The living ocean

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Key messages

- Australia's marine biodiversity is highly diverse with many unique components.
- Multi-scale patterns in species, habitats and the environment reflect both geological history and current environmental conditions.
- Australia's marine biodiversity has been mapped to define 'bioregions' for management purposes.
- The distribution and abundance of many marine species are changing in response to local and global drivers including resource extraction, habitat loss, marine pollution, ocean warming and more acidic oceans.
- The consequences of these changes for biodiversity and the marine products and services that currently benefit the Australian community remain unclear.
- Australia has started nationally consistent programs to monitor changes in its marine resources and inform future management of marine biodiversity.

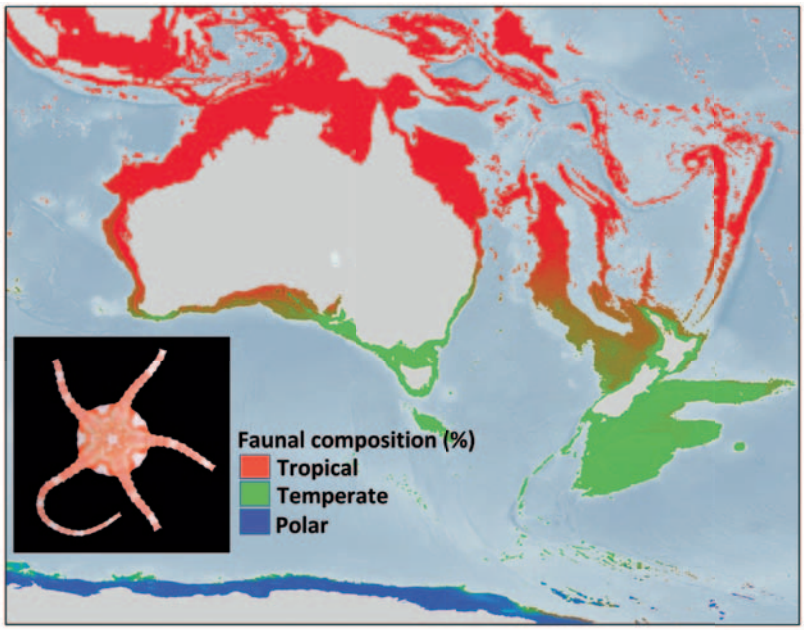
INTRODUCTION

The oceans surrounding Australia and the Australian Antarctic Territories are among the biologically most diverse in the world. Australia's complex geological history and large geographical scale have helped create this wealth of marine biodiversity that spans the tropics to Antarctica, from the inter-tidal zone to abyssal depths. Many of our marine habitats remain unexplored and their biological inhabitants poorly known but we know enough to recognise that our marine estate contains extraordinary biological diversity. Australians value this biodiversity for its aesthetic qualities but marine biodiversity also contributes to a range of commercial values. Marine tourism, for example, contributes about A$11.6 billion to the Australian economy annually, while commercial marine fisheries and aquaculture were valued at A$2.4 billion in 2012–13. Healthy, biodiverse marine ecosystems also deliver services harder to value in monetary units, such as coastal stabilisation by coral reefs, mangroves and seagrasses – the value of which may be realised only following their removal or after major storm events.

THE SCALE, DIVERSITY AND CLASSIFICATION OF AUSTRALIA'S MARINE ESTATE

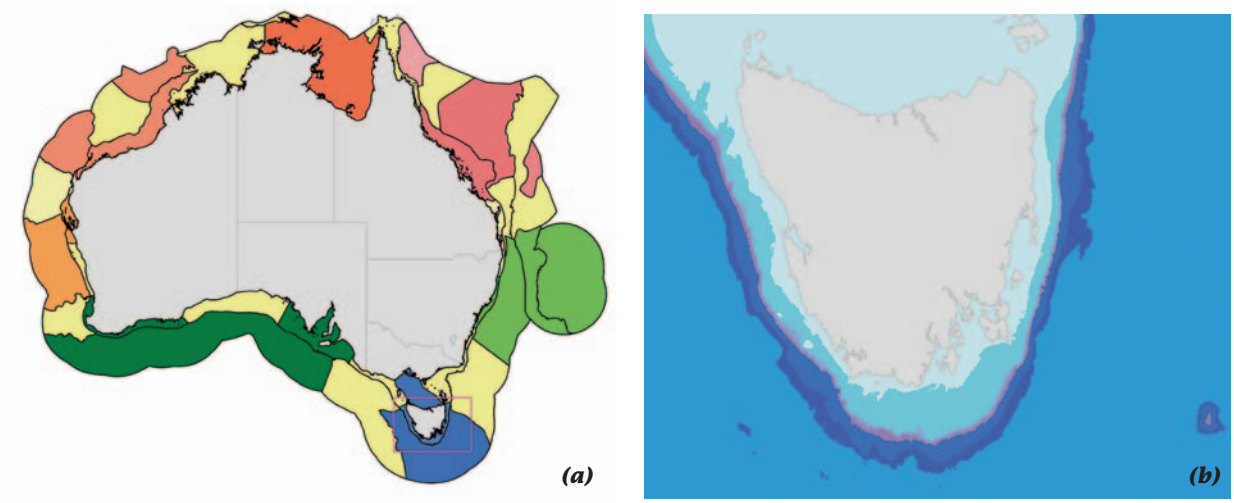
Australia's marine estate is the third largest in the world (Chapter 8). Some 33 000 marine species, mainly animals, have been recorded from Australian waters. About 17 000 others have been collected but not catalogued, making Australia's marine biota among the most diverse worldwide. Many new species still are being discovered. It is estimated that only 10–20% of Australian marine organisms may have been sampled – so there may be as many as 250 000–500 000 Australian marine species, not including microscopic plants and animals. Biodiversity is known best at depths shallower than 200 m and poorly known at greater depths. There have been few samples of any kind collected beyond 2000 m depth. It is likely that as many as half of all species in new collections from the deep ocean will be new to science.

Australia's marine habitats presently span tropical to polar latitudes and occupy parts of three oceans (Pacific, Southern and Indian) and four marginal seas (Timor, Arafura, Coral and Tasman). Evolutionary processes linked to geological history and modern day processes such as sediment movements, temperature gradients, nutrient input and productivity, and ocean circulation have created the distributional or 'biogeographic' patterns we see today, including strong north–south and depth-related patterns (Fig. 3.1). The northern tropical biota is highly diverse, with many species shared with the 'megadiverse' Indo-West Pacific region. Our southern biota, in contrast, is characterised by a high level of endemism (species found nowhere else).



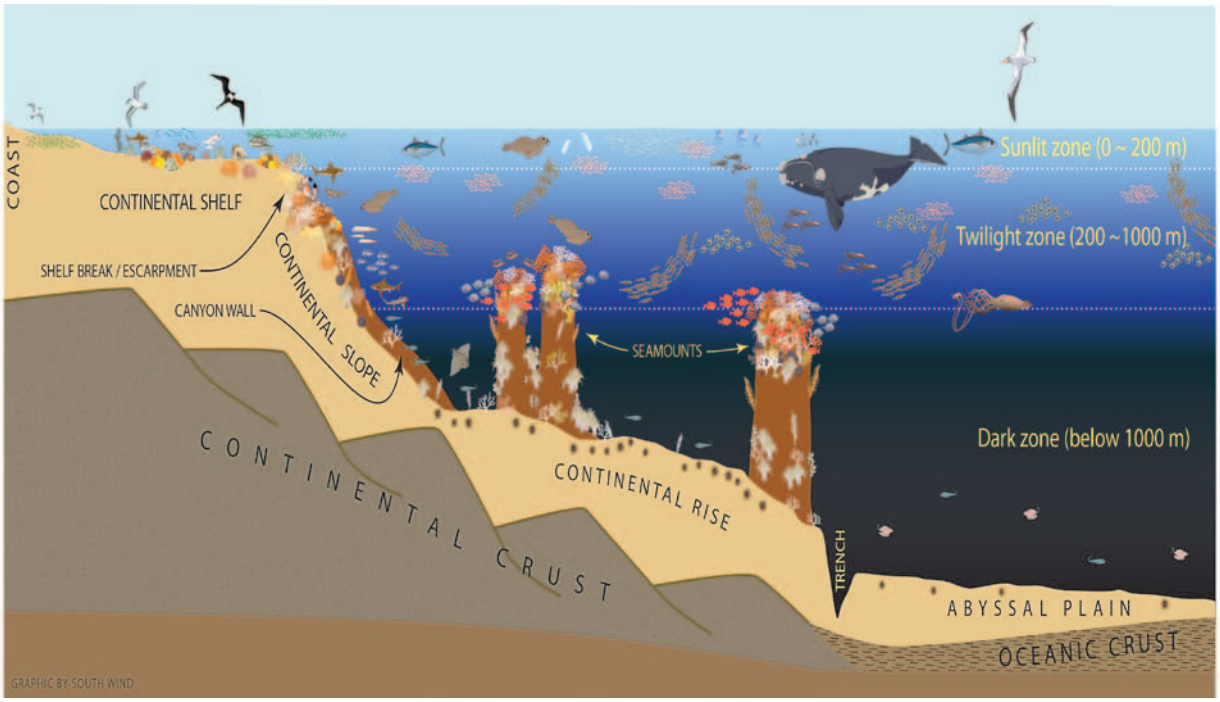
◂ ***Figure 3.1****: Brittlestar communities show strong north–south and depth-related patterns of species composition and distribution that is typical for Australia's marine biota (Sources: reprinted from O'Hara* et al. *(2011)[1] with permission from Elsevier; inset image courtesy Karen Gowlett-Holmes).*

Biodiversity is influenced by environmental properties at regional scales (100–1000 km^2) and can be modified by particular water column and seabed features at finer spatial scales. Water column features such as oceanic fronts, eddies or upwelling provide areas of enhanced productivity where animals aggregate. Geological seabed features such as submarine canyons or undersea mountains (seamounts) provide scarce rocky substrata in the predominantly muddy deep sea that can support modified or unique biodiversity. These multi-scale patterns have been mapped collectively in a process called 'marine bioregionalisation' that has been used by the Australian Government to define 'bioregions' for management purposes (Fig. 3.2).



▴ ***Figure 3.2****: Marine bioregionalisation for Australia showing* ***(a)*** *bioregions at national scale, and* ***(b)*** *finer scale pattern around Tasmania representing the strong influence of depth on biodiversity distribution[2] (Source: CSIRO).*

Most marine life ultimately depends on sunlight for energy, though some ecosystems around geothermal vents at great depths are supported entirely by chemical processes. Two-thirds of the oceans are below the sunlit zone, however, and half below the twilight zone. Adapting to this range of light levels and distance from primary production – the basis of most ecosystems – are key elements structuring marine habitats (Fig. 3.3).



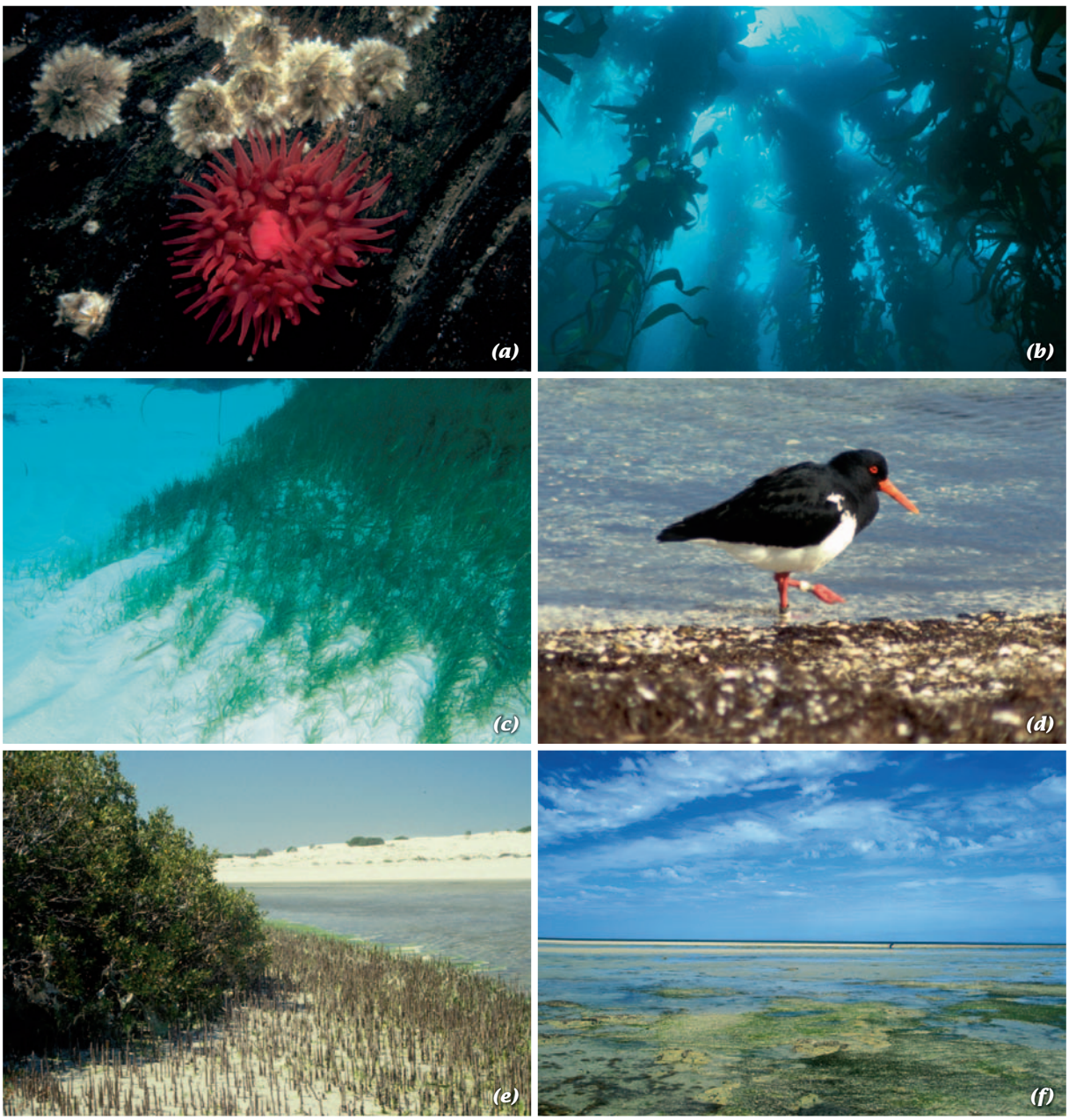
▲ ***Figure 3.3****: Schematic representation of broad habitat types from the coast to abyssal depth in Australian seas (Source: Peter Boyer, South Wind Graphics).*

BROAD HABITAT TYPES AND COMMUNITIES OF THE MARINE ESTATE

Coasts

Australia's coastal marine habitats include rocky shores, cobble and sand beaches, mudflats, mangroves and wetlands. Coastal communities broadly can be considered as 'supratidal', 'intertidal' and 'subtidal'. Organisms in supratidal areas are submerged in sea water only rarely but are exposed to fresh water, large changes in temperature, and a great variety of predators including land animals and seabirds. The intertidal areas between high and low water marks are characterised by varying degrees of submergence and the effects of wave action and turbulence. Mobile aquatic animals are able to forage here at high tide and retreat to deeper water, hide in refuges or seal-up at low tide, while algae and non-mobile aquatic animals living here are

adapted to survive short periods out of water during low tides. Subtidal areas are covered in sea water permanently and generally experience more stable environments with lower variation in temperature, salinity and sunlight. Typical organisms in the coastal habitats include molluscs, sea-stars, crabs, urchins, anemones, corals, sponges, fishes, and a great variety of algae, including kelp forests. All of these groups have high diversity in tropical and temperate Australian seas.



Australia's coastal marine habitats include rocky shores, cobble and sand beaches, mudflats, mangroves and wetlands: ***(a)*** *intertidal sea anemone and barnacles in a rock pool;* ***(b)*** *giant kelp forest;* ***(c)*** *seagrass bed;* ***(d)*** *pied oystercatcher foraging on a sandy beach;* ***(e)*** *mangroves at low tide;* ***(f)*** *mudflat at low tide (Source: all images Karen Gowlett-Holmes).*

The continental shelf

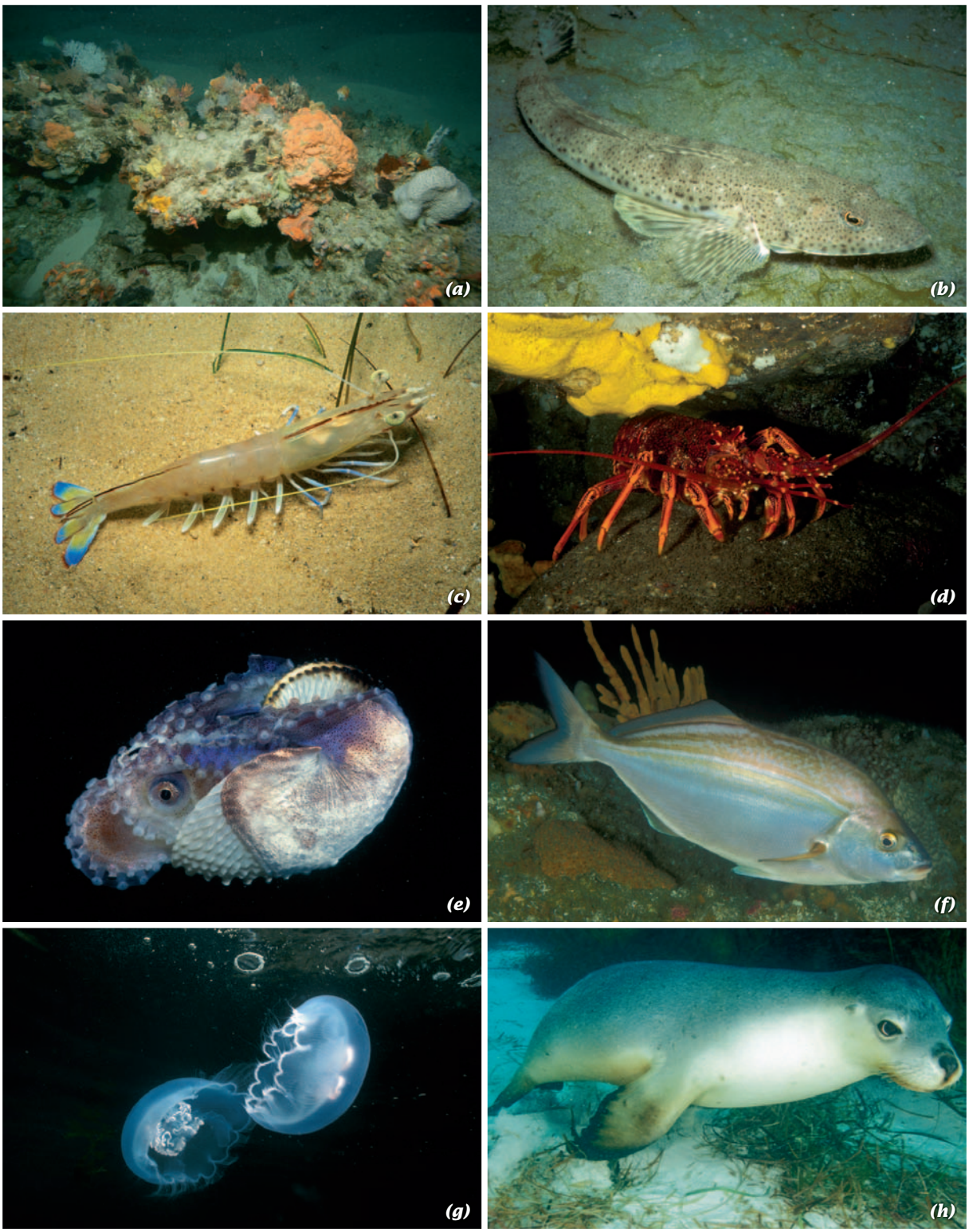
Subtidal habitats change as ocean depth and distance from the Australian coast increases across the continental shelf – the gently sloping seabed that extends to ~140–200 m depth before dramatically steepening at the 'shelf break'. The width of Australia's continental shelf varies considerably, from ~10 km in places such as off the Ningaloo coast of north-west Western Australia and off central New South Wales to 500 km in parts of the Great Australian Bight. Habitat types include rocky reefs and extensive plains of land-derived sediments that typically grade from coarse-grained sands to fine mud as distances from coasts increase and wave influences diminish. Biological production in continental shelf waters is high relative to the deeper ocean because the shelf's sunlit (photic) environment, well-oxygenated water and higher nutrient levels collectively fuel photosynthesis in phytoplankton (free-floating microscopic plants) and algae (seaweeds). This primary production is the base of food webs supporting larger animal plankton and herbivores including euphausids (krill), copepods, jellyfish and amphipods. Many larger carnivorous animals are found in both water column (pelagic) and seabed (benthic) habitats, including many of the species most familiar to Australians as seafood or the targets of recreational fishing (e.g. prawns, lobsters, squids and fishes), megafauna (e.g. turtles, seabirds and mammals) or iconic species (e.g. white shark, seals and whales). Biological diversity and abundance generally are high in shelf waters and on the seabed.

Coral reefs are well-known habitats that extend from the intertidal to subtidal zones in warm, typically nutrient-poor waters. Reefs are formed mostly from calcium carbonate skeletons of stony corals and calcareous algae. Coral reefs are extremely diverse ecosystems that include species from almost all known taxa. Australia's Great Barrier Reef (GBR) is the world's largest reef system, made up of over 3000 individual reefs and shoals and extending over 2600 km from the south coast of Papua New Guinea to just north of Fraser Island. The GBR supports over 1500 species of fish, 30 marine mammal species, six species of sea turtle, 215 visiting or nesting species of birds, and 17 sea snake species. Over 4000 species of invertebrates – including corals, sea cucumbers, sea stars, crabs, shrimps, molluscs and worms – also are known from the GBR, and many more are undescribed. Abundance of reef-forming corals has declined by around 50% over the past three decades, causing great concern nationally and internationally.

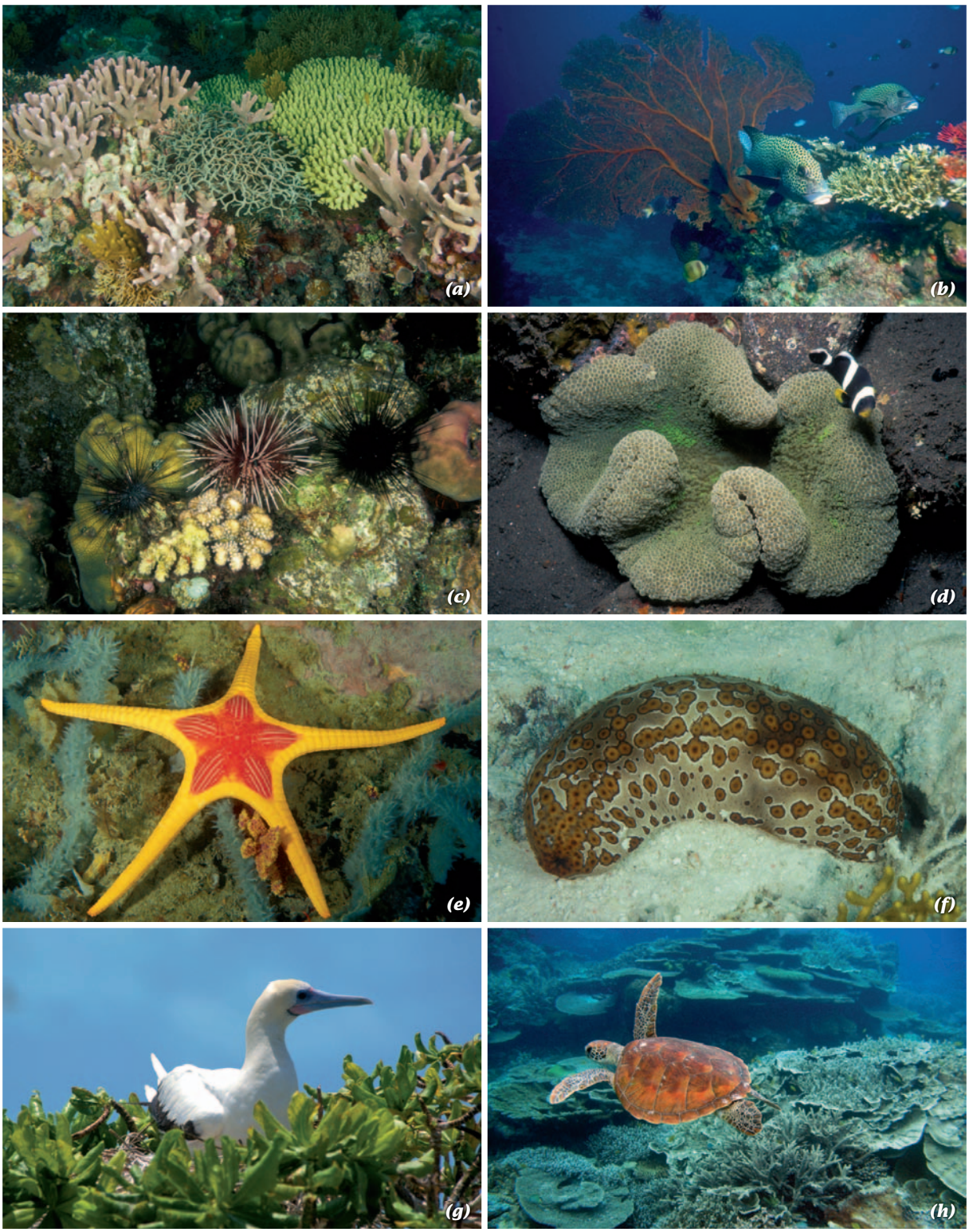
The deep ocean

Most of Australia's marine estate lies beyond the continental shelf break. The seabed drops steeply from the shelf break, at around 200 m depth, through the steep continental slope and deeper continental rise to 3000 m depth. Vast, relatively flat expanses of muddy sediments form the abyssal plain beyond these features in depths exceeding 3000 m.

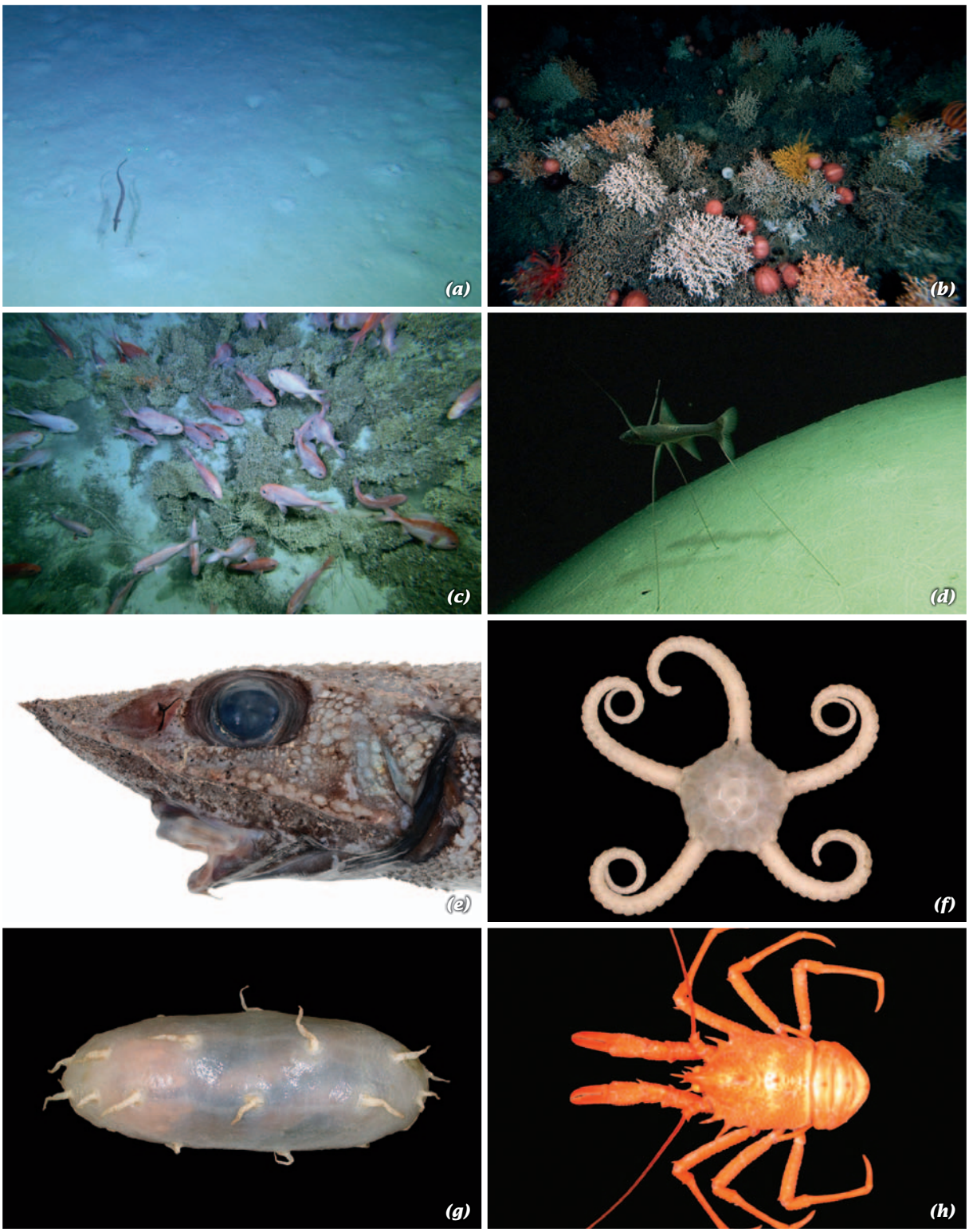
Animals live in total darkness beyond ~1000 m depth, at extreme pressure, with relatively low oxygen levels, and at temperatures of less than 4ºC. No plants live at these depths. Food arrives at the seabed mainly as sinking particulate matter (detritus) composed of bodies and fragments of dead animals and faecal material from the water column above. There typically is an exponential decrease in animal biomass with increasing ocean depth and most biomass in the offshore ocean is in the water column rather than on the seabed.



Australia's continental shelf provides habitats for many familiar marine species: ***(a)*** *sponges on a reef at 100 m depth;* ***(b)*** *southern sand flathead;* ***(c)*** *western king prawn;* ***(d)*** *southern rock lobster;* ***(e)*** *argonaut;* ***(f)*** *bastard trumpeter;* ***(g)*** *moon jellyfish;* ***(h)*** *Australian sea lion (Sources: reef image CSIRO; all other images Karen Gowlett-Holmes).*

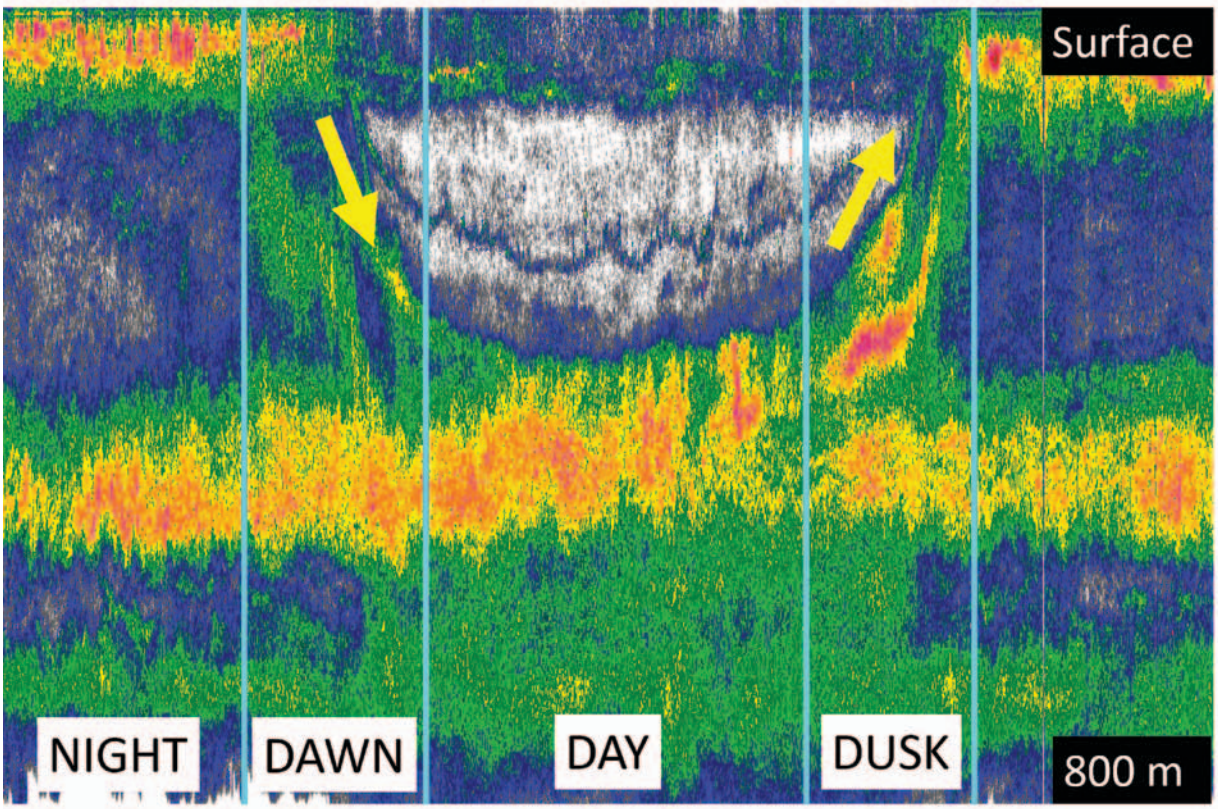


A great diversity of species is associated with coral reefs: ***(a)*** *reef composed of stony corals;* ***(b)*** *fan corals and fishes;* ***(c)*** *coral reef with feeding sea urchins at night;* ***(d)*** *sea anemone with anemonefish;* ***(e)*** *seastar on sponges;* ***(f)*** *tigerfish holothurian;* ***(g)*** *red-footed booby on a nest;* ***(h)*** *green turtle swimming above a coral reef (Sources: green turtle and reef slope vistas GBRMPA, Commonwealth of Australia; all other images Karen Gowlett-Holmes).*



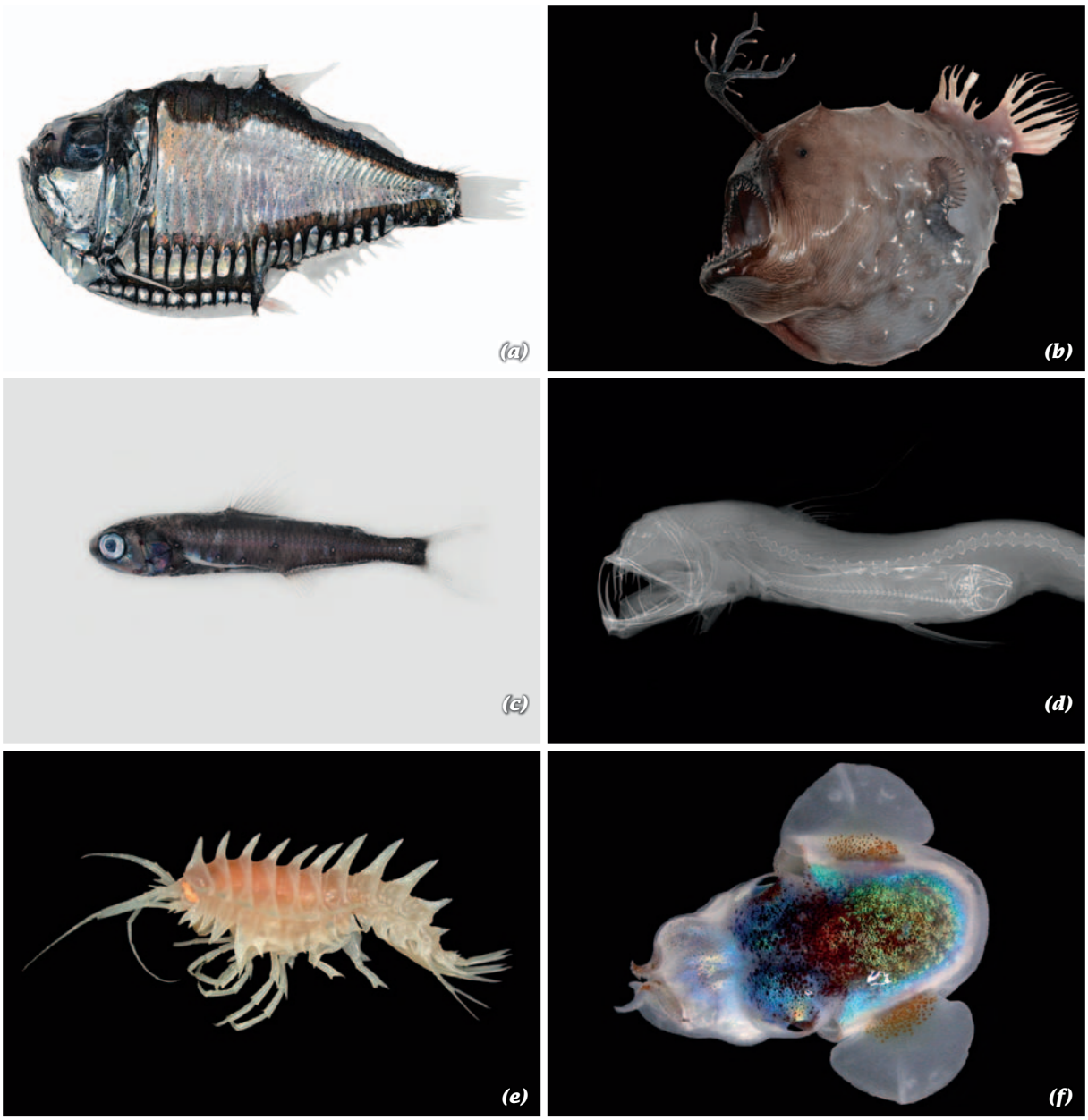
Views of the deep ocean seabed and its biodiversity: ***(a)*** *muddy seabed with an eel at 1600 m depth;* ***(b)*** *reef-forming stony coral with urchins and soft coral on a seamount at 1200 m depth;* ***(c)*** *a small school of orange roughy on a seamount targeted by commercial fishers at 950 m depth;* ***(d)*** *tripod fish;* ***(e)*** *head of a rat-tail fish;* ***(f)*** *brittlestar;* ***(g)*** *seapig holothurian;* ***(h)*** *squat lobster (Sources: a–c CSIRO; d–e National Fish Collection, CSIRO; f–h Karen Gowlett-Holmes, CSIRO).*

Many ocean inhabitants move up and down through the water column daily to either avoid predators or pursue prey. Nighttime ascent of large numbers of animals is seen by ships' echo-sounders and referred to as diel migration of the 'deep scattering layers' (Fig. 3.4); the majority are lanternfishes.



▲ ***Figure 3.4****: A ship's echo-sounder records the twilight vertical migration (descending at dawn and ascending at dusk, yellow arrows) of a myriad of small organisms making up the 'deep scattering layers' in the upper 800 m of open ocean. The colour gradient from white to blue, green, yellow and red depicts increasing biomass (Source: CSIRO Bioacoustics Group).*

Animals living at great depth show many adaptations and specialisations for finding food, avoiding predators and communicating in near complete darkness. Adaptations of body form are most striking in fishes living in the deep water column, such as the anglerfishes, dragonfishes and their relatives, where lures for prey, large mouths, long teeth and highly distensible stomachs maximise the chances of encountering, capturing and digesting scarce prey.



Examples of biodiversity in the deep open ocean: ***(a)*** *hatchetfish showing large light organs;* ***(b)*** *anglerfish with lure on head;* ***(c)*** *lanternfish with small light organs;* ***(d)*** *dragonfish with large meal as shown by X-ray;* ***(e)*** *amphipod;* ***(f)*** *bottle-tail squid (Sources: a–d National Fish Collection, CSIRO; e–f Karen Gowlett-Holmes, CSIRO).*

Antarctic waters

Australia's Antarctic Territories contain a full range of coastal to deep ocean habitats, albeit in very cold waters (typically below 2ºC). Antarctic biodiversity includes many iconic bird species such as penguins and albatross and marine mammals including many species of whales and seals. The Antarctic krill (*Euphausia superba*) is a keystone species in the marine food web, with biomass measured in hundreds of million tonnes, which is food for many fish, bird and mammal species. Antarctic waters also support diverse benthic communities characterised by sponges, corals, seastars and brittlestars.

Examples of Antarctica's rich biodiversity: ***(a)*** *minke whales;* ***(b)*** *seabed invertebrates;* ***(c)*** *krill;* ***(d)*** *black-browed albatross;* ***(e)*** *elephant seals;* ***(f)*** *king penguins (Sources: a Frederique Oliver, Australian Antarctic Division (AAD); b Cooperative East Antarctic Marine Census Project 2007–09, AAD; c Rob King, AAD; d James Doube, AAD; e Karen Gowlett-Holmes; f Barend Becker).*

HUMAN PRESSURES ON BIODIVERSITY

Human pressures including pollution, climate change and acidification, exploitation, invasive species, and habitat loss are affecting marine communities. Human pressures vary around the Australian and Antarctic coastlines, depending on population densities and locations of industries and land uses, but some pressures, such as ocean acidification and pollution, have effects throughout the ocean over long timescales. Many marine species will adapt to new pressures but some species might not be able to adapt rapidly enough for local survival. Species inhabiting the continental shelf off southern Australia, for example, will have fewer options to respond to warming oceans, such as by range extension, because they already are at the edge of the available habitat or environmental conditions they require. Understanding the nature and amount of both natural and human-induced changes in Australia's marine biodiversity is key to deciding how to conserve and use biodiversity appropriately now and in the future, and to measure the effects of management interventions and changing environment. The quantitative, nationally consistent and long-term monitoring programs and infrastructure required to underpin such understanding are being designed and implemented by the Australian Government, for example through the Integrated Marine Observing System (IMOS) and Marine National Facility new research vessel *Investigator*.

***(a)** Australia's new research vessel* Investigator *has enhanced Australia's capacity to understand its marine biodiversity.* ***(b)** Biodiversity sampling equipment on the vessel's back deck (Source: CSIRO, Stewart Wilde).*

CONCLUSION

Australia's marine biological communities are dynamic over a range of timescales that reflect adaptations to the geological past over millions of years and responses to modern day environments. Multi-scale spatial patterns in species and habitats have been mapped to define 'bioregions' for management purposes. Increased knowledge and measurement of changes in the distributions of marine species and structure of marine communities are part of Australia's strategy for managing its biodiversity into the future.

FURTHER READING

Australia's Antarctic biodiversity: The Biogeographic Atlas of the Southern Ocean, <http://atlas.biodiversity.aq/index.html>.

Australia's Integrated Marine Observing System (IMOS), <http://imos.org.au/about.html>.

Australia's marine biodiversity: conservation, management and marine reserves, <http://www.environment.gov.au/marine>.

Biodiversity on the Great Barrier Reef, <http://www.gbrmpa.gov.au/about-the-reef/biodiversity>.