Chapter 3
Coral Bleaching in Space and Time

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3.1 Introduction

Coral reefs are facing a range of serious anthropogenic threats that may significantly alter their ecological composition and reduce their capacity to deliver essential ecosystem services. Human influences such as destructive fishing, terrestrial runoff, pollution, and uncontrolled coastal development have a direct and immediately apparent impact on reefs. However the impacts of human-induced climate change are increasingly being seen as a more pernicious and intractable problem to resolve which probably requires concerted social action at a global scale and over many generations (Hughes et al. 2003). Large-scale bleaching of reef corals, resulting in mass mortality, has emerged as a critical global threat to coral reefs and is clearly attributable to thermal stress. Thermal stress on coral reefs has clearly increased over the past century (Chap. 4). As global temperatures continue to rise, largely due to anthropogenic greenhouse gas emissions, the threat to coral reefs is expected to increase significantly.

Predictions based on climate models and thermal tolerance of corals suggest regular widespread catastrophic bleaching within the next 15–25 years (Hoegh-Guldberg 1999; Donner et al. 2005; Chap. 10). However, climate models deal with large-scale atmospheric and oceanic processes, which in themselves are highly complex with many parameters and feedback loops that are difficult to quantify. There is additional uncertainty in foreseeing human trajectories of resource use and change. Predictions of the impacts of climate change are thus uncertain even over large (ocean basin) scales. At the scale of coral reefs this uncertainty is compounded further by the physical and biological complexity of coral reef environments. Physical complexities include currents, tides, bathymetry, depth, water quality, 3D habitat structure, and weather, all of which can affect the temperature and light environment and hence the susceptibility of corals to bleaching. Biological complexities include the variable responses of coral species, the interaction of corals with their diverse and differentially susceptible symbionts, interactions with pathogens, acclimatization, and adaptation processes (Chap. 7). Coral mortality and reef recovery depend on numerous local factors, human use, and conservation. It follows then that the degree of destruction and the permanence of the impacts are uncertain over

M.J.H. van Oppen, J.M. Lough (eds.) *Coral Bleaching.*
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large spatial scales and that the extent and severity of coral bleaching actually observed may not be as simple as predicted from climate models. These uncertainties increase as scales become smaller. Many of these complexities may never be fully understood; however much can be learnt from studying spatial and temporal patterns in bleaching records. An analysis of past records is, therefore, useful in identifying large-scale spatial and temporal patterns in coral bleaching and identifying key data gaps and data deficiencies which can be addressed in the future.

In the following analysis we investigate the spatial and temporal patterns of coral bleaching that can be detected in the ReefBase global database of bleaching records. In particular we address the following questions:

1. Can discrete global bleaching events be identified from the records of bleaching?
2. How many global events have occurred in the past three decades?
3. Are major bleaching events increasing in frequency and intensity?
4. Is background (low-level) bleaching increasing in frequency and extent?
5. Are there any clear spatial patterns of coral bleaching at global, regional, and subregional scales?
6. Do the observed periods of significant global bleaching correspond with the periodic occurrence of El Niño–Southern Oscillation (ENSO) events?

3.1.1 Early Bleaching Records (Pre-1982)

The earliest confirmed record of reef-wide bleaching due to thermal stress is probably that of Yonge and Nicholls (1931). They mention that, during a period of high summertime temperatures at Low Isles (Great Barrier Reef; GBR) in 1929, many corals died and several corals (particularly *Goniastrea* spp., *Favia* spp.) were observed to have lost their zooxanthellae and turned white. Some weeks later these corals were observed to be recovering their colouration, and histological inspection revealed that they had lost and then started to recover their zooxanthellae populations.

Shinn (1961) notes that *Acropora cervicornis* that had been transplanted to an inshore site in the Florida Keys bleached on their upper surfaces during periods of maximum summertime temperatures. This was not, however, a normal habitat for these corals and no observations of bleaching in normal populations were recorded. Goreau (1964) is probably the first person to publish a specific report on mass bleaching of corals in the reefs around Port Royal, Jamaica, during the aftermath of Hurricane Flora in 1963. He concluded, however, that the main cause of this bleaching was low salinity following heavy rains and floodwaters, rather than the high temperatures associated with current mass bleaching events. It is also possible that the report by Mayer (1914), in which he refers to corals not exposed to the air being "injured" after exposure to several hot calm days, represents a bleaching event. There is no mention, however, in his paper of loss of colour or bleaching. There is a total of 26 records of coral bleaching before the first well documented global-scale coral bleaching event of 1982–1983.