Corals in a changing world

Coral reefs are among the world's richest ecosystems, but environmental change is fast putting them at risk. Scientists are revisiting fundamental questions in coral research to understand how corals will fare in the future. David Suggett and colleagues explain.

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Productive and diverse coral reef ecosystems exist because of coral growth. To grow optimally, corals need specific conditions of light intensity, temperature and pH. But these conditions appear to be changing faster than ever, as tropical waters are subjected to both global climate change and local problems like pollution and sedimentation. How such altered environments will affect reefs is still largely unknown, but certainly any change to the rate and extent of coral growth will be vital in determining reefs' future form and function.

We can already see the effects of rapid environmental change on how fast corals grow. For example, slower growth rates of *Porites*, a key reef-building coral, have been recorded within the Great Barrier Reef over the last two decades, alongside accelerated increases of seawater temperature. However, it is unlikely that temperature alone is fully responsible. Warmer waters are ultimately driven by more CO_2 in the atmosphere; this CO_2 also dissolves into seawater to lower pH, making it more acidic – a process known as Ocean Acidification (OA).

Several experimental studies now show that OA not only slows corals' growth, but may also make them more vulnerable to temporary stresses that can cause coral bleaching – this is when corals turn pale and ultimately die. Physiological resistance to transient stresses, such as unusually warm or cool waters, requires corals to use energy that they would otherwise be able to invest in growth. The findings to date are alarming but highlight a key issue: we need to consider the combined effects of multiple climate change variables to predict future coral growth accurately. Curiously, many studies have focused on temperature and OA, but little attention has yet been paid to the key limiting resource for coral growth in every reef – light.

Too much of a good thing?

The availability of light is the main regulator of coral growth, and is also predicted to change in future environments, along with temperature and CO_2, and hence acidity. The tiny animals that build coral reefs are dependent on a symbiotic relationship with algae, called zooxanthellae. These algae live within the coral animals' surface tissue; the carbon they fix by photosynthesis is used to 'feed' the coral. Up to a point, more light means more photosynthesis, to the benefit of the coral.

But too much light eventually makes the zooxanthellae – and in turn the corals – more susceptible to the stresses that lead to coral bleaching. Photosynthesis increases the rate at which corals can 'calcify', or lay down their calcium carbonate skeletons. But unfortunately, calcification also becomes compromised as seawater becomes more acidic – hence the lower growth rates seen under OA.

So the ultimate effect of climate change on the form and function of tropical reefs depends on the combined changes of light, temperature and OA, as well as on how specific corals and zooxanthellae respond to these changes. This is where we come in.

Since 2004, several NERC-funded research projects within the University of Essex's photosynthesis laboratory have focused on the responses of marine organisms, in particular a globally abundant phytoplankton species, *Emiliania huxleyi*, to OA. Unfortunately, mimicking the effects of OA in the laboratory is not as easy as simply tweaking water's pH by adding acid or alkaline substances. Adding biology to the picture further complicates the inorganic carbon chemistry that determines the pH of seawater. Organisms change the pH of their surroundings through photosynthesis and/or respiration, and by producing calcium carbonate (chalk) skeletons or shells.

This meant that from the outset of our OA projects, we needed to develop and optimise experimental 'microcosm' systems to provide full control over the continually changing chemistry. In developing this technology, we produced the crucial tool needed to examine the complex interactive effects of light, temperature and pH on coral growth. This is the subject of a new NERC-funded project within Essex's Coral Reef Research Unit (CRRU): 'A community metabolism approach to examine the environmental regulation of coral growth'.

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▶ Measuring corals.

How do corals grow?

This new project has reignited a key question. Just how – and how fast – do corals really grow? This may seem like an obvious question, yet it still remains unanswered. Surprisingly few publications report coral-growth rates. Such a lack of core information highlights a central problem: how does a coral grow and how is growth best measured?

The growth form, or 'architecture', of a coral colony is highly variable. Environmental conditions such as exposure to currents and light levels can play major roles in sculpting a coral colony, but the extent to which environments regulate architecture varies within and between species. The complexity and variability of coral architecture makes assessing colony growth – defined as the change in a reef's size per unit of time – extremely difficult. No single measure can be truly reflective of growth. So to find out how changing climates will influence colony growth, we need to learn how to assess coral growth accurately, as well as to identify the factors that control it.

This has led to another new NERC-funded project, the Coral Aquarist Research Network (CARN), also run within Essex's CRRU. To assess what drives growth requires the capacity to carefully control (and manipulate) the environment for as many species as possible; the resources for this are far outside the scope of most research facilities.

But they are readily available in the industrial sector, specifically from coral growers and national and public aquaria, which for many years have independently been establishing the best way to grow coral species. CARN was launched to provide a forum through which UK coral researchers and academics could exchange information with the nation's aquarist and coral husbandry industry. It is primarily focused on how to benefit industry by exchanging detailed knowledge of coral growth, mortality and fecundity.

Initiating these two new NERC-funded projects alongside existing research within the CRRU has encouraged further investment by the University of Essex, which has funded a new coral-growth aquarium facility.

This facility has been designed in close collaboration with the coral husbandry industry and will provide a resource for researchers to continue the UK's momentum in coral science, which until now has largely been based on studies in the field. Such investment is certainly a sign of the times. Our environment is changing quickly, and so are the priorities for the research community. We are revisiting perhaps the central issue in coral research, so as to shed new light on how corals grow, both now and in the future.

MORE INFORMATION

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FURTHER READING

CARN is the main information gateway (and will ultimately act as the central data repository) for all aquarists, including scientists, industry and the general public interested in the Coral Aquarists Research Network. www.carnuk.org.

Riebesell U, Fabry VJ, Gattuso JP. *Guide to Best Practices in Ocean Acidification* (www.epoca-project.eu/index.php/Home/Guide-to-OA-Research). This document is a reference to provide guidance for research in the rapidly growing field of OA.