

## The nature of reef stressors

Three topics are outlined: (1) synergies, (2) resilience and (3) domino effects.

**Synergies** Reef deterioration may occur as a direct response to an individual stressor such as mass bleaching, but more commonly occurs in response to synergies of different stressors acting simultaneously and in different combinations. Rising sea-levels, increasing numbers of high intensity storms, deterioration in water quality and various biotic influences are the principal stressors that will exacerbate the effects of mass bleaching and ocean acidification

Coral reefs and coral communities are highly sensitive to water quality, largely a matter of sediment loads (which affects light penetration), nutrients and environmental contaminants. Terrestrial runoff from urban development, agriculture and deforestation are the principal causes of diminished water quality. Runoff impacts have become such a worldwide phenomenon that only reefs well removed from highly populated land masses have escaped degradation of some sort. This is now the subject of considerable mitigation expenditure on the Great Barrier Reef as it offers one of the few management options that will enhance reef resilience prior to critical threshold levels being reached due to climate change.

**Resilience** – the capacity of a reef to recover from major disturbance – is primarily determined by the frequency, intensity and nature of stressors, the extent and nature of the damage, and the ‘health’ of the reef and its environment.

Since their first occurrences in the late 1970s, most mass bleaching events in the Indo-Pacific have been linked to El Niño cycles which occur at intervals of 4-7 years. The intensity of events has varied, but at these frequencies most reefs have made at least partial recovery. In future, mass bleaching events will become more frequent as they de-couple from El Niño cycles, and more severe as ocean temperatures rise. As damage becomes more extensive, the capacity of corals to regrow from fragments or from immigration of larvae will inevitably decline.

A degraded environment, whether natural or human-induced, has a strong influence on reef resilience. Thus, over-fishing and water quality degradation (through increased sedimentation and nutrient pollution, as commonly occurs throughout the Caribbean, south-east Asia and the Indian Ocean perimeter) reduce the resilience of reefs to bleaching. These chronically stressed reefs are now at high risk of reverting to semi-permanent algal or cyanobacterial communities. In contrast, reefs remote from additional human stresses can make rapid recoveries, returning to their former diversity in as little as a decade.

**Domino effects** Coral reefs occupy a truly unique position on Earth, for they are geological structures made by combinations of living organisms that have evolved the capacity to harness the abundant resources of air, seawater and sunlight. Reefs grow on solid substrates, but only at the interface of sea and atmosphere and only where light and temperature permit. To do this, reef-building organisms have evolved complex ecologies with tight interdependencies between key species, all dominated by many types of symbiotic relationships between plants and animals.

Reefs are particularly vulnerable to environmental changes, especially disruptions to the pathways of the carbon cycle on which they are totally dependent. Unlike any other major ecosystem, such disruptions can be of both marine and terrestrial origin. Reefs are likely to be the first major planetary-scale ecosystem to collapse in the face of climate changes now in progress.