Corals as climate monitors/Monitoring corals: Both sides of the coral coin.

by
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Corals as environmental/climatic monitors

Simply put, corals have no equal as climate monitors. Every healthy coral reef contains large coral heads that retain at least a century's worth of climate record. In some exceptional cases the record has been extended more than 1,000 years into the past. Dating precision is usually annual, plus corals are affected neither by bioturbation nor transport, the twin scourges of the microfossil record. The major drawback is geographic distribution: obviously, reef corals are restricted to the tropics.

Analysis of the stable isotope ratios of oxygen ($\delta^{18}O$) has been the workhorse of climate studies. Because this ratio is dependent on temperature (among other factors), the record in skeletal organisms is a proxy for ocean temperature. Using long cores extracted from reef corals, paleotemperature records several centuries long have been obtained, allowing us to identify (as one example) the timing and magnitude of past El Niño events, and a record of past upwellings.

Although there are several well-funded groups obtaining past climate records using $\delta^{18}O$ analyses, these must be viewed with caution. Recently, it has been shown that this record is profoundly influenced by so-called Kinetic Isotope Effects (KIE): corals growing in the same pool have yielded $\delta^{18}O$ analyses that differed so greatly as to imply an 8° spread in water temperatures. The $\delta^{18}O$ record evidently is affected by growth as well as temperature. For this reason, other ocean temperature proxies are being investigated, such as Sr/Ca and Mg/Ca ratios.

For now, this area of paleoclimate research must be viewed cautiously. Temperature records that use at least two parallel traverses up a coral head, or that verify the $\delta^{18}O$ record with Sr/Ca analyses or the "lines" technique, are probably highly dependable. Published records that report only one traverse of $\delta^{18}O$ values may need verification.

Recent advances suggest that the future of this field of research will lie with the New Archive in the skeletons of ahermatypic corals. These corals live in all oceans, all latitudes: although they are sometimes referred to as "deep-water" corals, they in fact live at depths from 2m to 4 km. Because they lack zooxanthellae, the isotopic record is not distorted by photosynthesis. Individual Scleractinians live more than a century, and the gorgonians at least several centuries.

The first successful application of this record to climate studies was work on corals from Orphan Knoll, in the North Atlantic: at a depth of 1 km, and hence directly in the Gulf Stream Return Flow (Smith et al., 1997). This work established a technique (the "lines" technique) by which dependable ocean temperature records could be obtained from any coral, anywhere, and went on to show that transition to the Younger Dryas Event took less than 5 years. From this, we can conclude that climate models that lack the sensitivity to allow for a cessation in the Gulf Stream (a major reorganisation of the ocean's thermohaline circulation) in less than 5 years will need to be adjusted.

There is a further area in which geochemical analyses of coral may be of great environmental use: sewage stress in nearshore habitats. Stable isotopic ratios of Nitrogen ($\delta^{15}N$) are a function of position in the food chain: the higher up you are, the higher your $\delta^{15}N$. On the basis that there is only one top carnivore that currently spreads its waste in shallow marine environments, several studies have shown that $\delta^{15}N$ is a sensitive, and cheap, measure of sewage stress. In reef environments, coral tissue analyses are a

dependable, cost-effective alternative to estimates of algal standing crop, or nutrient analyses, both widely-used and widely-disputed measures of sewage stress.

Monitoring coral reefs

There is now no doubt that, worldwide, coral reefs are in serious decline. There has been much recent attention given to the impact of "global change", and the possible connection with widespread coral bleaching events. Clearly, future projected changes in ocean chemistry and sea level will have massive impacts on reefs-if reefs are still around. Ocean temperatures could rise above the upper lethal limit of reef corals, oceanic pH could drop to the point that corals are unable to make skeletons. Although a rise in sea level could conceivably result in landward transgression of reefs, as has happened in the past, it needs to be stated that similar transgressions have had a lag period of about 1,000 years (the newly-flooded areas need to be cleaned up-winnowed of fine sediments and colonised by precursor organisms-before corals will settle).

Concerns about future global change, however, must be viewed in the light of the damage that reefs have already suffered due to land-based sources of pollution. Corals can and will recover from bleaching events, but they cannot recolonise the silted areas left by deforestation. The scientific results to date make it abundantly clear that widespread damage has already occurred: most Caribbean reefs are under serious stress, the Florida Reef Tract has lost 40% of its coral cover in the past five years, and in the heart of marine biodiversity, central Indonesia, reefs have disappeared, and 30% of coral genera have been extirpated. At present rates of extermination, most of the world's reefs will be long dead before there is any major change in the temperature and chemistry of the oceans.

Focussing on global change as a threat to reefs ignores the ongoing stress from land-based sources. It may be politically easier to place the blame on faraway processes and agents, but it would be incorrect. Most of the participants at this meeting are signatories to the UN Convention on Protection of the Marine Environment from Land-Based Sources of Pollution, and land-based, local sources are the cause of most of the stress we see to-day.

Many nations have responded to the observed stress on their reefs by adopting coral reef monitoring programs. In general, these use some form of the line transect method first described 30 years ago (Risk, 1972), and most are designed and run by marine biologists. The methodology employs either diver-obtained intercept data, or uses image analysis of underwater video or still photography. In any event, details of the methods are unimportant: all currently-used methods, properly run, give identical results at the precision generally used for management decisions.

There are some problems with most reef monitoring programs:

- because they have been set up by reef biologists, they concentrate on corals.
- the time span needed to identify change conclusively will be very long, on the order of several decades.
- by the time a coral-based monitoring program has detected change, corals will have started dying.
- time-intensive survey methods using trained biologists are inappropriate in a Third World setting.

It has been suggested that coral reef monitoring programs be either replaced with, or supplemented by, rapid assessment programs based on bioindicators. These methods are far faster and cheaper than standard assessment methods currently in use. They may also be used by people with little or no formal training, thereby providing a measure of local control over local resources. The concept of using bioindicators parallels recent developments in water quality assessment, where large programs measuring hundreds of parameters are replaced with bioindicators that identify "hotspots". Then the necessary analytical tools can be brought to bear on the hotspot, feeding into a regulatory process.

There are several types of bioindicators that have been shown to be of value in reef environments: butterfly fish, stomatopods, coral associates, boring sponges, degree and number of necrotic patches on corals,

bioerosion. Several studies have linked bioerosion to degree of nutrient stress, and its use would seem to be indicated, although each situation is unique.

Ideally, monitoring programs focus on methodology that indicates stress, and are directly linked with follow-on programs that use geochemistry to identify the stress, in a detection-identification-remediation chain. In Florida, the process seems to be working the way it should (although it may be too late). Monitoring programs with many assessment sites have identified a catastrophic rate of decline of the reefs. Detailed monitoring effort has now been scaled back, bioerosion rapid assessment techniques added, and there are programs under way to identify sources of stress via methodology that can withstand court challenges.

In short, monitoring programs are not an end in themselves. There has been far too much debate on details of methods, and this needs to cease. To be effective, monitoring must be linked to the political/regulatory process, and unless there exists the political will to initiate remediation, all the money spent on monitoring will have been wasted.