Too hot in paradise!

Despite a traditional and sustainable approach to managing resources, a remote Pacific atoll finds itself on the front line of a warming world.

By **Michael White**.

Tongareva (09° South; 158° West) is the largest and remotest atoll in the Cook Islands. The population is small, living in two villages, with a mainly subsistence lifestyle gathering food and daily resources from nature. There is a peripheral need for money to pay power and phone-bills and order bulk cargo, such as rice, flour and coffee, from Hawai'i. Shipping, however, is rare.

The Community has a sacred duty to pass on a healthy, diverse and abundant ecosystem to our descendants, as our Ancestors passed it down to us: "We would not want our great-grandchildren to think we did not care enough to leave them food and resources to live their lives".

We achieve sustainability through *rahui*—traditional opening and closing of a harvest. When *rahui* is in place it is *tapu* (forbidden) to take that particular resource. An important aspect of *rahui* is to monitor the closed stock, so wise decisions can be made whether to re-open the harvest or extend prohibition. As this is a Community decision it needs no enforcement. This approach has allowed islanders to survive remotely for centuries, so we have, or had until recently, a pristine environment that has people as an integral part.

In May 2015, the El Niño Southern Oscillation occurred, causing changes to prevailing weather and ocean patterns. Apart from reduced rainfall and winds shifting southwards Tongareva was untouched until December 2015. Suddenly, the lagoon water temperature rose to 33–35°C all month and on the ocean surface sometimes to 32°C. The author found the first coral bleaching on 21 December. During rapid surveys, bleaching was found along most areas of the outer reef (77 km circumference). Worse was that many *toka* (coral heads) in the huge lagoon (233 km^2) had suffered badly. These *toka* are important habitats for shellfish and myriad fish species. One of our most important resources is *pasua,* the small giant clam (*Tridacna maxima*). This clam is always protected by *rahui*; typically we only open the harvest for a week every 18 months or so. Religion is woven deeply through every aspect of society, so harvesting of *pasua* begins with prayers, after which both villages collect shellfish every day. It is hard work; we open and clean our shells overnight. At the weekend we say prayers of thanks and have a Community feast to celebrate a successful and safe harvest.

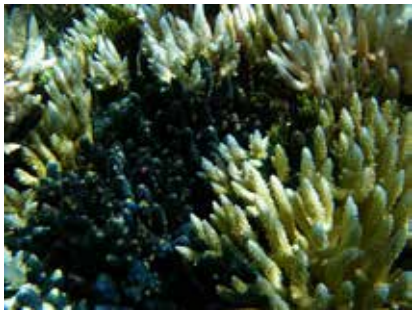
The upper surface of a coral head shows some resistance to bleaching; corals probably acclimatize to higher temperatures during diurnal low water.

In January 2016 we found that most *pasua* in the southern two-thirds of the lagoon were dead. The presence of bleached corals everywhere explained their likely fate. Corals have zooxanthellae living within their tissues, and these symbiotic dinoflagellates photosynthesize making high-energy food from CO_2 using solar energy. Most nutrition (95%) goes to the coral host. Elevated seawater temperature, increased solar radiation, or more likely increased ultraviolet radiation, causes zooxanthellae to produce nutrients faster (4–8 times) than corals can manage. Under these conditions some radical oxygen molecules become toxic so corals expel the dinoflagellates by shedding dermal cells: the symbionts provided the bright colouring and thus *bleaching* is the white carbonate skeleton remaining. Corals can still filter-feed on zooplankton, but may no longer have sufficient gastrodermal cells for survival. *Pasua* colouring also derives from zooxanthellae. Some clams were observed with a coloured half and

Live *pasua* (small giant clam, *Tridacna maxima*), and blue algae colonizing dead corals.

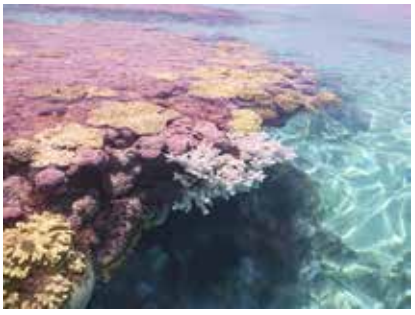
Various coral species are bleaching and blue algae is encroaching; it is unclear what will happen to the resident fishes.

Two metres depth, bleaching is at different stages and blue algae also making an impact.

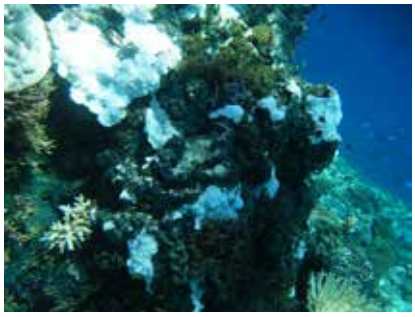


Bleaching starts from tips of coral branches.

About 4 metres depth: it is likely that in a few days all colour will have gone.



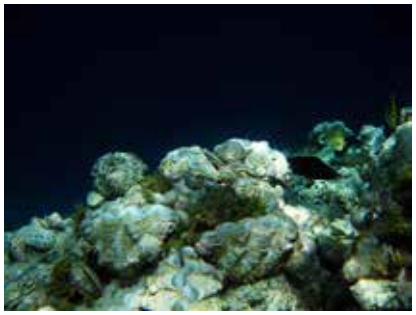
Some species seem very vulnerable to warming, several of the deeper corals are bleached too.



Blue algae creeping over dead corals.

Intermediate expulsion of zooxanthellae from the small giant clam *Tridacna maxima*.

Most zooxanthellae gone from a small giant clam.



Dead clams at 8-10 m depth: these may have a more limited temperature range than shallower clams.

the other already bleached: the process of death seems to happen in stages. Once clams died other creatures ate them.

The northern part of the lagoon still had a few clams alive, but a blue (algae) growth had colonized dead corals and was rapidly spreading across living ones and other bivalves that were more resilient to high temperatures. Presumably this is also a consequence of a changing ecosystem.

For many people in the industrial–consumer world climate change is something that means little, or perhaps it may occur at some far off time in the future; maybe it isn't even true! For us in the South Pacific it is real, current and serious. Our atolls are mainly less than a metre above sea level, but we would delay leaving our homelands by building stilt-houses, and using solar-powered hydroponics; freshwater is all rainfall anyway.

I'll mention two more things. A year ago our atoll got overwashed, thanks to a combination of super-moon, king tides and, unusually, a westerly wind. A wall of water built up and rushed through the village into the lagoon; we even had a sea turtle (*honu*) washed ashore. Tongareva is the most important *honu* habitat in the Cook Islands; we have mating, juvenile development and year-round nesting on one uninhabited *motu* (islet). We let them nest in peace.

In 2015 much of the forest fell down due to high levels of windborne salt, little rain and very hot weather. Most trees behind the main *honu* nesting-beach have died. The sex of *honu* embryos is determined by temperature—females from warmer nests, more males from cooler clutches—so the absence of shade skews towards feminization. Our Community Environmental Society *Hakono Hararanga* (Incorporated) is busily restoring the forest, but it is a 20 km trip in a small boat and the lagoon can be rough.

The most amazing thing learned from this environmental disaster is just how successful our traditional management approaches are; there were many thousands of large clams and new ones growing. These *pasua* would have served us well for years. Sadly, neither *rahui* nor legislation can protect us from human folly. Our prayer to the world is that you end your carbon-intensive lifestyle and learn the true consequences of your consumer habits. *Kia Manuia*.

Dr Michael White (crwban681@yahoo.co.uk) Principal Investigator for sea turtles in the Cook Islands and President of *Hakono Hararanga*.

Acknowledgements

Special thanks go to our *Hakono Hararanga* members, especially Ru Taime our Chairman.