Australia's biodiversity: major features

Leo Joseph, David K. Yeates, Joseph Miller, David Spratt, Daniel Gledhill and Alan Butler

Key messages

- In the millions of years since Australia separated from Antarctica and drifted north, our continent's biodiversity has evolved mostly in isolation, while periodically taking on new 'passengers' from Asia.
- Australia's biodiversity has been greatly influenced by isolation and drying; as the continent's climate became increasingly arid and variable over the last 25 million years, fire increased in prevalence and has been a powerful evolutionary force on terrestrial life.
- Compared with those from the arid zone, the plants and animals of wetter coastal habitats are often on older, deeper branches of the evolutionary tree, particularly in the hotspots of diversity in the Wet Tropics rainforests and the south-west corner of Western Australia.
- Most of Australia's territory is marine; it contains one of the most diverse arrays of organisms worldwide, reflected in the Great Barrier Reef and along the southern coast.
- The majority of species of Australia's fauna and flora, both terrestrial and marine, are still being discovered and described.
- Modern DNA analysis is revealing ever more surprises about the evolution of Australian biodiversity, reinforcing its special place in the world's natural heritage.

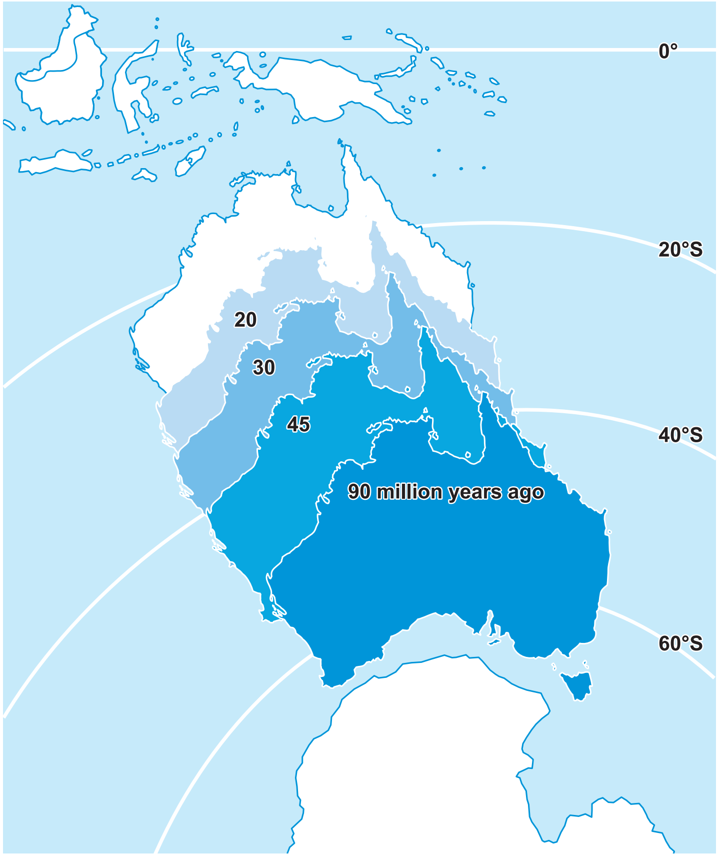
GLOBAL CONTEXT: HOW AND WHY AUSTRALIAN BIODIVERSITY IS SPECIAL

Australia is renowned for its biodiversity. Why is our biodiversity so distinctive, and why is it important that we understand the origins, connections, and differences of individual plants and animals? This chapter builds on the idea that understanding the evolution of Australian biodiversity deepens our appreciation of the living organisms with which we share our continent and its seas. The fact that Australian biodiversity is of profound scientific value, though, is only one reason for wishing to uncover its secrets: we also want to improve knowledge so as to guide conservation, environmental management and biosecurity. This chapter gives an overview of our current knowledge about Australia's biodiversity. To develop effective management, we need to know what we are dealing with, how it got there, and the differences and similarities with other parts of the world. The chapter outlines essential elements of Australia's biodiversity in this context.

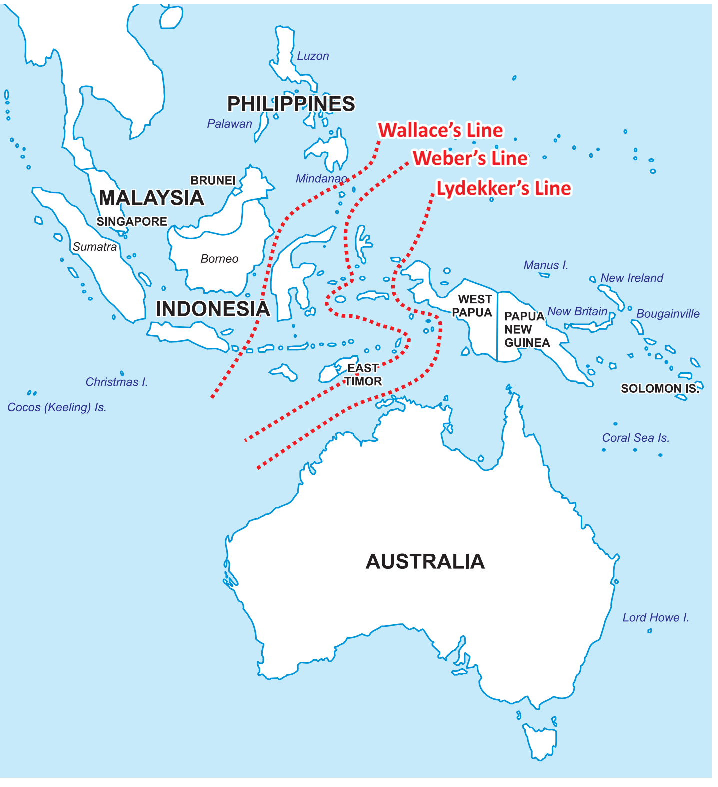
Origins and history

Australia's separation from Antarctica during the break-up of the ancient super-continent Gondwana began approximately 85 million years ago and was complete 30 million years ago, so it has been isolated through much of the last 65 million years (Figure 2.1).[1] Furthermore, during the Pleistocene (the geological epoch lasting from 2.6 million to 12 000 years ago), there were many changes in sea level that rearranged the connections between Australia's coast and the islands of present-day Indonesia and New Guinea. This geological history has provided the two key benefits of isolation and time which evolutionary processes require for the modification of existing species and generation of new species. The long process of continental drift itself is a third ingredient that constantly moulds the shapes and positions of the world's continents and, thus, how organisms can disperse among them.

The continental plate on which Australia is rafting northward first collided with the Eurasian plate approximately 25 million years ago. New combinations of species and ecosystems appeared as land-bridges allowed dispersal and intermixing. Biologists have long recognised the result of this collision by drawing lines on maps – such as Wallace's Line – to mark out regions that have different complements of biodiversity (Figure 2.2). Many organisms such as fishes, corals, crustaceans and birds have distinctive representatives on either side of the Line, and still others occur only on one side of it. Although many marine species disperse over huge distances, surprisingly there are also many unable to colonise new areas readily, either because they lack dispersive life-stages or because unfavourable currents act as barriers. Such species are still limited today to the geological structures on which they arrived from Gondwana. Some migratory birds, however, can fly over such lines with ease (Box 2.1).



▸ ***Figure 2.1***: *Diagram showing the northward movement of Australia as it separated from Antarctica. Australia's approximate position at 90 (prior to separation), 45, 30 (separation now complete) and 20 million years ago, and the present day is shown.*[2]



▸ ***Figure 2.2***: *Locations of three 'biogeographical lines' that have been proposed to differentiate the faunas and floras of the Australian, New Guinean and Pacific regions to the east of the lines, from the Asian and European regions to their west. Each is named after a biogeographer; Wallace's Line, first proposed by Alfred R. Wallace, is the most widely recognised of these lines.*

Box 2.1: Migratory birds and Wallace's Line

Most birds that migrate within Australia are land birds or waterfowl such as ducks. They may have regular or irregular patterns of movements, but do not move north of Wallace's Line. Just a few groups of birds (although millions of individuals are involved) move between the northern and southern hemispheres across Wallace's Line. Migratory shorebirds are one such example. They are unaffected by Wallace's Line, moving between breeding grounds in the northern hemisphere and non-breeding grounds in the Australian region.[3]

(a) *Among a flock of various species of shorebirds, mostly bar-tailed godwits,* Limosa lapponica, *one stands out with its yellow leg flag-coded. This indicates to any observer where on its migratory pathway the bird was flagged – in this case Broome, Western Australia.* ***(b)*** *Shorebirds gather in their thousands on the north-west coast of Australia before beginning their northwards migration to breeding grounds as far away as Siberia. Here, something can be appreciated of the scale of these flocks. Photos: Clare Morton.*

Evolutionary biologists find the challenge of identifying evolutionary links between components of Australia's biodiversity and that on other Gondwanan remnants, such as South America and New Zealand, to be fascinating but difficult. Did species such as bunya pines and their relatives in the genus *Araucaria* attain their current patchy distributions through passive drifting after the break-up of Gondwana? Or were their ancestors widespread before Australia drifted north, such that extinction and dispersal created the present distributions? These types of questions may be resolved by examining the record contained in the genetic make-up of species as encoded in their DNA, as well as by studying the form of today's plants and animals (i.e. morphology), and fossils.[4] We find that the answers are complex and vary with species, as shown in Table 2.1.

Table 2.1: Examples of vertebrate animals of differing evolutionary origins[5,6]

Originated in Gondwana before Gondwana break-up	Arrived in Australia after break-up	Uncertain
Geckos of the families Diplodactylidae, Carphodactylidae and Pygopodidae	Other geckos, some skinks, dragon lizards, front-fanged elapid snakes, blind snakes and pythons	Ratite birds such as emus and cassowaries in Australia, and rheas, ostriches, moas and kiwis elsewhere

Whatever the particular cause, though, elements of Australia's biodiversity are related to groups elsewhere in Gondwana's remnants. For example, mound-building birds such as the mallee fowl, *Leipoa ocellata*, have closest living relatives in South and Central America (the curassows and guans),[6] and the Maugean skate, *Zearaja maugeana*, a ray found in estuaries in south-western Tasmania, has its closest living relatives in New Zealand and South America.[7] The challenge is to understand how these relationships do or do not explain present-day distributions.

Australia's Gondwanan inheritance is evident in the rainforest fragments along its eastern seaboard, especially the unique rainforest plants of the World Heritage-listed Wet Tropics. Sixteen of the 28 ancestral lines that branched off early in the history of flowering plants are present today in the Wet Tropics, and include species that occur nowhere else in the world. Conditions have remained suitable for these plants since Australia separated from Antarctica, so the Wet Tropics is a global refuge for these early branches of the evolutionary tree of plants. Of course, evolution has continued in the Wet Tropics since the break-up of Gondwana, and today's vegetation reflects dispersal, speciation and divergence in a flora of multiple origins.[4]

The period following separation from Gondwana is known as the Miocene Epoch, lasting from approximately 23 million years ago to 5.3 million years ago, when Australia began drying (Figure 2.3). The Miocene Epoch saw the evolutionary origin of many present-day lineages, including both *Eucalyptus* and *Acacia*. Following the next epoch, the Pliocene, came the turbulent Pleistocene, from 2.6 million years to 12 000 years ago. Globally, it was a time of cyclical climatic upheavals, and there were repeated, lengthy glaciations in the northern hemisphere. In Australia, terrestrial environments mostly remained free of ice, although they experienced cycles of severely cold, dry climates. The most recent cycle, the Last Glacial Maximum at 20 000 years ago, was cold, arid and windy. These circumstances moulded the geographical distributions and genetic diversity of many of Australia's present-day species.

GEOLOGICAL TIME SCALE

ERA	PERIOD	EPOCH	MILLION YEARS BEFORE PRESENT DAY
Cenozoic	Quaternary	Holocene	0.012
		Pleistocene	2.6
	Neogene	Pliocene	5.3
		Miocene	23
	Paleogene	Oligocene	34
		Eocene	56
		Paleocene	66
Mesozoic	Cretaceous		145
	Jurassic		201
	Triassic		252

▸ ***Figure 2.3**: The geological epochs pertinent to this chapter. Much of the history discussed here in relation to the evolution of Australian biodiversity happened from the Cretaceous through to the present day. In particular, the drying out of Australia began in the Miocene. The Pleistocene saw worldwide cycles of glaciation, which shaped and moulded pre-existing biodiversity into present-day patterns.*

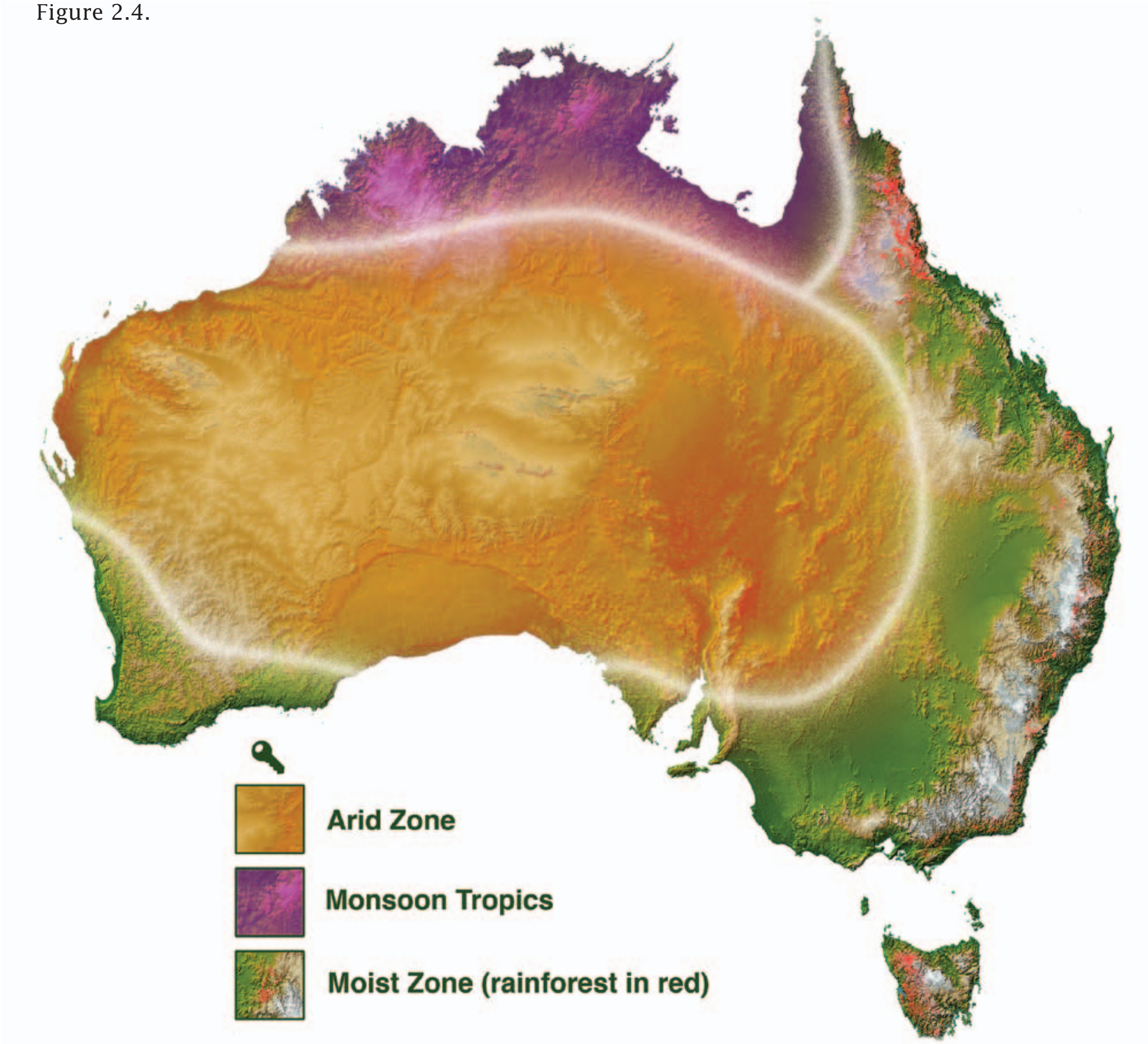
The dispersal and distribution of terrestrial animals, including humans, and diversification among some near-shore marine species, were also affected by sea level changes in the Pleistocene. Land-bridges were exposed when glaciers locked sea water into the polar ice-caps, thereby drastically lowering sea levels. Oceanic temperature changes also caused splitting of ancestral marine species into new, daughter species.

Fire began shaping Australian biodiversity, at least since drying set in during the Miocene. Banksias, for example, require the heat of a fire before their fruits will open and expose the seeds for dispersal. After a fire, eucalypts often produce new growth along trunks and branches, known as 'epicormic re-sprouting'. Whether fire drove the evolutionary change in eucalypts, however, or whether the eucalypts themselves created flammability in vegetation for some other reasons, remains uncertain.[8]

Epicormic growth on eucalypts after fire. ***(a)*** *Close-up of an epicormic sprout on a eucalypt four months after Black Saturday bushfires, Strathewen, Victoria, and* ***(b)*** *a view of a eucalypt forest showing epicormic growth three years after a fire, Tidbinbilla, Australian Capital Territory. Photos: (a) Robert Kerton, (b) Murray Fagg.*

AUSTRALIAN BIOMES

Australia's terrestrial biomes – entire landscapes and the species inhabiting them – are depicted in Figure 2.4.



▲ ***Figure 2.4**: Many schemes have been proposed to illustrate how the Australian continent can be divided up into biomes or biogeographical regions, each with a distinctive complement of fauna and flora. Common to most such proposals is a vast, inland arid zone (orange), a northern tropical region spanning the continent from east to west (purple), and wetter regions of tropical to temperate habitats in eastern and south-western Australia (green and red).*

Terrestrial environments

The arid zone

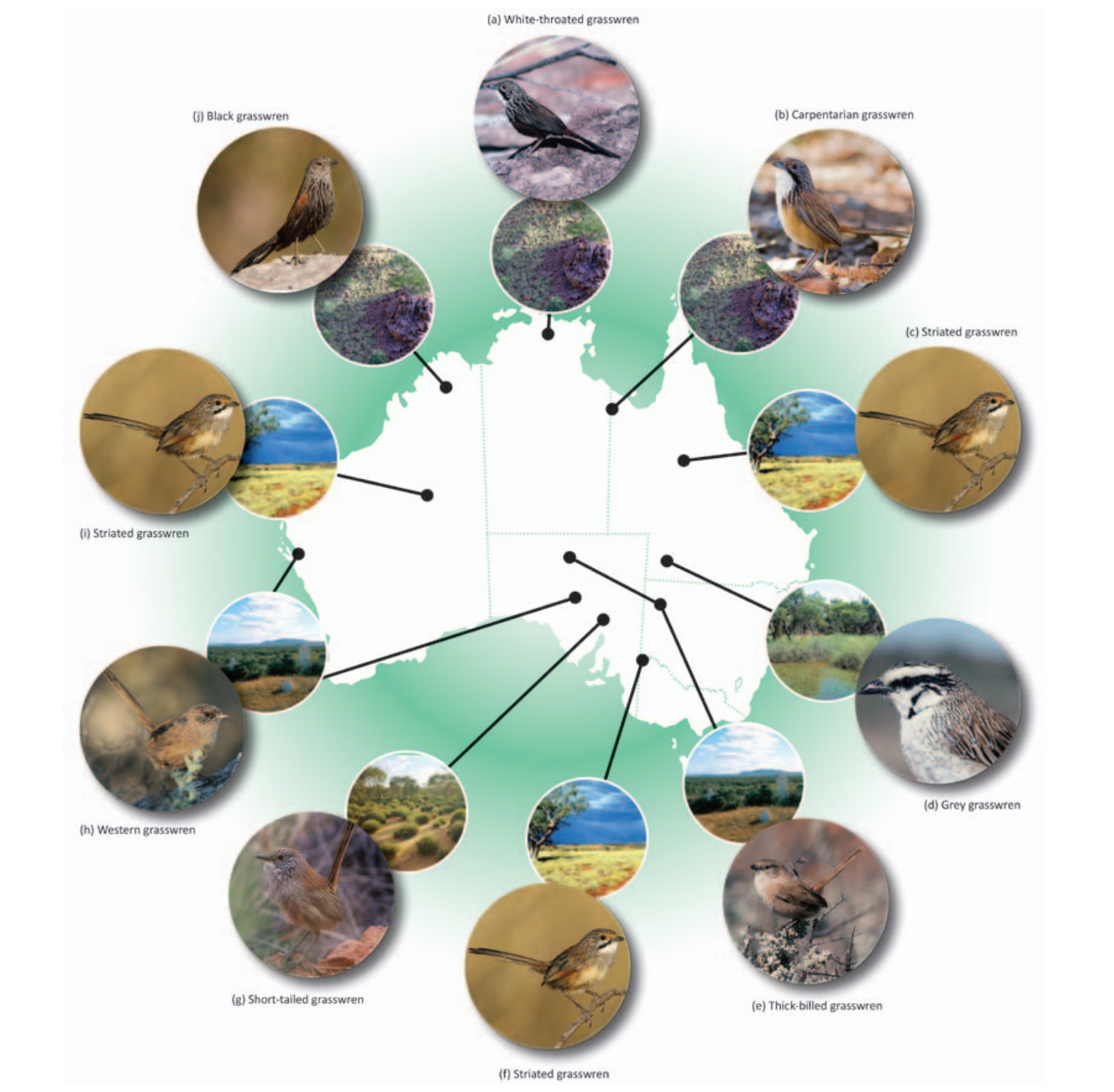
Australia's arid zone dominates the centre and west of the continent, excluding the monsoonal tropics and moist zone in the south-west. It is a series of deserts, each infertile because of long-term weathering of soils. Yet, after rain, the deserts are flush with plant productivity, far from the popular image of Sahara-like sand dunes. In the arid zone, lizards known as skinks have undergone one of the most strikingly diverse evolutionary radiations of any terrestrial vertebrate, and from just a few ancestors now there are 240 species.[9]

The arid zone occupies most of the Australian continent. Diverse habitats make up the arid zone, such as ***(a)*** *the stony deserts, and* ***(b)*** *the grasslands on sandplains and dunes in which spinifex,* Triodia*, is dominant. Photos: (a) Len Zell, (b) Aaron Greenville.*

Scientists long theorised that arid-zone species evolved from ancestors in wet forests and woodlands, but it is now clear that the story is more complex. Isolation of organisms, driven by fine-scale variation in soil types and the supply of groundwater across the arid zone, has caused complex evolution. Molecular studies show that, especially among animals, the deserts have been a cradle of evolution rivalling familiar 'natural laboratories' such as the Galapagos Islands (Box 2.2). Plant speciation tends to be highest, however, at the edges of the arid zone where species may arrive from other biomes.[9]

Box 2.2: Grasswrens – among the most Australian of Australian birds

Found only in Australia, grasswrens mostly inhabit grasslands of spinifex, *Triodia*, growing on sandy or rocky substrates in remote or difficult-to-access parts of arid and tropical Australia. One species inhabits canegrass swamps of inland eastern rivers. The experience of seeing these birds after difficult searches can be described as electric: the sharp white striations of their plumages on a black or chestnut ground colour, their buzzing calls, and their scurrying movements between hummocks of spinifex. Their spinifex habitats are also home to diverse groups of reptiles, insects, and even land-snails.



Grasswrens of the genus Amytornis *are members of the family Maluridae, which includes the better known fairy-wrens,* Malurus. *Not all species and their various populations could easily be shown here. Diagrammatic indications of where species occur are accompanied by photos that broadly indicate the birds' remote habitats. Habitats range from rocky spinifex-clad ranges of tropical Australia to chenopod plains, lignum swamps and mallee, especially with spinifex. Photos of birds: (a), (d), (e), (g), and (h) Lynn Pedler; (b) and (j) Mark Sanders; (c), (f), and (i) Rob Drummond. Photo of habitats: (a), (b) and (j) Tim Dolby, all others CSIRO.*

The monsoonal tropics

This region of intense annual wet and dry seasons comprises Australia's north – the Kimberley, Top End and Cape York Peninsula. Its most physically distinctive features are the basalt or sandstone escarpments and ranges of the Top End and Kimberley that also protect isolated rainforest pockets, and the region's savannas – the most extensive in the world. Once more, DNA studies reveal far more diversity than earlier had been appreciated. For example, many more toadlets of the genus *Uperoleia* have been so identified;[10] and what has long been thought of as one northern Australian species of short-eared rock-wallaby, *Petrogale brachyotis*, comprises eight geographically discrete lineages, at least some of which may eventually be recognised as separate species.[11] Among plants, too, the monsoonal tropics show high levels of recent speciation, such as in *Acacia* and *Glycine*, the wild relatives of the soybean. Many plants also have evolutionary links to Australia's near neighbours because of dispersal as the continent moved northward.[4]

Monsoonal Australia has spectacular sandstone escarpments and nearby wetlands that together form 'biodiverse islands' in a sea of eucalypt savanna. Photo: Parks Australia.

Toadlets of the genus Uperoleia *symbolise the revolution taking place in the understanding of biodiversity in monsoonal northern Australia.* Uperoleia *is the most species-rich genus (27 species) in the frog family Myobatrachidae, and the majority of the species are in the tropics. True species diversity of these frogs has long confounded scientists due to their small size and unvarying body plan, but now several new species have been described, including* Uperoleia lithomoda *from the Hervey Range, Queensland. Photo: Stewart McDonald, courtesy Renee Catullo.*

The eastern forests and woodlands

Relative to the rest of Australia, the forests and woodlands along Australia's eastern seaboard are rich in species. Diversity is generally higher in eucalypt forests, woodlands and heaths than in rainforests. Perhaps there were higher rates of extinction over evolutionary time in the relatively small remnants of the rainforests; conversely, rainforests may retain some of the oldest branches of the evolutionary tree of flowering plants. Many of the wetter biome's elements, including its rainforests, have evolved from ancestors that dispersed into Australia from the north. Over millions of years, contraction and fragmentation of habitats, extinction of some species, and dispersal inwards by others from outside the regions have contributed to the biodiversity of today.[4]

The south-west of Western Australia is effectively a western isolate of this biome. Additionally, it is a globally significant hotspot of plant biodiversity. Over 50% of plant species are endemic, generated by long-term climatic stability that provided opportunities for localised specialisation. The area has been a major evolutionary refuge during the drying of the continent for the two largest genera of Australian plants, *Acacia* and *Eucalyptus*.[4]

Forests and woodlands of temperate eastern Australia. ***(a)*** *Regenerating mountain ash,* Eucalyptus regnans, *decades after the 1939 bushfires, Donna Buang Road, Victoria.* ***(b)*** *From Mount St Leonard, Victoria, looking south towards the Victorian Central Highlands.* ***(c)*** *Rainforest gully with tree ferns,* Dicksonia antarctica, *Donna Buang Rainforest Gallery Walk, Victoria.* ***(d)*** *Spotted gum forest,* Corymbia maculata, *with understorey of cycads,* Macrozamia communis, *Potato Point, NSW South Coast. Photos: Stephen Roxburgh.*

Gilbert's potoroo, Potorous gilbertii*, is an example of a species found only in south-western Western Australia. It was thought extinct for more than 100 years; it was rediscovered in 1994 and is now the subject of successful community conservation and research. Photo: Dick Walker, Gilbert's Potoroo Action Group (www.potoroo.org).*

Marine environments

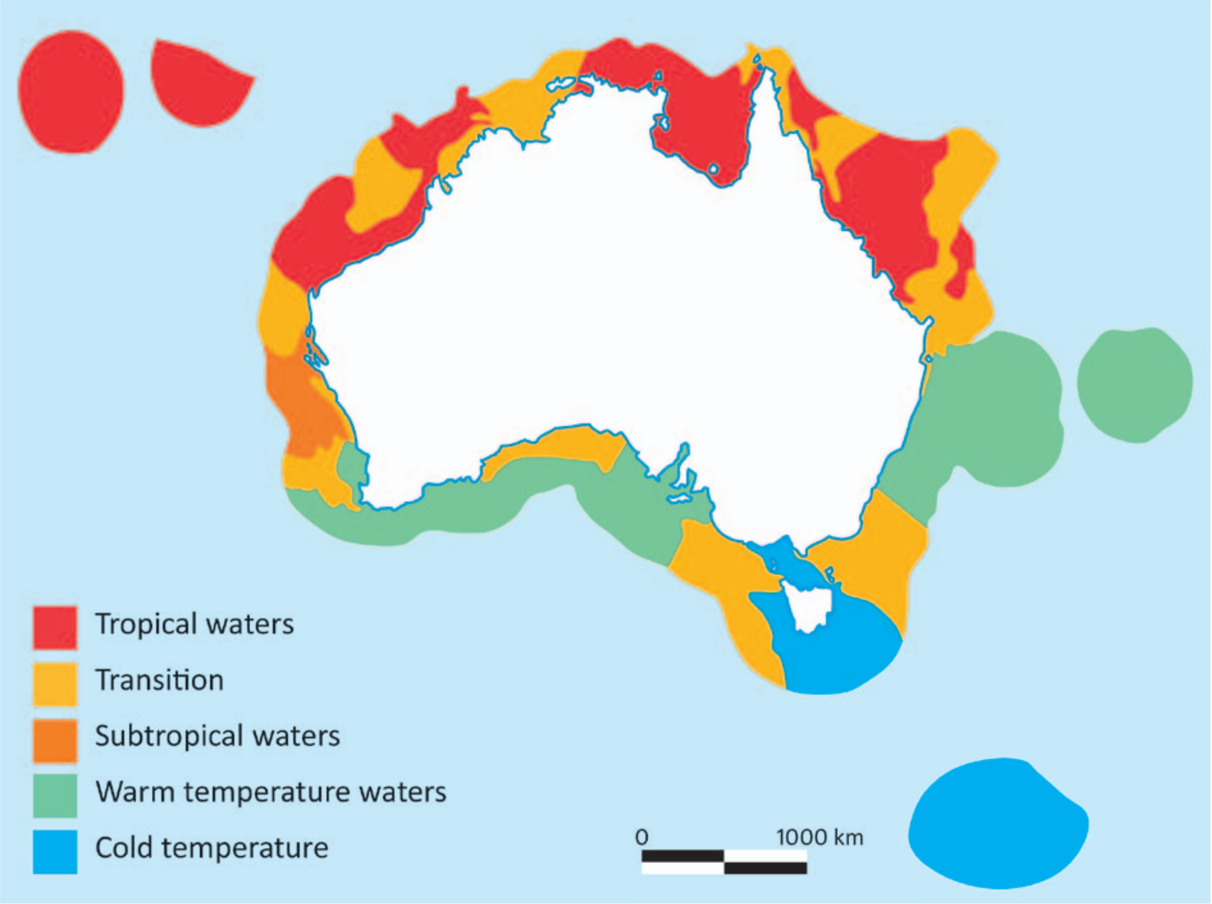
Marine environments are equally diverse. Aside from gross differences from place to place – the water column, the bottom of the continental shelf, or even deeper on the sea floor's abyssal plain – many factors govern evolution and distribution of marine organisms: climate, water temperature, salinity, light and nutrients, or presence of habitat such as soft sediments. Scientists divide the environment into depth-related zones: the intertidal, coastal, neritic (the water column over the continental shelf), or abyssal (deeper than 2000 m). Even mobile species cannot always move freely to new zones, or across deep-water trenches, and many organisms are attached to the sea floor. The distribution of organisms is influenced by where their juvenile forms (larvae) eventually attach as adults, and whether their eggs remain on the sea floor or drift with the currents. Overlying these effects are climatic and biogeographic differences among large regions, such that we can recognise several marine bioregions around Australia (Figure 2.5).[12]

The tropical zone

This zone is characterised by coral reefs and shorelines fringed with mangroves, with much in common with seas of the Coral Triangle (Papua New Guinea, Indonesia and the Philippines, plus Australia). Species diversity in the tropical zone is high. A common pattern is that of closely related but distinct species replacing each other geographically from east to west, partially because of separation of each pair's common ancestor on the two sides of the land-bridge during periods of low sea level.[12]

The warm temperate zone

This is where the shallow sea floor is dominated by seaweeds and seagrasses rather than by corals, and with correspondingly different species of fishes, invertebrates and plants. Along the south coast, in particular, there are high numbers of endemic species of animals and seaweeds. Again, there are distinctions between eastern and western Australia. There are complicated overlaps along the southern margin of the continent, partly due to the past isolation of ancestral populations by a land-bridge connecting Tasmania to the mainland when sea level was lower in the Pleistocene.[12]



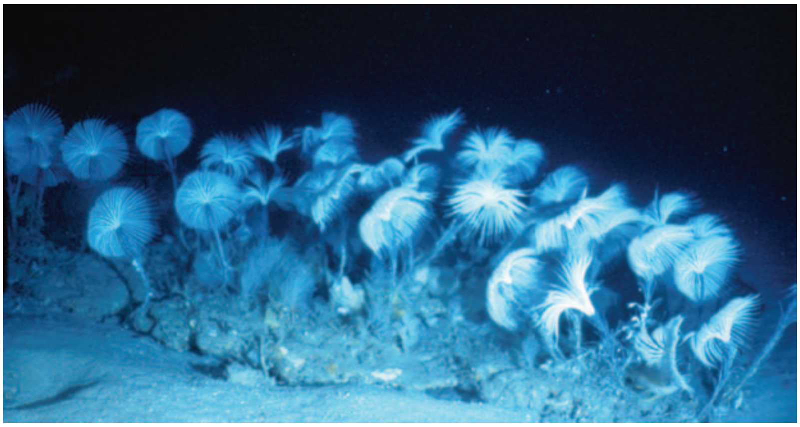
▲ ***Figure 2.5***: *Seafloor marine bioregions of Australia. Adapted from www.environment.gov.au/coasts/mbp/imcra/nmb.html.*

The cool temperate zone

Cool waters around Tasmania support fewer species than tropical waters, but may have higher proportions of endemic species. Forests of giant kelp, *Macrocystis pyrifera*, occur nowhere else in Australia (though they form in cold waters elsewhere in the world). Other examples include a newly discovered species of sand fish, *Lesueurina*, which is confined to the south coast of Tasmania, and an alga, *Cystoseira trinodis*, limited just to Blackmans Bay, Tasmania.[12]

Canyons

For millennia, sea water flowing across the continental shelf has tumbled into underwater cascades across Australia's continental slopes, carving deep canyons – the Perth Canyon off the Swan River, Western Australia, the Murray Canyons from the mouth of the Murray River, South Australia, and, even more spectacularly, the Tasman Fracture Zone in deeper water south-west of Tasmania, a relic of the rifting of Australia from Antarctica. The Tasman Fracture Zone contains a canyon over 400 km long, and because of its striking nature is included in a Marine Protected Area. The rocky walls of marine canyons are habitats for rich and varied organisms that prosper in the rapid

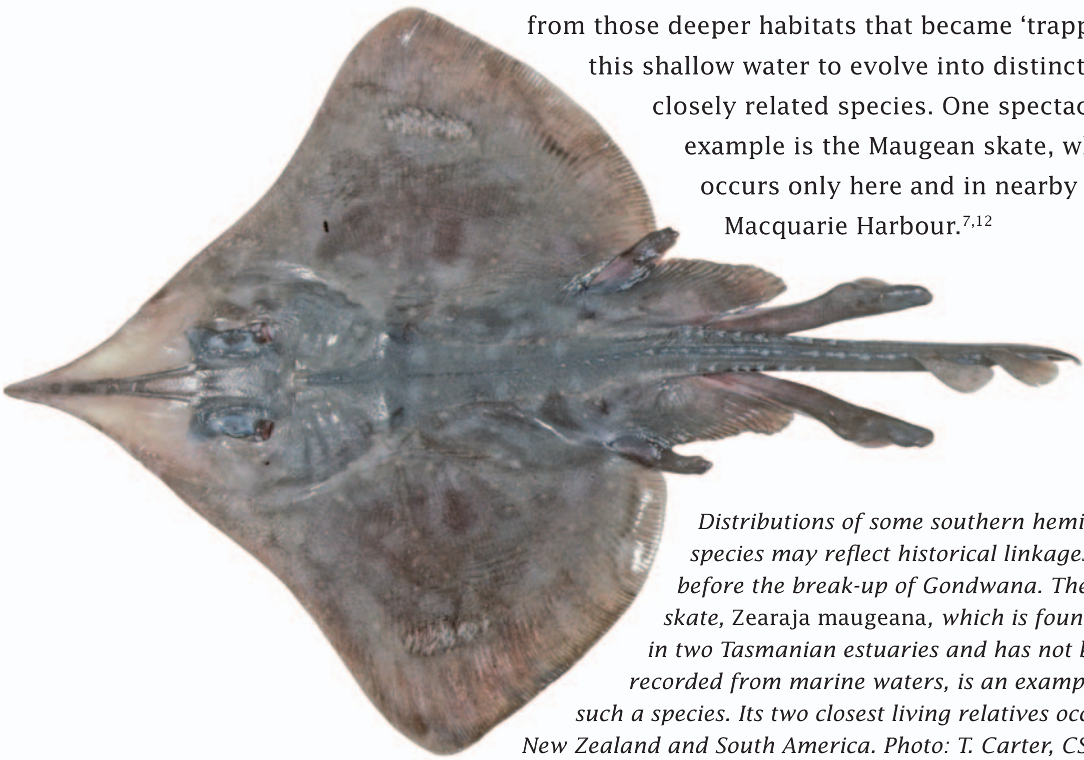


Stalked crinoids or sea lilies, Metacrinus cyaneus*, are echinoderms related to seastars and sea urchins. This species, occurring on the edge of Australia's southern continental shelf, is notable as a 'living fossil' – many of its relatives are extinct, and the form has remained the same for a long time. Photo: CSIRO.*

currents, among them soft corals, sponges, bryozoans and stalked crinoids. The canyons are also home to many large fishes, and in some cases constitute spawning or nursery areas for a range of commercial species.[12]

Estuaries

Estuaries straddle land and sea as they mix fresh and saline waters. Port Davey and Bathurst Harbour, in south-west Tasmania, make up an estuary with a difference. Long isolated, and cold by Australian standards, its waters carry a surface layer stained dark from tannins flowing from the adjacent rainforests. This layer reduces penetration by light, thereby making even shallow waters and the animals in them resemble deeper waters far down the continental slope. Isolation has fostered evolution, allowing ancestral populations from those deeper habitats that became 'trapped' in this shallow water to evolve into distinctive but closely related species. One spectacular example is the Maugean skate, which occurs only here and in nearby Macquarie Harbour.[7,12]



Distributions of some southern hemisphere species may reflect historical linkages from before the break-up of Gondwana. The Maugean skate, Zearaja maugeana*, which is found only in two Tasmanian estuaries and has not been recorded from marine waters, is an example of such a species. Its two closest living relatives occur in New Zealand and South America. Photo: T. Carter, CSIRO.*

SOME AUSTRALIAN BIODIVERSITY ICONS

Having briefly surveyed Australia's major biomes, we now look at some of our best-known examples of biodiversity.

Terrestrial plants and animals

Australia's approximately 140 species of marsupials, the pouch-bearing mammals, are among the natural wonders of the world. They evolved to live in almost every terrestrial ecosystem; the only thing they do not do is feed on flying insects, which remains the job of birds and bats. There are marsupial species that burrow through sand, live on trees and shrubs, inhabit rock piles, rainforest canopies, and deserts, and even species that glide through the air. Australia is also home to two species of egg-laying mammals, the platypus and echidna. These special mammals are also known as monotremes, which means 'single opening' – that is, they have a single opening for reproduction, urination and defecation. Echidnas are also represented in New Guinea. Both of these groups of mammals contrast with placental mammals, which are distinctive in giving birth to well-developed young. Among the placental mammals, Australia has a diverse range of bats and rodents.[13]

Some of Australia's unique mammals: ***(a)*** *a western grey kangaroo,* Macropus fuliginosus, ***(b)*** *an echidna,* Tachyglossus aculeatus, ***(c)*** *a platypus,* Ornithorhynchus anatinus, *and* ***(d)*** *a koala,* Phascolarctos cinereus. *Photos: (a) and (d) Bruce Webber, CSIRO, (b) Willem van Aken, CSIRO, (c) Healesville Sanctuary.*

Woodlands dominated by mulga, Acacia aneura, *typify vast parts of inland Australia, occurring on rock and sand and often with understoreys that spring to life after rain. Photo: Joe Miller.*

(a) *A scribbly gum moth,* Ogmograptis racemosa, *and* ***(b)*** *a scribbly gum,* Eucalyptus haemastoma, *showing the scribbles that are diagnostic of particular species of moths. Photos: (a) Carla Flores and Marianne Horak, (b) Natalie Barnett.*

The eucalypts and acacias are examples of the power of isolation in evolution, and today they dominate vast tracts of the continent (but see Box 2.3). With over 1000 species, *Acacia* is the largest plant genus in Australia, and there are also nearly 700 eucalypts, with both being notably diverse in south-western Australia. Nodules on the roots of *Acacia* contain special bacteria that absorb nitrogen from the air and make it available as ammonia to the host plant, a process vital for plant survival and thereby a factor in assisting diversification of *Acacia* in the face of infertile soils. *Acacia* and *Eucalyptus* also host a spectacular diversity of insects and fungi. A familiar example is the scribbly gum moth, whose larvae feed on tissues just below the epidermal cells of tree trunks to produce the 'scribbles' so often seen on gum trees.[14]

Many of Australia's birds are as Australian as kangaroos and gum trees. Resemblances to northern hemisphere namesakes, such as robins and wrens, reflect convergent evolution – the process by which unrelated species performing similar roles evolve to resemble one another.[15]

The mallee emu-wren, Stipiturus mallee, *is a member of the Maluridae, a family of birds unique to Australia and New Guinea. The word 'wren' reflects the difficulty Europeans had when they first tried to name many Australian birds; there is no close relationship to northern hemisphere wrens, although because they perform similar roles in the ecosystem they have come to resemble them superficially. Photo: Simon Bennett.*

The major plant-eating animals in Australia might best be thought of as termites rather than the more familiar kangaroos and wallabies. Strictly decomposers rather than grazers of vegetation, termites are akin to ecosystem engineers in northern Australia's tropical savannas, where infertile soils and seasonal rainfall mean that the populations of large herbivorous mammals that one finds in African savannas are absent. Famous for their mounds, which store harvested plant material, termites also help store water in soils by creating numerous openings into the ground.[16] Australia is also a global centre of ant diversity. In most regions of the world, rainforests have the richest ant diversity, whereas in Australia the richest areas are the deserts and savannas. Put simply, termites, ants and other invertebrates like earthworms maintain nutrient cycling and ecosystem function across most of Australia.[17]

Abundant termite mounds in most monsoonal Australian landscapes demonstrate the importance of these animals in maintaining a flow of nutrients through grasslands and woodlands. Photos: (a) Leigh Hunt, (b) Adam Liedloff, CSIRO.

Box 2.3: An enduring question – why are there palm trees in central Australia?

Scattered among the eucalypts and acacias of arid inland Australia are some unusual plants, among them the palms, *Livistona*, of central Australia. The answer to their puzzling presence reveals how interconnected biomes may be in evolutionary terms. One argument was that Palm Valley has been a refuge for plants since the mid-Pleistocene. The notion was that water has been stored in sediments around the Valley over time-spans of 100 000 years or more, such that some plants endured through arid phases of the Pleistocene. However, the hypothesis that the palm is an ancient relic is not supported by the evidence. Genetic studies reveal instead that a single *Livistona* ancestor colonised Australia from the north 10–17 million years ago, and that the populations in Palm Valley could have been established by immigrant seeds from the Roper River about 15 000 years ago. It is most likely that the palms are a legacy of dispersal, either by Aborigines or by birds and other animals.[18]

The low vegetation typical of arid Australia is in stark contrast with tall Livistona*, Palm Valley, Northern Territory. Photo: Jurriaan Persyn.*

Marine plants and animals

Sharks and rays are fishes characterised by skeletons made of cartilage rather than bone. Australian marine and estuarine waters support more than 320 species, representing 25% of the global total. Some barely exceed 20 cm, such as the small-eye pygmy shark, *Squaliolus aliae*, whereas the largest whale sharks, *Rhincodon typus*, exceed 12 m. New samples and methods reveal under-appreciated richness, with around 100 new Australian species having been recently described. Nearly half of the 11 known species of wobbegong sharks have been recognised only since 2001.[19]

Most of us know that there are strange animals in the deep, such as angler fish and giant squid, but an equivalent world of smaller organisms goes unnoticed. Sea floor 'grab' samples can contain hundreds of individual invertebrate animals and dozens of species. Specimens are sent to specialists around the world for examination and naming. It is remarkable how many species there are, how sparsely scattered they seem to be, and how few have been seen before. A recent voyage off Western Australia collected 108 species of sponges (70% of them new to science), 141 species of soft corals (80% new), 462 species of molluscs (67% new), 326 species of echinoderms (38% new), 529 species of crustaceans (30% new), over 50 species of ascidians (80% new) and 74 species of polychaete worms (30% new). Most were rare, and 50% of species occurred in only one sample!

Grab-sampling: from a staggering diversity of mostly undescribed organisms heaved out of the ocean during surveys of marine biodiversity, preliminary sorting into major groups sets the scene for later study. The scale of undescribed diversity in the oceans begins to be apparent from such trawls. Photo: Alan Butler, CSIRO.

Reef-building corals are well known in shallow tropical waters. In Australia's cold waters, however, there are horny and soft corals as well as stony corals that lack the symbiotic algae of tropical corals. On seamounts south of Tasmania they form spectacular 'forests' – not like the reefs in tropical seas but certainly a habitat for many kinds of animals. They grow very slowly: some have been aged at over 300 years (and perhaps thousands).

Parasites

Perhaps it is an unusual honour, but Australia possesses one of the most spectacular radiations of internal mammalian parasites in the world. The nematodes of kangaroos, wallabies and potoroos comprise 39 genera and 294 described species in one subfamily, the Cloacininae. The complex fore-stomach of the kangaroos is the centre of fermentative digestion, rather than the bowel as in placental mammals, so setting the evolutionary stage for this radiation. The marsupial hosts themselves came into being within the last 10 million years, so the evolution of the parasites can be dated to this time.[20]

Extinction of the megafauna and its aftermath

Just a few thousand years ago, Australia's terrestrial and marine environments were inhabited by many more very large species than today. Among this 'megafauna' in Australian seas and elsewhere was an enormous shark, *Carcharodon megalodon*, estimated to have reached 16 m in length and to have had teeth 17 cm long. It died out approximately 1.5 million years ago. On land, enormous marsupials became extinct as recently as 40 000 years ago. The giant grazer, *Diprotodon*, and the marsupial lion, *Thylacoleo*, are among the more famous. Explanations for their extinction are contentious. Did the arrival of humans lead to their extinction through hunting – or was climate change the cause? Perhaps both, but population modelling suggests that such animals were at risk of extinction under even low levels of hunting due to their slow rates of reproduction.[21]

Plants, too, tell of the extinct megafauna. In the Wet Tropics, fruit of the tree *Idiospermum australiense* are the largest of any Australian plant, weighing 225 g and measuring 8 cm in diameter. No living animal can swallow the fruit, which are starchy and contain toxins. Although musky rat-kangaroos, *Hypsiprymnodon moschatus*, may move and bury the seeds, the primary means of dispersal now is to roll downhill. We can only ask whether its seeds were once dispersed by giant animals, in the way some rainforest tree seeds today require passage through the gut of a cassowary for germination and for scattering from the parent.[22]

A painting of the fruits of the rainforest tree Idiospermum australiense*, which is unique to the Wet Tropics. Each fruit is about 8 cm across and cannot be swallowed by any living animal. Its primary means of dispersal is to roll downhill. Painting: WT Cooper.*

SPECTACULAR YET CRYPTIC RADIATIONS OF BIODIVERSITY

The molecular revolution of DNA analysis, and advances in sampling techniques, have led to the discovery of many unusual species among notable groups of organisms. This section discusses a few highlights.

Orchids

Australia is home to over 200 genera of orchids, including not only familiar species that are terrestrial and epiphytic (i.e. living on but not parasitising trees) but also the underground orchid, *Rhizanthella*. Orchid taxonomists have tended to split populations into separate species, although recent DNA analysis does not support many of these divisions. On the other hand, intriguing work in the genus *Chiloglottis* suggests that different species are visually similar but use very different chemical odours to attract their insect pollinators.[23]

Reptiles and amphibians

Australian desert reptiles have long been known to be rich in species, and now the molecular revolution has revealed even more diversity. Descriptions of new species in the last decade show the scale of the revolution in Australian reptiles and amphibians: a new desert taipan as venomous as its two closest relatives; a new goanna from the Pilbara; some 15 new species of frogs from across the continent; several new dragon-lizards from the deserts of Queensland and Western Australia; several new species in three genera of skinks; and new leaf-tailed geckos. The Kimberley, in particular, is emerging as a hotspot of new reptile and amphibian species.[24]

Stygofauna

An unusually rich example of stygofauna – animals such as aquatic beetles living underground – was discovered in the Yilgarn region of Western Australia in the late 1990s. This radiation of stygofauna has emerged as one of the world's most spectacular, having occurred in groundwaters ranging from freshwater to marine salinities, in both coastal and continental locations. The range of habitats and water quality, as well as the variety of evolutionary origins of the fauna, all help explain the stygofauna's diversity. Typically, species have tiny geographical ranges associated solely with local aquifers.[25]

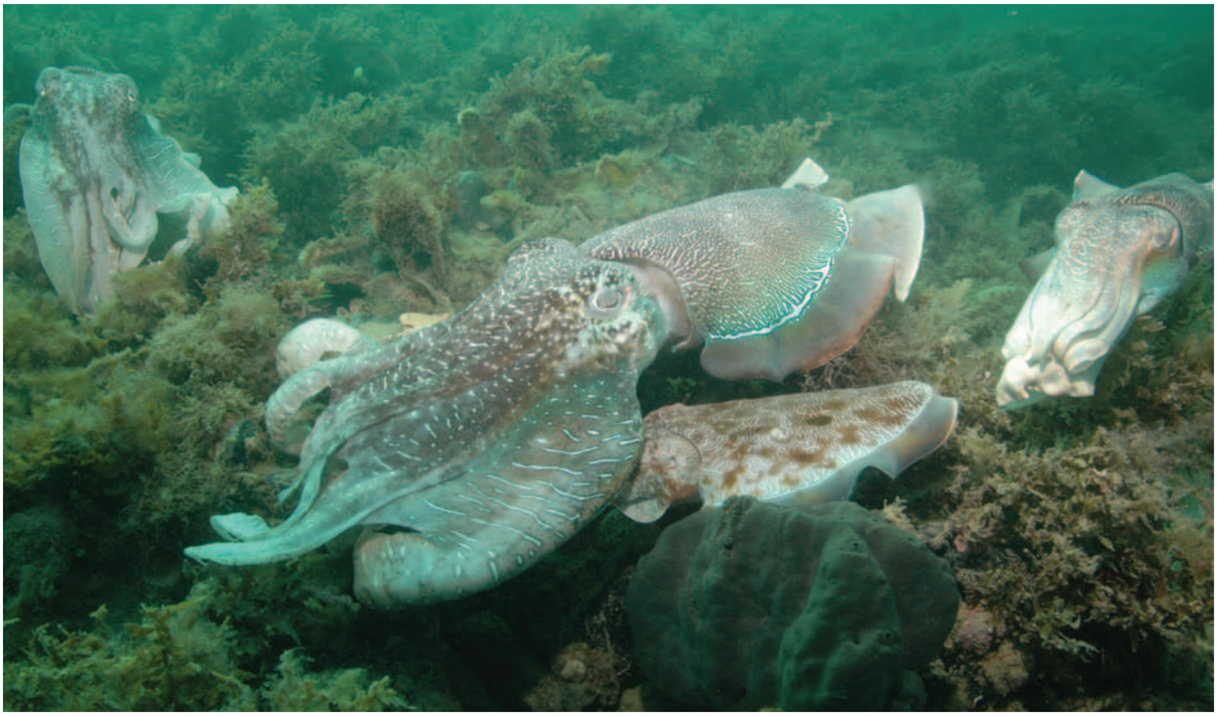
Handfish

Among Australia's many unique marine species are the aptly named handfishes (family Brachionichthyidae), which have modified fins on which they 'gallop' across the floor of estuaries and seas between 2 and 30 m in depth. A fossil handfish is known from Italy from some 50 million years ago, but the 14 living species occur only in southern and eastern Australian waters and seven are restricted to Tasmania.[26]

A spotted handfish, one of Australia's most unusual marine species, pictured with its egg-mass. Living members of the family survive only in temperate Australian waters although fossils have been found in the present-day northern hemisphere. Photo: CSIRO.

Cuttlefish

Australia is home to some special cuttlefish, squid and octopus. The giant cuttlefish, *Sepia apama*, is the largest cuttlefish in the world, sometimes reaching a metre in length, and ranging throughout temperate Australian waters. In upper Spencer Gulf, South Australia, more than 200 000 gather annually from May to August to spawn on a shallow reef. Two groups of offspring are produced: fast growers that spawn in their first year; and slow growers that only spawn at a large size when two years old. The reasons behind this unique aggregation, and the significance of the dual spawning pattern, are still uncertain.[27]



Giant cuttlefish, which can weigh up to 5 kg, gather in huge numbers to breed in upper Spencer Gulf, South Australia. Photo: Graham Edgar.

Plant–animal interactions

Australia contains many intricate examples of plants and animals that have evolved together with interactions that require detective work to unravel. For example, many insects (flies, wasps, thrips and scale insects) cause excessive growth of plant tissues called galls, often in association with fungi and other dependent organisms. The insect causing the gall uses the structure to shelter its young from heat and dry conditions. In particular, flies of the family Fergusoninidae have a symbiotic relationship with nematode worms.[28] Female flies carry the nematodes around in their abdomens, and deposit nematodes with their eggs in eucalypt flowers, leaves and stems. The nematodes feed on the plant tissue and form the gall on which the fly larvae feed. When mature, the female nematodes migrate back into female fly larvae. On emergence from the gall, the female flies

A gall of Fergusonina *growing on red stringybark,* Eucalyptus macrorhyncha*, Canberra, Australian Capital Territory. The gall is a microcosm of complex interactions among the life histories of flies, nematodes and plants. Photo: Michaela Purcell, ANU/CSIRO.*

then carry a new generation of nematode larvae to lay with their eggs. The flies are specific to the particular host eucalypt and even to the leaf, flower or stem of the host species.

CONCLUSION

There is still a huge amount of scientific work to be done on the complex evolutionary history and ecology of Australia's biodiversity. Australia has many unique elements to its biodiversity relative to that found elsewhere in the world, but also has much in common with other places, particularly our nearest northern neighbours. This chapter demonstrates that understanding of Australian biodiversity helps develop deeper appreciation of the living organisms with which we share our continent and its marine waters. For us this is a passion, as scientists and authors, but it is also imperative for guiding future management. The chapters that follow will probe further the intricacies of our biodiversity, the challenges it faces in a modern world, and the work being done to help ensure its future.

FURTHER READING

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