for the Conservation Commission of Western Australia. In 2005, a draft plan was released for public comment. The draft *Cape Range National Park Draft Management Plan 2005* provides management strategies relating to the protection of ecological and cultural values, provision for appropriate visitor use, sustainable resource use, community involvement, and research and monitoring.

Consultation with the local community, key stakeholders, park users and other interested parties was a key aspect to development of the plan. A community advisory committee (the Coral Coast Parks Advisory Committee) was formed and meetings were conducted to discuss management issues and facilitate community input during development of the plan. The Coral Coast Park Council, which represents the local Indigenous community, also provided advice, with a particular focus on cultural matters and potential joint management arrangements. The plan is expected to be finalised in 2010.

The Conservation Commission measures the success of management plans using key performance indicators and other mechanisms as appropriate. Each key performance indicator comprises evaluation of a measure or target, reporting requirements and a management response to any shortfall. These components provide a basis for adaptive management—management is altered if necessary to meet a desired outcome.

Ongoing research is identified in management plans as an important part of the management framework for conservation reserves; it can result in direct management changes.[26] For example, the Western Australian Department of Conservation and Land Management (now DEC) commissioned a research program to identify and monitor the effects of boat tours and tourists on the wildlife at Yardie Creek following representations from the National Parks and Nature Conservation Authority (now the Conservation Commission) and the then Minister for the Environment.

Data were collected on the effects of boat tours, walkers, climbers and swimmers on the behaviour of nesting birds and black-footed rock wallabies during the spring of 2000 and 2001. The results suggested that black-footed rock wallabies do not see boats or their passengers as a threat and boats and their passengers have no noticeable effect on nesting birds. In contrast, walkers, climbers and swimmers were observed to agitate nesting birds and chicks along the main nesting wall. In response, the Western Australian Department of Conservation and Land Management implemented the recommendation of the researchers to prohibit access to the southern side of Yardie Creek where the main nesting wall occurs. This area remains out of bounds to walkers and climbers as a wildlife sanctuary zone. However, boat tour passengers can view nesting birds from the boat without causing disturbance.[27]

Learmonth Air Weapons Range management plan (2010)

The Learmonth Air Weapons Range management plan is currently being developed by the Royal Australian Air Force (RAAF). The site is currently managed in accordance with the Australian Government Department of Defence Environmental Management System. The Environmental Management System reflects the commitment of the Department to environmental best practice, and the principles of sustainable development and natural resource conservation. Monitoring and other conservation activities in the range are undertaken in accordance with Western Australian state legislation and complement the management of the rest of the Cape Range peninsula. In November 2008, the RAAF undertook clearance of unexploded ordinance in the impact area and re-established firebreaks. There has also been extensive work on the remediation of South Yardie Well, to protect Bundera Sinkhole.

Proposed conservation and recreation areas

As outlined in Section 5.C, areas of six pastoral leases are identified as 'proposed conservation and recreation areas' and are expected to be managed consistent with the formal conservation reserve system of Western Australia by 2015. The pastoral stations are currently managed by pastoral leaseholders who are issued a lease by the Pastoral Lands Board. The role of the Pastoral Lands Board includes ensuring pastoral leases are managed on an ecologically sustainable basis. Pastoral activities managed on this basis are low-impact and do not threaten the National Heritage and potential World Heritage values of the nominated property.

The 'proposed conservation and recreation areas' have been identified by the Western Australian Government for the management of high conservation and/or recreation values. It is intended that these areas will be given appropriate tenure and management arrangements following negotiation with pastoral leaseholders. The land will be managed consistent with the objectives and underlying principles of the management plan for Cape Range National Park. Further management planning will be undertaken where required. The proposed conservation and recreation areas are included in the nominated property; however, they do not include homestead and other improvement areas that are negotiated to remain in or associated with ongoing pastoral leases.

Ningaloo Coast Unallocated Western Australian Crown Land Management Framework (2009)

Approximately 39 per cent of the area of Western Australia (or 890,000 square kilometres) is assigned as unallocated Crown land or unmanaged Crown reserves.[28] DEC has management responsibilities for this land. An area of unallocated Crown land lies within the nomination area. Management arrangements for this area are outlined in the *Ningaloo Coast Unallocated Crown Land Management Framework* (2009).

Ningaloo Coast Regional Strategy Carnarvon to Exmouth

As previously outlined in Section 5.D, the *Ningaloo Coast Regional Strategy Carnarvon to Exmouth* is a long-term strategic plan that sets the framework for statutory planning decisions in the region.

5.F SOURCES AND LEVELS OF FINANCE

AUSTRALIAN GOVERNMENT FUNDING

The Australian Government has an obligation to ensure that the objectives of the World Heritage Convention are met for World Heritage properties. These objectives include the obligations to identify, protect, conserve, present, and where necessary, rehabilitate and transmit to future generations the World Heritage values of the property.

The Caring for our Country program provides funding assistance to protect and manage Australia's most important natural heritage places. World Heritage places are a priority under this program. The Caring for our Country program as a whole will provide funding of AU$2.25 billion over four years (2008–2012) to meet a range of environmental objectives. The Ningaloo Coast may have access to a portion of these funds, as protection and management of the area falls under a number of priority areas of the program, such as protection of biodiversity and natural icons.

FIGURE 5.15 Ningaloo Reef: A garden under the sea. Photograph Axel Passeck © Western Australian Department of Environment and Conservation

In addition, DEWHA provides funding of approximately A$100,000 per annum to the Western Australian Department of Environment and Conservation and Department of Fisheries for the day-to-day management of Ningaloo Marine Park (Commonwealth Waters). Funded activities include providing on-the-ground management intervention, compliance and enforcement, and communication and education activities and initiatives. The Department of Defence also allocates funding for special projects, such as a project to protect Bundera Sinkhole.

WESTERN AUSTRALIAN GOVERNMENT FUNDING

The management of the Ningaloo Coast is funded primarily by the Western Australian Government, which expends approximately AU$5 million on the management of the whole property.[29] The budget provides funds for staff and offices in the region, the preparation and implementation of management plans, and actions related to education, compliance, maintenance, monitoring, research, nature conservation and visitor services, as well as development control and implementation of the *Ningaloo Coast Regional Strategy Carnarvon to Exmouth*. In addition to the annual budget, one-off capital funding is allocated annually for specific projects. For example, funding was allocated to DEC in 2007–2008 to contribute to specific projects including a hybrid solar power station in Cape Range National Park, a goat control program and a regional turtle conservation project. A further amount of approximately AU$700,000 is allocated annually by the Western Australian Government for domestic and international tourism promotion of the area by the regional tourism organisation, and to contribute to the Ningaloo Whale Shark Festival held biannually in Exmouth.

FIGURE 5.16 All entry fees collected at Cape Range National Park go towards the management of the Ningaloo Coast. Photographs © BJK Ben Knapinski

Revenue raised from visitors contributes to protecting and managing the property. As part of the *Whale Shark Interaction Management with Particular Reference to Ningaloo Marine Park: Western Australian Wildlife Management Program No. 27* run by DEC, passengers on whale shark interaction tours pay a whale shark levy. Licensed commercial whale shark tour operators collect the fee on behalf of the department. Annual revenue collected by DEC from whale shark operators within the property is approximately AU$110,000, which is used for whale shark management and research. As revenue raised cannot cover the entire cost of management and research, partnerships with industry, research institutions, not-for-profit organisations and community groups support the implementation of the whale shark management program.[30]

Local government, landowner and leasehold funding

Funding is also provided for management by the Shire of Exmouth of Jurabi Coastal Park, Bundegi Coastal Park and Muiron Islands, and for road maintenance. The Lighthouse Caravan Park, pastoral stations and other leaseholders within the nominated property provide funds for management for areas under their remit.

Collaborative research funding

The Ningaloo Research Program brings together an estimated AU$30.5 million over five years for research activities associated with the Ningaloo Coast that are conducted through DEC, Western Australian Marine Science Institution, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Wealth from Oceans Flagship—Ningaloo Collaboration Cluster, the Australian Institute of Marine Science, various universities, the Western Australian Museum and the Cooperative Research Centre for Sustainable Tourism.

FIGURE 5.17 Revenue collected by DEC from whale shark tour operators supports whale shark management and research. Photograph © Cam Skirving

FIGURE 5.18 An estimated AU$30.5 million dollars is being spent on research at the Ningaloo Coast, including tracking of whale sharks. Photograph Tony Howard © Western Australian Department of Environment and Conservation

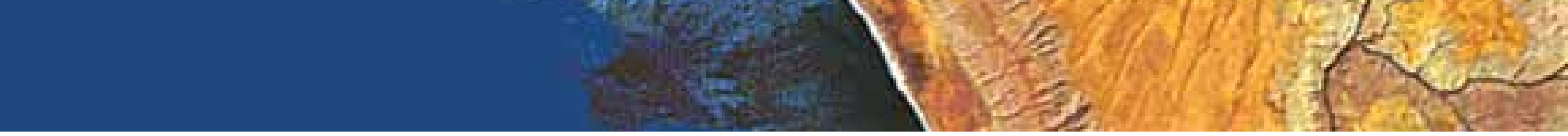
5.G SOURCES OF EXPERTISE AND TRAINING IN CONSERVATION AND MANAGEMENT TECHNIQUES

Managers of Australian heritage sites can draw on specialist advice from a large pool of professional services within government departments and private practice. As the agency responsible for managing most of land and water assets within the nomination area, DEC has a wealth of expertise and experience in conservation and management from on-ground staff through to specialists.

Staff in the local Exmouth office of DEC include specialists in nature conservation, marine management and monitoring, business planning, visitor services and interpretation and community education, as well as operations and land management. The local office is supported by a regional office in Karratha and seeks specialist advice as required from the various divisions of DEC in Perth, including specialists in landscape architecture, management planning, community participation, interpretation and education, public affairs, publications, nature conservation, marine science, strategic policy and fire management. Consultants and contractors are engaged as required.

The Coral Coast Park Council includes Indigenous representatives who have expertise in traditional land management and cultural heritage. The Ningaloo Coast Advisory Committee, which will represent local community, recreational and commercial interests, provides feedback on management matters.

The Western Australian Department of Environment and Conservation is a registered training organisation that also supports the ongoing learning and development of staff. Training provided by DEC includes subjects such as conservation and land management; cross cultural awareness; fire management; law enforcement; recreation planning and management; development of guided interpretive experiences and ecotours; volunteer management; 'leave no trace' minimal impact ethics; tactical communication; geographic information systems; occupational safety and health; visitor risk management; flora conservation; fauna management; disease risk management; weed management; leadership; incident management; public participation; customer service; cultural heritage management; licensing and regulation; and pollution response. DEC also supports the ongoing training of volunteers and workers in the tourism industry. For example, in 2007, a whale shark interaction training course was held for whale shark industry members.



‘Dan-joo Dabacaan’—translated as ‘together, steady, steady’—describes the approach of DEC to ensuring that Indigenous people are strongly represented, and involved, in conservation and land management. To achieve a just and equitable Aboriginal employment outcome on conservation lands and waters, DEC developed its award-winning Mentored Aboriginal Training and Employment Scheme. This is a multifaceted employment and training program carried out in conjunction with nongovernment training providers and land management organisations. This approach has seen DEC embark on a 10-year plan to ensure Aboriginal people make up 10–15 per cent of its full-time workforce by 2016. In addition, the Western Australian Department of Environment and Conservation Aboriginal Heritage Unit aims to develop awareness, understanding and support for Aboriginal heritage in Western Australia.

DEWHA provides advice on matters relating to the EPBC Act, including the identification, protection, conservation and promotion of National Heritage and World Heritage properties. DEWHA is also responsible for advising and monitoring the implementation of the World Heritage convention and operational guidelines. The department also provides advice and training to officers employed by DEC and the Department of Fisheries who enforce the EPBC Act on behalf of the Australian Government. The Department of Defence employs officers with heritage and conservation management expertise to contribute to and oversee the management of Learmonth Air Weapons Range.

5.H VISITOR FACILITIES AND STATISTICS

Each year the Ningaloo Coast receives an influx of visitors, mainly between April and October—an estimated 180,000 people stay either within the property itself or in the adjacent towns of Exmouth, Coral Bay and Carnarvon. Around 30 per cent of visitors to the Shire of Exmouth, within which most of the nominated property is located, are from overseas; around 20 per cent come from areas in Australia other than Western Australia; and about 50 per cent of visitors are from within Western Australia.[31] Most visitors to the Ningaloo Coast visit Cape Range National Park at least once, and the park is also popular with locals. The park receives approximately 220,000 visits each year, mainly between April and October.[32] Statistics show that the number of visitors to Cape Range National Park is increasing. Visits to the Park in 2007–2008 numbered nearly two and a half times mid-1990s figures.[33]

The town of Exmouth, which lies outside the nomination boundary, hosts the Ningaloo Whale Shark Festival at the start of the whale shark season. The festival is organised by the community and highlights the community’s relationship with the whale shark. Partnerships between the Western Australian Government, whale shark industry members and community members are a strong feature of the festival. Displays, workshops and exhibits contribute to education and awareness about the need to protect whale sharks and their surrounding environment.

FIGURE 5.19 Self-guided walking trails allow visitors to experience significant areas of the Cape Range National Park, such as Yardie Creek.
Photographs (a) Jacinta Overman © Western Australian Department of Environment and Conservation
(b) Dennis Sarson © Lochman Transparencies

A wide range of tours, activities and facilities are available for visitors. These include: glass-bottom boat tours; self-guided walk trails; dive trips; snorkel tours; safari tours; and interpretive activities during school holidays. Visitor facilities and interpretive information are provided throughout the nominated property, including at Milyering Visitor Centre and Shop, Jurabi Turtle Centre, picnic areas and key interpretive sites. Environmentally friendly toilets at day-use areas and certain campgrounds, and clearly marked car parks and pedestrian paths at popular sites contribute to visitor safety and ensure that visitor impacts are managed at key sites.

Boat launching facilities are available, though only at three key sites within the property. Visitors pay an entry fee to DEC to access Cape Range National Park and are provided with information about the area. Web sites provide visitors with extensive information about the Ningaloo Coast. In addition, visitor information centres in gateways adjacent to the property (such as Exmouth, Carnarvon and Coral Bay) provide information for visitors.

Camping along the Ningaloo Coast is a popular activity for visitors and local residents. Camping nodes have been identified along the Ningaloo Coast to ensure human impacts are managed. Each node has a maximum number of overnight guests, which range from 50 to 500 people, depending on the node classification. Many campgrounds managed by DEC or by pastoral leaseholders are assisted in the peak season by volunteer campground hosts.

FIGURE 5.20 The whale shark's delicate patterning looks like an extension of the ripples on the surface of the glassy waters of the Ningaloo Coast.
Photograph © Cam Skirving

5.1 POLICIES AND PROGRAMS RELATED TO THE PRESENTATION AND PROMOTION OF THE SITE

The Parks and Visitor Services Division of DEC aims 'to provide world-class recreation and tourism opportunities, services and facilities for visitors to the public conservation estate while maintaining in perpetuity Western Australia's natural and cultural heritage'. To deliver this objective, activities are guided by a policy statement and detailed policy guidelines in *Policy Statement No. 18: Recreation, Tourism and Visitor Services*. Strategies to present and promote the Ningaloo Coast are implemented by DEC through a variety of policies and programs including the following:

- Interpretive activities for adults and children are offered in Cape Range National Park and Ningaloo Marine Park during school holidays.
- Interpretive activities for turtle conservation are held at Jurabi Turtle Centre.
- The Ningaloo turtle monitoring program involves the local community and visitors in turtle monitoring during the nesting season. Through their involvement in the program, turtle monitoring volunteers actively learn about threats to turtles and the importance of protecting these species.
- The commercial operations licence system allows commercial operators to conduct tours in Western Australian conservation reserves. Each licensed operator is issued with a *Tour Operator Handbook* which aims to educate and inform operators to help maintain and protect natural and cultural values for the long-term benefit of the Western Australian tourism industry. There are around 156 commercial operations licences currently issued by DEC for the Ningaloo Coast.
- The whale shark interaction training course provides tour guides with hands-on practical training aimed at ensuring the whale shark tourism industry is run in a manner consistent with ecotourism principles. The aims of the course are also to increase the level of education and interpretation provided to people during whale shark tours, and to ensure that impacts of the tourism industry on whale sharks are minimised.[34]
- Whale shark public information talks are held throughout the whale shark season in both Exmouth and Coral Bay and an information brochure, *Experiencing Whale Sharks in Ningaloo Marine Park*, is distributed to the public.[35]
- The turtle tour guide education training course provides participants with the knowledge and practical experience required to work as a tour guide leading beach-based interactive tours with marine turtles. The course aims to educate tour guides in order to minimise the impact of tourism on marine turtles; to ensure that the turtle tourism industry is sustainable; and to help guides provide information and interpretation to people during turtle tours.
- Websites, park notes and brochures provide information on the Ningaloo Coast.

FIGURE 5.21 Interpretive materials are provided onsite for visitors to the Cape Range National Park; in the background, the Yardie Creek boat provides visitors with an in-depth, carefully managed tour of significant aspects of the Cape Range karst system.
Photographs (a) Jacinta Overman © Western Australian Department of Environment and Conservation
(b) Tony Howard © Western Australian Department of Environment and Conservation

FIGURE 5.22 Visitors learn about sea turtles at the open-air Jurabi Turtle Centre.
Photographs Tony Howard © Western Australian Department of Environment and Conservation

Jurabi Turtle Centre

With increasing numbers of visitors to the Ningaloo Coast and a keen interest from people wanting to witness turtle nesting activities, there is a need to ensure visitors do not disturb nesting turtles. To minimise the impact of human disturbance on nesting marine turtles, the Shire of Exmouth, Tourism Western Australia and the Western Australian Department of Environment and Conservation worked together to establish the Jurabi Turtle Centre.

The centre, only 13 kilometres from Exmouth and adjacent to a significant turtle rookery, has been established as an open-air, small-scale educational facility that is open to the public at all times. The centre provides information about turtle biology, behaviour and conservation as well as clear guidelines on how to watch turtles without disturbing them.

During the 2007–2008 turtle nesting season, 24 volunteers, both from the local community and from elsewhere, assisted with the running of the centre. During January to March 2008, regular, supervised, turtle-watching activities were conducted from Jurabi Turtle Centre. On activity nights, community guides educate visitors by guiding turtle watching experiences, explaining turtle watching guidelines to visitors and collecting data on turtle nesting behaviour and visitor experiences.

Milyering Visitor Centre

FIGURE 5.23 The Milyering Visitor Centre provides a focal point for interpretive activities in the Cape Range National Park.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

Milyering Visitor Centre comprises a visitor centre, shop and toilets in Cape Range National Park and is attended by an information officer. The centre is a focal point for visitors to the Ningaloo Coast and is open seven days a week. It offers displays, audiovisual presentations, a small reference library, information brochures and interpretive activities for adults and children during busy periods.

The centre promotes the wide range of interpretive and other activities that are provided across the nominated property. The building itself incorporates energy efficient design and materials, and is powered by a hybrid solar power station.

Ningaloo Marine Park also forms the beginning of the Warlu Way, a 2480-kilometre self-drive journey through the Gascoyne, Pilbara and Kimberley regions of Western Australia. The journey follows the warlu, a giant Dreamtime serpent, taking the visitor back in time when the warlu emerged from the sea and travelled through the red lands of Western Australia, forming rivers and pools along the way.

The Warlu Way drive trail was established to promote and invite visitors to experience north-western Australia, to provide a focus for communities, towns and individuals to celebrate their culture and their landscape, and to engage in tourism opportunities. The concept was developed in partnership with DEC, Tourism Western Australia and Australia's North West Tourism. It now forms a major component of the tourism marketing efforts of this region.

5.J STAFFING LEVELS

A range of professional, technical, operational and maintenance, and administration staff are employed at the Ningaloo Coast on a permanent basis and on temporary contracts. A number of specialist support staff for the Ningaloo Coast are employed in Perth on a permanent or temporary basis. Staff are also employed by the Australian Government in Canberra to manage the Ningaloo Marine Park (Commonwealth Waters) and to oversee the strategic management of Australian National and World Heritage-listed sites.

A Department of Defence ranger based in Exmouth is responsible for the day-to-day management of the Learmonth Air Weapons Range, with assistance from other local Defence officers when necessary. Perth and Canberra-based staff provide additional support and specialist advice.

In addition, each year approximately 150 registered volunteers work on projects at the Ningaloo Coast, collectively contributing more than 42,000 hours.[36]

	NUMBER OF STAFF IN OCCUPATIONAL CATEGORY				TOTAL NUMBER OF STAFF
	OPERATIONS	PROFESSIONAL AND TECHNICAL	CUSTOMER SERVICE	ADMINISTRATION	
Australian Government*	2	0	0	0	2
Western Australian Government**	17	16	9	5	47
TOTAL	**18**	**16**	**9**	**5**	**48**

TABLE 5.6 Staffing and occupational categories

* In addition to the dedicated staff in the Ningaloo Coast area, additional support is provided as required by Australian Government officers.

** In addition to the dedicated staff in the Ningaloo Coast area, additional support is provided as required by specialists in regional and head offices; these staff are not included here.

Ningaloo Coast volunteers

FIGURE 5.24 Volunteers care for injured birds such as this Little eagle (*Hieraaetus morphnoides*).
Photograph Tristan Simpson © Western Australian Department of Environment and Conservation

Volunteers come from around Australia and the world to contribute to the conservation of the special heritage values of the Ningaloo Coast. The Western Australian Department of Environment and Conservation (DEC) works with many volunteers, including local residents and international tourists, who assist with conservation work. The Cape Conservation Group (based in Exmouth) contributes volunteer hours to monitoring activities of marine turtles, birds, bats and rock wallabies. The local wildlife care group rehabilitates sick or injured wildlife, including wallaroos, red kangaroos and birds.

During the tourist season volunteers take part in the DEC campground host program. During the 2008 season, 32 registered campground hosts volunteered in Cape Range National Park. Hosts meet and greet visitors, allocate campsites, keep the campground clean and tidy and provide information to visitors on Cape Range National Park, Ningaloo Marine Park and on regulations to protect the natural environment.

Bush Rangers visit the Ningaloo Coast once a year. The DEC Bush Rangers program involves school children learning about conservation and gives them the opportunity to carry out conservation works in protected areas. In 2008, 22 Bush Rangers collected rubbish that had spread during a cyclone-related flood, and helped install bollards and a drip line around a car park to help protect vegetation.

Conservation Volunteers Australia, a nongovernment organisation, also visits the Ningaloo Coast twice a year. During 2008, 13 volunteers placed bush matting along sand dunes to stop erosion, collected rubbish, and installed bollards and drip lines to help protect vegetation.

(ENDNOTES)

1 These Acts apply on lands and waters depending on the presence or absence of heritage listed places, Aboriginal heritage, and water to which the Rights in Water and Irrigation Act (WA) applies.

2 The Western Australian Department of Environment and Conservation has certain responsibilities under the Conservation and Land Management Act 1984 (WA) in accordance with a memorandum of understanding with the former Department for Planning and Infrastructure.

3 The process to create reserves for the proposed conservation and recreation areas is expected to commence following the expiry of pastoral leases in 2015. Following the creation of reserves, the provisions of the Conservation and Land Management Act 1984 (WA) are expected to apply to the reserved area. Some areas may be placed into the conservation reserve system earlier than 2015. If this occurs, the Conservation and Land Management Act 1984 may apply to some areas earlier than 2015.

4 This may apply to waters that are not within the limits of the State, which are on the landward side of waters adjacent to the State, or that are within the Australian fishing zone, in accordance with relevant Commonwealth law(s).

5 Australian Heritage Database (www.environment.gov.au/heritage/ahdb).

6 WAPC 2004b.

7 If the Minister gives approval to a proposal, s/he can set conditions with agreement from any other Minister relevant to the proposal.

8 Fisher 2003.

9 Rights in Water and Irrigation Act 1914 (WA), s 4(1).

10 CALM & DPI 2004; Government of Western Australia 2006

11 Shire of Exmouth & Department of Conservation and Land Management 1999.

12 Environment Australia 2002a; CALM 2005a; CALM 2005b.

13 Water and Rivers Commission 1999.

14 Section 179(5) of the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 defines a vulnerable species as a native species which, at that particular time is not found to be critically endangered or endangered, and is facing a high risk of extinction in the wild in the medium term future.

15 Policy Statement No. 44 Wildlife Management Programs aims to conserve and manage threatened, specially protected, or harvested taxa of flora and fauna and their habitats, threatened ecological communities and other taxa in need of intensive management by the preparation and implementation of written wildlife management programs. Policy Statement No. 50 Setting Priorities for the Conservation of Western Australia's Threatened Flora and Fauna aims to ensure that conservation reserves are allocated on a priority basis to the most threatened taxa of plants and animals.

16 CALM 1997.

17 In Western Australia, the dugong is protected under a Wildlife Conservation (Specially Protected Fauna) Notice 2008(2). In Australia, the dugong is protected as a migratory species under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999.

18 Environment Australia 2003.

19 Department of Environment and Heritage 2005.

20 The species is listed in Appendix II in both of the conventions.

21 Environment Australia 2002b.

22 Wilson et al. 2007.

23 DEWHA 2009.

24 http://austlii.law.uts.edu.au/au/legis/cth/consol_reg/epabcr2000697/

25 Shire of Exmouth 1999.

26 CALM 2005b; CALM 1987.

27 Teale et al. 2002.

28 CALM and DPI 2004.

29 The figure for annual expenditure includes approximately AU$1 million of revenue received by the Western Australian Department of Environment and Conservation through national park entry fees, the Yardie Creek Boat Tour, Milyering Visitor Centre and revenue from whale shark tours.

30 Mau 2008.

31 Visitors to the Shire of Exmouth averaged 96,700 per annum over the period 2005–2007. Tourism Western Australia (2008) Local Government Area Fact: Sheet Shire of Exmouth 2007, Government of Western Australia (www.tourism.wa.gov.au). Additionally, small numbers of tourists also visit areas in the lower end of the nominated property, which are located in the Shire of Carnarvon.

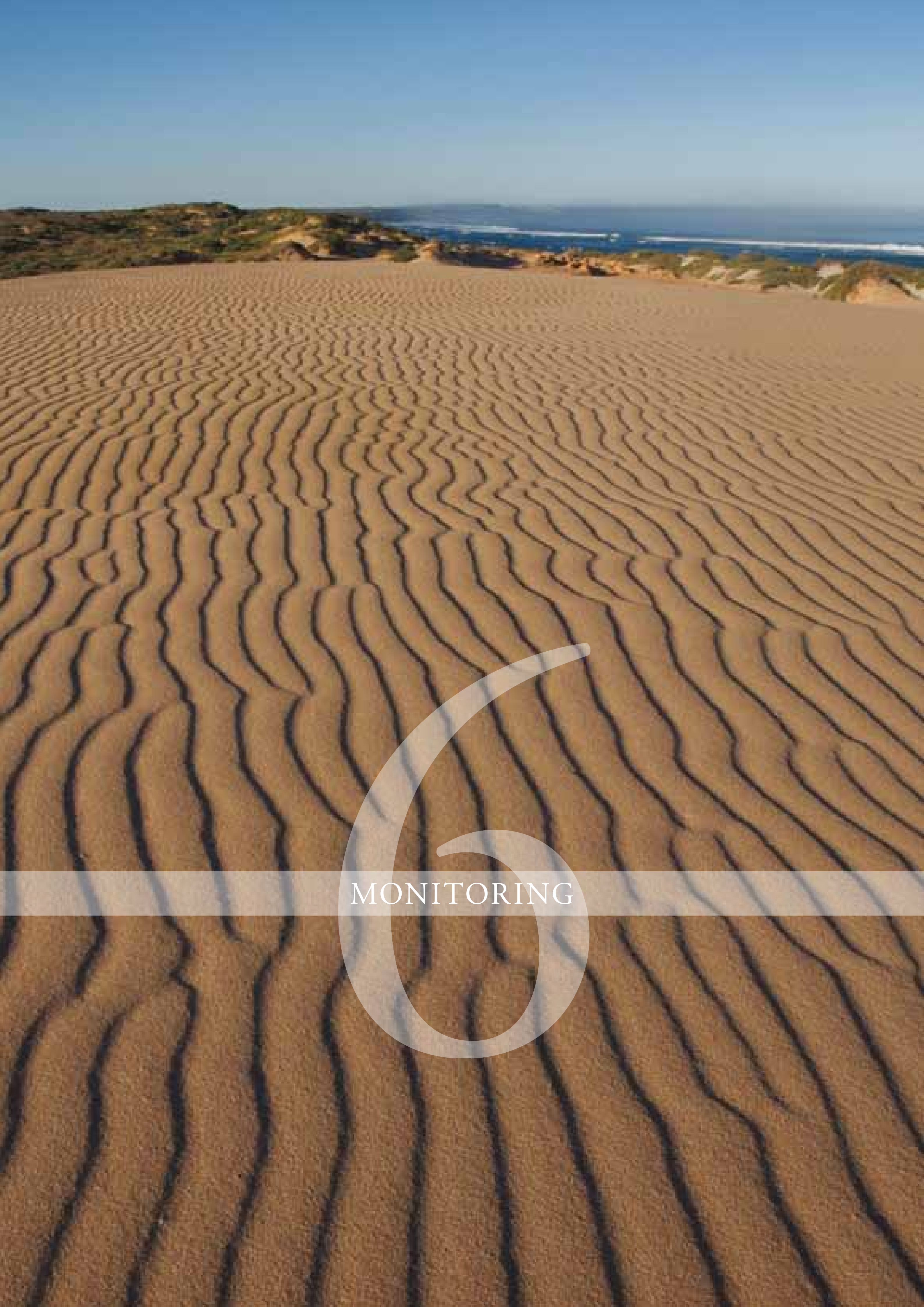
32 Western Australian Department of Environment and Conservation Visitor Information and Statistics (VISTAT) corporate database.

33 VISTAT shows that 91,000 people visited Cape Range National Park in 1994–1995 and shows an overall trend of increasing visitation with 224,520 visitors recorded for Cape Range National Park in 2007–2008.

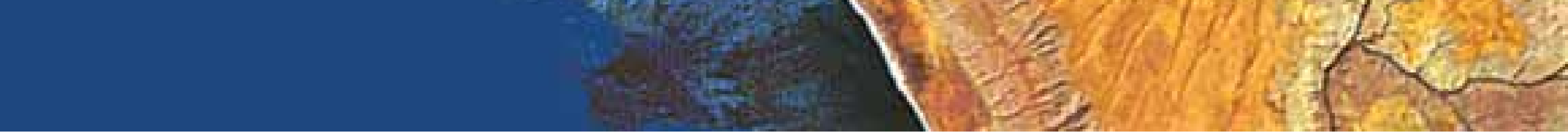
34 Wilson et al. 2007.

35 Wilson et al. 2007.

36 As recorded by the Western Australian Department of Environment and Conservation Community Involvement Unit.



6 MONITORING



6. MONITORING

The Ningaloo Coast has a comprehensive monitoring regime in place to measure the state of conservation of the landscape and environment. Monitoring measures have been in place for Ningaloo Marine Park (State and Commonwealth Waters) and Cape Range National Park since the late 1980s. The key performance indicators for Ningaloo Marine Park (State Waters) and Cape Range National Park are detailed in Section 6.A. Records for the indicators are located with the Western Australian Department of Environment and Conservation (DEC) (see Section 6.B).

The Ningaloo Research Program, discussed in Section 6.C, ensures that government decisions are based on sound scientific information. The program aims to improve the understanding of ecological resources within Ningaloo Marine Park, the processes that support them, and the effectiveness of monitoring programs and management strategies. The program undertakes and analyses marine-based research to ensure the preservation of the outstanding natural values. In addition, a number of research programs focus on the terrestrial ecosystems of the nominated property. DEC manages these programs and coordinates research to ensure that findings and outcomes are recognised, integrated and used in decision making. The wealth of research and monitoring currently underway is outlined in *Current Marine Research in Ningaloo Marine Park 2007.*[1]

FIGURE 6.1 Researchers from the Australian Institute of Marine Science tag reef sharks at the Ningaloo Coast—tracking the movements of the sharks will help to determine the long-term patterns of habitat use and dispersal.
Photographs © Conrad Speed

PREVIOUS PAGE Photograph © Brett Calcott

6.A KEY INDICATORS FOR MEASURING STATE OF CONSERVATION

Key performance indicators and management strategies in the management plans are used by DEC to protect Ningaloo Marine Park (State Waters) and Cape Range National Park. The performance indicators reflect priorities for research and monitoring, and contribute to DEC's adaptive management of the area. Under the *Conservation and Land Management Act 1984*, the Conservation Commission of Western Australia and the Marine Parks and Reserves Authority have responsibilities for assessing and auditing DEC's performance in implementing the management plans. Research and monitoring that is undertaken on the marine environment is summarised in the Ningaloo Marine Park research and monitoring plan. Management plans for other parts of the nominated property also specify monitoring indicators and measures.

FIGURE 6.2 Christmas tree worms at Ningaloo Marine Park
Photograph © Tourism WA

KEY INDICATORS	PERIODICITY
MARINE	
Water quality • No change in water quality of the Ningaloo Marine Park waters from 'background' levels as a result of human activities [2]	3 years
Coral reef communities • No loss of coral communities as a result of human activity • No loss of living coral biomass as a result of human activity	3 years
Mangrove communities, including mudflats • No loss of mangrove community diversity as a result of human activity • No loss of mangrove biomass as a result of human activity	3 years
Coastal biological communities • No further loss of coastal biological community diversity as a result of human activity • No further loss of coastal biological community biomass as a result of human activity (apart from development approved by an appropriate authority)	3 years
Benthic communities • No loss of benthic communities as a result of human activity	3 years
Marine fauna • No loss of marine fauna diversity as a result of human activity • No loss of protected species abundance as a result of human activities • Abundance and size composition of finfish species in sanctuary zones and conservation areas to be at natural levels • No loss of whale sharks as a result of human activities	3 years

TABLE 6.1 Key indicators for measuring the state of conservation

KEY INDICATORS	PERIODICITY
Turtles	
• No loss of turtle diversity as a result of human activity • No loss of turtle abundance as a result of human activity	3 years
Seascapes	
• Maintenance of aesthetic values of designated seascapes	3 years
Wilderness	
• To designate wilderness areas and develop guidelines for the maintenance of the heritage values within 3 years • Maintenance of aesthetic values of designated wilderness areas in the reserves	3 years
TERRESTRIAL	
Geoheritage	
• No significant reduction of the geoheritage conservation and scientific values (excluding natural processes)	5 years
Karst system	
• No significant adverse change to the karst hydrology, including groundwater quality, quantity, anchialine stratigraphy and hydrological regimes (excluding natural seasonal or other cyclic variations)	3 years
Flora	
• No significant decrease in known level of diversity and condition of native plant communities	3 years
• No decrease in the cover and condition of threatened, priority or otherwise significant flora species or communities (e.g. disjunct, range end, locally restricted)	5 years or as per recovery plans
Fauna	
• No loss of known diversity of native fauna species and habitat	5 years
• Population numbers and range of specially protected fauna species, threatened ecological communities remain stable or increase (subject to natural variations)	5 years
• No significant visitor-related impacts on turtles, nesting birds sensitive to disturbance and rock wallabies	3 years
• Decrease in known level of predation on nesting turtles	3 years
Weeds	
• Decrease in the cover of environmental weed species rated as high priority	3 years
Pest and problem animals	
• Decrease in the area significantly impacted by goats	5 years

TABLE 6.1 Key indicators for measuring the state of conservation (continued)

In addition to the indicators for monitoring natural values (Table 6.1), monitoring of human behaviour is also given a high priority by managing agencies. A number of strategies are in place to monitor human activities on the Ningaloo Coast, including aerial surveys recording visitor locations and activities, and patrol logbooks recording observations and compliance actions. In addition, an extensive research project is underway to develop a baseline dataset on human activities focused on the lagoon and coast of Ningaloo Marine Park. The researchers are mapping results along 300 kilometres of coastline. The data are expected to provide an important baseline to inform management approaches, including the location of appropriate coastal infrastructure and conservation of marine biodiversity.[3]

In terms of community input, DEC coordinates the Coral Coast Park Council and the Coral Coast Parks Advisory Committee, which enable community members to discuss and advise on management issues. These forums capture public knowledge, attitudes and expectations, and support DEC's aim for community involvement in management of conservation reserves. Visitors also have the opportunity to have input into management through visitor feedback forms available at Milyering Visitor Centre in Cape Range National Park. Visitor feedback forms provide data on visitor satisfaction, as well as reasons for visiting, details on activities visitors undertook while visiting and suggestions for improved management.

FIGURE 6.3 The historic lighthouse at Cape Range is an attraction for sightseers. Human activities at the Ningaloo Coast are carefully monitored to help improve management and education of visitors.
Photograph Lorraine Haslem © Department of the Environment, Water, Heritage and the Arts

FIGURE 6.4 The natural beauty and diversity of the Ningaloo Coast is an attraction for visitors to the region.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

Education is a key part of compliance activities by the Western Australian Government. DEC's Exmouth District Trip Logbook allows staff to record information about vehicles, camping, boating, and recreational and commercial activities. It is also designed to capture information about the efforts to manage human behaviour and increase public awareness of marine sanctuary zones. Information is recorded on visitor contact with staff, verbal warnings, written cautions and infringements, which provides an indication of high-use areas and any areas where illegal activities keep occurring. This allows agencies to adapt and target education, surveillance and enforcement effort to where it is needed.

6.B ADMINISTRATIVE ARRANGEMENTS FOR MONITORING PROPERTY

A number of Australian Government and Western Australian Government agencies have responsibility for monitoring and coordinating information about the Ningaloo Coast. Names and contact information are shown in Table 6.2.

MONITORING AGENCY AND CONTACT DETAILS	NINGALOO MARINE PARK (COMMONWEALTH WATERS)	NINGALOO MARINE PARK (STATE WATERS)	MUIRON ISLANDS MARINE MANAGEMENT AREA	CAPE RANGE NATIONAL PARK	MUIRON ISLANDS AND BUNDEGI AND JURABI COASTAL PARKS	WESTERN AUSTRALIAN UNALLOCATED CROWN LAND	PROPOSED CONSERVATION AND RECREATION AREAS AND PASTORAL LEASES	LEARMONTH AIR WEAPONS RANGE FACILITY
Department of the Environment, Water, Heritage and the Arts Assistant Secretary Tropical Marine Conservation Branch GPO Box 787 Canberra ACT 2601 Tel: +61 2 6274 1111	✓							
Department of Environment and Conservation Mr Arvid Hogstrom District Manager PO Box 201 Exmouth WA 6707 Australia Tel: +61 8 9947 8000 Email: arvid.hogstrom@dec.wa.gov.au		✓	✓	✓	✓	✓	✓	✓
Kelly Waples Science Coordinator Locked Bag 104 Bentley Delivery Centre WA 6983 Tel: +61 8 9219 9796 Email: kelly.waples@dec.wa.gov.au		✓						
Department of Defence Mr Rick Zentelis Director Heritage and Biodiversity Conservation Department of Defence BP3-2-B030 Brindabella Park Canberra ACT 2600 Tel: +612 62668060 Email: rick.zentelis@defence.gov.au. www.defence.gov.au/ environment								✓

TABLE 6.2 Administrative arrangements

6.C RESULTS OF PREVIOUS REPORTING EXERCISES

A wide range of reports have been produced on the state of conservation of the nominated property. This includes major reports on keystone marine and terrestrial species (i.e. whale sharks, turtles, and black-footed rock wallabies, as well as subterranean fauna communities and reef ecology). Management strategies have been informed by these reports as part of the adaptive management cycle, and a number of examples are provided in the following subsections.

STATE OF THE ENVIRONMENT REPORT

A state of the environment report is required every five years under the *Environment Protection and Biodiversity Conservation Act 1999*. It is compiled by the Australian Government, with contributions by the Western Australian Government, and other state and territory governments. An independent committee oversees the preparation and determines the findings of the report.

The main report and associated products seek to assess the 'state of the environment' in terms of its current condition, the pressures on it, the drivers of these pressures and the impact of societal responses to environmental concerns, including major factors affecting the sustainability of Australia's natural heritage. Topics of particular relevance to the Ningaloo Coast include biodiversity, implementation of a system of marine conservation reserves, degradation of marine habitats, contamination of the marine environment and the impact of tourism, fisheries and mining industries. The report is an important monitoring mechanism and contributes to policy development and improved conservation measures.

NINGALOO RESEARCH PROGRAM

Established in 2005, the Ningaloo Research Program is an integrated program of research into biodiversity, species distribution and human-use patterns within Ningaloo Marine Park.[4] The program brings together Ningaloo Coast-related research activities being conducted through state government departments; the Western Australian Marine Science Institution; the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Wealth from Oceans Flagship—Ningaloo Collaboration Cluster; Australian Institute of Marine Sciences; Western Australian universities; and industry.

The Ningaloo Research Coordinating Committee oversees the research program by coordinating and integrating the research, and establishing linkages between researchers, managers and the broader community. DEC manages programs and coordinates research to ensure that findings and outcomes are recognised and used in decision making. A wide range of monitoring and research projects document important findings on the state of conservation of marine flora and fauna within the nominated property. Research reports address pressures on outstanding heritage values and may make recommendations for the relevant state and national governments.

A key part of the research program is the establishment of comprehensive baseline data, which will enable ongoing monitoring of visitor impacts, climate change, and other pressures on ecosystems and habitats. For example, several benthic surveys have been conducted in the Commonwealth waters of Ningaloo Marine Park. The surveys indicated that the benthic community in the Commonwealth waters is dominated by soft corals such as gorgonians; along with sponges. Fish diversity has been found to be the greatest in areas with the highest density of sponge and octocorals. A further survey in the deeper waters of the Ningaloo Marine Park is currently underway and a range of additional research programs target specific marine species. The wealth of research and monitoring currently underway is outlined in *Discovering Ningaloo: Latest Findings and Implications for Management*.[5]

FIGURE 6.5 Western Australian Department of Environment and Conservation workers carry out a number of monitoring programs in Ningaloo Marine Park.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

The Ningaloo Research Program is producing a vast quantity of science that will answer management questions and fill knowledge gaps to support sound management decisions.[6] Information about ecological processes and the impact of increased recreational use and tourism on Ningaloo Marine Park and adjacent areas will ensure that decisions about long-term management are based on sound scientific information. The program ensures that a framework exists for knowledge to be transferred between scientists and managers.[7] For example, surveys are being completed on the distribution and diversity of sharks, rays and key fish species. The findings help to assess the effectiveness of sanctuary zones within the park, and provide baseline data necessary for ongoing adaptive management.[8] Outcomes of all research will inform the next review of management of the park, including the zoning scheme (described under the *Conservation and Land Management Act 1984* section in Part 5). In addition, research results will continue to feed into the adaptive management cycle for the park and provide a better understanding of natural values and how best to manage them effectively.

REPORTS ON REEF ECOLOGY

A number of recent reports have focused on the health and diversity of reefs, particularly in relation to potential climate change impacts. The Global Coral Reef Monitoring Network report, *Status of Coral Reefs of the World: 2008* describes best practice management of the Great Barrier Reef and the Western Australian reefs; acknowledges the high degree of biological diversity of Australian reefs; and notes that human pressures on these reefs are lower than in other parts of the world.[9] The report outlines the importance of effective monitoring and management to ensure the conservation of reef ecosystems.[10]

Examples of important scientific monitoring programs for maintaining the health of Ningaloo Reef include the Ningaloo Marine Park *Drupella* long-term monitoring program to address the spread of the coral-eating snail, *Drupella cornus*,[11] and the Coral Bay reef recovery study. This study aims to determine the conditions that offer resilience from environmental disturbances and human activities.[12]

REPORTS ON WHALE SHARKS

Monitoring and management of whale sharks has been long established on the Ningaloo Coast under the Western Australian Wildlife Management Program No. 27.[13] Monitoring has provided a basis for management decisions, including the renewal of commercial tour operator licenses and the development of an industry code of conduct. Annual progress reports collate research, provide monitoring information, address management issues and make recommendations on the preservation of the whale shark.[14] DEC facilitates annual pre and post-season whale shark tour operator meetings, which allow tour operators the opportunity to provide feedback regarding management of the whale shark tourism industry. The ECOCEAN Whale Shark PhotoID Library has provided a central database that is readily accessible via the internet and provides links to sightings around the globe (see Part 5).

REPORTS ON TURTLES

The Ningaloo Turtle Program undertakes extensive monitoring of the conservation of turtles. The program comprises four components: the Ningaloo community turtle-monitoring program; the Jurabi Turtle Centre; monitoring expansion and outreach to communities in the region; and collaboration with turtle conservation research programs at the Ningaloo Coast.[15]

The Ningaloo community turtle-monitoring program is a community-based monitoring program designed to promote the long-term survival of turtle populations on the Ningaloo Coast.[16] The program includes the Jurabi Turtle Centre and research at the Ningaloo Coast. The program was originally established through a partnership between DEC, Murdoch University and two conservation groups (WWF Australia and Cape Conservation Group). The program represents a successful ongoing collaboration between government and the community. Throughout the program, data are gathered on successful nesting emergences, false crawls, disturbances, and spatial and temporal distribution of the loggerhead, green and hawksbill turtles. Volunteers spend approximately two to three hours daily collecting data on turtle nesting beaches from December to February each year.

The program provides sound information on the conservation status of turtle nesting on the Ningaloo Coast. It also engages the community and increases awareness and understanding of the need to protect turtles. The threat of disturbance during the nesting season by people seeking a viewing opportunity has been significantly reduced since the program was launched. The Jurabi Turtle Centre promotes turtle conservation to a wide audience. Visitors are taken to viewing areas where their presence causes minimal disturbance to the turtles. The centre provides interpretive information about turtles and appropriate behaviour while observing them. Many tourists have become volunteers and are actively involved in the Ningaloo Turtle Program.

The Ningaloo Turtle Program has monitored nesting marine turtle activities on the Ningaloo Coast since 2001–2002. In 2008, the availability of historical data over eight nesting seasons enabled the monitoring data itself to be analysed. The data were used to provide recommendations for future monitoring and resulted in a recommendation that monitoring effort could be substantially reduced without compromising the accuracy of data collected.[17] As a result, the survey design is being changed for future monitoring, which will allow the Ningaloo Turtle Program to be managed in a more cost-effective manner with the amount of survey days considerably reduced.

Data collected during future seasons of the Ningaloo Turtle Program will be analysed to allow for ongoing evaluation of nesting trends, such as seasonal distribution in nesting, turtle activity peaks, estimates of nest success and estimates of the number of nesting turtles. The first of these comprehensive seasonal summaries was produced in 2008, and the report indicated increasing population trends for green and hawksbill turtles over a six-year period.[18] These annual reports will continue to inform the Ningaloo Turtle Program, as well as the management plan for Ningaloo Marine Park and Muiron Islands Marine Management Area, and allow for adaptive management for the protection of turtles on an ongoing basis.

FIGURE 6.6 Western Australian Department of Environment and Conservation (DEC) staff work with volunteers as part of the Ningaloo Coast community turtle monitoring program
Photographs (a) Grant O'Grady and (b) Laura Kelly © Western Australian Department of Environment and Conservation

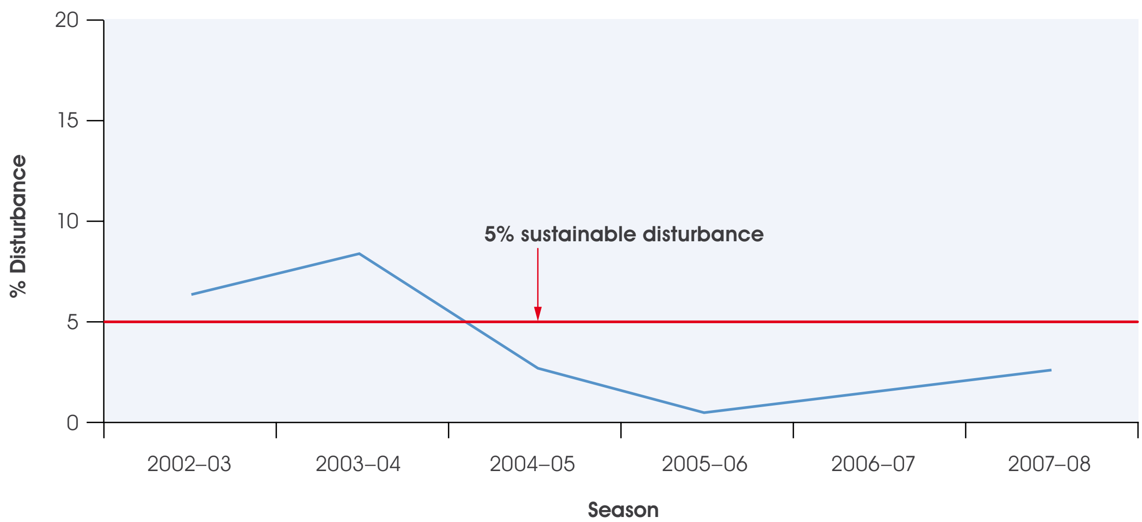


FIGURE 6.7 Monitoring results of marine turtle nesting at the Cape Range peninsula, disturbance sustainability [19]

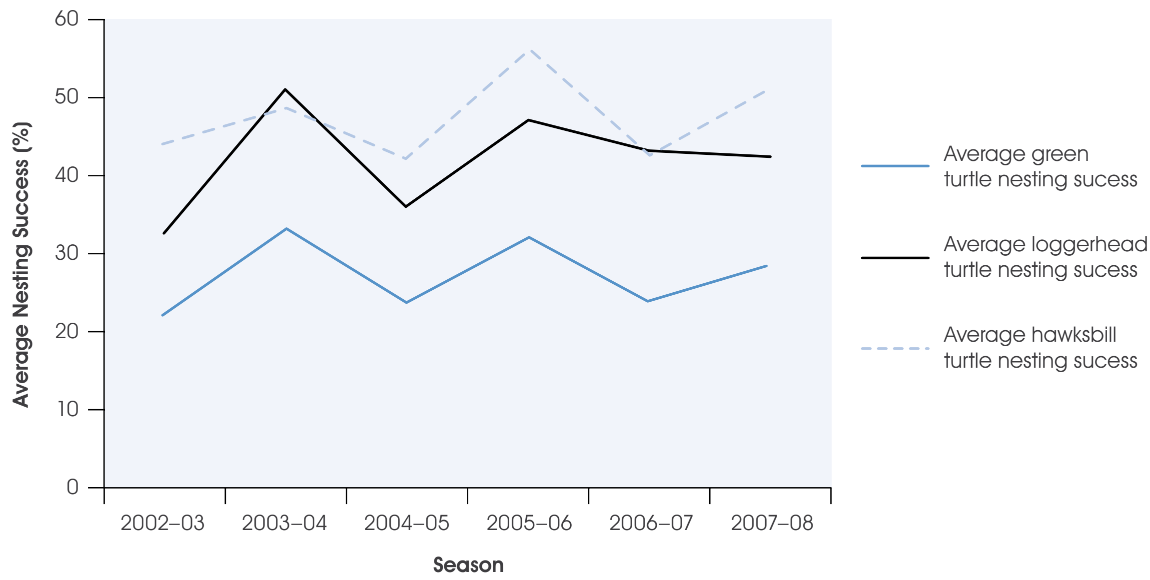


FIGURE 6.8 Monitoring results of marine turtle nesting at the Cape Range peninsula, average nesting success [20]

FERAL FOX CONTROL PROGRAM

The Ningaloo Turtle Program has identified the most significant nesting beaches for turtles on the Ningaloo Coast and was used to inform the implementation of DEC's fox control program.[21]

Foxes are a key threat to the recovery of black-footed rock wallabies (*Petrogale lateralis*) and to turtle populations (because they predate turtle nests). The fox control program has been expanded and is now being implemented at five significant turtle-nesting locations along the Ningaloo Coast. The baiting program uses 1080 poison (sodium monofluroacetate) that is fatal to introduced species. Native species have an adapted tolerance to 1080, as the substance is derived from a native Western Australian plant species. The program has met its target by successfully reducing fox predation of turtle nests to below five per cent of the total nests laid. This rate is considered to have no significant impact on population levels. In some areas, the program has effectively eliminated fox predation. A measure for the success (or otherwise) of baiting for the protection of the black-footed rock wallaby has not yet been established. However, bait use and predation has been recorded.

Harold E. Holt Naval Communication Station VLF towers, North West Cape, Department of Defence land	Bateman Bay, near Coral Bay, adjacent Cardabia Station	Jane's Bay, adjacent Ningaloo Station	Five Mile to Trisel beaches, Jurabi Coastal Park	Bundera Coastal Protection Area and Boat Harbour, Cape Range National Park	Yardie Creek, Cape Range National Park	Cape Range National Park
Ground baiting since 2001–02	Ground baiting since 2002–03	Ground baiting since 2003–04	Ground baiting since 2004–05	Ground baiting since 2005–06	Aerial baiting since 2005–06	Aerial baiting since 1996

TABLE 6.3 History of fox control baiting using 1080 poison implemented by the Western Australian Department of Environment and Conservation at the Ningaloo Coast

SUBTERRANEAN FAUNA REPORTS

Several reports have monitored subterranean fauna in the nominated property. A priority for monitoring subterranean fauna has been Bundera Sinkhole. Ongoing monitoring also measures the impacts of groundwater abstraction on subterranean fauna. This work contributes to the growing body of information on rare subterranean species of troglobites and stygofauna.

Research reports on the rare and diverse subterranean fauna of the Ningaloo Coast have confirmed that the area is one of the world's hotspots for subterranean faunal diversity. More than 80 taxa have been recorded in the Cape Range peninsula. Significant taxonomic work has been completed to identify, name and describe both stygofauna and troglobites.

FERAL GOAT CONTROL PROGRAM

Control of the feral goat (*Capra hircus*) population in the nominated property is essential to maintaining the integrity of the landscape structure and the health of the terrestrial ecosystems, both of which contribute to the outstanding aesthetic and biological value of the Cape Range peninsula. Land degradation caused by the activity of livestock, goats and rabbits may reduce water quality draining into the subterranean system, compromising the underground ecosystems and potentially also the water quality of the reef.

The feral goat control program has been a highly successful nature conservation program and the associated report documents the present state of conservation in relation to this threat.[22] Following monitoring and implementation of the program in 2006, there has been a reduction of 86 per cent of goats observed in the Cape Range peninsula.

DEC has been working with the West Australian Field and Game Association Inc since 1981 on goat culling in Cape Range National Park. Anecdotally, since goat shooting began in 1981, a significant improvement in the vegetation condition at the top of the Cape Range peninsula near Yardie Creek has been observed, with vegetation now covering areas that used to be goat tracks. Black-footed rock wallabies have also been observed recently in the same area.[23] Monitoring of the program in 2007 has shown a reduction of 86 per cent of goats observed in Cape Range National Park and a further 64 per cent reduction in the remaining population in 2008. Following the success of the 2007 and 2008 aerial goat-shooting programs, intensive future shoots will not be undertaken until goat numbers show an observed increase. Opportunistic goat shooting by DEC staff will continue. Future plans include the installation of vegetation-exclusion plots to allow for assessment of vegetation diversity and biomass as a performance criterion.

Goats and good neighbours—business and conservation working together

Goats are a significant feral animal within Cape Range National Park and are widespread throughout the Cape Range peninsula.[24] Without collaboration between neighbours, control of goats presents a near impossible challenge. Hundreds of goats had been observed regularly visiting a water source on Yardie Homestead Caravan Park, north of Cape Range National Park. Caravan park owner, Mr James Roscic, offered to allow the land and water source to be used as a goat-trapping site. Mr Roscic requested that all proceeds from the sale of trapped goats be donated to the local St John Ambulance service.[25] This project aligned with the Western Australian Department of Environment and Conservation's Good Neighbour Policy, which aims to establish and maintain good relations with all its neighbours and work together on land management projects, including feral animal control programs like this one.[26]

(ENDNOTES)

1 Waples 2007.

2 This indicator is specified in the environmental quality management framework in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

3 Beckley 2009.

4 Waples & Hollander 2008.

5 Waples & Hollander 2008.

6 Simpson 2009.

7 Waples & Simpson 2009.

8 Babcock 2009.

9 Wilkinson 2008, pp. 7–8, p. 17.

10 Chin 2008, pp. 159–176.

11 Chin 2008, p. 168; Armstrong 2008, pp. 26–27.

12 Armstrong 2008, pp. 28–30.

13 CALM 1997.

14 Wilson 2007.

15 Ningaloo Turtle Program 2009.

16 Markovina 2008.

17 Whiting 2008.

18 Whiting 2009.

19 Markovina 2008.

20 Markovina 2008.

21 DEC 2007a.

22 DEC 2007b.

23 Carson 2009.

24 CALM 2005b.

25 DEC 2007b.

26 DEC 2007e.

7 DOCUMENTATION

7

7.A PHOTOGRAPHS, SLIDES, IMAGE INVENTORY AND AUTHORISATION TABLE AND OTHER AUDIO VISUAL MATERIAL

ID. NO.	FORMAT	CAPTION	DATE TAKEN (MO/YR)	PHOTO-GRAPHER / DIRECTOR	COPYRIGHT OWNER	CONTACT DETAILS OF COPYRIGHT OWNER	NON-EXCLUSIVE CESSION OF RIGHTS
1	JPEG	Hikers at Charles Knife Gorge in the Cape Range National Park	n/a		Tourism WA	**Peter Carwardine** Image, Video and Production Coordinator, Tourism WA Level 9, 2 Mill Street, Perth WA 6000 GPO Box X2261, Perth WA 6847 Tel: 08 9262 1818 Fax: 08 9262 1735	Yes
2	JPEG	Swimming with whale sharks at Ningaloo Reef	n/a		Tourism WA	**Peter Carwardine** Image, Video and Production Coordinator, Tourism WA Level 9, 2 Mill Street, Perth WA 6000 GPO Box X2261, Perth WA 6847 Tel: 08 9262 1818 Fax: 08 9262 1735	Yes
3	JPEG	Nudibranch	n/a	Sasha Unger	Sasha Unger	**Sascha Unger** aabz-imaging PO Box 899, Exmouth, WA 6707, Australia Tel: +61 (0)439 976912 Email: s_unger@aabz-imaging.com	Yes
4	TIFF	Remipede	n/a	Danny Tang	Danny Tang	**Danny Tang** Laboratory of Aquaculture, Department of Bioresource Science, Graduate School of Biosphere Science, Hiroshima University, 1-4-4 Kagamiyama, Higashi-Hiroshima 739-8528 Japan Tel: +81-82-424-7989 Email: copepods@graduate.uwa.edu.au	Yes
5	JPEG	Fossilised coral at Cape Range	2008	Tony Howard	Western Australian Department of Environment and Conservation	**Tony Howard** District Interpretation Education Officer Western Australian Department of Environment and Conservation Tel: (08) 9947 8023 Fax: (08) 9947 8050 Email: tony.howard@dec.wa.gov.au	Yes

PREVIOUS PAGE Photograph Geoff Taylor © Lochman Transparencies

7.A PHOTOGRAPHS, SLIDES, IMAGE INVENTORY AND AUTHORISATION TABLE AND OTHER AUDIO VISUAL MATERIAL (continued)

ID. NO.	FORMAT	CAPTION	DATE TAKEN (MO/YR)	PHOTO-GRAPHER / DIRECTOR	COPYRIGHT OWNER	CONTACT DETAILS OF COPYRIGHT OWNER	NON-EXCLUSIVE CESSION OF RIGHTS
6	JPEG	Aerial view of Yardie Creek	2008	Tony Howard	Western Australian Department of Environment and Conservation	**Tony Howard** District Interpretation Education Officer Western Australian Department of Environment and Conservation Tel: (08) 9947 8023 Fax: (08) 9947 8050 Email: tony.howard@dec.wa.gov.au	Yes
7	JPEG	Aerial view of Ningaloo Reef	2008	Tony Howard	Western Australian Department of Environment and Conservation	**Tony Howard** District Interpretation Education Officer Western Australian Department of Environment and Conservation Tel: (08) 9947 8023 Fax: (08) 9947 8050 Email: tony.howard@dec.wa.gov.au	Yes

FIGURE 7.1 The crystal clear waters of the Ningaloo Coast.
Photograph Tony Howard © Western Australian Department of Environment and Conservation

7.B TEXTS RELATING TO PROTECTIVE DESIGNATION, COPIES OF PROPERTY MANAGEMENT PLANS OR DOCUMENTED MANAGEMENT SYSTEMS AND EXTRACTS OF OTHER PLANS RELEVANT TO THE PROPERTY

LEGISLATION

Australian Government legislation

Environment Protection and Biodiversity Conservation Act 1999

Defence Act 1903

Government of Western Australia legislation

Conservation and Land Management Act 1984

Environmental Protection Act 1986

Wildlife Conservation Act 1950

Planning and Development Act 2005

Land Administration Act 1997

Western Australian Marine Act 1982

Fish Resources Management Act 1994

Rights in Water and Irrigation Act 1914

Country Areas Water Supply Act 1947

Local Government Act 1995

MANAGEMENT PLANS

Management plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area (2005–2015)

Jurabi and Bundegi Coastal Parks and Muiron Islands Management Plan (1999–2009)

Ningaloo Marine Park (Commonwealth Waters) Visitor Services Plan (2009)

Cape Range National Park Management Plan (1987–1997)

Cape Range National Park Management Plan (published draft 2005, under review 2009)

Management Framework for Ningaloo Coast Unallocated Western Australian Crown Land (in preparation, 2009)

SPECIES-SPECIFIC CONSERVATION PLANS

Cape Range Remipede Community (Bundera Sinkhole) and Cape Range Remipede Interim Recovery Plan (2000–2003)

Whale shark interaction management Ningaloo Marine Park wildlife management program no 27

Dugong (Dugong dugon) Management Plan for Western Australia 2007–2016

Recovery Plan for Marine Turtles in Australia (2003)

Whale shark (Rhincodon typus) recovery plan (2005–2010)

Great white shark (Carcharodon carcharias) recovery plan (2002)

OTHER RELEVANT DOCUMENTS

Ningaloo Coast Regional Strategy Carnarvon to Exmouth (2004)

Exmouth Water Reserve water source protection plan (2000)

Review of the Ningaloo Coast Management Plan against National and International requirements for the protection of potential World and National Heritage values

Whale Shark Interaction Management Ningaloo Marine Park Progress Report: 2007 Whale Shark Season

7.C FORM AND DATE OF MOST RECENT RECORDS OR INVENTORY OF PROPERTY

The management plans listed above and detailed in Section 5 outline the most recent records and inventory of the property.

7.D ADDRESSES WHERE INVENTORY, RECORDS AND ARCHIVES ARE HELD

Australian Government
Department of the Environment, Water, Heritage and the Arts
GPO Box 787
Canberra
ACT 2601

Government of Western Australia
Department of Environment and Conservation
Locked Bag 104
Bentley Delivery Centre
WESTERN AUSTRALIA 6983

FIGURE 7.2 The technicolour shock of a nudibranch
Photograph Axel Passeck © Western Australian Department of Environment and Conservation

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Western Australian Government
Department of Environment and Conservation
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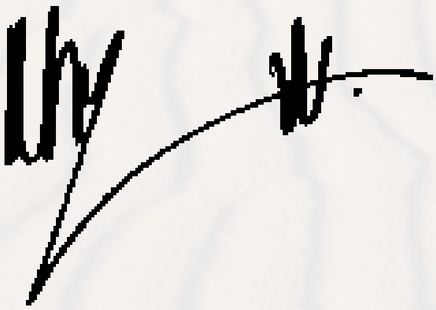

The Hon. Peter Garrett AM MP
Minister for the Environment, Heritage and the Arts
January 2010

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APPENDICES

A

PROTECTED SPECIES LIST

COMMON NAME	SCIENTIFIC NAME	BILATERAL MIGRATORY BIRD AGREEMENTS	IUCN RED LIST	BONN CONVENTION	EPBC ACT
MARINE					
Minke Whale	*Balaenoptera acutorostrata*	n/a	Least concern		
Common Dolphin	*Delphinus delphis*	n/a	Least concern		
Risso's Dolphin	*Grampus griseus*	n/a	Least concern		
Pygmy Sperm Whale	*Kogia breviceps*	n/a	Data deficient		
Pygmy Killer Whale	*Feresa attenuata*	n/a	Data deficient		
Short Finned Pilot Whale	*Globicephala macrorhynchus*	n/a	Data deficient		
Sei Whale	*Balaenoptera borealis*	n/a	Endangered		Vulnerable
Blue Whale	*Balaenoptera musculus*	n/a	Endangered	Appendix 1	Endangered
Manta Ray	Manta birostris	n/a	Near Threatened		
Bryde's Whale	*Balaenoptera edeni*	n/a	Data deficeint		
Black–tip Reef Shark	*Carcharhinus melanopterus*	n/a	Lower Risk/near threatened		
Grey Reef Shark	*Carcharhinus amblyrhynchos*	n/a	Lower Risk/near threatened		
Fin Whale	*Balaenoptera physalus*	n/a	Endangered		Vulnerable
Loggerhead Turtle	*Caretta caretta*	n/a	Endangered	Appendix 1	Endangered
Green Turtle	*Chelonia mydas*	n/a	Endangered	Appendix 1	Vulnerable
Leatherback Turtle	*Dermochelys coriacea*	n/a	Critically Endangered		Endangered
Dugong	*Dugong dugon*	n/a	Vulnerable	Appendix 2	
Hawksbill Turtle	*Eretmochelys imbricata*	n/a	Critically Endangered	Appendix 1	Vulnerable
Olive Ridley	*Lepidochelys olivacea*	n/a	Vulnerable		Endangered
Humpback Whale	*Megaptera novaeangliae*	n/a	Least concern	Appendix 1	Vulnerable
Tawny Nurse Shark	*Nebrius ferrugineus*	n/a	Vulnerable		
Sperm Whale	*Physeter macrocephalus*	n/a	Vulnerable		
Whale Shark	*Rhincodon typus*	n/a	Vulnerable	Appendix 2	Vulnerable
Indo–Pacific Humpback Dolphin	*Sousa chinensis*	n/a	Near Threatened	Appendix 2	
Spinner Dolphin	*Stenella longirostris*	n/a	Data deficient	Appendix 2	
White–tip Reef Shark	*Triaenodon obesus*	n/a	Lower Risk/near threatened		
Southern Right Whale	*Eubalaena australis*	n/a	Least Concern		Endangered
Flatback Turtle	*Natator depressus*	n/a	Data deficient		Vulnerable

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COMMON NAME	SCIENTIFIC NAME	BILATERAL MIGRATORY BIRD AGREEMENTS	IUCN RED LIST	BONN CONVENTION	EPBC ACT
BIRDS					
Cape Petrel	*Daption capense*		Least concern		
Painted Firetail Finch	*Emblema pictum*				
Pacific Gull	*Larus pacificus*		Least concern		
White-Faced Storm-Petrel	*Pelagodroma marina*		Least concern		
Pied Cormorant	*Phalacrocorax varius*		Least concern		
Little Shearwater	*Puffinus assimilis*		Least concern		
Sooty Tern	*Sterna fuscata*		Least concern		
Rufous–Crowned Emu–Wren	*Stipiturus ruficeps*		Least concern		
Peregrine Falcon	*falco peregrinus*		Least concern		
Gull-Billed Tern	*Sterna nilotica*		Least concern		
Roseate Tern	*Sterna dougallii*		Least concern		
Great-Winged Petrel	*Pterodroma macroptera*		Least concern		
Australian Pelican	*Pelecanus conspiciatus*		Least concern		
Australasian Gannet	*Morus serrator*		Least concern		
Silver Gull	*Larus novaehollandiae*		Least concern		
White-Winged Tern	*Chlidonias leucoptera*	JAMBA, CAMBA	Least concern		
Yellow-Nosed Albatross	*Diomedea chlororhynchus*		Endangered	Appendix 2	Vulnerable
Eastern Reef Egret	*Egreta sacra*	CAMBA	Least concern		
Beach Stone Curlew	*Esacus neglectus*		Near Threatened		
Lesser Frigatebird	*Fregata ariel*	JAMBA, CAMBA, ROKAMBA	Least concern		
White-Bellied Sea-Eagle	*Haliaeetus leucogaster*	CAMBA	Least Concern		
Southern Giant Petrel	*Macronectes giganteus*		Near Threatened	Appendix 2	Endangered
Wilson's Storm-Petrel	*Oceanites oceanicus*	JAMBA	Least concern		
Osprey	*Pandion haliaetus*		Least concern	Appendix 2	
Flesh-Footed Shearwater	*Puffinus carneipes*	JAMBA, ROKAMBA	Least concern		
Hutton's Shearwater	*Puffinus huttoni*		Endangered		
Wedge-Tailed Shearwater	*Puffinus pacificus*	JAMBA	Least concern		
Bridled Tern	*Sterna anaethetus*	JAMBA, CAMBA	Least concern		
Lesser Crested Tern	*Sterna bengalensis*	CAMBA	Least concern		
Crested Tern	*Sterna bergii*	JAMBA	Least concern		
Caspian Tern	*Sterna caspia*	CAMBA	Least concern		
Common Tern	*Sterna hirundo*	JAMBA, CAMBA, ROKAMBA	Least concern		
Soft-Plumaged Petrel	*Pterodroma mollis*		Least concern		Vulnerable
Fairy Tern	*Sterna nereis*		Vulnerable		
Brown Booby	*Sula leucogaster*	JAMBA, CAMBA, ROKAMBA	Least concern		

COMMON NAME	SCIENTIFIC NAME	BILATERAL MIGRATORY BIRD AGREEMENTS	IUCN RED LIST	BONN CONVENTION	EPBC ACT
TERRESTRIAL					
Sandy Inland Mouse	*Pseudomys hermannsburgensis*	n/a	Least concern		
Short Beaked Echidna	*Tachyglossus aculeatus*	n/a	Least concern		
Black Flanked Rock Wallaby	*Petrogale lateralis*	n/a	Near Threatened		Vulnerable
Red-Tailed Phascogale	*Phascogale calura*	n/a	Near Threatened		Endangered
Shark Bay Mouse	*Pseudomys fieldi*	n/a	Vulnerable		Vulnerable
Central Rock-Rat	*Zyzomys pedunculatus*	n/a	Critically Endangered		Endangered
STYGOFAUNA					
Cape Range Remipede	*Lasionectes exleyi*	n/a			Vulnerable
Blind Gudgeon	*Milyeringa veritas*	n/a			Vulnerable

* Please note this is not an exhaustive list of all species found at the Ningaloo Coast

B

STYGOFAUNA OF CAPE RANGE

PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
CHORDATA	Actinopterygii	Perciformes (fish)	Eleotridae	***Milyeringa*** *veritas* (blind gudgeon)	Freshwater caves and in seawater in anchialine systems. Salinity varies between fresh and seawater at different locations and depths and *M. veritas* uses the different water bodies opportunistically. *M. veritas* is associated with the only other stygobitic cave vertebrate in Australia, the blind cave eel, *Ophisternon candidum*. Listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian Wildlife Conservation Act. Listed as vulnerable under the Commonwealth EPBC Act *M. veritas* has been recorded from 25 sites however, a number of these sites are insecure or have been lost. Six sites are within Cape Range National Park. *M. veritas* is the only stygobitic species of eleotrid known in the world and occupies a wide range of physico-chemical environments. The monotypic genus *Milyeringa* is endemic to the Cape Range peninsula and Barrow Island but its phylogenetic relationships within the Eleotridae have not been established. There is evidence of genetically distinct subpopulations along the coastal plain of the Cape Range peninsula. The two fish species (blind gudgeon, blind cave eel) are the only known stygobitic cave vertebrates in Australia. They occur sympatrically over much, and possibly all of their ranges. Globally, there are few occurrences of sympatric species of cave fishes.	coastal plain bordering Cape Range *M. veritas* occurred exclusively in the past land forms adjacent to the North West Shelf of WA where it is found within 150 m of the coast and up to 4.3 km inland. It inhabits the lower foothills and the coastal plain of Cape Range peninsula, and the freshwater lens on Barrow Island.

Genera in **bold** are endemic to the area, as are all the species with the exception of some of the copepod species

PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
CHORDATA (continued)		Synbranchiformes (ray finned fish)	Synbranchidae	*Ophisternon candidum* # (blind cave eel)	Freshwater caves and in seawater in anchialine systems. It is associated with the only other stygobitic cave vertebrate in Australia, the blind cave gudgeon, *Milyeringa veritas*. Listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian Wildlife Conservation Act. Listed as vulnerable under the Commonwealth EPBC Act The world's longesvt cavefish.	coastal plain bordering Cape Range
ARTHROPODA Subphylum CRUSTACEA	Malacostraca	Decapoda (shrimps)	Atyidae	***Stygiocaris*** *lancifera* ***Stygiocaris*** *stylifera* ***Stygiocaris*** sp. Bundera	Anchialine caves. *S. lancifera* and *S. stylifera* are widespread within the Cape Range coastal plain. *S. sp.* Bundera is found only at a single location, Bundera Sinkhole. *S. lancifera* is listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian Wildlife Conservation Act.	coastal plain bordering Cape Range
		Amphipoda: Suborder Gammaridea# (Gammarid amphipods)	Superfamily: Hadzioidea Family: Melitidae	***Nedsia*** *douglasi* ***Norcapensis*** *mandibulis*	Caves in perched groundwater at elevations of approx 200 metres altitude in Cape Range. Melitid amphipods are a marine family that has invaded inland waters and those high in Cape Range probably uplifted with the range.	coastal plain bordering Cape Range
			Family: Hadziidae**	*Liagoceradocus branchialis*	Caves Is listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian Wildlife Conservation Act.	coastal plain bordering Cape Range
		Isopoda	Cirolanidae**	*Haptolana pholeta* #	Anchialine caves. *H. pholeta* is the first cirolanid isopod recorded from subterranean waters in Australia. Prior to the description of *H. pholeta*, there was only one record of a subterranean cirolanid isopod from the Southern Hemisphere, in Madagascar. The genus *Haptolana* contains three species, one from Cuba, one from Somalia and one from Australia. All species are from tropical regions that would have been under the sea prior to the sea-level changes of the Miocene.	coastal plain bordering Cape Range

** Congeneric with marine troglobites of the Atlantic

The stygofauna of Cape Range Peninsula includes the sympatric occurrence of a number of taxa with disjunct Tethyan distributions

Genera in **bold** are endemic to the area, as are all the species with the exception of some of the copepod species

PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
ARTHROPODA Subphylum CRUSTACEA (continued)		Thermosbaenacea**	Halosbaenidae	*Halosbaena tulki* #	Anchialine cave. One species only (*i.e. H. tulki*) within the order of Thermosbaenacea, occurs in the Southern Hemisphere. *H. tulki* belongs to a genus previously known only from saline waters in the West Indies, Columbia and Canary Islands. Thermosbaenacea are a rare order of considerable biogeographic interest because their known distribution is so scattered. Thermosbaenaceans are an order of eyeless, unpigmented peracarid crustaceans represented by very few species from subterranean waters. The Thermosbaenacea are primarily marine, with only 18 species recorded in fresh water conditions or in brackish inland waters whose salinity does not derive from dilution of seawater. They occur in limestone caves, the interstitial medium associated with alluvial deposits, or in thermo-mineral springs. The distribution of the Thermosbaenacea matches precisely the area covered by the ancient Tethys Sea or its coastlines. They are probably relicts of a once widespread shallow-water marine Tethyan fauna stranded in interstitial or crevicular groundwater during marine regressions.	coastal plain bordering Cape Range
	Ostracoda: (ostracods)	Halocyprida	Thaumatocyprididae	*Danielopolina kornickeri* #	Anchialine cave, in seawater. Listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian Wildlife Conservation Act. The first occurrence of this genus in the southern hemisphere and the Indo-west Pacific region. Occurs as a Tethyan element in the anchialine system at Cape Range. Fossils in marine cave facies in Czech Republic suggest this lineage was already inhabiting marine caves in the Jurassic.	Bundera sinkhole. No other site known in Australia that gives access to deep anchialine habitat.
	Copepoda: (copepods) [a zooplankton]	Harpacticoida (copepods)	Tetragonicipitidae	*Phyllopodopsyllus wellsi*	Anchialine ecosystem. It is the only known occurrence of the genus in Australia as well as the first outside strictly marine habitats however it displays clear stygomorphies.	northern end of the Cape Range peninsula

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Genera in **bold** are endemic to the area, as are all the species with the exception of some of the copepod species

PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
ARTHROPODA Subphylum CRUSTACEA (continued)	Copepoda: (copepods) [a zooplankton] (continued)	Cyclopoida (copepods)	Cyclopoidae	*Metacyclops mortoni* *Microcyclops varicans* *Apocyclops dengizicus* *Halicyclops iongifurcatus* *Halicyclops spinifer* *Halicyclops* sp. (undescribed) #	Anchialine. The genus *Metacyclops* has five species and subspecies in Australia and is widespread in tropical and temperate regions. Anchialine. Five species in genus *Halicyclops* in Australia. *H. spinifer* was sampled from hand-dug pastoral well near the coast and also at 200 metres above sea level in a deep cave in central Cape Range.	coastal plain bordering Cape Range *H. longifurcatus* known only from Bundera Sinkhole.
		Calanoida (copepods)	Pseudocyclopiidae	*Stygocyclopia australis* #	Anchialine ecosystem. Seems to be restricted to waters of raised salinity (>18‰) avoiding the more desalinated reaches of the anchialine system. Co-exists with *Speleophria bunderae* in the deeper higher salinity layers of a single sinkhole. Listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian Wildlife Conservation Act. First pseudocyclopiid calanoid to be reported from Australia. Genus consists of three strictly anchialine species. *Stygocyclopia australis* seems to be much more closely related to *S. balearica* from the western Mediterranean and the Canary Islands than to its geographically closer relative *S. philippensis,* from the Philippines. The placement of these two taxa in strictly stygobiont genera represented by very localized and disjunct species distributed over regions flooded by the late Mesozoic seas, lends support to their interpretation as true Tethyan relicts, and hence to the inclusion in the past of the north-west portion of Australia in the Tethyan realm.	Bundera Sinkhole

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PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
ARTHROPODA Subphylum CRUSTACEA (continued)	Copepoda: (copepods) [a zooplankton] (continued)		Epacteriscidae	***Bunderia*** *misophaga*	Anchialine. In oligoxic waters of near marine salinity. Listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian Wildlife Conservation Act. Epacteriscids are considered to be specialised predators. The first epacteriscid calanoid known from Australia, which represents the third genus of this family of mainly stygobiont copepods recorded in the Indo-Pacific region. The closest relative of the new genus is the monotypic *Enantronoides* from on anchialine cave on the Bahama Islands. This suggests an ancient, relictual status for the new taxon.	Bundera Sinkhole
		Misophriodidea (copepods)	Speleophriidae	*Speleophria bunderae*	Anchialine. Coexists with *Stygocyclopia australis* in the deeper higher salinity layers [raised salinity (>18%o)] of a single sinkhole. Listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian Wildlife Conservation Act. First representative of the order Misophrioida known from Australia. Only two described species were known to date, viz. *S. biuexilla* Boxshall & Iliffe, 1986, from Bermuda (NW Atlantic), and *S. gymnesica* Jaume & Boxshall, 1996, from Mallorca (Balearic Is., Mediterranean), although reports of the presence of unnamed species of the genus in the Yucatan peninsula of Mexico have been made elsewhere. Tethyan affinities, refer to *Stygocyclopia australis* above.	Bundera sinkhole/ Cape Range peninsula

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PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
ARTHROPODA Subphylum CRUSTACEA (continued)	Remipedia:** (blind crustaceans found in deep caves connected to salt water)	Nectiopoda	Speleonectidae	*Lasionectes exleyi*	Anchialine ecosystem. Listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian *Wildlife Conservation Act*. Listed as vulnerable under the Commonwealth EPBC Act Bundera Sinkhole includes the only known site for the Crustacean class Remipedia in the southern hemisphere. *L. exleyi* is the only species in southern hemisphere. Bundera Sinkhole is listed under Cape Range Remipede Community, a Threatened Ecological Community under the Western Australian *Wildlife Conservation Act*. Globally, there are 17 extant species in the Order Nectiopoda.	Single location of Bundera Sinkhole; coastal plain bordering Cape Range
ARTHROPODA	Insecta	Hemiptera	Gerridae (water striders)			
		Diptera	Chironomidae (non-biting midges)	*Kiefferulus intertinctus*		
		Coleoptera	Dystiscidae (predaceous water beetle)	*Copelatus irregularis*	Anchialine; Cave 80 metres deep	Single cave; coastal plain bordering Cape Range
PLATYHELM-INTHES	Turbellaria	(flatworms)		? (1 species)	The first records of this subfamily from non-marine waters in the southern hemisphere	

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Genera in **bold** are endemic to the area, as are all the species with the exception of some of the copepod species

PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
ANNELIDA	**Clitellata**	*Haplotaxida* (earthworms and aquaworms)	Naididae (formerly known as Tubificidae)	*Aktedrilus parvithecatus* *Pectinodrilus ningaloo*	Anchialine groundwater. The phallodriline worms were found in two sites within the Bundera Limestone: an artificial well and small karst window.	Cape Range
	Polychaetae (annelid worm)		Spionidae	*Prionospio thalanji*	The genus *Prionospio* is dominated by marine species, with a few estuarine representatives; none are known from truly freshwater or anchialine habitats. Thus, *Prionospio thalanji* is apparently a sister taxon to a marine species, although it not known which one. *P. thalanji* is apparently the first spionid polychaete recorded from cave environments. Spionids are rare in freshwater environments, although two species of *Boccardia* are known from coastal dune freshwater lakes in south-eastern Australia and *Orthoprionospio cirriformia* is widespread in areas of reduced salinity in south-eastern Australia.	Bundera Sinkhole
		Aciculata	Syllidae	*Sphaerosyllis centroamericana* *Typosyllis* (*Ehlersia*) cf. *broomensis*	*S. centroamericana* - Bundera Sinkhole as well as from small shallow karst windows—Tantabiddi Rockholes, Wobiri Rockhole, C-414 and C-506. Specimens were also obtained from Javis Well C-362, a deep pastoral well. *T.* (*Ehlersia*) cf. *broomensis* –in the deep well, Javis Well. In contrast to the other polychaete, *Prionospio thalanji*, both species were characterized as 'normal' marine forms, so are also opportunistically stygal.	Cape Range
Mollusca		Gastropoda (snails, slugs)	Iravadiidae	*Iravadia* sp.	The brackish part of Bundera Sinkhole, where it is exposed to full sunlight. This species belongs to a genus that is otherwise estuarine.	Bundera Sinkhole

** Congeneric with marine troglobites of the Atlantic

The stygofauna of Cape Range Peninsula includes the sympatric occurrence of a number of taxa with disjunct Tethyan distributions

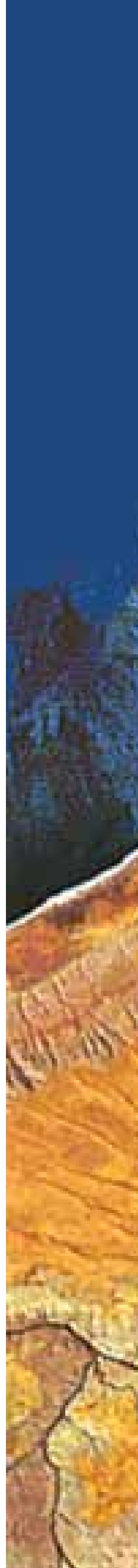
Genera in **bold** are endemic to the area, as are all the species with the exception of some of the copepod species

C

TROGLOBITIC FAUNA OF CAPE RANGE

PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
ARTHROPODA Subphylum CHELICERATA	Arachnida	Schizomida (wind scorpion)	Hubbardiidae	* ***Draculoides*** *vinei* ** ***Draculoides*** *julianneae* * ***Draculoides*** *brooksi*	The genus occurs in subterranean cave or fissure environments in a variety of karst systems. *D. brooksi* and *D. julianneae* are listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian *Wildlife Conservation Act*. The genus Draculoides has six species endemic to Cape Range, Barrow Is and Pilbara; three species are endemic to Cape Range, one species to Barrow Island and two species to the Pilbara. 'It seems probable that most species of Schizomida have highly restricted localised distributions that reflect their narrow environmental tolerances and low dispersal capabilities.' (Humphreys et al. 1989)	*D. vinei* in humid caves situated within the Tulki Limestone along the central elevated section of the Cape Range peninsula. *D. julianneae* occurs within coastal limestone on the western side of the Cape Range peninsula. *D. brooksi* occurs in the north-eastern portion of the Cape Range peninsula.
				**Bamazomus vespertinus* **Bamazomus subsolanus*	Sister species. *B. vespertinus* and *B. subsolanus* are listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian *Wildlife Conservation Act*.	coastal plain on western side of Cape Range peninsula; coastal plain on eastern side of Cape Range peninsula
	Arachnida	Pseudoscorpionida (false scorpion)	Hyidae	****Indohya*** *humphreysi* ****Indohya*** *damocles*	Caves; under stones in dark zone *I. damocles* is listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian *Wildlife Conservation Act*. All the species of *Indohya* are short range endemics, having very small distributional range. Affinities of the genus lie with Gondwana and relatives occur in north-western Australia, southern India and Madagascar	Cape Range coastal plain of Cape Range peninsula

* Exhibit extreme troglomorphies; the remaining taxa are likely to be restricted to cave environments.
Genera in **bold** are endemic to the area, as are all determined species.
** Only genus of *Schizomida* endemic to Australia.



PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
ARTHROPODA Subphylum CHELICERATA (continued)			Chthoniidae	**Tyrannochthonius brooksi* **Tyrannochthonius butleri*	Caves; under rock in dark zone. Both species are found over a small area and are considered to represent a short-range endemic species. As well as *T. brooksi* and *T. butleri,* nine troglobitic species from the family Chthoniidae have been described from the semi-arid zone of Western Australia illustrating the diversity of pseudoscorpions in the region.	Cape Range Peninsula; several caves. Several caves and bores.
				Austrochthonius easti	Caves; under stones	Cape Range
			Syarinidae	*Ideoblothrus papillon* *Ideoblothrus woodi*	Caves; under stone in dark zone. Cave; under stone in dark zone. Of the seven Australian species of *Ideoblothrus,* five species occur within subterranean habitats and all are from the semi arid/ arid zones of Western Australia. The only other subterranean species in the genus occurs in Mexico. All of the Australian species can be regarded as short-range endemic species.	Cape Range Peninsula; one cave only, Papillon Cave. one cave only, Cave C-167.
	Arachnida	Opilionida (harvestmen)	Assamiidae	**Anjolus* sp. (undescribed)	Caves; the two species of Opiliones are both probably rainforest relicts although the wider affinities of both families are unknown.	Cape Range
			Phalangodidae	*Gen. indet.# *Glennhuntia glennhunti*	Caves	coastal plain of Cape Range peninsula
	Arachnida	Araneae (Spiders)	Hahniidae (dwarf sheet spider)	*Gen.	Caves	coastal plain of Cape Range peninsula; Cape Range

* Exhibit extreme troglomorphies; the remaining taxa are likely to be restricted to cave environments.

Genera in **bold** are endemic to the area, as are all determined species.

** Only genus of *Schizomida* endemic to Australia.

First blind Phalangodidae in Australia, though usual in European caves.

^ *Myllocerus sp. 2* is found outside caves.

PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
ARTHROPODA Subphylum CHELICERATA (continued)			Desidae	*Gen & sp. indet. (Harvey et al 1993)	Caves	coastal plain of Cape Range peninsula; Cape Range
			Ctenidae (wandering spider)	***Gen**. nov. & sp. l (Harvey et al 1993)	Caves. Endemic to Cape Range.	Cape Range
			Pholcidae (daddy long-legs spider)	*Trichocyclus septentrionalis*	Caves	Cape Range
			Symphytognathidae	**Anapistulu troglobia*	Three humid caves. The most troglobitic symphytognathid recorded and is only the second recorded from caves. The first occurs in Venezuela and does not appear to exhibit any extreme troglobitic tendencies, unlike *A. troglobia*. Of the seven troglobitic spiders recognized by Harvey et al (1993) from the Cape Range karsts, *A. troglobia* is the smallest, and one of the most troglomorphic.	Cape Range
			Theridiidae	**Steotoda* sp. l. (Harvey et al 1993) **Pholcomma* sp. (Harvey et al 1993)	Caves	Cape Range Cape Range
			Linyphiidae	**Dunedinia occidentalis* **Chthiononetes tenuis*	Caves	Cape Range Cape Range
			Tengellidae	*Bengalla bertmaini*	Caves	Cape Range
			Filistatidae	***Yardiella*** sp. (undescribed)	Caves. Monotypic genus	Cape Range

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PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
ARTHROPODA Subphylum CHELICERATA (continued)			Oonopidae (goblin spiders)	*Camptoscaphiella infernalis*	Limestone bore. The first cavernicolous members of the Oonopidae family from Australia, were described in 2007. The three species occur in Western Australia, one species each from Cape Range, the Pilbara and the Kimberley. Only five species worldwide are currently attributed to the genus Camptoscaphiella. *C. infernalis* differs from all other described species of Camptoscaphiella, except *C. sinensis* from south-west China, by the complete lack of eyes.	Cape Range
	Arachnida Sub Class Acarina	Sarcoptiformes (mites)	Pediculochelidae	*Paralycus lavoipierrei*	Dry cave	Cape Range
ARTHROPODA Subphylum MYRIAPODA	Diplopoda (millipedes)	Polyzoniida (millipedes)	Siphonotidae	*Gen. & sp. indet.	Caves	Cape Range; single cave
		Polydesmida (millipedes)	Paradoxosomatidae	******Stygiochiropus*** *communis* ******Stygiochiropus*** *isolatus* ******Stygiochiropus*** *sympatricus*	Caves; only in areas with high relative humidity and organic carbon content. The genus *Stygiochiropus* is endemic to Cape Range. *S. isolatus.* and *S. sympatricus* are listed under Schedule 1 'Fauna that is rare or is likely to become extinct' under the Western Australian *Wildlife Conservation Act*.	Cape Range; *S. communis* is found in numerous caves throughout the karst region. *S. isolatus* and *S. sympatricus* are known only from single caves in the northern part of the generic range.
ARTHROPODA Subphylum HEXAPODA	Insecta	Diplura (two-pronged bristletails)	Japygidae	*Indjapyx* n. sp. 1 *Indjapyx* n. sp. 2 **Gen. nov.** & sp. nov. 1 **Gen. nov.** & sp. nov. 2	Caves	Cape Range Cape Range Cape Range Cape Range

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** Only genus of *Schizomida* endemic to Australia.
# First blind Phalangodidae in Australia, though usual in European caves.
^ *Myllocerus sp. 2* is found outside caves.

PHYLUM	CLASS	ORDER/ COMMON NAME	FAMILY	GENUS / SPECIES	HABITAT	LOCALITY
ARTHROPODA Subphylum HEXAPODA (continued)			New family or sub-family		Caves	coastal plain of Cape Range peninsula
		Thysanura (silver fish, bristletails)	Nicolctiidae		Caves	Cape Range
			Atelurinae	**Trinemura troglophila*	Caves	Cape Range
		Blattodea (cockroach)	Nocticolidae	**Nocticola flabella*	Caves; world's most troglomorphic cockroach, which is distinguished by its pale, fragile, translucent appearance	Cape Range
ARTHROPODA Subphylum HEXAPODA (continued)		Orthoptera (pygmy cricket)	Nemobiinae, Gryliidae	****Ngamarlanguia** luisae*	Cave; only troglobitic cricket in Australia; endemic to Cape Range (cited in Humphreys 2004)	Cape Range
		Coleoptera (beetles)	Curculionidae Polydrosinae	*Myllocerus* sp. 1 *Myllocerus* sp. 2 ^	Caves	Cape Range
ARTHROPODA Subphylum HEXAPODA (continued)		Hemiptera (true bugs, hoppers, aphids, scale insects, lerps, mealy bugs)	Meenoplidae (planthopper)	**Phaconeura proserpina* **Phaconeura* sp. 1 **Phaconeura* sp. 2 *?gen.	Caves; those parts of caves that contain root systems and where the air is nearly saturated with water.	coastal plain of Cape Range peninsula coastal plain of Cape Range peninsula Cape Range Cape Range
			Cixiidae (planthopper)		Caves	Cape Range
ARTHROPODA Subphylum CRUSTACEA	Malacostraca	Isopoda (slaters, pillbugs, sowbugs, woodlice)	Philosciidae	*Gen. & spp. indet. >2	Caves	coastal plain of Cape Range peninsula Cape Range
			Oniscidae	Gen. & spp. indet.	Caves	Cape Range

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D

MARINE RESEARCH CURRENTLY TAKING PLACE AT THE NINGALOO COAST

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
Long term monitoring of Ningaloo Marine Park: Status of Drupella and shallow water benthic reef communities	Armstrong, Shannon	Department of Environment and Conservation	1989	ongoing	Determine changes to Drupella density and percentage cover of coral communities at Ningaloo Marine Park over time.
Bills Bay Coral Recovery Research and Monitoring Project	Armstrong, Shannon	Department of Environment and Conservation	1989	ongoing	Determine the recovery of corals in Bills Bay after the 1989 anoxic coral spawning event.
Broad scale fish surveys in Ningaloo Marine Park lagoon waters to assess the effectiveness of sanctuary zones for protecting exploited sub-tidal fish species	Babcock, Russ	Commonwealth Scientific and Industrial Research Organisation, University of Western Australia, Edith Cowan University			Provide an assessment of indirect effects on fish community structure from fishing activities in Ningaloo Marine Park.
Persistent organic pollutants in Southern Ocean Humpback Whales	Bengston Nash, Susan	University of Queensland	2008	2010	To quantify fluctuating contaminant burdens throughout the migratory journey and associated detoxification enzymal response in neighbouring dermal layers.
Intertidal invertebrates at Ningaloo Marine Park and the effectiveness of sanctuary zones in protecting exploited species	Black, Bob	University of Western Australia			Provide an assessment of indirect effects on invertebrate community structure from fishing activities in Ningaloo Marine Park.
ScenarioLab - a desktop modelling tool for managers	Boschetti, Fabio	Commonwealth Scientific and Industrial Research Organisation			To develop a modelling tool that can be used by managers/policy makers to consider the application of various management strategies in marine park management.

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
Using hyperspectral imagery to determine human impact (track making) on turtle nesting sites along Ningaloo coastline, WA	Bunning, Jessica	Murdoch University	2008		Quantify the relationship between potential turtle nesting sites and beach accessibility, determine the correlation between beach accessibility and categories of human-made roads, and evaluate the degree of human interference at different turtle nesting beaches.
Estimation and integration of socioeconomic values of human use of Ningaloo: models for recreational fishing and non-recreational fishing choices	Burton, Michael	University of Western Australia, Australian National University	2006	2010	To develop an empirical model to explain choice of recreational sites and use as a basis for economic welfare and policy evaluation. To understand destination choice for users of the Ningaloo Marine Park. To estimate economic values associated with recreational fishing in the Ningaloo Marine Park through random utility models (RUMs). To estimate economic values associated with other recreational activities in the Ningaloo Marine Park through RUMs.
Creefs Project of the Census of marine life	Caley, Julian	Australian Institute of Marine Science			Ningaloo Reef will serve as one reference site in the global project censusing marine life.
Sustainability of the whale shark tourism industry at Ningaloo	Catlin, James	Curtin University	2006	2009	n/a
Coral associated microbes of Ningaloo Reef	Ceh, Janja	Murdoch University			To investigate the dynamics of coral-associated microbial communities over a one year period in Ningaloo Reef.
Population and migration of manta rays at Ningaloo Reef, WA	Cerutti, Florencia	Charles Darwin University	2007	2011	To estimate manta ray population demographics and genetic structure. To define local movement, site fidelity and migratory patterns. To determine if there is genetic exchange with other populations in the Indo Pacific.
International and domestic tourist perceptions and experiences of Ningaloo	Chandler, Philippa	Curtin University			To examine the experiences and attitudes of people who regularly holiday at Ningaloo Marine Park. To evaluate the potential influence of repeat visitors attitudes and values on future tourism planning in the region.
Impacts of tourism in the Ningaloo Marine Park	Chapman, Kelly	Edith Cowan University			n/a
Assessment of coastal groundwater and linkages with Ningaloo Reef	Collins, Lindsay	Curtin University		2009	To characterise the hydrological and geological aquifer system of Ningaloo including the coastal seawater/ freshwater interface and pathways to the Ningaloo Reef lagoon. To develop our understanding of the behaviour of the freshwater/seawater interface in relation to seasonal, tidal and episodic events.

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
Characterisation of geomorphology, growth history and surface sediments	Collins, Lindsay	Curtin University	2006	2009	To characterise the coastal and seabed geomorphology of the reef system, including the deeper reserve areas offshore of the fringing reef. To characterise the surficial sediments of the shallow (lagoonal) waters. To characterise the morphology and growth history of the reef system and identify growth characteristics relevant to maintenance of marine biodiversity and climate change impacts.
Qualitative modelling for sustainable tourism development	Dambacher, Jeff	Commonwealth Scientific and Industrial Research Organisation and Western Australian Marine Science Institution		2010	Develop alternative constructs of socio-economic and ecological system modelling based on patterns, processes and responses; explore the consequences of model structure and system dynamics; and facilitate stakeholder involvement in the process.
Management Strategy Evaluation (MSE) for the Ningaloo Region	De la Mare, Bill	Commonwealth Scientific and Industrial Research Organisation and Western Australian Marine Science Institution	2007	2010	Develop and provide the integrated modelling and analysis for multiple use Management Strategy Evaluation of the Ningaloo region.
Resident survey of social impacts of tourism	Deery, Marg	Victoria University		2010	Compile information on residential views of the impacts of tourism for inclusion into the Ningaloo coast dynamic model.
Methods for monitoring the health of benthic communities	Depczynski, Martial	Australian Institute of Marine Science	2006	2010	To design parameters for a long term monitoring program for coral and fish communities in Ningaloo Marine Park addressing recruitment, and spatial and temporal replication. Provide baseline data for this program.
Stock assessment of target invertebrates	Depczynski, Martial	Australian Institute of Marine Science, University of Western Australia	2008	2010	Assess status of target species; characterise habitats associated with abundance and compare abundance in relation to human use.
Assessment of economic values of tourism	Dwyer, Larry	University of New South Wales		2010	Provide an assessment of the economic value of tourism in the Ningaloo Coast area to the socio-economic tourism model.
Impact of climate variability and climate change on coastal marine ecosystem	Feng, Ming	Commonwealth Scientific and Industrial Research Organisation		2011	Quantify the climate variability in the Leeuwin Current physical forcing on the coastal ecosystem.
Lagoonal and cross shelf patterns in the trophic structure of demersal fish assemblages	Fitzpatrick, Ben	University of Western Australia		2009	Characterise the fish biodiversity and assemblages associated with habitat types and dominant macro benthic communities in sanctuary zones and nearby comparison sites in lagoon and deeper waters of Ningaloo Marine Park northern areas.

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
Assessing the resilience of corals from tropical waters	Foster, Taryn	Murdoch University	2008		To assess natural variability in photosynthetic performance of reef building coral within one colony and between colonies. To assess the resilience of *P. domicornis* from WA tropical waters to higher sea surface temperatures predicted due to climate change, in an aquarium setting.
Species inventory database for Ningaloo deep waters	Fromont, Jane	Western Australian Museum, Australian Institute of Marine Science		2010	Collect voucher specimens to form the foundation of a species inventory database for Ningaloo deeper waters.
The significance of historical collections: Ningaloo	Fromont, Jane	Western Australian Museum			Database the common marine invertebrates from Ningaloo as indicated from historical collections dating back to the 1960s.
Integrated software for multiple use management strategy evaluation	Fulton, Beth	Commonwealth Scientific and Industrial Research Organisation		2010	Simulate using a variety of factors including biophysical, social, assessment, monitoring and management policy for multiple use management strategy evaluation
Economic valuation of biodiversity conservation. Citizen's non-use value for Ningaloo Reef	Gazzani, Flavio	Murdoch University			Estimate the benefits of the non-use values of the Ningaloo Reef and how choices may be related to socio-economic characteristics using Choice Modelling.
Australian Telemetry and Acoustic Monitoring System	Harcourt, R	Integrated Marine Observing System			Initiate both a fine and broad scale acoustic curtain at several sites along the Ningaloo Marine Park to enhance research projects identifying fine and large scale movement of particles and species.
Fish biodiversity associated with habitat types in sanctuary and adjacent zones in deeper waters	Harvey, Euan	Australian Institute of Marine Science		2010	Characterise the fish biodiversity associated with habitat types and dominant macro benthic communities in sanctuary zones and nearby comparison sites in waters between 20-100m depth.
Deepwater Communities at Ningaloo Reef	Heyward, Andrew	Australian Institute of Marine Science	2006	2010	Assess the biodiversity value of the deeper waters seawards of the reef crest in the Ningaloo Marine Park with a focus on representativeness of sanctuary zones.
Deep water habitat types	Heyward, Andrew	Australian Institute of Marine Science		2010	Characterise the habitat types and dominant macro benthic communities in sanctuary zones and nearby comparison sites in waters between 20-100m depth.
Coring of Porhytes to determine impacts of climate change	Heyward, Andrew	Australian Institute of Marine Science			n/a

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
Reef coral population dynamics and annual recruitment processes of spawning coral	Heyward, Andrew	Australian Institute of Marine Science			n/a
Coral reef disease - White Syndrome	Heyward, Andrew	Australian Institute of Marine Science			Detect whether Ningaloo has been infected with white syndrome.
Distribution and abundance of dugongs in Ningaloo Marine Park and Exmouth Gulf	Hodgson, Amanda	James Cook University	2001	Ongoing (every 5 years)	Establish the abundance of dugong in Ningaloo Marine Park in relation to Shark Bay and Exmouth Gulf.
Movement patterns of serranids as they relate to marine park planning at Ningaloo Marine Park	How, Jason	Edith Cowan University	2008	2009	To look at the movement patterns of serranid species to determine its home range, and see if an existing sanctuary zone boundaries provide adequate protection for the species from fishing activities. To examine movement of fish across reef passes and determine whether they provide a natural barrier to fish movement.
Environmental load survey of accommodation providers	Hughes, Michael	Curtin University		2010	Develop a dynamic model of Ningaloo incorporating social, economic and environmental management assessment of tourism along the Ningaloo coast.
Suspension feeders and energy flow through reefs	Humphries, Stuart	University of Western Australia	2005	2009	n/a
Geographical and temporal boundaries for whales of Ningaloo	Jenner, Curt	Centre for Whale Research	1997	ongoing	Identify the movement and distribution patterns of humpback whales relative to the Ningaloo Marine Park.
Managing coral reefs - the importance of working with functional groups to maintain resilience	Johansson, Charlotte	James Cook University			The objective is to assess potential variations within ecological functions for herbivorous populations on Ningaloo and the Great Barrier Reef, to understand how these are structured and how they contribute to the build up of resilience.
Ningaloo destination model for scenario evaluation and collaborative planning	Jones, Tod	Curtin University		2010	Develop a dynamic model of Ningaloo incorporating social, economic and environmental management assessment of tourism along the Ningaloo coast.
An assessment of likely dispersal patterns for marine organisms based on hydrodynamic and population genetic models	Keesing, John	Commonwealth Scientific and Industrial Research Organisation	2006	2010	The distribution of genetic structure throughout the WA range of two (or more) widespread urchin species with differing reproductive and larval biology and contrasting dispersal potential will be characterised using DNA sequence information.

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
Sustainability of the wilderness experience: a case study in environmental stewardship	Kingham, A	Curtin University	2005		n/a
Hyperspectral mapping - Habitats	Kobryn, Halina	Murdoch University	2006	2009	Develop a high resolution characterisation of the reef and shallow water habitats of the Ningaloo Marine Park that will provide the basis for future multiple use management and planning.
Temperature profiles of sea turtle nesting beaches in Western Australia	Kuchling, Gerald	University of Western Australia, Department of Environment and Conservation	2004	2007	Provide an overview of temperature variation at sea turtle nesting beaches and allow rough estimates of sex ratio variations according to published male and female producing temperatures for the different species.
The trophic ecology of the grazing sea urchin *(Echinometra mathaei)* within Ningaloo Marine Park: comparing the effects of different closure regimes on urchin distribution and trophodynamics	Langdon, Mark	Murdoch University			To add to our understanding of coral reef ecology, in particular the role of sea urchins.
Sustainable camping along the Ningaloo coast: how campsite location, facilities and activities influence environmental impacts	Lewis, Anna	Curtin University	2008	2011	Assess campsite environmental impacts, and determine how impacts vary between sites. Assess the average level of waste, water and energy consumption per camper and how waste is disposed of. Assess camper activities and determine influence on campsite selection. Develop indicators to assist in future monitoring of campsite environmental impacts. Identify whether camping on the beach or dunes create the least environmental impact and determine suitability of campsite locations.
ElfSim	Little, Rich	Commonwealth Scientific and Industrial Research Organisation		2010	Assess the impact of existing zonal management strategies on key target fish species and biodiversity using background data and knowledge currently held or being gathered.
Nutrient limitation and impact of nutrient enrichment on arid zone mangroves	Lovelock, Cath	University of Queensland	1999		Understand the degree of connectivity between the terrestrial environment and estuaries in the arid tropics of Australia.

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
Hydrodynamics of Fringing Reef Systems	Lowe, Ryan	University of Western Australia	2007	2009	Develop a model that will predict circulation on reefs and other similar coastal systems for the Ningaloo Reef, providing insight into various ecological processes that are linked to hydrodynamics and threatening processes.
Hydrodynamic control of nutrient uptake and reef metabolism using a portable flume mesocosm at Ningaloo Reef	Lowe, Ryan	University of Western Australia	2009		To conduct process-based experiments to study the impact of key physical parameters (water motion, light, temperature) on nutrient uptake by reef communities at Ningaloo.
Benthic productivity and calcification on Ningaloo Reef: role of oceanic forcing and response to climate change	Lowe, Ryan	University of Western Australia	2007	2009	n/a
Stock assessment of spangled emperor	Marriott, Ross	Department of Fisheries			To assess spangled emperor stock in Ningaloo Marine Park for integrated fisheries management of the Gascoyne bioregion.
Sand temperature data loggers in turtle nesting beaches	Mawson, Peter	Queensland	2008		To gather data on sand temperature over time at turtle nesting beaches.
The policy relevance of Choice Modelling: an application to Ningaloo Marine Park	McCartney, Abbie	University of Western Australia	2007	2010	Investigate the suitability of Choice Modelling (CM) as a tool for valuing marine parks and coral reefs using Ningaloo Marine Park as a case study. Investigate the differences between traditional and non-market valuation payment vehicles and tax reallocation using CM for an environmental good. Contribute towards determining the policy relevance of CM.
High resolution data on cross shelf bathymetry and sediment facies	McCauley, Rob	Curtin University, Australian Institute of Marine Science		2010	Improve the understanding of the biophysical domain via high resolution data on cross shelf bathymetry and distribution of sediment facies.
Passive acoustics off Exmouth, whales and fish	McCauley, Rob	Curtin University, Centre for Water Research	2000		To gather information on marine mammal presence and movement patterns on the north west shelf.
Economic and social aspects of recreational fishing in WA	McElroy, Seamus	University of Western Australia			n/a

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
Trophic ecology of Manta Rays within lagoonal systems of the Ningaloo Marine Park	McGregor, Frazer	Coral Bay Progress Assoc., Department of Environment and Conservation, North West Research Association, Murdoch University University	2007	2009	Investigate the tropic links between manta rays and the Ningaloo reef using mark recapture studies and assessing primary production.
Whale sharks, migration and ecology, movements and behaviour of whale sharks with use of acoustic, satellite, PAT, critter cam and genetic tagging.	Meekan, Mark	Australian Institute of Marine Science, Commonwealth Scientific and Industrial Research Organisation, National Oceanic and Atmospheric Administration	2006		Determine movement and behaviour of Whale Sharks - part of the Whale Shark Management Program.
Herbivorous fish of Ningaloo	Michael, Peter	Edith Cowan University		2010	Qualitatively characterise species specific algal-herbivore interactions across reef habitats.
Using the past to understand the future: the effects of climate change on regional diversity patterns of coralline algae	Moore, P	University of Queensland			Investigate the regional effects of climatic warming on the community composition and biogeographic range of crutose coralline algae along a 12 degree latitudinal gradient of Western Australia's coral reefs.
Whale sharks	Norman, Brad	Ecooceans		ongoing	Collect baseline data on whale sharks at Ningaloo Marine Park by photo identification, whale shark sex and size, deployment of data logging tags and collection of plankton samples to determine whale shark prey items.
Ecological effects of climate change on regional diversity patterns of WA coral reefs	Pandolfi, John	University of Queensland			n/a
Characterisation and modelling of oceanographic processes in Ningaloo Reef and adjacent waters	Pattiaratchi, Chari	University of Western Australia	2007	2010	Develop the capacity to numerically simulate waves, currents, sediment transport and particle dispersion in a shallow complex reef environment over temporal and spatial scales.

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
Transient coastal upwelling along Western Australia: the dynamics of the Ningaloo Current system	Pattiaratchi, Chari	University of Western Australia	2009	2011	The principal aim of this project is to conduct the first detailed study into the dynamics of coastal upwelling along the North West Cape by: 1) characterising the spatial and temporal variability of upwelling at Ningaloo through field experiments 2) Develop a three-dimensional circulation model of the Ningaloo region 3) use the model to develop suitable parameterizations to predict the meteorological and oceanic conditions responsible for generating upwelling (including annual frequency, duration and cumulative effects over seasons 4) apply the numerical model to assess the role of upwelling on the overall cross shelf exchange of material between Ningaloo and offshore, and investigate how these exchange processes may be affected by forecasted climate related changes to regional meteorological and oceanic forcing.
SERPENT: Scientific and Environmental ROV Partnership using Existing Industrial Technology	Pattiaratchi, Chari	University of Sydney, University of Western Australia, University of Wollongong, University of Technology Sydney, Woodside, Santos, Chevron			International project in collaboration with oil and gas industry to undertake deep-sea research using ROV technology.
West Australian Integrated Marine Observation System	Pattiaratchi, Charitha	University of Western Australia			The WA component of Integrated Marine Observing System, real time monitoring concentrated along the Jurien-Cape Peron coastal stretch and 3 long term reference sites; Dampier, Rottnest and Esperance.
Turtle tagging program	Prince, Bob	Department of Environment and Conservation			Long term monitoring program of marine turtle nesting populations in the Ningaloo Marine Park.
Economic strategies for disaster risk-reduction in coastal areas: a case study of Exmouth Gulf	Roberts, Rebecca	Murdoch University	2007		To assess the socio-economics of vulnerability on communities who live in the coastal area of Exmouth.
Role of science in managing the impacts of wildlife tourism	Rodger, K	Murdoch University, Sustainable Tourism Cooperative Research Centre	2006		n/a

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
The use of hyperspectral imagery in detecting linkages between marine sediment and terrestrial soil types in the Cape Range Peninsula	Rouillard, Denis	Murdoch University	2008		Produce a classification of distinct soil and sediment types within the Osprey Sanctuary Zone.
Production and transport of particulate matter in a regional current system	Rousseaux, Cecile	University of Western Australia			To quantify the mechanisms governing the amount of offshore primary production that crosses the continental shelf off Ningaloo Reef to contact the reef front, ultimately entering the Reef via wave-driven lagoon circulation.
Establishing a high magnitude wave event at Coral Bay and the response of the adjacent coral reef ecosystem	Scheffers, Anja Marie	Southern Cross University	2008	2008	Establish the time and mechanism for mechanical destruction and investigate the influence of large scale mechanical destruction on the adjacent coral communities and coral reef system of Coral Bay.
Modelling whale shark distribution	Sleeman, J	Charles Darwin University	2004	2007	n/a
Diversity, abundance and habitat utilisation of sharks and rays	Stevens, John	Commonwealth Scientific and Industrial Research Organisation, Department of Fisheries	2007	2009	Characterise shark and ray diversity and abundance in the reserves and support development of management targets for them.
Range and habitats of whale sharks in the Eastern Indian Ocean	Stewart, Brent	Hubbs SeaWorld Research Institute, Commonwealth Scientific and Industrial Research Organisation, Australian Institute of Marine Science, National Oceanic and Atmospheric Administration	2005	2008	Document the seasonal movements and habitat use of whale sharks at Ningaloo Marine Park between March and June using satellite tags.
NREP Client outreach	Symes, Geoff	Commonwealth Scientific and Industrial Research Organisation		2010	Integrate the Western Australian Marine Science Institution and Cluster research and ensure implementation of outcomes through relevant stakeholders.
Hydrodynamic processes in the Ningaloo Reef System	Taebi, Soheila	University of Western Australia		2010	To develop hydrodynamic models of circulation in lagoon areas of Ningaloo Marine Park.
The influence of place attachment on the management of marine parks and their hinterlands	Tonge, Joanna	Murdoch University			To measure and understand visitor attachment to the Ningaloo Marine Park. To use this information to better inform management and development.

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
Reef connectivity and conservation: an empirical and theoretical synthesis	Treml, Eric Anton	University of Queensland	2008	2011	Evaluate connectivity (larvae dispersal) between reefs in the Coral Triangle and the Great Barrier Reef using physical and genetic methods. Use this information to predict the impact of climate change on connections among reefs to prioritise their conservation.
Conservation of the endangered loggerhead turtle (*Caretta caretta*): health assessment and hatching success of Western Australian populations	Trocini, S.	Murdoch University, Department of Environment and Conservation	2007		To identify and quantify various biotic and abiotic risk factors that reduce hatching success of loggerhead turtles.
Mapping geomorphology and sedimentary environments for conserving marine biodiversity of the Ningaloo marine park	Twiggs, Emily	Curtin University		2009	To characterise the coastal and seabed geomorphology of the reef system, including the deeper reserve areas offshore of the fringing reef. To characterise the surficial sediments of the shallow (lagoonal) waters.
Investigating the importance, diversity and host specificity of photosynthetic symbionts in marine sponges from tropical and temperate regions	Usher, Kayley	Department of Environment and Conservation/University of Western Australia	2008	2010	Determine the percentage of photosynthetic sponges on temperate and tropical reefs, the diversity of photosynthetic symbionts of sponges, the biogeography of symbiont classes, the abundance of symbiont classes and the range of host sponges.
Habitats and Biodiversity of Ningaloo Reef lagoon	van Keulen, Mike	Murdoch University, Curtin University, University of Queensland	2006	2010	Provide comprehensive information on habitats and biodiversity in the Ningaloo Marine Park. Qualitatively and quantitatively describe the biodiversity values of selected areas of the reef in relationship to the bio-physical environment, patterns of reef use and access from land, linking these with physical and biological surrogates to enable specific biodiversity values to be applied across the Ningaloo Marine Park. Identify hot spots and develop an understanding of the environmental and habitat factors that explain the distribution of these hotspots.
Biodiversity - soft corals, macroalgae, macro invertebrates	van Keulen, Mike	Murdoch University			Provide comprehensive information on habitats and biodiversity with a focus on sponges, soft coral and macroalgae.
Seagrasses and macroalgae of Ningaloo	van Keulen, Mike	Murdoch University	2002		n/a

TITLE	PRINCIPLE RESEARCHER	INSTITUTION	START DATE	END DATE	OBJECTIVES
Assessment of trophic cascade effects	Verges, Adriana	Commonwealth Scientific and Industrial Research Organisation, Edith Cowan University		2009	Provide an assessment of indirect effects on benthic community structure from fishing activities in Ningaloo Marine Park.
The biological oceanography of Ningaloo Reef: coastal plankton as a food source for the reef. Assessing the vulnerability of Ningaloo Marine Park to pollution.	Waite, Anya	University of Western Australia	2006		n/a
A study of hatching success and sea turtle health in Western Australia	Warren, Kristin	Murdoch University	2006	2009	Determine disease prevalence, health risk factors, causes of mortality, and factors influencing hatching success in three sea turtle species.
Southern Surveyor Voyage	Williams, Alan	Commonwealth Scientific and Industrial Research Organisation			n/a
Social and economic assessment of tourism along the Ningaloo Coast: a dynamic modelling approach (Socio-economics of tourism)	Wood, David	Cooperative Research Centre, Curtin University, Edith Cowan University, Murdoch University	2006	2009	Develop a dynamic model of Ningaloo incorporating social, economic and environmental management assessment of tourism along the Ningaloo coast. Assess the social-economic implications of tourism to the Ningaloo coast. Use the model to investigate the impacts of different tourism and development scenarios on the economy, communities and environments of Ningaloo and its surrounding regions.
Continuation of long term survey of visitation	Wood, David	Curtin University			n/a
Trophic ecology of coral reefs: the role of oceanographic-to-organism scale processes in trophodynamics and benthic-pelagic coupling	Wyatt, Alex	University of Western Australia			Link benthic ecology and biological oceanography to elucidate the extent and mechanisms by which coral reefs are nutritionally linked to the surrounding pelagic environment and susceptible to its alteration.