Chapter 25

The 2016 coral bleaching event

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Massive colony of the genus *Porites*, d'Entrecasteaux Reefs, March 2016. © IRD/F. Benzoni

Coral reefs: a fragile and threatened ecosystem

Coral reefs are among the most diverse ecosystems in terms of species diversity and economic importance. Colorful, diverse and rich, they form a protective interface between land and ocean, which attracts and concentrates human activities. While they cover less than 0.2% of the world's ocean surface, they support almost 30% of the known marine biodiversity and provide resources upon which 500 million people depend directly or indirectly. In addition to their ecological value, coral reefs provide essential ecosystemic, economic and cultural benefits to industries and human societies through fishing, coastal protection, tourism and access to new natural molecules.

Entirely bioconstructed by biological organisms such as corals and calcareous algae, coral reefs are natural structures, which are particularly sensitive to changes in the environment. Their fragile equilibrium is threatened by a combination of factors including overexploitation of the environment and resources, and the overall degradation of the physical environment (sedimentation, pollution, etc.), all of which are exacerbated by population growth, the emergence of specific coral diseases and climate change. Their decline is observed worldwide. The situation is unquestionably clear today: 20% of the reef communities have totally changed, 15% have been seriously affected and are at risk of disappearing within a decade, and 20% are threatened with extinction within the next 40 years. Climate change affects the circulation,

temperature, pH, salinity and nutrients of the seas. Warming of surface waters, either progressive or as a result of severe weather or climatic anomalies, has resulted in coral bleaching in many coral reefs around the world and this, has occurred on several occasions in recent decades.

Coral bleaching

Reef-building corals, as well as some other taxa (sea anemones, giant clams), live in symbiosis with unicellular microscopic algae belonging to the genus *Symbiodinium* and commonly referred to as "zooxanthellae". These algae live in polyps, the soft parts of corals, and contribute to their hosts' energy budget by accelerating the calcification of their skeleton. With their green and brown photosynthetic pigments, zooxanthellae also contribute to the color of living coral tissues. The substantial or complete loss of symbiotic algae by animal tissue and/or decreased concentrations of photosynthetic pigments in algae result in a discoloration of the host. It is this phenomenon of polyp depigmentation that is known as coral bleaching. Visually, the animal tissue becomes translucent, revealing the white calcareous skeleton. While this may be reversible, it has consequences for the life of corals as it affects their growth, fertility and reproduction. If the symbiosis is not re-established, then bleaching leads to coral death (Fig. 1).

Coral bleaching is usually caused by abrupt environmental changes to which the coral is unable to adapt, such as increased seawater temperature, high UV radiation, desalination or bacterial infection. However, most large-scale massive bleaching events seem to have occurred due to an increase in mean maximum surface temperatures of only 1-2°C but which have lasted for several weeks in a row.

A major event in New Caledonia during summer 2016

Until the austral summer 2016, the reefs of New Caledonia had been spared by massive bleaching events. Only one earlier bleaching event had been reported and documented in January 1996, but limited data were available for only two sites of Grande Terre and did not suggest a major event. In February 2016, an unprecedented event of massive bleaching was observed.

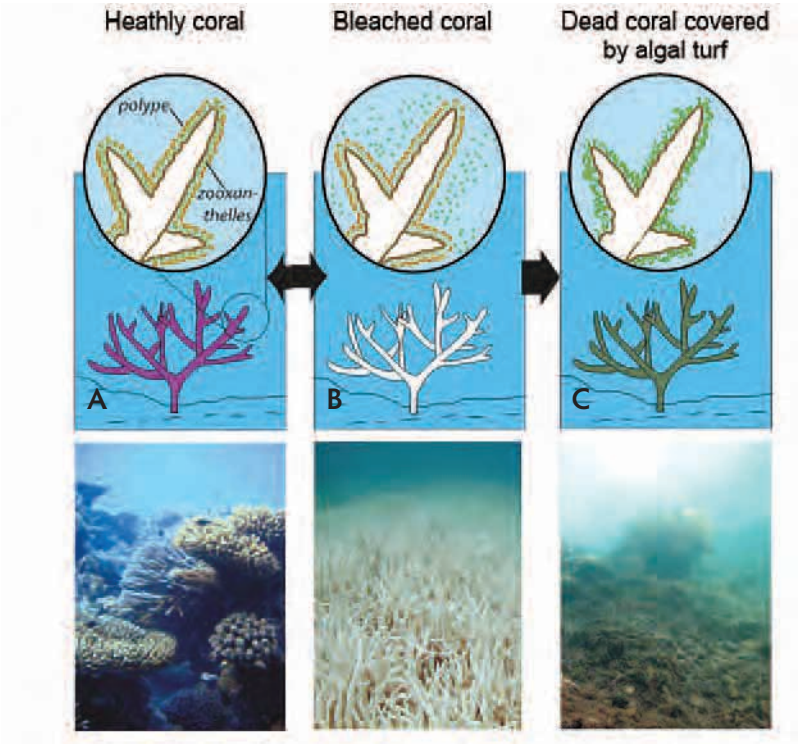


Figure 1: Diagram of coral bleaching at colony level (top) and community level (bottom).
A: Healthy coral with zooxanthellae and normal coloration.
B: Bleached coral after expelling zooxanthellae.
C: Algal turf on dead coral skeleton.
Adapted from http://www.gbrmpa.gov.au/managing-the-reef/tareats-to-the-reef/climate-change/what-does-this-mean-for-species/corals/what-is-coral-bleaching,

In New Caledonia, sea surface temperatures were unusually high during the austral summer 2016. This period was also marked by an estimated 10% increase in UV radiation due to the absence of wind and cloud cover. Temperatures ranged from 27°C to 31°C between January and May 2016, with the warmest recorded temperatures in February at 1-2°C above the region's climatic maximum (Fig. 2). Values of 1°C for this index (Coral Bleaching Hotspot) and 4°C-Weeks (Degree Heating Week) for cumulation over time are considered to be thresholds that can lead to coral bleaching and are used for predicting risk areas. The 4°C-Weeks threshold was exceeded between February and mid-May 2016, with the highest values (above 8°C-Weeks) occurring in March and April 2016 (Fig. 2).

This meteorological anomaly, making this period the warmest season recorded in New Caledonia for the last 30 years, would be the cause of an exceptional bleaching event. It has already been established that 2015 was the warmest year ever recorded worldwide. It is not surprising that the combination of global warming and regional weather events had an impact on coral reefs.

Many observations made by IRD researchers (BLANCO and SUR-BLANCO programs[10]) and by a participative monitoring organized by the Pali Dalik association, among others, indicated that the event had affected almost all the fringing reefs of Grande Terre and intermediate reefs and islets of the lagoon. Bleaching was also observed at the Loyalty Islands and d'Entrecasteaux Reefs, but no data is available for the remote reefs of the Chesterfield Islands. In total, over 300 observations were made between March and April 2016, either by diving or aerial surveys. The presence or absence of bleaching is generally in good alignment with the Degree Heating Week map (Fig. 3).

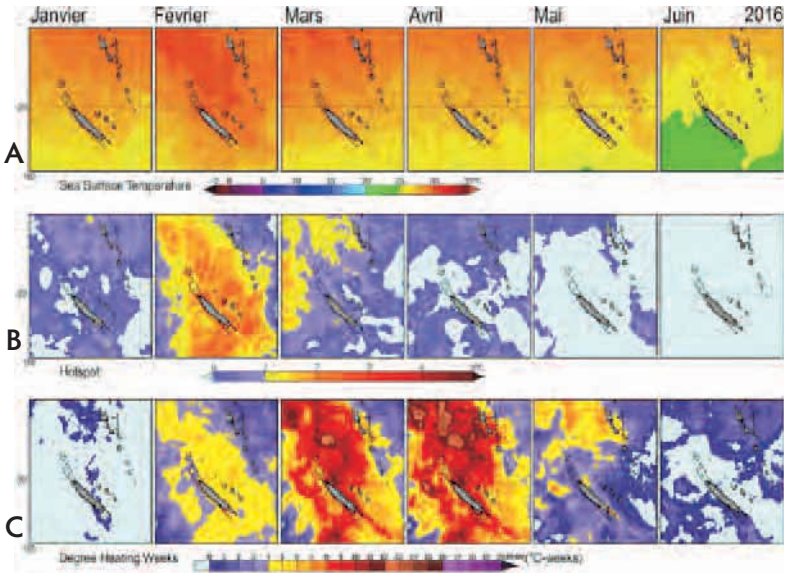


Figure 2: Sea surface temperature maps
A: of the Coral Bleaching Hotspot.
B: of the Degree Heating Week around New Caledonia during first semester 2016.
C: Data for 15th day of each month.
https://coralreefwatch.noaa.gov/satellite/bleaching5km/index.php

A variable impact

While most of the reefs were impacted, the extent of the damage varied between severe, moderate and mild depending on the species and types of coral communities. A bleached coral is not a dead coral, but without symbiotic algae its energy supplies are severely limited and in the event that stress conditions persist, corals will eventually die. While moderate and mild impacts may allow for a rapid return to normality, severe damage results in a much higher chance of death.

In general, coastal and lagoon reefs with a majority of branching corals were more affected than barrier reefs and external reef slopes, with bleaching rates reaching 90% of the coral cover. For the d'Entrecasteaux Reefs, bleaching affected the entire reef complex, with more severe damage inside the atolls' lagoons than outside. Massive corals, which exist in the form of balls and are usually less vulnerable, have been particularly affected on coastal reefs making this event particularly remarkable.

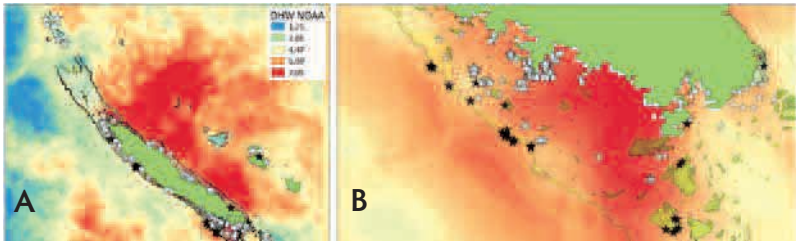


Figure 3: Location of observations (stars) made between March and April 2016.
A: Around Grande Terre.
B: In the Southern Lagoon and compared to Degree Heating Week map in °C-weeks, mid-February 2016 (NOAA 50-km SST Anomaly Product). The presence or absence of bleaching is marked by white (observed bleaching) or black (no bleaching) stars, respectively.
Adapted from BENZONI *et al.*, 2017

A dynamic event

Thanks to a monthly monitoring carried out since February 2016 at several sites in the lagoon of New Caledonia, researchers have been able to demonstrate the dynamics of the event. They mapped the sensitivity of species from several thousand colonies which had been observed and monitored during an annual cycle. The event lasted from February 2016

[10] The BLANCO program is funded by MOM, IFRECOR New Caledonia and the IRD. The SUR-BLANCO oceanographic campaign aboard the Amborella is funded by the New Caledonia government.

to the end of March 2016, gradually decreased with the arrival of austral winter and lower temperatures and disappeared completely in August 2016. Two months after bleaching started at sites in the Nouméa lagoon, 70 to 80% of the bleached colonies had fully recovered their zooxanthellae and vitality, 10 to 20% were partially dead and less than 10% had died.

Reef monitoring after the 2016 event

Apart from the event reported during the austral summer 1995-1996, other events did not affect New Caledonia, even those of 1998 and 2002, although they had a major impact on the Great Barrier Reef. However, the 2016 event will remain a massive and global issue, having severely affected many different parts of the world.

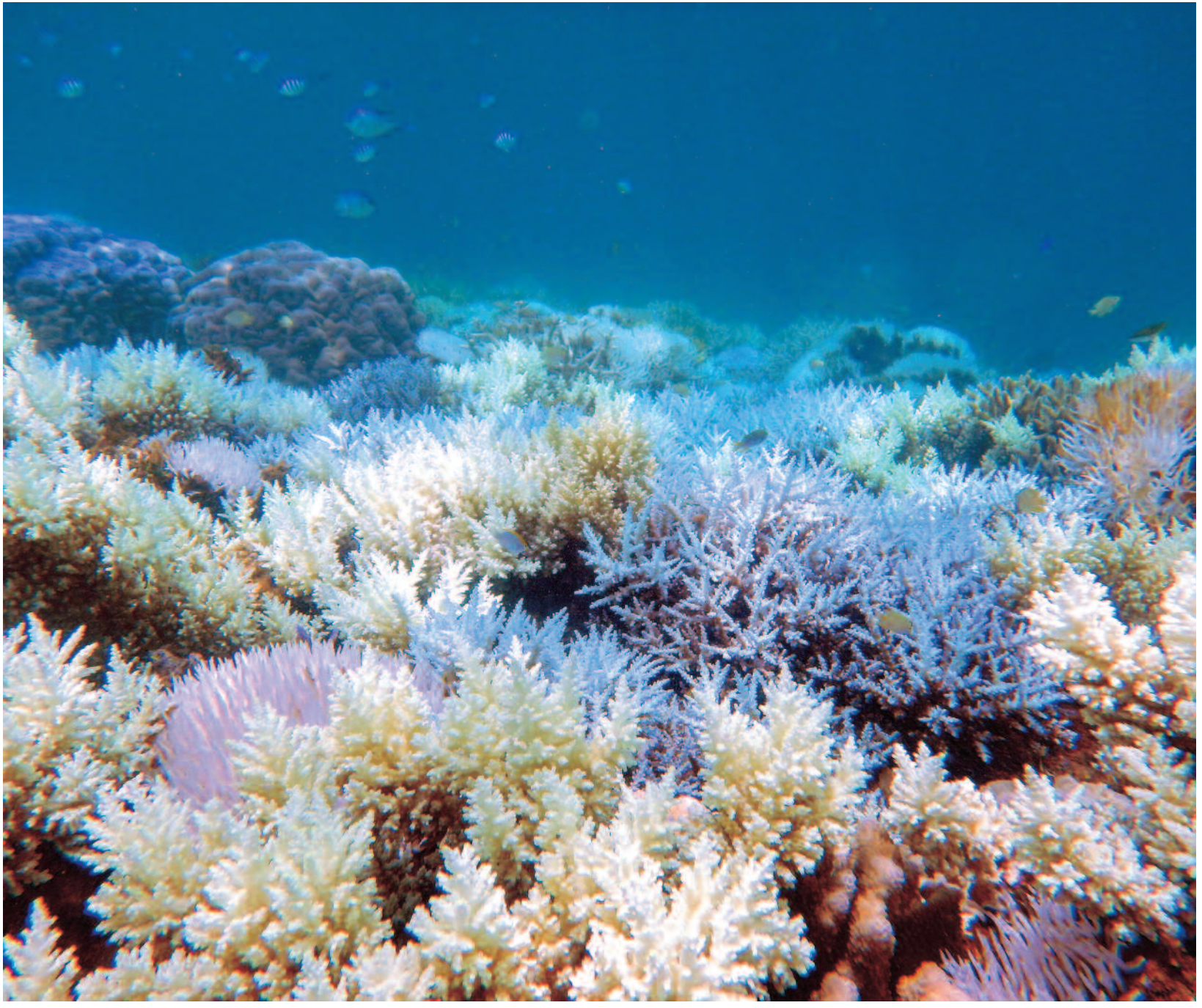
While in January 2017, several areas of the Great Barrier Reef were experiencing a consecutive year of coral bleaching, the vast majority of New Caledonia's reefs were spared. During the February 2017 monitoring (POST-BLANCO campaign[11]), researchers reported a higher mortality rate for coral communities at d'Entrecasteaux Reefs and on the east coast of Grande Terre. These were attributed to the 2016 bleaching event and the fact that the waters are warmer at these sites than on the rest of the coast of Grande Terre. Meanwhile, the monitoring carried out in the Chesterfield Islands in April 2017 (POST-BLANCO-2 campaign) revealed some signs of recent bleaching, the origin of which remains to be established.

What are the solutions?

Global warming and the associated rise in sea surface temperatures over the coming decades are no longer in question according to IPCC forecasts. Australian researchers have estimated that given the scale of the reef, it will take 10 years for the damaged corals to recover their vitality. Although they cannot control climate change, the mobilization of researchers is essential to warn others about environmental degradation, investigate its various aspects and ultimately study the resistance, or even resilience, of relevant species. Scientists are also working on combining the observations of the 2016 event with those available for regional coral communities. Their objective is to provide coral sensitivity maps that could be used by decision-makers when prioritizing conservation areas.

Comparison of two aerial views of Kuendu Beach Bay in Nouville, Nouméa, at the end of January 2016 (left) and at the end of February 2016 (right). The white spots visible in the right photograph correspond to the massive bleaching of corals. © IRD/F. Benzoni

[11] http://umr-entropie.ird.nc/index.php/home/actualites/depart-imminent-de-la-campagne-post-blanco-suivi-de-letat-des-recifs-apres-lepisode-de-blanchissement-massif-de-2016



Coral community of fully bleached branching corals. Roche Blanche Reef, south coast of Grande Terre, February 2016. © IRD/ F.Benzoni

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