Steady decline of coral reefs in the Anthropocene

Tropical coral reefs are one of the most biologically diverse, socially, ecologically and economically valuable, and environmentally sensitive ecosystems of the planet. Their ecosystem engineers are reef-building corals, close relatives of jellyfish that live in an intimate symbiosis with unicellular algae and a range of other microbes, including bacteria. Corals practically function as carnivorous underwater trees: they can feed as animals, trapping small food particles from the water, but can also photosynthesise. This extraordinary association between a plant and an animal makes it possible for corals to thrive in nutrient poor waters and build otherwise energetically expensive calcium carbonate skeletons that form the three-dimensional structure in which myriads of species find shelter, food and habitat. 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 coexist. The diversity of their morphology and other aspects of their biology translates into a diversity of functions they provide to 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 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 that manifests in a steady warming of the oceans, as well as extreme weather events, such as heat anomalies and increased intensity of storms. Intense storms physically destroy coral reefs, while anomalously high temperatures cause the breakdown of the fine-tuned symbiosis between the coral and its algae, leading to the expulsion of the latter. This stress reaction deprives corals from their primary food source, and typically leads to the death of colonies. Different coral species withstand these disturbances to differing degrees, which means that with the increasing frequency of such events, the composition of coral assemblages is changing faster and faster. And because different species bring different functions to the reef, it is important that we understand how coral assemblages are changing as climate change progresses, to be able to predict changes in functions and ecosystem services they provide. Moreover, due to intricate ecological feedback loops on the reef we are concerned that entire coral reef ecosystems may collapse if certain functions are lost. For example, a well-described feedback loop is herbivory and structural complexity. The more structurally complex the reef, the more fish life it supports. The more fish, the more algae are grazed back on the reef, providing suitable substrate for the recruitment of new coral, and giving competitive advantage to corals over algae.

To understand how cyclones and bleaching affect the composition of coral reefs, we analysed a 20 year-long dataset of benthic cover. The data was collected on the same reef locations throughout the study period, recording every single coral colony along belt transects. This gave us an insight into the dynamics of coral populations 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 resulted in 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 dynamics of the coral assemblage. Our results suggest that shallower reefs will be increasingly dominated by weedy coral species, but altogether the recovery time for the coral assemblage on both shallow and deep reefs is longer than the return time of disturbances, resulting in a steady decline of the reef. 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. 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.