Coral Bleaching, an Imminent Threat to Marine Biodiversity

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For thirty years, the ocean mean temperature has been incessantly increasing, which reinforces the intensity and length of coral bleaching. From 2014 to 2016, following an unusual increase in ocean water temperature notably reinforced by a rather marked El Niño phenomenon, scientists observed an exceptionally intense and major bleaching event which could extend beyond 2017. Climate models expect a temperature increase of surface waters from 1 to 3 °C by the end of the 21st century, which threatens the survival of coral reefs around the world beyond the year 2050. The resilience level remains low and limited; the stress coral reefs endure is emphasized by other anthropogenic factors (acidification, sea-level rise, overexploitation, pollution…). In order to protect this natural heritage, which over 500 million people depend upon around the world, it is necessary for governments to take action, beyond local measures, towards reducing human impacts on climate.

Despite their ecological and economic importance, coral reefs are affected by many stress factors at both a local level (overexploitation, destructive fishery techniques, tourism pressure, marine pollution, and coastal development) and at a global level with, for instance, increasing temperature of surface waters and ocean acidification. Anthropogenic pressure and climate change currently threaten most reef ecosystems around the world. Over time, these stress factors can lead to a rupture between the coral host and its photosynthetic symbiotes, a phenomenon called "bleaching" which is, as the name suggests, a lack of color or bleaching of the organism (loss of symbiotes and/or associate photosynthetic pigments) over a more less long period of time.

A moderate decrease in symbiotes and/or associate photo pigment concentration is due to a seasonal and natural phenomenon. This occurs when surface water temperature exceeds seasonal mean maximum temperature over a short period of time which varies according to observed sites. However, for thirty years, the ocean mean temperature has been steadily increasing, due to global warming, reinforcing the intensity and length of the phenomenon scientists define as "bleaching", which now affects reef areas around the world, from the Pacific to the Indian Ocean, including the Caribbean and Red Sea.

BLEACHING: A RECURRENT PHENOMENON IN HISTORY

The first coral bleaching episode was seemingly reported by Yonge and Nicholls regarding the Great Barrier Reef in March 1929, when surface water temperature had reached 35 °C, but it is not until the 1980s that the frequency, intensity and expansion of bleaching episodes increased around the world. This is caused by a "record" increase of ocean surface water temperature due to climate change, combined with the reinforcement of the El Niño phenomenon. Two major bleaching events were reported in 1998 and 2010. The 1998 episode involved 60 island states and nations across the Pacific Ocean, the Indian Ocean , the Atlantic Ocean (Caribbean), the Persian Gulf and the Red Sea.

The areas covering the Indian Ocean were particularly affected, with over 70% of mortality observed over a gradient depth up to 50m. Significant ocean surface water temperature irregularity caused a loss of over 16% of coral reefs around the world. In fact, 1998 was the first "global bleaching episode" declared by the National Oceanic and Atmospheric Administration (NOAA). Again, in 2010, an intense El Niño phenomenon triggered extreme coral bleaching, affecting all reefs throughout the world with, in some regions such as South East Asia, greater consequences in terms of expansion and mortality.

2014-2016: AN EXCEPTIONALLY INTENSE AND MAJOR EVENT

The current bleaching event, spreading over three major ocean basins (Pacific, Atlantic and Indian) is caused by the combined effect of an unusual rise of ocean water temperature, emphasized by global warming, and a particularly marked El Niño phenomenon, described as one of the most intense ever observed. This exceptional bleaching event began in June 2014 in the West Pacific, near Guam and the Mariana Islands and spread to the Hawaiian coasts. It then propagated to the South Pacific, affecting British territories in the Indian Ocean, the Caribbean, and the Florida Keys, covering Cuba, the Dominican Republic and the Marshall Islands.

In October 2015, NOAA officially announced an ongoing 3rd global bleaching event in the three principal ocean basins, threatening 95% of American coral reefs. By the end of 2015, 32% of world reefs had been exposed to a temperature irregularity of 4°C, causing mortality on more than 12 000 km^2. The beginning of 2016 was marked by the propagation of the phenomenon in the South Pacific as well as along the Great Barrier Reef and the Australian West Coast.

During March 2016, the ocean water mean temperature was over 1.5 to 2°C compared to measurements registered between 1971 and 2000 in the Northern area of the Great Barrier, at the same time of the year. Aerial and underwater survey programs showed that out of a total of 911 individual reefs observed on the Great Barrier, 93% were affected and in particular, the 1000km coastal area along the North of Port Douglas, yet considered until then as perfectly protected because the area is isolated from human activity.

"*We had never seen such a large scale bleaching phenomenon until now. The Northern area of the Great Barrier Reef looks as if 10 hurricanes had occurred at the same time*" stated Professor Terry Hughes , Director of the Australian Institute of Marine Science (AIMS). Large hundred-year-old colonies are dying, showing the exceptional nature of this phenomenon. Again, in the Pacific, severe bleaching event were reported in New Caledonia, Fiji Islands and Kiribati, where the mortality rate has reached 80% (Eakin, 2016, person comm, 8th of April). The event is gradually spreading to the West Indian Ocean, the Maldives, Kenya and the Seychelles, with particularly severe consequences in the Coral Triangle area, in Indonesia. Significant temperature irregularities were also registered in the Middle East: the Persian Gulf, the Gulf of Aqaba, and the Gulf of Suez are ranked at a level 2 alert (associated with bleaching and significant and widespread mortality events), while the Gulf of Oman and the Red Sea Reef area attached to Egypt remain at a level 1 alert (associated with bleaching and significant mortality events). Other bleaching events are expected in Japan and the Caribbean during the summer of 2016. NOAA scientists have suggested that global bleaching observed could extend beyond 2017.

THE FUTURE OF CORAL REEFS: BETWEEN HOPE AND CONCERN

In 2015, the mean temperature of ocean surface waters was 0.74°C above 20th Century average temperatures, exceeding by 0.11°C the record for 2014. Climate models expect a temperature increase of surface waters of 1 to 3°C between now and the end of the 21st century. In fact, until recently temperatures only rarely and punctually exceeded the thermo tolerance limit, which causes coral to bleach. However scientists expect this phenomenon to occur on an annual or bi annual basis, thus threatening the survival of coral reefs around the world by 2050. Consequences are alarming because an increase in bleaching frequency, such as that observed in the Caribbean (1995, 1998, 2005 and 2010) for instance, limits ecosystem resilience periods

and can cause, in the long term, higher mortality rates. Recent studies have shown coral acclimatization potential to severe temperature anomalies[1]. For instance, certain coral species can modify their symbiotic algae population in order to optimize their resistance to thermal stress or even regulate their genes to reinforce their defense mechanisms. However, this resilience level is rather low and punctual. It is in fact unlikely that it might have a significant role while the ocean temperature steadily rises. Furthermore, the combination with other environmental factors, such as ocean acidification and sea-level rise paired with local threats (overfishing, pollution, physical damage, land erosion, etc.), have to be taken into consideration when predicting the future of coral reefs. The synergetic effect of these stress factors (marine pollution and overfishing) can deteriorate trophic relationships between organisms within the coral reef ecosystem, by stimulating excessive growth of filamentous algae to the detriment of coral which becomes more vulnerable to diseases and infections.

THE NEED FOR AWARENESS

These recent events have raised concern among the scientific community and have sparked awareness of the necessity to act in order to protect coral reefs. New technologies and many resources have been set up in order to follow the geographical spread and evolution of bleaching for a better understanding and apprehension of coral response. For instance, the "Catlin Seaview Survey" Expedition, launched in 2012, created a coral reef monitoring around the world. As a similar action, France is celebrating the 15 year anniversary of the French initiative for coral reefs (Ifrecor). These efforts can lead to the implementation of local actions to reduce human print on reef ecosystems. For instance, Mumby & Harborne (2010) have proved the efficiency of marine protected areas for reef resilience in the Caribbean. Likewise, in 2014, New Caledonia announced the establishment of a "Coral sea natural park", one of the biggest marine protected areas in the world (1.3 million km^2). Biological engineering solutions have been proposed, suggesting the use of "optimized" coral colonies according to new environmental conditions in order to restore deteriorated reefs. Some scientists suggest using "assisted evolution" to modify the coral's resilience limit by performing an in lab artificial selection, consisting in exposing coral to various stress or by selecting thermo tolerant symbiote stem cells.

Local authorities and non-governmental organizations (NGOs) have a crucial role in protecting this heritage, which over 500 million people depend upon. Beyond local actions, governmental decisions have been made to reduce human impact on climate. In December 2015, an international agreement, setting a goal for a global warming limit of 1,5 °C - 2 °C by 2100 was validated by 195 countries (including France) participating in the international climate conference (COP21). In September 2016, China and the USA, two superpowers and major world polluters, ratified this agreement, joining the worldwide common effort. In order to preserve reefs for future generations, we need to propose realistic solutions through unifying programs, addressed to all: decision-makers, industry, general public, youth and directly concerned communities. An efficient protection of biodiversity relies on improving local communities living conditions and their ability to sustainably manage the ecosystem resources which they depend upon[2].

1 https://www.coralcoe.org.au/media-releases/only-7-of-the-great-barrier-reef-has-avoided-coral-bleaching

2 See NGO actions such as Coral Guardian (www.coralguardian.org/association-coral-guardian/).

REFERENCES

- AIMS, 2016 – Western Australian reefs feel the heat from global bleaching event, www.aims.gov.au/docs/media/featured-content.html/-/asset_publisher/Ydk18I5jDwF7/content/western-australian-reefs-feel-the-heat-fromglobal-bleaching-event.
- AINSWORTH T. D. *et al.*, 2016 – *Climate Change Disables Coral Bleaching Protection on the Great Barrier Reef.* Science 352, 338-342 (2016).
- BAHR K. D., JOKIEL P. L. and RODGERS K. S., 2015 – *The 2014 Coral Bleaching And Freshwater Flood Events In Kāne'ohe Bay*, Hawai'i. PeerJ 3, e1136.
- BROWN B., 1997 – *Coral Bleaching : Causes and Consequences.* Coral reefs 16, S129-S138.
- DONNER S. D., SKIRVING W. J., LITTLE C. M., OPPENHEIMER M. and HOEGH-GULDBERG O., 2005 – *Global Assessment of Coral Bleaching and Required Rates of Adaptation under Climate Change.* Global Change Biology 11, 2251-2265.
- EAKIN C. M. *et al.*, 2010 – *Caribbean Corals in Crisis : Record Thermal Stress, Bleaching, and Mortality in 2005.* PloS one 5, e13969.
- FABRICIUS K. E., CSÉKE S., HUMPHREY C. and DE'ATH G., 2013 – *Does Trophic Status Enhance or Reduce the Thermal Tolerance of Scleractinian Corals ? A Review, Experiment and Conceptual Framework.* PloS one 8, e54399 (2013).
- FISCHLIN A. *et al.*, 2007 – *Ecosystems, Their Properties, Goods and Services.*
- FITT W., MCFARLAND F., WARNER M. and CHILCOAT G. – *Seasonal Patterns of Tissue Biomass and Densities of Symbiotic Dinoflagellates in Reef Corals and Relation to Coral Bleaching.* Limnology and oceanography 45, 677-685 (2000).
- GLYNN P., 1993 – *Coral Reef Bleaching : Ecological Perspectives.* Coral reefs 12, 1-17.
- GLYNN P. W., PEREZ M. and GILCHRIST S. L., 1985 – *Lipid Decline in Stressed Corals and their Crustacean Symbionts.* The Biological Bulletin 168, 276-284.
- HERON S. F. *et al.*, 2016 – *Validation of Reef-Scale Thermal Stress Satellite Products for Coral Bleaching Monitoring.* Remote Sensing 8, 59.
- HOEGH-GULDBERG O. and RIDGWAY T., 2016 – *Coral Bleaching Hits Great Barrier Reef As Global Temperatures Soar.* Green Left Weekly, 10.
- HOEGH-GULDBERG O., 1999 – *Climate Change, Coral Bleaching and the Future of the World's Coral Reefs.* Marine and freshwater research 50, 839-866.
- ISRS, 2016 – Reef Encounter, 31.
- JOKIEL P. and COLES S., 1990 – *Response of Hawaiian and Other Indo-Pacific Reef Corals to Elevated Temperature.* Coral reefs 8, 155-162. PALUMBI S. R., BARSHIS D. J., TRAYLOR-KNOWLES N. and BAY R. A., 2014 – *Mechanisms of Reef Coral Resistance to Future Climate Change.* Science 344, 895-898.
- MUMBY P. J. and HARBORNE A. R., 2010 – *Marine Reserves Enhance the Recovery of Corals on Caribbean Reefs.* PLoS ONE 5, e8657, doi : 10.1371/journal.pone.0008657.
- NICHOLLS R. J. *et al.*, 2007 – *Coastal Systems and Low-Lying Areas.*
- NOAA, 2015 – *Noaa Declares Third Ever Global Coral Bleaching Event : Bleaching Intensifies in Hawaii, High Ocean Temperatures Threaten Caribbean Corals.* www.noaanews.noaa.gov/stories2015/100815-noaa-declares-third-ever-global-coralbleaching-event.html.
- NOAA, 2015 – *NOAA Coral Reef Watch : 2015 Annual Summaries of Thermal Conditions Related to Coral Bleaching for NCRMP Jurisdictions.*
- NOAA., 2015 – *State of the Climate : Global Analysis for Annual 2015.* National Centers for Environmental Information, www.ncdc.noaa.gov/sotc/global/201513.
- NORMILE D., 2010 – *Restoration or devastation ?* Science 327, 1568-1570.
- PALUMBI S. R., BARSHIS D. J., TRAYLOR-KNOWLES N. and BAY R. A., 2014 – *Mechanisms of Reef Coral Resistance to Future Climate Change.* Science 344, 895-898.

- Studies, C.C.A.C.o.E.C.R., 2016 – *Only 7 % of the Great Barrier Reef Has Avoided Coral Bleaching*. www.coralcoe.org.au/media-releases/only-7-of-the-greatbarrier-reef-has-avoided-coral-bleaching.
- VAN OPPEN M. J. H., OLIVER J. K., PUTNAM H. M. and GATES R. D., 2015 – *Building Coral Reef Resilience Through Assisted Evolution.* Proceedings of the National Academy of Sciences 112, 2307-2313, doi : 10.1073/pnas.1422301112.
- VEGA THURBER R. L. *et al.*, 2014 – *Chronic Nutrient Enrichment Increases Prevalence and Severity of Coral Disease and Bleaching*. Global change biology 20, 544-554.
- WAKE B., 2016 – *Snapshot : Snow White Coral.* Nature Climate Change 6, 439-439.
- WILKINSON C. R., SOUTER D. N. and NETWORK G. C. R. M., 2008 – *Status of Caribbean Coral Reefs after Bleaching and Hurricanes in 2005*. Global Coral Reef Monitoring Network.
- YONGE C. M., NICHOLLS A. G. and YONGE M. J., 1931 – *Studies on the Physiology of Corals*. Vol. 1, British Museum.
- ZANEVELD J. R. *et al.*, 2016 – *Overfishing and Nutrient Pollution Interact with Temperature to Disrupt Coral Reefs Down to Microbial Scales*. Nat Commun 7, doi : 10.1038/ncomms11833.