Chapter 3

Changes in fish stocks, marine biodiversity and marine ecosystems

3.1 As noted in the previous chapter, evidence received by the committee noted that climate change represents only one threat to the marine environment; for example, the Environmental Defenders Offices of Australia (EDOA) noted that coastal development, pollution and over-exploitation of fisheries are other concerns.[1] It was also noted that effects of climate change 'are likely to be cumulative' and initially may be non-lethal (such as 'reduced reproduction, changes in timing of reproduction and reduced rates of calcification in some species').[2]

3.2 Nevertheless, there is evidence of various changes in Australian ecosystems that have been attributed to climate change. For example, the Australian Fisheries Management Authority's (AFMA's) submission provided the following list:

- changes to phytoplankton productivity;
- changes to macroalgal species abundance;
- changes to growth rates in abalone, rock lobster, fish and coral;
- changes to the life cycle of southern rock lobster;
- changes to the distribution of seaweeds, plankton, fish and sea urchins;
- coral bleaching on the Great Barrier Reef and Ningaloo Reef;
- reduced calcification rates of corals; and
- various developments relating to microalgae, including warm water macroalgae extending ranges poleward and reduced ranges of coldwater macroalgae.[3]

3.3 AFMA's submission also provided a list of predicted changes, as follows:

- increased sediment discharge to estuaries and reef waters;
- acidification expected to affect 'various calcifying taxa' such as corals, coralline algae and calcareous plankton;
- the Great Barrier Reef and other low latitude reefs to be negatively affected by warming and acidification, with thermal stress, reduced calcification and increased frequency of bleaching resulting;

---

1 Environmental Defenders Offices of Australia (EDOA), *Submission 4*, p. 3.

2 Australian Marine Sciences Association, *Submission 5*, p. 2.

3 Australian Fisheries Management Authority (AFMA), *Submission 9*, pp. 8–9 (citations omitted).

- 'uncertain but potentially major negative impacts to krill abundance in Southern Ocean';
- 'scouring of benthic habitats by sea ice/icebergs around Antarctica';
- increased phytoplankton production in the Southern Ocean;
- continued changes to warm water and cold water macroalgae ranges;
- increased disease outbreaks;
- stressors to seagrasses exacerbated by temperature increases; and
- benefits for mangroves (where space is available) arising from temperature and sea level impacts.[4]

3.4 This chapter discusses the current and projected implications of climate change in Australian waters for fish stocks, marine biodiversity, marine ecosystems, and marine pests and diseases.

Implications for fish stocks, marine biodiversity and ecosystems

3.5 The Australian Institute of Marine Science (AIMS) advised that several factors will influence the extent that rising ocean temperatures will affect individual marine species. Some of these factors include:

- 'current species distribution and thermal thresholds';
- 'generation time and capacity to adapt/evolve to changing conditions';
- habitat dependence (for example, obligate coral reef dwellers); and
- mobility.[5]

3.6 Much of the evidence received by the committee related to the consequences of warming ocean temperatures. This issue is discussed first, followed by consequences arising from other changes to the physical attributes of the oceans. Particular consequences for coral reefs, which have an especially important role in marine biodiversity, are also examined.

Consequences of rising temperatures

3.7 Professor Stewart Frusher from the Institute for Marine and Antarctic Studies (IMAS) explained that 'most animals have what we call a thermal envelope—a temperature which they can survive in'. Professor Frusher added that temperature tolerances vary among species, and that some species 'can enjoy a wide range and so warming temperatures are not that much of an issue'.[6] However, if temperature

---

4 AFMA, *Submission 9*, pp. 9–10.

5 Australian Institute of Marine Science (AIMS), *Submission 10*, p. 2.

6 Professor Stewart Frusher, Institute for Marine and Antarctic Studies (IMAS), *Committee Hansard*, 21 February 2017, pp. 1, 2.

increases cause species to reach their thermal limit, to survive those some species will need to adjust in-situ or, if able, move to an area where the temperature is suitable.[7] AIMS submitted the following overview of how species can respond:

> Movement to new areas would result in range shifts in distribution. Species that have low mobility or rely on specific habitats for survival may or may not be able move to new or more suitable habitats. Sessile species such as marine plants, corals and other invertebrates obviously cannot move. In these cases, if species cannot evolve quickly enough their distribution range may shrink as populations are no longer viable in areas beyond their thermal tolerance.[8]

3.8 Professor Frusher noted that, for species with narrow temperature tolerance ranges, 'a slight change in temperature can spell doom for them'.[9] Likewise, Dr Alistair Hobday, a senior principal research scientist at CSIRO, commented that species which cannot move further south in response to warming temperatures 'will not persist in the way that we would like them to'. Using the flathead species in southern Tasmanian waters as an example, Dr Hobday explained that 'there is nowhere south of Tasmania…that is shallow enough for those animals to live'. Dr Hobday summed up the lack of suitable habitat southward for that species as follows: 'Imagine being pushed off the top of [a] mountain'.[10]

3.9 Numerous observations of mortalities and changes to species distributions were presented to the committee, a selection of which is discussed in the following paragraphs. Overall, however, the Sydney Institute of Marine Science (SIMS) advised that the poleward shift in the distribution of marine organisms is up to 'ten times faster' than the species responding on land. The average speed is 72 kilometres per decade, with the fastest poleward distributions being phytoplankton (470 kilometres/decade) and bony fish (278 kilometres/decade). The changes in distributions are expected to 'become faster in the next few decades'.[11] At present, Dr Hobday advised that there is 'really strong evidence of over 100 species of fish changing distribution down the east coast of Australia'.[12]

---

7 IMAS, *Submission 1*, p. 15; AIMS, *Submission 10*, p. 2.

8 AIMS, *Submission 10*, p. 2.

9 Professor Stewart Frusher, IMAS, *Committee Hansard*, 21 February 2017, p. 2.

10 Dr Alistair Hobday, Senior Principal Research Scientist, CSIRO, *Committee Hansard*, 17 March 2017, p. 5.

11 Sydney Institute of Marine Science (SIMS), *Submission 8*, p. 2.

12 Dr Alistair Hobday, CSIRO, *Committee Hansard*, 17 March 2017, p. 2.

3.10 In Western Australia, the 2011 heat wave in the Indian Ocean caused substantial mortalities in some species, such as 99 per cent mortality in Roe's abalone (*Haliotis roei*) in a particular region. Reductions in the recruitment of scallops and prawns were also observed.[13] In addition, the heat wave appears to have resulted in the 'tropicalisation' of fish in waters off Western Australia.[14]

3.11 In south-east Australia, a southward shift in certain species has been observed and further changes are predicted. IMAS explained:

> The warming observed off Maria Island, Tasmania, since the 1940s is a function of the increase in strength of the East Australian Current, and represents a shift in the coastal water isotherms such that the water seen off Maria Island today would be equivalent to what was recorded off Eden in the 1940s—a 350km southern shift in water temperatures. Thus those animals adapted to the water temperatures off Eden in the 1940s would now find their preferred niche off Maria Island. We are seeing a large number of species beginning to make Tasmania their home, or an increase in abundance of species that were previously rare or uncommon in Tasmanian waters.[15]

3.12 The Fisheries Research and Development Corporation (FRDC) submitted that east coast species that have undergone a southward shift or extended their range include mahi-mahi (*Coryphaena hippurus*) caught recreationally in Tasmania, 'many recreational target species' and long-spined sea urchins (*Centrostephanus rodgersii*). Modelled predictions also suggest that along the Tasmanian east coast, the southern rock lobster will be replaced by eastern rock lobster (*Sagmariasus verreauxi*).[16]

3.13 The poleward shift of species to Tasmanian waters is considered 'especially noteworthy' for certain species as 'the capacity for further shifts poleward is limited in this region due to a lack of suitable habitat, especially for coastal and shelf species'.[17] Professor Frusher commented:

> One of the problems we have in Tasmania is that the animals that are specific to cold and shallow water have nowhere to shift to once our waters warm. So we would expect to see, as our waters warm, extinctions. It is a long hop, step and jump to get to Macquarie Island, and they are not going to be able to do that. Some species can move into deeper waters which are cooler, but if you are dependent on, for instance, algae for food and light sources then shifting into deeper water is not an option for you as far as habitat goes.[18]

---

13 Fisheries Research and Development Corporation (FRDC), *Submission 2*, p. 7.

14 Australian Marine Sciences Association, *Submission 5*, p. 2.

15 IMAS, *Submission 1*, pp. 3–4 (emphasis omitted).

16 FRDC, *Submission 2*, p. 7.

17 Australian Marine Sciences Association, *Submission 5*, p. 2.

18 Professor Stewart Frusher, IMAS, *Committee Hansard*, 21 February 2017, p. 2.

3.14 Other developments observed include the loss of kelp beds in Western Australia and eastern Tasmania due to higher ocean temperatures.[19] The loss of kelp forests[20] off the coast of eastern Tasmania was highlighted by several witnesses; for example, Dr Barrett from IMAS submitted:

> There are lots of species of algae out there—literally 1,500 red algae and another 400 or 500 brown and green algae in southern Australia. A lot of those are endemic and a lot of those will be lost. A classic example is *Macrocystis*, the giant string kelp. This is not endemic to Tasmania—it is found globally—but it is an indication of the sorts of changes we are going to see. The particular species formed extensive forests up our east coast, since from forever until 30 years ago. Those forests were up to 30 metres in height and could extend one kilometre, or more, offshore where there was enough reef habitat. They were a major three-dimensional structural habitat, really important to a whole range of our species on the coastline. With that warming, we have basically tipped over their upper thermal limit and we have seen a major decline. We do not see those forests at all on our east coast…the forests are gone. The species has not gone and there are still some forests on our south coast that are subject to more Antarctic water influence, or subantarctic water influence, but the forests themselves and the habitat are gone. The forests are now listed under the [*Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)] as a threatened ecological community. That is a major negative change.[21]

3.15 Mr Michael Baron, who owns a diving business located on the east coast of Tasmania, described the changes to the kelp forest as 'devastation…like a natural disaster in the scheme of things'. He remarked:

> Not only is it the forest that disappears…it is the disappearance of what I would consider a natural reserve. Try to imagine huge acreages—and I am talking huge areas—of forest that you could not net in, you could not pot in, you could not run a hooker through. They acted as a natural marine reserve. As a result of that, I would suggest from an amateur point of view that some of the decreases in a lot of the species down our way are a direct result of the loss of the reserve for the juveniles of those species and the settlement of, for example, rock lobster.[22]

---

19 IMAS, *Submission 1*, p. 4. Giant kelp forests in south-east Australia were listed under the EPBC Act in 2012 'with one of the major threats identified to be associated with climate change'. CSIRO, *Submission 15*, p. 10.

20 Dr Barrett explained that the giant kelp is important for the productivity of the east coast of Tasmania. He described the giant kelp as being an 'extremely productive plant—it produced a large amount of biomass that drifted off and fed grazers like abalone and fed the other invertebrates that rock lobsters feed on'. Dr Neville Barrett, IMAS, *Committee Hansard*, 21 February 2017, p. 5.

21 Dr Neville Barrett, IMAS, *Committee Hansard*, 21 February 2017, p. 4.

22 Mr Michael Baron, Owner, Eaglehawk Dive Centre, *Committee Hansard*, 21 February 2017, p. 14.

3.16 It was noted that the changes have both positive and negative implications. As an example of a positive development, Dr Barrett from IMAS observed that yellowtail kingfish and snapper are starting to be found in Tasmania.[23] However, it is considered that, for Tasmania, most of the developments have been negative for biodiversity. Dr Barrett explained:

> There are a lot of species here [in Tasmania] that are endemic to this part of the world. They are not found anywhere else; they are only found in Tasmania or southern parts of southern Australia. If it warms up another degree it is outside of their thermal tolerance; they have nowhere else to go. We are going to lose species like red handfish, spotted handfish, bull kelp—and there are hundreds of others I can list where we have modelled their likely disappearance over the next one degree Celsius temperature increase that, under the best-case scenario, will happen by the end of the century and, under the worst-case scenario, will happen, at the latest, by the 2060s. We will lose a whole lot of species and have major issues needing to manage them in aquaria or just wave them goodbye.[24]

3.17 Potential implications of rising temperatures for the migration and reproduction of certain species were also noted. AIMS explained that rising temperatures 'may have more profound effects on long-lived species (which are unlikely to evolve quickly enough to adapt to the change) or those requiring specific temperature cues as part of their life cycle'. For example, AIMS advised that the sex of marine turtles 'is dictated by sand temperature with females typically more common in nests in warm sands'. AIMS referred to recent evidence of female bias in hatching production for several species and added that female biased populations will continue to be created if temperatures at nesting beaches increase.[25]

3.18 Rising temperatures may also affect the size of individuals within a species. AIMS noted that 'some species may be [a] smaller size in warmer water and growth rates may change', although the extent of this outcome would vary by species.[26]

3.19 IMAS added that the change in distribution of certain species has consequences for the population of other species. IMAS used the example of long-spined sea urchins to demonstrate the effects:

> Temperatures off Tasmania's east coast are now warm enough for long spined sea urchin larvae to survive during their winter spawning period, leading to a climate-driven increase in the distribution and abundance of

---

23 Dr Neville Barrett, IMAS, *Committee Hansard*, 21 February 2017, p. 3.

24 Dr Neville Barrett, IMAS, *Committee Hansard*, 21 February 2017, p. 4. On the handfish, which is a species that is endemic to Tasmania and which cannot live in the Southern Ocean, Mr Jon Bryan from the Tasmanian Conservation Trust noted that it 'is basically stuck here in Tasmania, and, if the habitat becomes unsuitable here, they will become extinct'. Mr Jon Bryan, Marine Campaigner, Tasmanian Conservation Trust, *Committee Hansard*, 21 February 2017, p. 27.

25 AIMS, *Submission 10*, p. 3.

26 AIMS, *Submission 10*, p. 4.

> this species. Urchins have now extensively overgrazed kelp forests to form extensive sea-urchin barrens largely devoid of kelp and other seaweeds. Formation of urchin barrens creates a massive loss of biodiversity and local collapse of abalone and rock lobster stocks.[27]

3.20 The arrival of particular species due to the 'tropicalisation' of southern waters can have negative consequences for existing habitats. When discussing the movement of tropical fishes southward past Sydney through the East Australian Current, Professor Booth noted that increases in the population of the tropical surgeonfish in those waters is concerning as they 'are known to denude algal beds and could potentially destroy temperate ecosystems'.[28]

3.21 Expected regional variances in the consequences for biodiversity of climate change-induced species shifts were highlighted. The Australian Marine Sciences Association explained that modelling suggests northern Australia and Papua New Guinea 'will experience the highest drops in species richness (number of species) of anywhere on the planet'. For Australia overall, however, 'a modest increase is actually expected (as tropical species not currently present move poleward into temperate Australian waters)'. The Association cautioned that the 'makeup of the species assemblage is quite likely to be changed considerably in any given location'.[29]

3.22 It was noted, however, that the effects of climate change can be more complex to identify in particular areas. For example, Professor Suthers contrasted the waters off New South Wales with those around Tasmania. Professor Suthers explained that fluctuations in the East Australian Current over a ten-year cycle have implications for observing changes in New South Wales waters as, during this cycle, there are changes in 'how much goes off to the east towards New Zealand and Lord Howe Island, and how much goes down to Tasmania'. As Tasmania is 'at the bottom of the pipe', changes can be observed more readily. Furthermore, Professor Suthers noted that New South Wales has 'a very urbanised coastline', which means that there are effects linked to population pressures and increasing urbanisation as well as climate.[30]

3.23 A different perspective about the changing distribution of marine organisms was presented in the submission prepared by Dr Alan Moran for the Australian Environment Foundation. Dr Moran argued:

> If temperatures in the ocean change animal and plant life responds by migrating. This process has been evident throughout history—fossil remains of tropical fish have been identified in places where they now could not conceivably survive.[31]

---

27 IMAS, *Submission 1*, p. 4.

28 Professor David Booth, *Committee Hansard*, 16 March 2017, p. 2.

29 Australian Marine Sciences Association, *Submission 5*, p. 2.

30 Professor Iain Suthers, SIMS, *Committee Hansard*, 16 March 2017, p. 19.

31 Australian Environment Foundation, *Submission 12*, p. 9.

Consequences arising from other changes

3.24 Changing ocean currents are also expected to alter marine environments. As noted in Chapter 2, the eddies that are a feature of the East Australian Current are expected to increase in formation. This is expected to result in increased plankton production. The stronger currents and greater mixing of ocean layers also may 'increase the production of pelagic fish, albeit in more southern latitudes'.[32]

3.25 Changes in currents and temperatures are also expected to be particularly problematic for species with a long larval lifetime. Dr Hobday explained that these species need to be able to release their eggs 'in one part of the coast and have them float around and come back'. Dr Hobday continued:

> As the currents change, you now end up maturing somewhere where the coast is nowhere near you or you are in the wrong part of the climate. So we think very long lived larval species will be particularly challenged. That includes species like rock lobster, which are very valuable for the Australian economy.[33]

3.26 More frequent and intense severe weather events are also expected to affect marine ecosystems. CSIRO submitted that 'cyclones have the capacity to destroy inshore critical nursery habitat for fishery species and cause recruitment failure in subsequent years'. Furthermore, an 'increase in the frequency of category 4 and category 5 cyclones increases the likelihood of regular major impacts to shallow coastal regions that may cause the loss of habitats such as seagrass and mangroves and restrict their reestablishment'.[34]

3.27 In relation to the Spencer Gulf and Gulf St Vincent in South Australia, the South Australian Government submitted that 'predicted increases in the frequency of storms and rises in temperature…are likely to adversely impact seagrass habitats which support the recruitment of early life history stages of many commercially important species'. The Government added that changes in 'gulf hydrological processes due to climate change may also affect larval transport processes and impact recruitment success'.[35]

3.28 Acidification is expected to affect corals and other organisms that form calcium-based skeletons and shells by reducing their ability to calcify.[36] This is discussed below.

---

32 SIMS explained that '[r]ecent observations suggest that eddies (swirls or vortexes) of the East Australian Current provide significant offshore habitats for larval fish compared to those on the continental shelf'. SIMS, *Submission 8*, p. 3 (citation omitted).

33 Dr Alistair Hobday, CSIRO, *Committee Hansard*, 17 March 2017, p. 5.

34 CSIRO, *Submission 15*, p. 13.

35 Government of South Australia, *Submission 21*, p. 4.

36 AFMA, *Submission 9*, p. 9; CSIRO, *Submission 15*, p. 11.

Particular consequences for coral reefs

3.29 When considering biodiversity in the marine environment, particular attention should be given to coral reefs. Globally, coral reefs cover less than one per cent of the Earth's surface, yet contain 25 per cent of all marine fish species.[37] The Great Barrier Reef, which is the largest living structure on Earth, is home to a vast array of species, including among others:

- 1625 species of fish, including 1400 coral reef species;
- more than 3000 species of molluscs;
- 630 species of echinoderm (starfish, sea urchins);
- 14 breeding species of sea snakes;
- 215 species of birds, including 22 species of seabirds and 32 species of shorebirds;
- six of the world's seven species of marine turtle;
- 30 species of whales and dolphins;
- dugongs; and
- 133 species of sharks and rays.[38]

3.30 Climate change presents particular challenges for corals and coral reef ecosystems. The committee received evidence discussing the impacts of climate change on reefs, particularly the Great Barrier Reef and reefs in Western Australia.

Warming ocean temperatures

3.31 Recent coral bleaching events caused by higher ocean temperatures have had 'significant ecological impacts' in the Great Barrier Reef and in Western Australian reefs.[39] Essentially, higher ocean temperatures cause corals 'to first bleach and then, if the warmth continues, to die'.[40] The higher temperatures also 'reduce the intervals for recovery after disturbances such as coral bleaching, by causing reduced calcification rates of corals and coral reproduction for several years'.[41]

---

37 L Burke, D Bryant, J McManus, and M Spalding, *Reefs at Risk*, World Resources Institute, 2008; cited in Reef Resilience Network, 'Value of Reefs', www.reefresilience.org/coral-reefs/reefs-and-resilience/value-of-reefs (accessed 27 October 2017).

38 Great Barrier Reef Marine Park Authority (GBRMPA), 'Animals', www.gbrmpa.gov.au/about-the-reef/animals; 'Facts about the Great Barrier Reef', www.gbrmpa.gov.au/about-the-reef/facts-about-the-great-barrier-reef (accessed 27 October 2017).

39 Dr Janice Lough, Senior Principal Research Scientist, AIMS, *Committee Hansard*, 30 August 2017, p. 34.

40 GBRMPA, *Submission 20*, p. 2.

41 AIMS, *Submission 10*, p. 2. See also CSIRO, *Submission 15*, p. 11.

3.32 The first bleaching event in the Great Barrier Reef occurred in 1998, followed by three further events in 2002, 2016 and 2017. Bleaching events in Western Australian reefs occurred in 1998, 2011 and 2016.[42] The AIMS submission discusses these bleaching events in detail.[43] The Reef and Rainforest Research Centre and tourism operators in the area also provided evidence regarding the Great Barrier Reef bleaching event.[44] Furthermore, the committee was advised of bleaching events that have occurred at Lord Howe Island[45] and of coral bleaching in coastal areas of east Arnhem.[46]

3.33 The current health of, and outlook for, the World Heritage listed Great Barrier Reef was a major focus of the evidence received. The Great Barrier Reef Marine Park Authority (GBRMPA) noted that the *Great Barrier Reef Outlook Report 2014* 'found the overall outlook for the Reef ecosystem is poor and worsening'. In its submission, GBRMPA explained that 'climate change remains the most serious threat to the Great Barrier Reef'.[47] GBRMPA added that:

> The current global mass coral bleaching event has caused significant damage to the Great Barrier Reef and demonstrates the potential of climate change to cause harm that cannot be ameliorated through local management or adaptation.[48]

3.34 The committee was advised that in the 2016 bleaching event, 80 per cent of reefs in the far northern Great Barrier Reef were 'severely bleached', with approximately two-thirds of corals on those reefs lost.[49] Furthermore, AIMS explained that bleaching events severely weaken corals, making them more susceptible to disease and affecting spawning. AIMS expects that the corals damaged by the most

---

42 Dr Janice Lough, AIMS, *Committee Hansard*, 30 August 2017, p. 34.

43 See AIMS, *Submission 10*, pp. 2–3.

44 See Sheriden Morris, Managing Director, Reef and Rainforest Research Centre, *Committee Hansard*, 29 August 2017, p. 1; Mr John Edmondson, Owner/Director, Wavelength Reef Cruises, *Committee Hansard*, 29 August 2017, p. 9.

45 See Dr Alan Jordan, Principal Research Scientist, New South Wales Department of Primary Industries (NSW DPI), *Committee Hansard*, 16 March 2017, pp. 50–51.

46 Northern Land Council, *Submission 17*, p. 5.

47 GBRMPA, *Submission 20*, p. 1. Other threats to the Reef include poor water quality from land-based run-off, impacts from coastal development and risks related to fishing, particularly illegal fishing. See GBRMPA, *Great Barrier Reef Outlook Report 2014*, 2014, pp. v–vi.

48 GBRMPA, *Submission 20*, p. 2.

49 Dr Andrew Hoey, Reef Ecologist, Australian Research Council (ARC) Centre of Excellence for Coral Reef Studies, James Cook University, *Committee Hansard*, 30 August 2017, p. 3.

recent bleaching event are unlikely to spawn during the annual coral spawning season for the Reef (that is, November 2017).[50]

3.35 In addition to the direct impact of bleaching events on corals, the committee was informed of how climate change affects the fish and other organisms in the reef ecosystem. Dr Andrew Hoey from the Australian Research Council Centre of Excellence for Coral Reef Studies, explained that bleaching events affect the structure of the ecosystem as '[d]ifferent fish will drop off at different times'. For example, Dr Hoey advised that butterfly fish, which eat live coral, have no food source once coral dies and 'are one of the first groups that drop off following a bleaching or a [severe] storm'. Dr Hoey added that species which rely on the habitat provided by live coral 'will drop off as well quite quickly'. Dr Hoey added that, once the coral structure starts to be lost, species which 'don't rely on live coral per se but rely on the physical structure' become affected. Dr Hoey explained:

> …there's evidence that around three-quarters of all fish species on the reef rely on live coral at some stage in their lifecycle—whether that be when they first come out of the plankton as larval fish and settle on the reef. The barcheek coral trout, for instance, settles around a particular type of coral surrounded by sand. So if that coral is missing that fish suddenly doesn't have its recruitment habitat. Where does it go?[51]

3.36 The future of coral trout was discussed by several witnesses. Dr Hoey indicated that, in his view, coral trout will 'most likely' disappear. Dr Hoey explained:

> We had a program looking at the effects of temperature. As temperature increases, they require more food. To keep up the metabolic rate, they do not move as much, and they are more susceptible to fishing. We have size limits on coral trout. If you catch a juvenile fish and release it, it is 50 per cent more likely to die in elevated temperatures.[52]

3.37 Evidence given by other witnesses, however, was less certain about the future of the coral trout. Dr Michelle Heupel, Senior Research Scientist, AIMS, stated:

> There are a few studies that are happening. Some of them are looking at the physiology, at the thermal tolerance of these species. So at what point do they start feeding less and moving more slowly, which can affect their survival by changing their behaviour? Bleaching per se is a little bit complicated because if the habitat structure is still there, they can still use

---

50 Dr Fabricius from AIMS explained that: 'We have done experiments in the past, with consistent results from all around the world—which show that corals that had bleached depleted their energy reserves so much that they were unable to spawn for one or two years after the bleaching stress'. Dr Katharina Fabricius, Senior Principal Research Scientist, AIMS, *Committee Hansard*, 30 August 2017, p. 37.

51 Dr Andrew Hoey, ARC Centre of Excellence for Coral Reef Studies, *Committee Hansard*, 30 August 2017, p. 2.

52 Dr Andrew Hoey, ARC Centre of Excellence for Coral Reef Studies, *Committee Hansard*, 30 August 2017, pp. 10–11.

> it. It will depend on the broader community. So do they have a prey base if they are still to survive? So there are a lot of factors that go into answering that question, and it is one that we are certainly aware of, and are thinking about, but there are lots of pieces to that puzzle.[53]

3.38 Dr David Wachenfeld, Director, Reef Recovery, GBRMPA, commented:

> Unfortunately, temperatures in the northern Great Barrier Reef in the past 18 months have exceeded 30 degrees Celsius for extended periods, and that's the temperature at which the reproduction, the larval development and the health of common coral trout are compromised. The implications of climate change for fisheries in the marine park are still unfolding, but a more cautious approach to fisheries management is being developed for both fisheries and biodiversity conservation purposes.[54]

3.39 Overall, Dr Hoey concluded that, although some fish numbers will increase after a bleaching event due to the availability of algae on dead coral skeletons, 'the vast majority of fishes decline in numbers following bleaching'. Evidence received from Professor David Booth supports this finding: Professor Booth noted that some of the fishes that feed on algae 'do well', however, he indicated that the same could not be said for many other species of fish.[55]

Ocean acidification and changes in water quality

3.40 In addition to bleaching events, as noted in Chapter 2, ocean acidification will have a significant effect on the ability of corals to calcify. Although acidification does not kill coral, AIMS explained that it makes coral 'grow more slowly and makes them recover more slowly'. Acidification, along with poor water quality, can also support the growth of seaweed, which competes with coral. Furthermore, acidification and poor water quality also 'make reefs more brittle and cause bio-erosion'.[56]

3.41 Water quality has implications for the impact of events which can damage the Reef, such as marine heat waves. Dr Katharina Fabricius, AIMS, explained that the current scientific understanding is that water quality can 'made a difference' to the speed of recovery following moderate heat stress events. Dr Fabricius explained:

> Our understanding is that during a moderate heat stress event water quality can still make a difference. If heat stress becomes as severe as it was in 2016-17 then the water quality is already starting to be almost irrelevant because the dominant stressor is the one which is killing the corals. From all the data we have got at this stage there is some evidence that we

---

53 Dr Michelle Heupel, Senior Research Scientist, AIMS, *Committee Hansard*, 30 August 2017, p. 42.

54 Dr David Wachenfeld, Director, Reef Recovery, GBRMPA, *Committee Hansard*, 30 August 2017, p. 46.

55 Professor David Booth, *Committee Hansard*, 16 March 2017, p. 2.

56 Dr Katharina Fabricius, AIMS, *Committee Hansard*, 30 August 2017, p. 40.

> can buy some time by cleaning our water quality because the thermal tolerance of corals is weakened if they are stressed from other causes, like poor water quality. But the main mechanism of how water quality affects the state of the reefs is that, in particular, sedimentation but also nutrient enriched sediments severely slow down the recovery of the reefs. After those stress events, if there are sediments in the ground or in the system, on the reef surfaces, then coral larvae don't like to settle and give severely delayed recovery.[57]

3.42 Other climate-related events also threaten reefs. AIMS submitted that '[l]ong-term warming of the ocean around Australia has been shown to increase the likelihood of record rainfall in north-eastern Australia, as occurred in early 2011'. This high rainfall 'can lead to substantial inputs of low salinity freshwater (and associated terrestrial contaminants)' into the Great Barrier Reef, which can lead to an outbreak of crown of thorns starfish (a predator of corals).[58]

Crown-of-thorns starfish outbreaks and cyclones

3.43 Although bleaching events have recently presented a significant threat to the Reef, over past decades cyclones and crown-of-thorns starfish outbreaks have been responsible for most coral losses. The damage caused by these different categories of events has cumulative impacts. Dr David Wachenfeld from GBRMPA explained that, since January 2016, three-quarters of the Great Barrier Reef Marine Park has been affected by either the 2016 or 2017 bleaching event or Tropical Cyclone Debbie (2017). Dr Wachenfeld added that the 'impacts of these events…have come on top of nine other severe cyclones since 2005'.[59]

3.44 Dr Hoey advised that it is generally considered its takes approximately 10–15 years for a reef to recover from a disturbance event. Accordingly, Dr Hoey concluded that 'it's simply the frequency of these disturbances that are causing real problems'.[60]

3.45 Although recent coral bleaching events have been the subject of much attention, cyclones and outbreaks of crown-of-thorns starfish continue to be significant threats to the health of the Great Barrier Reef.[61] AIMS submitted that when

---

57 Dr Katharina Fabricius, AIMS, *Committee Hansard*, 30 August 2017, p. 36.

58 AIMS, *Submission 10*, pp. 5–6.

59 Dr David Wachenfeld, GBRMPA, *Committee Hansard*, 30 August 2017, p. 46.

60 Dr Andrew Hoey, ARC Centre of Excellence for Coral Reef Studies, *Committee Hansard*, 30 August 2017, p. 1.

61 Dr Fabricius explained that coral losses observed in the Great Barrier Reef through long-term monitoring over 27 years up to 2012 were attributed to cyclones (48 per cent of losses), crown-of-thorns starfish (42 per cent) and bleaching (10 per cent). As a result of the two severe bleaching events since 2012, however, Dr Fabricius reasoned that these three sources of damage could now be 'almost equal in their destructiveness'. Dr Katharina Fabricius, AIMS, *Committee Hansard*, 30 August 2017, p. 43.

crown-of-thorns starfish populations reach 'plague proportions', the living coral cover on the Great Barrier Reef can be reduced to 'a few per cent'. AIMS advised that since the 1960s, populations of crown-of-thorns starfish have 'erupted at approximately 15 year intervals', with four major outbreaks overall. AIMS advised that at present, prediction of the effects of climate change on the factors that lead to outbreaks has a high level of uncertainty, however, AIMS submitted that 'the current most widely accepted hypothesis is that primary outbreaks are promoted through increased nutrient availability, such as observed after significant flood events'.[62] AIMS further added that:

> A change in the magnitude and timing of floods due to climate change, as indicated in an analysis of long-term rainfall records, might result in changes to the frequency and/or severity of [crown-of-thorns starfish (CoTS)] outbreak.[63]

3.46 AIMS noted that how other climate change effects for oceans generally affect crown-of-thorns populations is unclear. AIMS explained:

> The direct influence of rising temperature and ocean acidification on CoTS is still debated. Recent research indicated positive effects on early life stages of CoTS, such as increased larvae survival and growth of juveniles, and that CoTS have a high potential for adaptation to climate change. Conversely, in other studies, ocean acidification decreased fertilisation rates and reduced settlement induction by crustose coralline algae.[64]

3.47 There are also potential consequences for the health of coral reefs arising from the projected increase in average cyclone intensity.[65] AIMS noted that cyclones 'can be a major driver of reef ecological condition' in the Great Barrier Reef. AIMS explained:

> The extent of development of coral communities on a reef depend on the time since disturbances such as cyclones, on the intensity of disturbance (extent of damage), and the rate of recovery through recolonisation by coral larvae and through regrowth of coral fragments. Thus if disturbances of any kind become more intense (requiring more extensive recolonisation and regrowth) or more frequent (allowing less time for recovery) or the rate of recovery is slowed (for instance through adverse effects of poor water quality on larval survival) then the reef community will be degraded from its former state. The predicted increase in intensity of cyclones, as well as

---

62 AIMS explained that increased nutrient availability 'increases phytoplankton, the food source of the planktonic CoTS larvae, which in turn increases their survival, ultimately increasing likelihood of CoTS population outbreaks'. AIMS, *Submission 10*, p. 6.

63 AIMS, *Submission 10*, p. 6.

64 AIMS, *Submission 10*, p. 6.

65 See AIMS, *Submission 10*, pp. 6–8.

> increased frequency of bleaching conditions will increase the overall rate of disturbances.[66]

3.48 Personal observations of damage to the Reef from cyclones were put before the committee. Ms Hayley Morris, Executive Director, Morris Group, which owns several tourism accommodation properties in north Queensland, provided the following account of changes caused by Cyclone Yasi (2011) given by the manager of Morris Group's Orpheus Island property:

> When at Lizard Island the swell caused by Cyclone Yasi devastated the Cod Hole (even though it crossed the coast south of Cairns) the site was unrecognisable and devoid of not only the fragile corals but also the smaller fish. Our guests were vocal about the damage 6 months on and it was several years before the employees felt that the reef was healthy again.[67]

3.49 It was noted that weather events, such as small storms and cloud cover, provide reefs with some protection from negative consequences associated with warming waters.[68] In fact, the southern part of the Great Barrier Reef escaped the 2016 bleaching event because of cloud cover from Cyclone Winston.[69]

3.50 More generally, the interrelationships between the three different categories of threats to the Great Barrier Reef and the cumulative pressure placed on the health of the Reef is demonstrated by the following evidence from Professor Burrows on how to respond to bleaching events. Professor Burrows likened severe bleaching events to bushfires; that is, an event which will override any management work that may have occurred. Professor Burrows stated:

> All you can do is manage it to as good a quality as you can between bleaching events, and make sure that it's as resilient as possible to bounce back after bleaching events. All those things are important—the zoning, the water quality, the [crown-of-thorns starfish] are important to that. If those 2,000 starfish hadn't been removed before that bleaching event, they would still be there after bleaching. They are not perturbed by the temperature. They are still there. You only have a much smaller remaining number of coral. Those crown-of-thorns are going to converge on that remaining coral and eat it. The coral that survived that bleaching event nominally may be more thermo-tolerant than their brethren that died. We don't know that yet, but it is a reasonable assumption. We are commissioning research to look at that under the next program that I manage.

---

66 AIMS, *Submission 10*, p. 7.

67 Ms Hayley Morris, Morris Group, *Submission 25*, p. 2

68 Sheriden Morris, Managing Director, Reef and Rainforest Research Centre, *Committee Hansard*, 29 August 2017, p. 5.

69 Dr Andrew Hoey, ARC Centre of Excellence for Coral Reef Studies, *Committee Hansard*, 30 August 2017, p. 11.

> If those coral are more thermally tolerant, and that is the reason they survived the bleaching, then you want them to propagate the next generation and spread their preferential thermo-tolerant genes. You don't want them to survive the bleaching and then get eaten by a crown-of-thorns starfish, a cyclone or whatever. You want to do the best you can to protect them. In that sense, people say to me, What do we do in a post-bleaching event?' The number one thing we can do is increase crown-of-thorns control.[70]

Particular consequences for mangroves

3.51 The implications of climate change for mangrove systems is another topic that was examined in detail during this inquiry. Mangroves are considered to be 'critically important habitats for a wide range of species' as they provide 'nursery, feeding and refuge areas and underpinning coastal food webs that support many commercial and non-commercial species'.[71] Mangroves also provide protection for coral reefs. Professor Damien Burrows explained:

> Mangroves are major trappers of sediments in particular; that is, mangroves are actually very good at colonising sediment. They trap it, they colonise it and stabilise those estuarine systems. So they are very much performing a protective role for the reef environment, especially for riverine sediments and nutrients coming down the river. They're reasonably tolerant, obviously. Unlike, say, the [Great Barrier Reef], which is sensitive to reef sediment nutrients, the mangroves are much more tolerant; hence why they are good at that trapping environment. So they are particularly important, and they are very important for fisheries as well. In particular, a lot of recreationally important fishery species will spend part of their lifecycle in mangrove and estuarine ecosystems.[72]

3.52 Mangroves are also considered to provide a wide range of other benefits. The Queensland Department of Environment and Heritage Protection has published the following overview of how mangroves protect the coast, absorb pollution and provide carbon sequestration:

> Mangroves protect the coast by absorbing the energy of storm-driven waves and wind. The only two yachts undamaged by Cyclone Tracy in Darwin in 1974 were sheltered in a mangrove creek. In 2006, mangroves protected vessels and the coastline during Cyclone Larry in far north Queensland. The damage bill would have been much higher if it wasn't for the existence of intact mangrove forests. As well as providing a buffer for the land, mangroves also interact with the sea. Sediment trapped by roots prevent

---

70 Professor Damien Burrows, *Committee Hansard*, 30 August 2017, p. 22.

71 Queensland Department of Environment and Heritage Protection, 'Mangroves', 30 January 2017, https://wetlandinfo.ehp.qld.gov.au/wetlands/ecology/components/flora/mangroves/ (accessed 28 July 2017).

72 The mangroves provide a nursery for these fish species. Professor Damien Burrows, *Committee Hansard*, 30 August 2017, pp. 14–15.

> silting of adjacent marine habitats where cloudy water might kill corals or smother seagrass meadows. In addition, mangrove plants and sediments have been shown to absorb pollution, including heavy metals. Mangroves are also very effective at storing carbon.[73]

3.53 Recent degradation of mangroves has been linked to extreme weather events. In 2017, researchers at the Centre for Tropical Water and Aquatic Ecosystem Research at James Cook University published a study on large-scale dieback of mangroves in the Gulf of Carpentaria.[74] The Northern Land Council also submitted that apparent impacts of climate change in the Northern Territory include the 'severe dieback of mangroves in the Gulf of Carpentaria'.[75]

3.54 Although there is research about mangrove dieback, it was suggested that what happens to marine species that live in and rely on mangrove systems is unknown. Mr Simon Rowe from OceanWatch Australia commented that 'hypothetically…maybe they will die', but he considers surveys of what is occurring under the water need to be undertaken to ascertain what is happening.[76] Professor Burrows noted that research has identified that mangroves are more tolerant of high temperatures than corals.[77] However, the ability of mangroves affected by dieback to recover is concerning due to the timeframe required and the potential for other events, such as cyclones, to disrupt the recovery. Professor Burrows explained:

> The thing that concerns us is that, of the 1,000 kilometres of that coastline where there is a lot of dieback, 200 kilometres of it is the actual mangroves right along the actual shorefront. The Gulf of Carpentaria is very flat, very low land, very prone to storm surges and things like that, and changes in the geomorphology from those storm surges. The mangroves provide a strong service in holding together those coastlines. Now those coastlines aren't being held together by those forests anymore. So they are particularly vulnerable to storm surges or cyclones in that area. They will recover—hopefully, in 15 years or so, if we don't get too many cyclones or big storms in that area.[78]

---

73 Queensland Department of Environment and Heritage Protection, 'Mangroves', 30 January 2017, https://wetlandinfo.ehp.qld.gov.au/wetlands/ecology/components/flora/mangroves/ (accessed 28 July 2017). Many of these points were also made by Mr Simon Rowe, Program Manager, Environment, OceanWatch Australia (see *Committee Hansard*, 16 March 2017, p. 39).

74 Norman Duke et al, 'Large-scale dieback of mangroves in Australia's Gulf of Carpentaria: a severe ecosystem response, coincidental with an unusually extreme weather event', *Marine and Freshwater Research*, CSIRO, 2017.

75 Northern Land Council, *Submission 17*, p. 5.

76 Mr Simon Rowe, OceanWatch Australia, *Committee Hansard*, 16 March 2017, p. 39.

77 Professor Damien Burrows, *Committee Hansard*, 30 August 2017, p. 15.

78 Professor Burrows clarified that the full recovery of the mangroves will take longer than 15 years; however, 15 years should allow 'a reasonable degree' of recovery. Professor Damien Burrows, *Committee Hansard*, 30 August 2017, p. 16.

3.55 Despite the link between extreme weather events and mangrove degradation, the committee was also informed that, if climate change led to areas receiving greater levels of rainfall, this fresh water could enable mangroves to grow taller and faster, and possibly expand.[79]

Knowledge gaps and other considerations

3.56 As is the case with changes in ocean attributes arising from climate change generally, there are apparent knowledge gaps about the effects of these changes on the marine environment. For example, IMAS submitted that '[e]xtensive change in the distribution of our species will result in extensive change in the structure, and therefore function, of our ecosystems.[80] However, IMAS advised that there is a 'limited understanding of how the climate impacts on many individual species, and the new combinations of species, will collectively change the structure and function of marine ecosystems as a whole'.[81] IMAS added:

> There are substantial differences among species in the magnitude of responses to warming…and we have little knowledge about the processes responsible for this vast variation in species responses.[82]

3.57 In particular, IMAS noted there is limited knowledge of the effects of climate change on key parameters, such as selectivity, growth and reproduction. It observed that '[d]ue to natural variability in many of these key parameters, long term data sets are required to determine trends'.[83]

3.58 Dr Hobday from CSIRO similarly noted:

> The major uncertainty we have is around how much the productivity of Australia's oceans will change. The temperature signal is very clear, but the question is whether the ocean becomes more or less productive, and in what parts of Australia that happens. We are working very hard to try and resolve that at the moment.[84]

3.59 The Government of South Australia submitted that, although some of the expected impacts of ocean acidification from climate change for ecosystems and species, particularly shellfish, 'may be predicted', it advised that 'the magnitude of each response remains largely uncertain as the effects on fish stock biomass are poorly understood'.[85] Dr Hobday noted that information about these fisheries, such as the

---

79 Professor Damien Burrows, *Committee Hansard*, 30 August 2017, p. 19.

80 IMAS, *Submission 1*, p. 16.

81 IMAS, *Submission 1*, p. 4.

82 IMAS, *Submission 1*, p. 15 (citation omitted).

83 IMAS, *Submission 1*, p. 32.

84 Dr Alistair Hobday, CSIRO, *Committee Hansard*, 17 March 2017, p. 2.

85 Government of South Australia, *Submission 21*, p. 4.

scallop fishery, can be limited due to the economic realities of the fishery. Dr Hobday explained:

> We call the scallop fishery in Australia a 'boom and bust' fishery. Some years it is open; some years it is closed. That means that the research interest or research funds available to study that are sometimes quite limited and, because we fund fisheries research through cost recovery, if the fishery is not worth very much it does not get very much attention. So I think the scallop fishery is likely to be quite low on the priority list for that effort, even though it is going to be very important to the people involved in that fishery.[86]

3.60 IMAS submitted that models need to be developed that 'can predict changes in species composition *and* abundance simultaneously'. IMAS considers such models would assist in 'understanding the interacting impacts of fisheries and climate change on ecosystems' and in making 'integrated ecosystem assessment of climate change a reality'.[87]

3.61 As noted in Chapter 2, scientific organisations explained that there is a lack of information available for understanding the implications of climate change due to the small number of long-term data sets. The lack of long-term data was also highlighted by Austral Fisheries, which explained how the absence of monitoring data has implications for understanding and managing particular fisheries. Mr Exel from Austral Fisheries discussed the effects of a heatwave on the Patagonian toothfish fishery off Heard Island and McDonald Island on fishing catch in 2016 and recounted Austral's surprise at the lack of data available. He explained:

> It was actually a combination of the El Nino from 2015, which travels across the top of Australia, and a thing called the Indian Ocean dipole, which is where there is very warm water off the east coast of Africa. It creates a very warm current. That gave us the record warmest temperatures at Kerguelen Plateau since records have been made, which is something like 80 or 90 years. The toothfish fishery catch rates reduced overnight by over 50 per cent. They stayed low for probably four months. By the end of the season we—and there was another company also fishing for toothfish there—left somewhere in the region of 650 tonnes of toothfish swimming that normally we would have caught very easily as part of our quota allocation.
>
> That was really the absolute pinnacle of what is wrong with the climate change debate, because when we then started to ask where is the monitoring and the oceanographic information, we were scrabbling for everything. We realised that there is no long-term monitoring dataset; there is no cohesive program looking at it.[88]

86 Dr Alistair Hobday, CSIRO, *Committee Hansard*, 17 March 2017, p. 6.

87 IMAS, *Submission 1*, p. 16.

88 Mr Martin Exel, General Manager Environment and Policy, Austral Fisheries, *Committee Hansard*, 21 February 2017, p. 23.

3.62 Since this discovery, Mr Exel advised that Austral, along with IMAS, the Australian Antarctic Division (of the Department of the Environment and Energy), CSIRO and other industry stakeholders, have invested in is conductivity temperature depth recorders and cameras to start compiling a dataset. Mr Exel noted that Austral has, to date, spent approximately $150,000–$200,000 on these efforts.[89]

3.63 In relation to marine pests, the Department of Agriculture and Water Resources (DAWR) submitted that the water temperature tolerance range of invasive marine species is not well established. Typically, invasive species are adaptable to a broad range of environmental conditions. While DAWR acknowledged that climate change will alter environmental conditions at ports, it expects that the rate of change will be relatively gradual.[90]

3.64 Research has been undertaken to consider possible responses to marine pests that become established in new areas. For example, IMAS has conducted research into potential management strategies of the long-spined sea urchin at Elephant Rock (near St Helens) and Southerly Bottom (near North Bay) on the easterly side of Forestier Peninsula. After the two research areas had restrictions placed on fishing for lobsters by the Tasmanian Department of Primary Industries, Parks, Water and Environment, the researchers found that rock lobsters are one of the few known predators of the long-spined sea urchin.[91]

3.65 Finally, a concern shared by stakeholders is that the significance of the transformations in the marine environment caused by climate change is not widely appreciated. In relation to the kelp forest losses off the coast of Tasmania, Mr Jon Bryan from the Tasmanian Conservation Trust stated:

> One can only imagine that if this sort of thing happened on land—if, for example, all the blue gums disappeared, or all the eucalypt forests or some similar terrestrial vegetation disappeared—it would create an uproar.[92]

3.66 On the same kelp bed development, Mr Michael Baron from Eaglehawk Dive Centre similarly commented:

> And I put it to you, as I said here, if this is how it had occurred on land, you would have been there having this inquiry over 25 years ago. But nobody sees it and therefore it does not have any effect. I have just been interviewed by three different TV stations. Yes, they are all keen to talk to you. As soon as you finish, they are off. It does not mean anything to them.[93]

---

89 Mr Martin Exel, Austral Fisheries, *Committee Hansard*, 21 February 2017, p. 23.

90 Department of Agriculture and Water Resources, *Submission 18*, pp. 5–6.

91 Tasmanian Department of Primary Industries, Parks, Water and Environment, 'Long Spined Sea Urchin Research Project', http://dpipwe.tas.gov.au/sea-fishing-aquaculture/recreational-fishing/area-restrictions/long-spined-urchin-research (accessed 8 December 2016).

92 Mr Jon Bryan, Tasmanian Conservation Trust, *Committee Hansard*, 21 February 2017, p. 27.

93 Mr Michael Baron, Eaglehawk Dive Centre, *Committee Hansard*, 21 February 2017, p. 17.