# Antarctica and the Southern Ocean: insights from the 2022 IPCC WGII report

AAPP
Australian Antarctic Program Partnership

ACEAS
Australian Centre for Excellence in Antarctic Science

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The Australian Antarctic Program Partnership (AAPP) is a partnership of Australia's leading Antarctic research institutions supported by the Australian Government Antarctic Science Collaboration Initiative. The AAPP will improve our understanding of the role of the Antarctic and Southern Ocean within the global climate system and its implications for marine ecosystems.

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The Australian Centre for Excellence in Antarctic Science (ACEAS) is a collaboration between Australian universities, government agencies and international research institutions supported by the Australian Research Council (Grant ID SR200100008). The goals of ACEAS is to help the world community prepare for climate risks emerging from East Antarctica and the Southern Ocean by integrating knowledge of the ocean, atmosphere, cryosphere and ecosystems, and their interplay.

Image by: Steve Rintoul

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Over time, greenhouse gas emissions have caused observable changes in Antarctica and the Southern Ocean, triggering a warmer climate, more extreme weather and sea-level rise. These changes affect planetary, and Antarctic and Southern Ocean systems.

Antarctic and Southern Ocean ecosystems and the human communities that depend on Antarctica are increasingly affected, including the 1.3 billion people living in low lying regions around the world.

In Australia, our fisheries, natural systems and human communities are encountering extreme weather and climate trends some of which are linked to the changes emerging in the Antarctic.

Achieving climate resilience is currently a challenge in the Antarctic Treaty System including management of protected areas.

Rapid and ambitious actions in the current decade will influence whether these changes can be avoided or will become irreversible for centuries to millennia.



## IPCC report opens window to our planet's future

The Intergovernmental Panel on Climate Change Working Group II report (IPCC WGII)[a], Climate Change 2022: Impacts, Adaptation and Vulnerability[1], was released on 28 February 2022. It reviewed and synthesised more than 34,000 scientific articles on the effects of climate change, with these key overarching messages:

- Unchecked climate change will amplify both impacts and hazards
- There are limits to adaptation
- It is possible to make things worse through poor adaptation
- The time available to avoid dangerous climate change by both adapting and mitigating for climate is reducing fast

The Antarctic Treaty 1959 preserves the Antarctic for science and other peaceful uses, free from nuclear explosions and military activities. The IPCC WGII report[1] makes clear that Antarctica and the Southern Ocean is already being impacted by human-induced climate change.

These impacts do not only affect the Antarctic – they are increasingly felt across Australia, our regional neighbours, and the world. Here in Australia, we are seeing the impact of changing weather systems – on agriculture, fisheries and coastal industries, and on infrastructure, housing and communities.

Unlike the Arctic, there are few Indigenous voices to speak for Antarctica in this IPCC WGII report[1]. With 42% of the Antarctic continent claimed as the Australian Antarctic Territory, and the associated exclusive economic zone lying off the coastline, Australia has a substantial national interest in and responsibility for Antarctica.

The IPCC WGII process is a science assessment of the impacts, adaptation and vulnerability from climate change. It aims to inform policymakers within global climate governance forums, such as the UNFCCC[b]/Paris Agreement[c] meetings, and institutions concerned with wider issues of environmental protection, such as the Antarctic Treaty System. The findings of this IPCC WGII report[1] will feed directly into upcoming UNFCCC/ Paris Agreement deliberations on national adaptation plans, climate finance (particularly additional climate funding to assist vulnerable developing states), and developing a loss and damage mechanism within the UNFCCC to help address the costs of climate change impacts.

The Antarctic Treaty System has focused on contributing to the global scientific effort to understand the drivers and impacts of climate change, and on reducing emissions from national science programs and associated activities in Antarctica.

However, the significance of the medium to long term impacts for the Antarctic region detailed in the IPCC WGII report[1] suggests that reducing emissions within Antarctica will only have minor effects, and the future of the Antarctic region will be primarily determined by the level of success of global efforts to mitigate greenhouse gas emissions and global warming.

## Observed and projected impacts on Antarctica and the Southern Ocean

Antarctica and the Southern Ocean are essential components of the Earth system and its planetary health. Research shows that Antarctic melt is adding to sea-level rise, while the Southern Ocean is warming, freshening and losing oxygen[2,3] with altered underwater light[4] and plant nutrient supply[5]. In the 2019 and 2021 IPCC Climate Change reports[6,7], these impacts were attributed to human influence on the atmosphere, which consequently alters the ocean and cryosphere.

Extreme weather events are characterised by maximum air temperatures which have reached 7°C – 9.2°C above the mean maximum in East Antarctica – and more than 18°C in West Antarctica[8,9]. Significantly, Antarctica is one of the last regions to report these abrupt and sometimes large environmental disturbances[5-8,10-12] which are threatening life in many ecosystems globally.

Antarctic and Southern Ocean ecosystems are at risk from the combined poleward expansion of ecosystems[3,13], especially by invasive species[14] and the narrow thermal windows of tolerance that characterise Antarctic species[4,15].

Together, these factors are leading to a reduction of habitat area for polar species (Figure 1). Distinct changes in terrestrial and ocean ecosystem structure

[a] Intergovernmental Panel on Climate Change Working Group II: (https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/)

[b] United Nations Framework Convention on Climate Change 1992

[c] Paris Agreement on Climate Change 2015

Image by: Australian Anarctic Division

have been observed, with both undergoing poleward range shifts, while terrestrial ecosystems have also undergone distinct changes in the timing of seasonal cycles[1].

The future evolution of sea ice, a defining feature of the Antarctic marine ecosystem, is uncertain[7]. Adult krill are a key food source for penguins, seals and whales, and depend on sea ice during their life cycle. While the climate-driven trend of sea-ice since the 1970s is unclear, there are regions where krill have been observed as declining and this trend is attributed to climate change.

Projections for these polar ecosystems for the near and longer-term future are for a southward contraction of their range, with severe and widespread impacts, and irreversible changes for these ecosystems in the highest-emission scenarios[1] (Figure 2). Unlike other regions influenced by the threats of climate change, species seeking an escape route from warming cannot migrate further south than Antarctica.

The onset of extreme events in Antarctica foreshadows future ecological threats to this region[5]. A major finding of IPCC 2022[1] is that extreme events such as marine heatwaves are driving major detrimental change in many ecosystems worldwide[6].

In the Southern Ocean and Antarctica, the recent onset of extreme events means that their impact on terrestrial and marine ecosystems has not been documented, although several changes to terrestrial hydrology have been observed[4]. For example, heat waves will alter many environmental properties, such as increasing moisture levels for arid terrestrial systems[8] and the adaptation of animal and plant life (biota) in all Antarctic and Southern Ocean regions. These biota are particularly prone to the abrupt and pronounced changes of the environment driven by extremes, because of their narrow thermal tolerances[15].

## Antarctica and the Southern Ocean impact on Australia and the world

Changes in Antarctica and the Southern Ocean impact the world, particularly sea-levels and ocean surface temperature. Antarctica currently contributes to around 12% of sea-level rise and, with Greenland and mountain glaciers, the cryosphere contributes around 50% of recent sea-level rise.

Under a high-emissions scenario, the fractional contribution from the Antarctic Ice Sheet will grow to about 20% by 2100, with the polar regions and mountain glaciers contributing about two thirds of the sea-level signal[6] (Figure 3).

The IPCC WGII report[1] reveals that sea-level is rising faster now than during any century in the last 3000 years, and this has consequences for human communities and economies globally. Under the high emissions scenario, coastal flooding will affect 2.5–9% of the global population and 12–20% of the global gross domestic product by 2100[5]. Some adaptation will be required to avoid disruptions to ports and other coastal infrastructure.

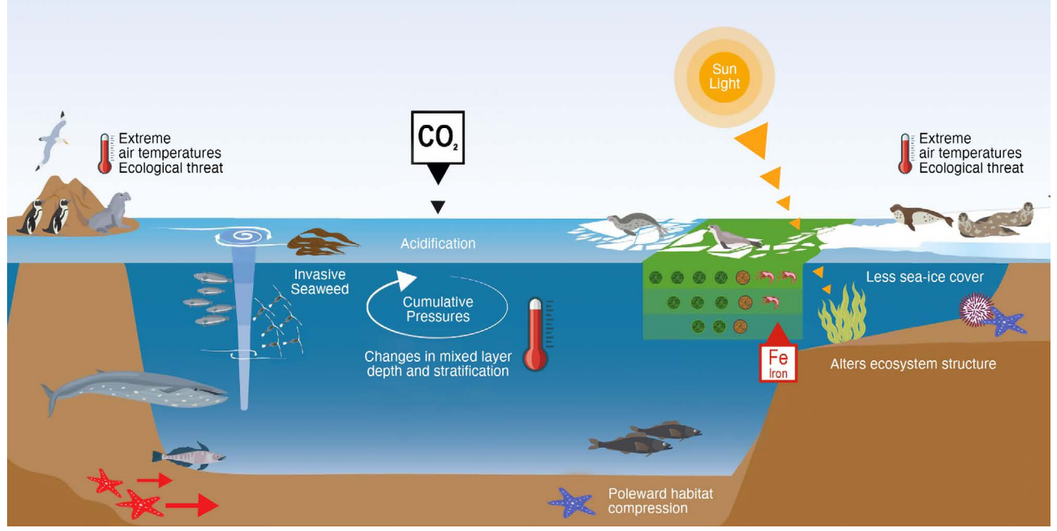



**Figure 1:** Observed anthropogenic changes to the Southern Ocean and Antarctica reported in IPCC WG2 2022. Extreme temperatures in the ocean or lower atmosphere have been reported in the subantarctic islands[16] and Antarctica[9] and may pose a threat to both terrestrial and marine ecosystems[4] due to the narrow thermal tolerance window that characterises most life in this region[17]. Poleward movement of invasives have been documented on both the seafloor[14] and by free-drifting macroalgae in the surface ocean[18]. There is also growing evidence of habitat contraction towards the Pole to avoid changing ocean conditions[4]. Concurrent changes in multiple ocean properties (stressors) such as warming, acidification and underwater light penetration[3] continue to exert cumulative pressures on marine life, e.g. reduced sea ice cover results in more light penetration in shallow water ecosystems, which in turn results in shifts in ecological structure to more seaweeds[4]. Together, these many changes represent a threat multiplier to ecosystems in the deep South.

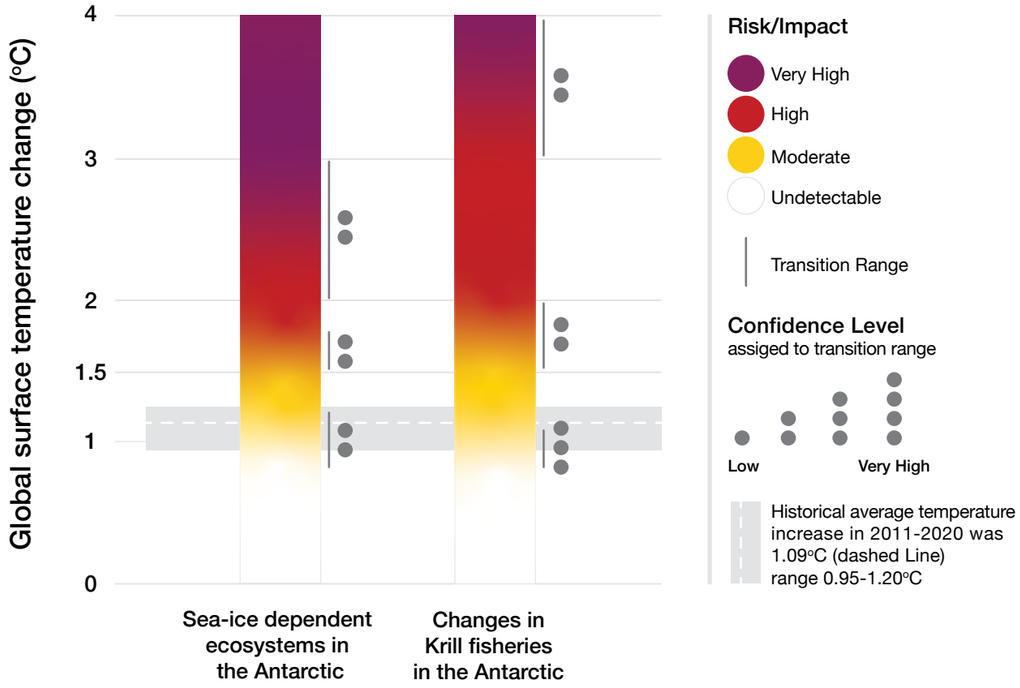



**Figure 2:** This 'burning ember' figure adapted from the IPCC WGII Summary for Policymakers[1] quantifies the risk of changes to sea-ice dependent ecosystems and Antarctic krill, where the contraction poleward has been reported in the Atlantic sector. Threats include altered structure (more macroalgae) of shallow-water communities due to increased penetration of sunlight following sea ice loss[1].

Past and future greenhouse gas emissions will produce changes projected to be irreversible for centuries to millennia – especially of our oceans, ice sheets and sea levels. The IPCC WGII report[1] concludes that sea-level effects on low-lying coastal zones and island nations represents an existential threat to communities, infrastructure and cultural heritage. Even with low emission scenarios and stabilisation of the Earth's climate at 2–2.5°C above pre-industrial levels, sea level rise will impact at least 25 megacities and low-lying areas where 0.6–1.3 billion people currently live.

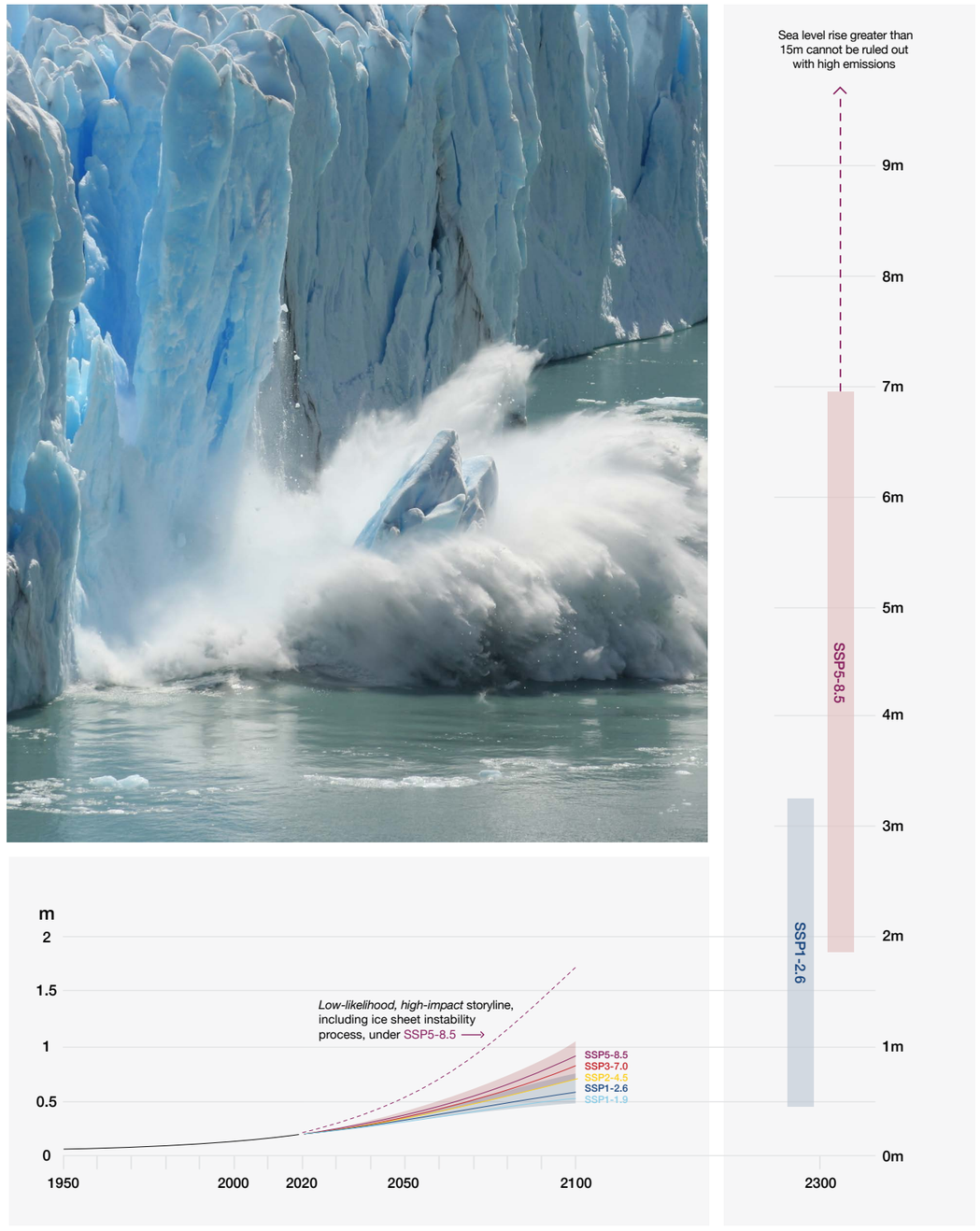
## Climate resilient development, Antarctica and Southern Ocean

Climate resilient development (CRD) is a process for integrating greenhouse gas mitigation and adaptation measures to achieve sustainable development for all[19]. Even though it does not have a resident population, Antarctica is a significant part of the global socio-ecological system.

Global sustainable development depends on Antarctica and the Southern Ocean, which provide many ecosystem services, notably carbon sequestration and fisheries. The region also holds important cultural values across the global community, including those of the Indigenous cultures of the Southern Hemisphere[4].

Given the Antarctic region only accounts for a very small fraction of global emissions, there are few options for reducing global greenhouse gas emissions there. However, the Antarctic Treaty System has worked on reducing the emissions from scientific activities.

There are no realistic options for undertaking adaptations in Antarctica to reduce climate risks emanating from Antarctica[4]. The rapid pace of change, such as sea-ice loss, can outpace ecological processes and induce substantial ecological shifts.




a) Global mean sea level change relative to 1900

b) Global mean sea level change in 2300 relative to 1900

**Figure 3.** Global mean sea level change in metres relative to 1900. Panels: (a) historical changes from measurements (black line and grey shading) and future changes from simulations of couple ocean atmosphere models, ice sheet models and glacier models (coloured lines with shading) for various emission scenarios; (b) the global mean sea level change at 2300 relative to 1900 – all changes in metres (m). Note: shaded area in panels (a) and (b) are likely ranges (66 percentile range). Much higher values cannot be excluded but are considered very unlikely[7].

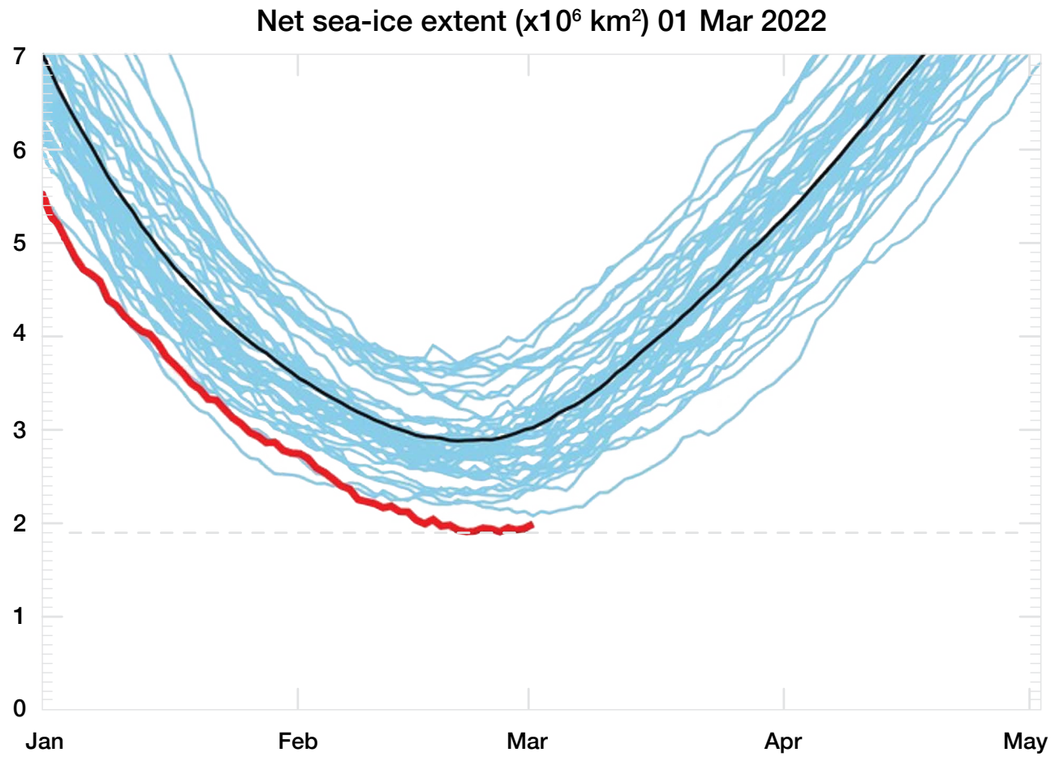



**Figure 4**: Annual cycle of Antarctic sea-ice extent since 1979, by area, i.e. millions of square kilometres. Black line is the median extent over the period. Red line shows the 2022 year falling well outside the historically-observed summer minimum, i.e. more than 1 million square kilometres below the median – a difference larger than the area of New South Wales. *Credit: Phil Reid and Will Hobbs .*

Antarctic contributions to global climate-change mitigation have been considered but none are mature. These include enhancing carbon draw-down from the atmosphere into the Southern Ocean through large-scale iron fertilisation. However, these measures are yet to be demonstrated and may negatively affect the ecosystem services of the region[20], and appropriate governance of these measures must also be developed.

Compound risks exist from the interaction between human activities, such as fisheries and tourism, and climate change and ocean acidification – but action can be taken to mitigate them. Strategies include using climate-informed, ecosystem-based management, which incorporates climate futures to determine which decisions will maintain or enhance climate resilience in Antarctic ecosystems[4].

Climate resilient development pathways can be further enhanced by working with relevant stakeholders, such as representatives from fisheries, tourism and conservation. This would increase transparency when developing climate-informed ecosystem-based management strategies[4], and can help to avoid compound risks and maladaptation.

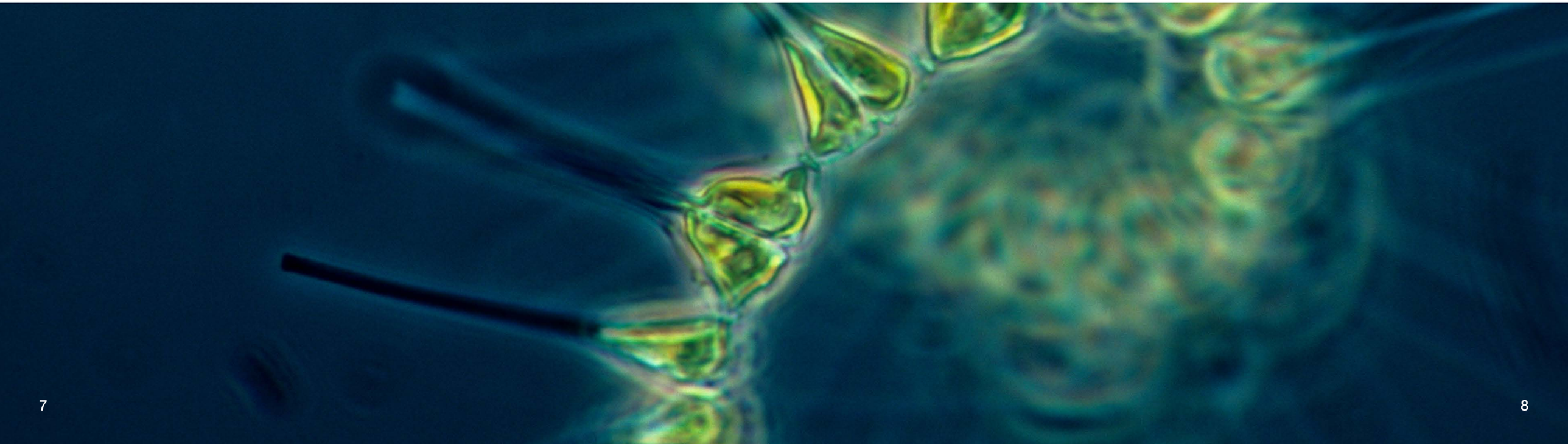
Maintaining the resilience of biodiversity and ecosystem services at a global scale depends on effective and equitable conservation of approximately 30% to 50% of Earth's land, freshwater and ocean areas, including currently near-natural ecosystems.

Globally, less than 15% of the land, 21% of the freshwater and 8% of the ocean are currently protected, with insufficient stewardship in most areas to reduce damage from, or increase resilience to, climate change[1].

Some Antarctic areas are protected through Antarctic Specially Managed Areas, Antarctic Specially Protected Areas, and Marine Protected Areas, with up to 3.5% of ice-free land areas protected[21] and up to 5% of marine areas fully protected[22].

Achieving climate resilience is currently a challenge in the Antarctic Treaty System[4]. A climate change response plan has been adopted for terrestrial and nearshore habitats. However, governance for managing climate impacts on marine ecosystems is poorly developed. While spatial planning to give attention to sensitive areas is increasingly identified as important for managing climate change, significant steps need to be taken to complete a representative system of protected areas around Antarctica.

Risks to Antarctica, the Southern Ocean and globally, from changes in Antarctica, can only primarily be reduced through global mitigation of greenhouse gas emissions[4].



## Act now: the window to a liveable future is closing

The changes occurring in the Antarctic now do not stop with the release of the IPCC AR6 reports. The 20th Century commencement of scientific exploration of the Antarctic has yielded great insights into this region and its future, but it also remains profoundly under-observed and often not well understood.

Surprises continue to emerge, including a reduction in sea-ice extent in 2016 of two million square kilometres against the backdrop of unchanging extent over 30 years (Figure 4). The summer of 2022 will see that record broken again. It is not known to what degree this reflects a shift to a new, possibly more unstable regime. Alarmingly, other aspects of the system may be passing unnoticed through tipping points or undergoing regime shifts because they are simply not observed.

While we emphasise climate resilient development, there are proposals for localised climate interventions in Antarctica to slow the melt of ice shelves and or to alter its capacity to reflect solar radiation (albedo)[23-25]. However, such proposals are arguably inconsistent with the Antarctic Treaty System and sustainable development pathways more generally.

Meanwhile, the responsibility Australia and populations globally have for protecting Antarctica has never been clearer. Establishing and adapting Marine Protected Areas in a changing climate is a key challenge identified by the IPCC 2022 report. While we do not yet know the extent of human impact on the observed sea-ice and ice-sheet change, this latest report makes it clear that there is no doubt the human-induced signal will emerge in the future[11], if it has not already.

A warming Antarctica and Southern Ocean region will also be more amenable to human activity, which is likely to bring its own environmental pressures to the region. For example, before the COVID-19 pandemic, nearly 75,000 tourists visited the Antarctic region each year[26] – and this is likely to increase with greater accessibility from a warming climate.

Importantly, the IPCC AR6 WGI and WGII reports reveal that much remains to be known about Antarctica and the Southern Ocean and how it will precisely impact the systems worldwide. But what we do know is clear: rapid and large-scale mitigation of climate change is critical to preserving Antarctica and protecting global populations from the climate-change risks that are and will continue to emerge from there.



Image by: Christopher Michel

## Links to other organisations and their statements/summaries of the AR6 WGII report

The Climate Systems Hub funded by the Australian Government under the National Environmental Science Program:

The Time for Adaptation is Now: Summarising the AR6 WGII report

The Australian Marine Sciences Association:

AMSA Position Statement – Climate Change

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