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Steady decline of coral reefs in the Anthropocene

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ABSTRACT
Coral reefs are in a steady decline worldwide due to a range of anthropogenic (man-made) stressors. For this study, we focused on the effect of the two main drivers of change on the reefs: ocean warming and increasing storm intensity. Both of these stressors result in changes in the composition of coral communities, and a decrease in coral cover, which in turn translates into functional changes on the reef.

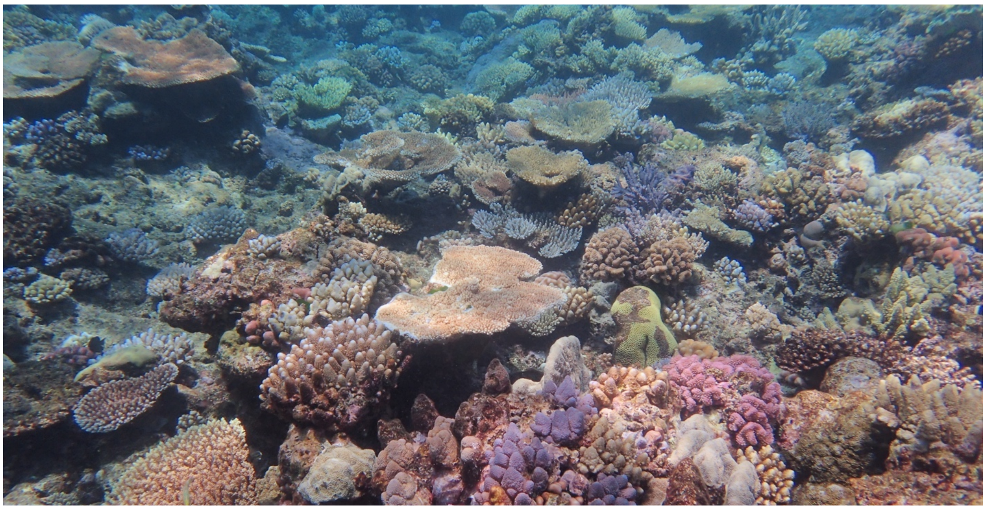

Image Credit: G. Torda, ARC Centre of Excellence for Coral Reef Studies

Tropical coral reefs are one of the most biologically diverse, socially, ecologically and economically valuable, and environmentally sensitive ecosystems of the planet. The engineers of this ecosystem are reef-building corals, close relatives of jellyfish that live in an intimate, mutually-benefitting relationship (symbiosis) with single-celled algae and a range of other microbes, including bacteria. Corals practically function as carnivorous underwater trees: they can feed, like animals, trapping small food particles from the water, but they can also harvest energy from the sun through photosynthesis, like plants. The waste products of the coral animal are used as nutrients by the algae that live inside its tissue, and in return the algae provide sugars and other nutrients to the coral. This efficient partnership allows corals to grow in waters with little nutrients and to produce skeletons of calcium carbonate in a diversity of three-dimensional structures that give shelter, food and habitat to many other species. Corals come in all shapes and forms – there are almost 1,000 coral species worldwide, and in the most diverse areas over 400 species can live together. Their different shapes and forms mean that they have different roles on the reef. For example, cushion-shaped branching corals provide home for juvenile fish; table-like corals provide shelter for larger fish; and boulder-like corals create a range of microhabitats (exposed boulder top, vertical sides, overhangs, etc.) that greatly increase the diversity of other marine flora and fauna.

Coral reefs are declining worldwide due to the unprecedented rate of environmental change that characterizes the Anthropocene, the era dominated by human activities. The main culprit is climate change, which results in the steady warming of the oceans, and in extreme weather events, such as heat anomalies and increased storm intensities. Anomalously high temperatures cause the breakdown of the fine-tuned symbiotic relationship between the coral and its algae, leading to the expulsion of their algae, in a process called 'bleaching'. This stress reaction deprives corals from their primary food source, and typically leads to the death of entire coral colonies. Intense storms physically destroy coral reefs, shattering coral colonies to rubble. Different coral species withstand these disturbances to differing degrees, which means that with the increasing frequency of such events, the composition of coral communities is changing faster and faster. And because different species bring different functions to the reef, it is important that we understand how coral communities are changing as climate change progresses, to be able to predict changes in functions and ecosystem services they provide to us, humans.

Moreover, due to intricate ecological feedback loops (self-reinforcing processes) on the reef, we are concerned that entire coral reef ecosystems may collapse if certain functions are lost. For example, a healthy coral community creates a structurally complex reef, which provides habitat to an abundance of herbivorous fish that graze back seaweeds. Because seaweeds compete with corals for space, herbivorous fish provide competitive advantage to corals, further increasing the structural complexity of the reef. This is a positive feedback loop. However, when corals die in large numbers in a bleaching or storm event, the habitat for fish disappears, so the fish population declines. With that, seaweed can grow up and inhibit the settlement and growth of new coral, and the coral reef ecosystem collapses.

To understand how cyclones and bleaching affect the composition of coral reefs, we analysed a 20 year-long dataset of coral cover of the Palm Islands, in the central Great Barrier Reef. The data was collected on the same reef locations throughout the study period, recording every single coral colony along the same lines. This gave us an insight into how coral populations changed over a period that included two major disturbance events: a mass bleaching event in 1998 and a category 5 tropical cyclone in 2011. Both of these perturbations caused major declines in coral cover, and both affected branching and plating corals more than massive boulder-like corals and encrusting corals. Interestingly, in both instances the cover of these latter two growth forms continued to decline in the aftermath of the disturbances, and only slowly started to recover years after the event. In contrast, the more affected branching and plating growth forms recovered remarkably faster. This, in tandem with higher damage but faster recovery on shallow reef sections compared to deeper slopes results in interesting changes in the coral community. Our results suggest that shallower reefs will be increasingly dominated by weedy coral species, while large colonies of slow-growing, boulder like corals will gradually disappear from the communities, resulting in a steep decrease in habitat complexity and diversity. The loss of slow growing massive corals is particularly alarming, because these methuselahs, and the functions they bring to the reef take centuries to replace. Clearly, if a 200-year-old colony dies, it will take 200 years for another one to grow up to that same size and provide the same functions. In general, our results show that reefs are not able to make a full recovery before the next disturbance hits, resulting in their steady decline. Our conclusion from this study stands in accord with that of many other studies: to conserve coral reefs and the services they provide to people, we urgently need to curb greenhouse gas emissions.