Shallow-reef species around Australia are declining with warming seas

Since 2008, population densities of shallow-reef fishes, invertebrates and seaweeds around Australia have generally decreased near the northern limits of species' ranges, and increased near their southern limits. Endemic invertebrates and seaweeds that prefer cold waters showed the steepest declines, and are prevented by deep-ocean barriers from moving south as temperatures rise.

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The problem

Society depends on nature for resources and services; however, the warming climate and other human-associated stressors are disturbing the natural world. These changes can directly affect the population numbers of various species in ways that remain largely unknown. No country systematically monitors trends in biodiversity. Yet, without reliable information about the state of the environment, conservation interventions tend to be inefficient. Particularly for the marine realm, in which species live out of sight, tracking population trends at continental and global scales has proved challenging. However, there are a few exceptions — some marine data are available for species that are visible above water (such as sea birds), commercially valuable species (such as tunas) and large, charismatic animals with a high public profile (such as whales). Although a few studies have investigated trends at regional scales (for example, ref. 1), no broader-scale investigation has compared population trends across the food web, from the plants and seaweeds that generate organic matter using sunlight all the way to the ecosystems' top predators.

The observation

By combining data from three long-running initiatives for monitoring reefs worldwide (namely, the Reef Life Survey[2], the Australian Temperate Reef Collaboration[3] and the Australian Institute of Marine Science programme[4]), we completed the largest assessment so far of species' population trends using standardized methods, for the period between 2008 and 2021. Data describing population changes for 1,057 species in the reefs around the Australian continent were collaboratively collected by researchers and scientifically trained recreational divers. Species were counted along 50-metre underwater transect lines along the sea bed at more than 1,636 sites between depths of 0 and 42 metres.

We found that most populations decreased in density near the warm edges of the species' geographical ranges and increased in density in cooler waters since 2008 (Fig. 1). Populations tended to grow in years when average temperatures were less than 0.5 °C above the 2008 baseline level but declined rapidly in years when this threshold was exceeded. Moreover, populations of species that prefer cold-water reefs decreased more consistently than did those that prefer warmer waters. This distinction was particularly pronounced for echinoderms (such as sea stars, sea urchins and sea cucumbers) and other bottom-dwelling invertebrate animals, which are rarely tracked by monitoring programmes. Notably, species recorded in cool waters were generally endemic to Australia, and many of them have deep evolutionary roots, suggesting that their loss could have large consequences for the continent and beyond. Widely reported losses of coral on the northern Great Barrier Reef after the 2016 and 2017 heatwaves were balanced at the continental scale by increased population sizes in other years and at other locations. Importantly, our investigation identified a huge gap in the level of public interest, scientific research and management effort directed at safeguarding temperate reefs as opposed to tropical ones, highlighting the conservation needs of these threatened ecosystems.

Future directions

Using standardized methods and objective criteria, our analysis revealed the high extinction risk faced by endemic reef species in southern Australian waters. Our study should be expanded to cooler waters of other continents, where population trends for reef species are largely undocumented and the ecosystem-wide impacts of climate change, fishing and other anthropogenic threats remain poorly understood.

Many findings described here were unexpected. The study outcomes are relevant to the challenge of assessing progress towards the United Nations' Sustainable Development Goals; practical biodiversity indicators are needed for tracking how well countries are achieving the targets.

Important next steps for safeguarding marine biodiversity include: the assessment of individual species with declining populations for inclusion on the International Union for Conservation of Nature's Red List of Threatened Species; targeted interventions to reduce the extinction risk of threatened marine species; the expansion of protected no-fishing areas in temperate seas; and reversing the global-warming trajectory by reducing greenhouse-gas emissions.

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EXPERT OPINION

"The study by Edgar *et al.* shows that populations of fish, invertebrates and algae in temperate waters around the coast of Australia are generally declining. The authors' conclusions have broad implications for marine conservation worldwide. Few papers have presented so much clear evidence of the need for increasing conservation efforts in coastal temperate regions in the face of global warming."

Sergio Floeter is at the Federal University of Santa Catarina, Florianópolis, Brazil.

FIGURE

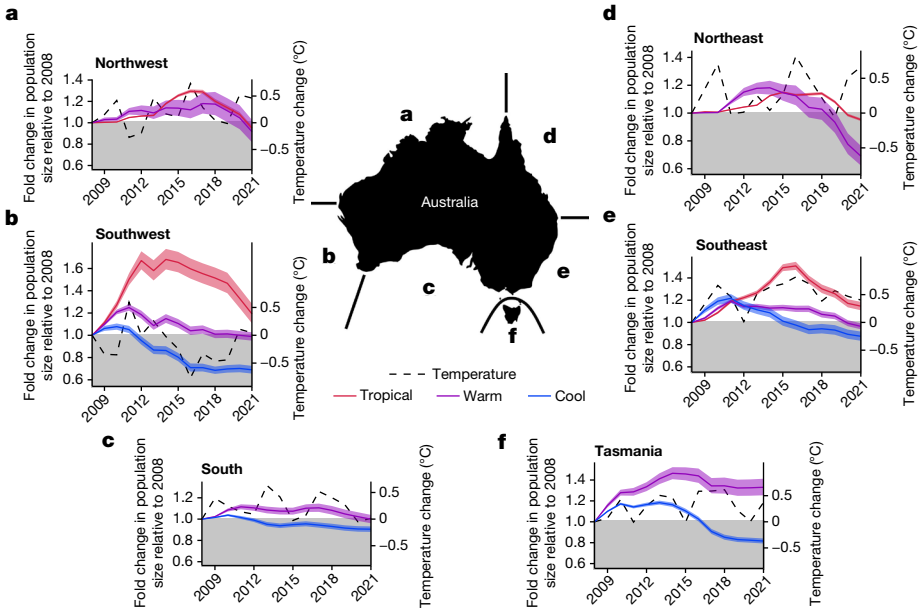

Figure 1 | Trends in species populations at Australian reefs between 2008 and 2021. a–f, Changes in mean densities for reef species in the indicated Australian regions relative to 2008 population sizes. Species were grouped into three categories depending on their preferred temperatures (tropical, mean site temperatures above 23 °C; warm temperate, 17.5–23 °C; cool temperate, below 17.5 °C). **a**, Northwest, Northern Territory, west coast north of 27° S. **b**, Southwest, west coast south of 27° S. **c**, South, south coast east of 148° S. **d**, Northeast, Queensland, Coral Sea. **e**, Southeast, New South Wales, and Victoria west to 148° S. **f**, Tasmania. Mean temperature differences relative to 2008 values are shown as dashed lines. Shading indicates ±1 s.e.m. Grey areas indicate population declines since 2008.

BEHIND THE PAPER

After 20 years of swimming along transect lines to count fish, invertebrates and seaweeds inside and outside marine reserves, we realized that a university research team was never going to be able to collect sufficient long-term data from enough sites to answer the most-important conservation-management questions. Our solution was to engage the skills and efforts of a collective of hundreds of recreational divers trained to a scientific level of data gathering. Thus, the Reef Life Survey was created[5]: a citizen-science programme involving divers who systematically record counts of species along 50-metre-long, GPS-referenced transect lines. The survey's data set now includes more than 22 million counts for more than 5,000 species at sites around 53 countries worldwide. All data are publicly available through the Reef Life Survey website (https://reeflifesurvey.com), which also includes photographic records and distribution information for shallow-reef species worldwide, and time-series plots for key indicators of reef condition.

G.J.E.

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FROM THE EDITOR

This paper stood out for the comprehensive assessment of changes in shallow-reef populations over a 13-year period, drawing on data from more than 1,000 species at around 1,600 sites. That temperate species could be faring worse than tropical species seemed like an important finding.

Editorial team, *Nature*