climate extremes
ARC centre of excellence

Australian Government
Australian Research Council

The impact of climate extremes on Australia's marine environment

A special briefing on the Intergovernmental Panel on Climate Change 6th Assessment Report by the ARC Centre of Excellence for Climate Extremes

- Marine environments are among Australia's most important assets. However, a new report by the Intergovernmental Panel on Climate Change (IPCC) has identified significant risks to some of the nation's most important marine ecosystems, including coral reefs and kelp forests.
- Climate change impacts on Australia's marine ecosystems, and the ecosystem services that they provide, are mostly negative, and further climate change is predicted to magnify impacts on ecosystems that are already evident.
- Longer and more frequent marine heatwaves are an aspect of climate change that is leading to many of the negative impacts on Australia's marine ecosystems. The ARC Centre of Excellence for Climate Extremes is working to understand marine heatwave predictability.

Why are Australia's marine environments important?

Marine environments along Australia's coastlines provide a range of important ecosystem services. These include food production, protection of the coast from erosion and inundation, and tourist attractions. They can also act to slow the rate of climate change by absorbing some of the carbon dioxide that is emitted into the atmosphere. Further from the coast, Australia's marine Exclusive Economic Zone extends up to 370km from the coastline of Australia and its external territories in the Indian, Pacific and Southern Oceans. The marine resources in this zone contribute $69 billion per year to the economy.

What are the key climate change risks for Australia's marine environment?

The latest comprehensive assessment of climate change impacts by the Intergovernmental Panel on Climate Change (IPCC), released in February 2022, has identified nine key climate change risks for Australia[1]. These include loss and degradation of coral reefs and, in southern Australia, loss of kelp forests. Extensive coral bleaching events and loss of temperate kelp forests have already occurred. The IPCC has very high confidence that there will be continued loss and degradation of coral reefs and associated biodiversity and ecosystem service value. Further climate change may cause irreversible damage, with limited scope for adaptation. The IPCC has high confidence that there will be continued loss of kelp forests in southern Australia. The impact of future climate change on Australia's kelp forests could be severe but can be reduced substantially by rapid, large-scale and effective mitigation and adaptation.

Which aspects of climate change are impacting marine environments?

The IPCC report highlighted warming of the ocean as a fundamental driver of the impacts on Australia's marine environments. Rising sea surface temperatures have exacerbated marine heatwaves. A marine heatwave is a prolonged period when the ocean is much warmer than usual for that time of year[2]. Marine heatwaves can damage marine ecosystems and the industries that rely on them[3]. Some of the largest, longest, and most intense marine heatwaves have occurred near Western Australia in 2011, the Great Barrier Reef in 2016, 2017 and 2020, and the Tasman Sea in 2015/2016, 2017/2018 and 2018/19[4,5,6,7,8,9]. These marine heatwaves temporarily increased the temperature of the sea surface by up to 4°C above usual and have lasted for several months. Marine heatwaves will increase in intensity, duration, and frequency as the ocean continues to warm[10].

Other important aspects of climate change are not directly related to marine heatwaves. For example, long-term warming of average ocean temperatures and greater ocean acidity resulting from increased ocean uptake of carbon dioxide can favour the geographical expansion of invasive macroalgae, at the expense of local species. Some impacts on marine resources even originate from climate change over the land, rather than over the ocean. For example, warming and drying in some areas, particularly southwestern Australia, have reduced freshwater river flows, reducing the flushing and amount of dissolved oxygen in estuaries and increasing their salinity.

How are marine species responding to climate change?

Field and lab studies have demonstrated a range of impacts of ocean warming on marine species. These include slower growth[11], changes in fish size[12], reduced activity[13], lower reproductive success[14,15], changes in sex ratios[16] and changes in plankton communities[17], with implications for the entire food chain. The geographical range of some marine species have moved poleward, extending further south but contracting at the equatorward edge. The IPCC report summarises these climate change effects. Impacted species include coral trout, one of Australia's most important commercial and recreational tropical fish, and important aquaculture species, including oysters and salmon.

Marine heatwaves can directly affect economically-valuable marine species. For example, the 2011 Western Australia marine heatwave resulted in mortality and reductions in spawning stocks of fisheries, abalone, prawns and rock lobsters, along with loss of seagrass in Shark Bay. Tasmanian oyster farms experienced the first occurrence of Pacific Oyster Mortality Syndrome (POMS) during the 2015-2016 Tasman Sea marine heatwave.

Climate change can also affect the health of entire ecosystems, and the ecosystem services that they provide, through impacts on the key habitat-forming organisms (e.g., corals, kelps, mangroves and seagrasses). Along 45% of Australia's coastline, there has been extensive mortality of habitat-forming organisms due to extreme events in 2011 and 2017.

In some instances, climate change is favourable to species that damage ecosystems that were previously beyond their geographical range. A striking example is the southward expansion of urchins in southeastern Australia, which has devastated Tasmania's kelp forests[18]. Less than 10% of Tasmania kelp was remaining in 2011. The IPCC expects that overgrazing due to urchins and herbivorous fish that experience climate-driven range extensions will contribute to further loss of kelp forests in southern Australia.

Bleached coral reef (Shutterstock)

What does the IPCC report say about Australia's coral reefs?

In addition to loss of kelp forests, the IPCC report highlights loss and degradation of coral reefs as a key climate change risk for Australia. Extensive coral bleaching events have already occurred due to ocean warming and marine heatwaves. In 2016 and 2017 the iconic Great Barrier Reef (GBR) experienced consecutive occurrences of the most severe coral bleaching in recorded history, transforming two thirds of the GBR into a highly degraded state[19,20].

Future Australian coral reefs are unlikely to resemble those of the mid 20th century. The IPCC has very high confidence that limiting global warming to 1.5°C above pre-industrial temperatures, in accordance with the UN's Paris Agreement, would be insufficient to prevent more frequent mass bleaching events, although occurrences of events like the 2016 bleaching could be reduced[21,22]. GBR bleaching events are projected to occur annually after 2051 under mid-range climate change projections, consistent with global warming of 2.1-3.5°C above pre-industrial temperatures by the end of the 21st century[23]. Annual bleaching is projected to occur as soon as 2044 under the most extreme climate change projections, consistent with global warming of 3.3-5.7°C by the end of the century.

The IPCC assessed, with high confidence, that continued damage to Australia's coral reefs due to climate change will result in negative impacts on tourism. It is estimated that, if coral bleaching continues at the current rate, A$1 billion per year in revenue and a total of 10,000 jobs would be lost due to a decline in tourism. However, negative impacts are not confined to tourism. The IPCC assessed with very high confidence that Australia's cultural well-being will be affected, with high confidence that coastal protection will be impacted and with medium confidence that there will be impacts on food provision.

What relevant research is the ARC Centre of Excellence for Climate Extremes doing?

The ARC Centre of Excellence for Climate Extremes is undertaking research that will ultimately improve predictions of ocean conditions around Australia. This includes efforts to improve the computer models on which long-term projections of ocean conditions are based. Our work on ocean productivity and carbon cycling aims to inform future climate trajectories, and current and future fisheries management. Another focus of the research is further understanding the drivers of marine heatwaves, with the ultimate aim of improving marine heatwave forecasts.

Created by

Peter Strutton is a Professor at the Institute for Marine and Antarctic Studies and the ARC Centre of Excellence for Climate Extremes at the University of Tasmania. His research focusses on the interaction between physical and biological processes in the ocean, and their impact on ocean productivity and climate. He has a PhD in Marine Science from Flinders university and has previously held positions at the Monterey Bay Aquarium Research Institute, Stony Brook University and Oregon State University.

Jules Kajtar is a Research Fellow at the Institute for Marine and Antarctic Studies and the ARC Centre of Excellence for Climate Extremes at the University of Tasmania. His research focusses on understanding the dynamics, evolution, and predictability of marine heatwaves. After completing his PhD at Monash University, he has also held postdoctoral appointments at the University of New South Wales and the University of Exeter, UK.

Ramkrushnbhai Patel is a Research Associate at the Institute for Marine and Antarctic Studies and the ARC Centre of Excellence for Climate Extremes at the University of Tasmania. He received his PhD in Quantitative Marine Science from the University of Tasmania in 2021. His work focuses on extraction of biogeochemical information from in-situ observations, satellite data and model outputs. He has also worked with the fishing industry to understand the impact of environmental variability on catches.

Ian Macadam leads the Knowledge Brokerage Team of the ARC Centre of Excellence for Climate Extremes. He has a PhD in Climate Science from the University of New South Wales and has previously worked for the ARC Centre of Excellence for Climate System Science, NSW Government, UK Met Office and CSIRO in a variety of applied climate science, project management and data provision roles. Ian has contributed to numerous scientific papers and reports, including reports by the Intergovernmental Panel on Climate Change and OECD.

References

1 Intergovernmental Panel on Climate Change (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. https://www.ipcc.ch/report/ar6/wg2/

2 Hobday et al. (2016). A hierarchical approach to defining marine heatwaves. *Progress in Oceanography*. https://doi.org/10.1016/j.pocean.2015.12.014

3 Smale et al. (2019). Marine heatwaves threaten global biodiversity and the provision of ecosystem services. *Nature Climate Change*. https://doi.org/10.1038/s41558-019-0412-1

4 Oliver et al. (2021). Marine Heatwaves. *Annual Review of Marine Science*. https://doi.org/10.1146/annurev-marine-032720-095144

5 Bureau of Meteorology (2020). 2020 marine heatwave on the Great Barrier Reef. http://www.bom.gov.au/environment/doc/2020-GBR-marine-heatwave-factsheet.pdf

6 Oliver et al. (2017). The unprecedented 2015/16 Tasman Sea marine heatwave. *Nature Communications*. https://doi.org/10.1038/ncomms16101

7 Perkins-Kirkpatrick et al. (2019) The role of natural variability and anthropogenic climate change in the 2017/18 Tasman Sea marine heatwave. *Bulletin of the American Meteorological Society*. https://doi.org/10.1175/BAMS-D-18-0116.1

8 Holbrook et al. (2020). Keeping pace with marine heatwaves. Nature *Reviews Earth and Environment*. https://doi.org/10.1038/s43017-020-0068-4

9 Kajtar et al. (2021). A catalogue of marine heatwave metrics and trends for the Australian region. *Journal of Southern Hemisphere Earth Systems Science*. https://doi.org/10.1071/ES21014

10 Oliver et al. (2019). Projected Marine Heatwaves in the 21st Century and the Potential for Ecological Impact. *Frontiers in Marine Science*. https://doi.org/10.3389/fmars.2019.00734

11 Morrongiello and Thresher (2015). A statistical framework to explore ontogenetic growth variation among individuals and populations: a marine fish example. *Ecological Monographs*. https://doi.org/10.1890/13-2355.1

12 Audzijonyte et al. (2020). Fish body sizes change with temperature but not all species shrink with warming. *Nature Ecology and Evolution*. https://doi.org/10.1038/s41559-020-1171-0

13 Johansen et al. (2014). Increasing ocean temperatures reduce activity patterns of a large commercially important coral reef fish. *Global Change Biology*. https://doi.org/10.1111/gcb.12452

14 Caputi et al. (2019). Factors Affecting the Recovery of Invertebrate Stocks From the 2011 Western Australian Extreme Marine Heatwave. *Frontiers in Marine Science*. https://doi.org/10.3389/fmars.2019.00484

15 Hughes et al. (2019). Global warming impairs stock–recruitment dynamics of corals. *Nature*. https://doi.org/10.1038/s41586-019-1081-y

16 Jensen et al. (2018). Environmental Warming and Feminization of One of the Largest Sea Turtle Populations in the World. *Current Biology*. https://doi.org/10.1016/j.cub.2017.11.057

17 Kelly et al. (2016). Zooplankton responses to increasing sea surface temperatures in the southeastern Australia global marine hotspot. *Estuarine, Coastal and Shelf Science*. https://doi.org/10.1016/j.ecss.2016.07.019

18 Butler et al. (2020). Multi-decadal decline in cover of giant kelp Macrocystis pyrifera at the southern limit of its Australian range. *Marine Ecology Progress Series*. https://doi.org/10.3354/meps13510

19 Hughes et al. (2018). Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. *Science*. https://doi.org/10.1126/science.aan8048

20 Hughes et al. (2019). Ecological memory modifies the cumulative impact of recurrent climate extremes. *Nature Climate Change*. https://doi.org/10.1038/s41558-018-0351-2

21 Lough et al. (2018). Increasing thermal stress for tropical coral reefs: 1871–2017. *Scientific reports*. https://doi.org/10.1038/s41598-018-24530-9

22 King et al. (2017). Australian climate extremes at 1.5°C and 2°C of global warming. *Nature Climate Change*. https://doi.org/10.1038/nclimate3296

23 Heron et al. (2017). Impacts of Climate Change on World Heritage Coral Reefs: A First Global Scientific Assessment. https://whc.unesco.org/document/158688

Contact

Prof Peter Strutton, University of Tasmania

peter.strutton@utas.edu.au

Follow *Climate Extremes:*

UNSW SYDNEY

MONASH University

THE UNIVERSITY OF MELBOURNE

Australian National University

UNIVERSITY *of* TASMANIA