Coral Reefing: Caribbean Events and Some Problem Areas for Future Research

Peter W. Glynn
Division of Marine Biology and Fisheries
Rosenstiel School of Marine and Atmospheric Science
University of Miami

Many workers now link coral reef bleaching and mortality with stressful elevated sea temperatures resulting from greenhouse warming conditions, particularly evident during the past two decades. Since the early 1980s this type of disturbance has been observed in all of the world's major Indo-Pacific and western Atlantic coral reef regions. Coral reef bleaching has occurred over the entire western tropical Atlantic region, from Bermuda and the Bahamas to the Florida Keys, the Gulf of Mexico, the greater Caribbean region and Brazil. Within this region, the severity of bleaching events have varied widely, e.g. in 1998 from minor bleaching (< 5%) and mortality (< 1%) at the Flower Garden reefs in the Gulf of Mexico (Wilkinson, 2000) to nearly universal bleaching (~ 100%) of all zooxanthellate species and ~ 100% mortality on central shelf lagoonal coral reefs in Belize (Aronson et al., in prep.). By some global climate models, if the seas' temperatures continue to increase at a projected rate of approximately 1 to 2°C per century, the upper thermal tolerances of reef corals would be exceeded, leading to mass coral mortalities in the next 30 to 50 years (Hoegh-Guldberg, 1999). Because of the severe negative responses thus far observed, it is urgent to assess the causes and effects of thermal stress on coral reef ecosystems, addressing specific problem areas related to reef degradation. Other predicted effects of global climate change, that may become evident during the next few centuries relate to (1) rapid sea level rise, which could cause reef submergence and increased erosion and sedimentation (Graus and Macintyre, 1998), and (2) increased CO_2 concentration that would decrease the aragonite saturation state in the world's tropical seas and thus reduce coral reef aragonite precipitation to perilously low levels (Kleypas et al., 1999).

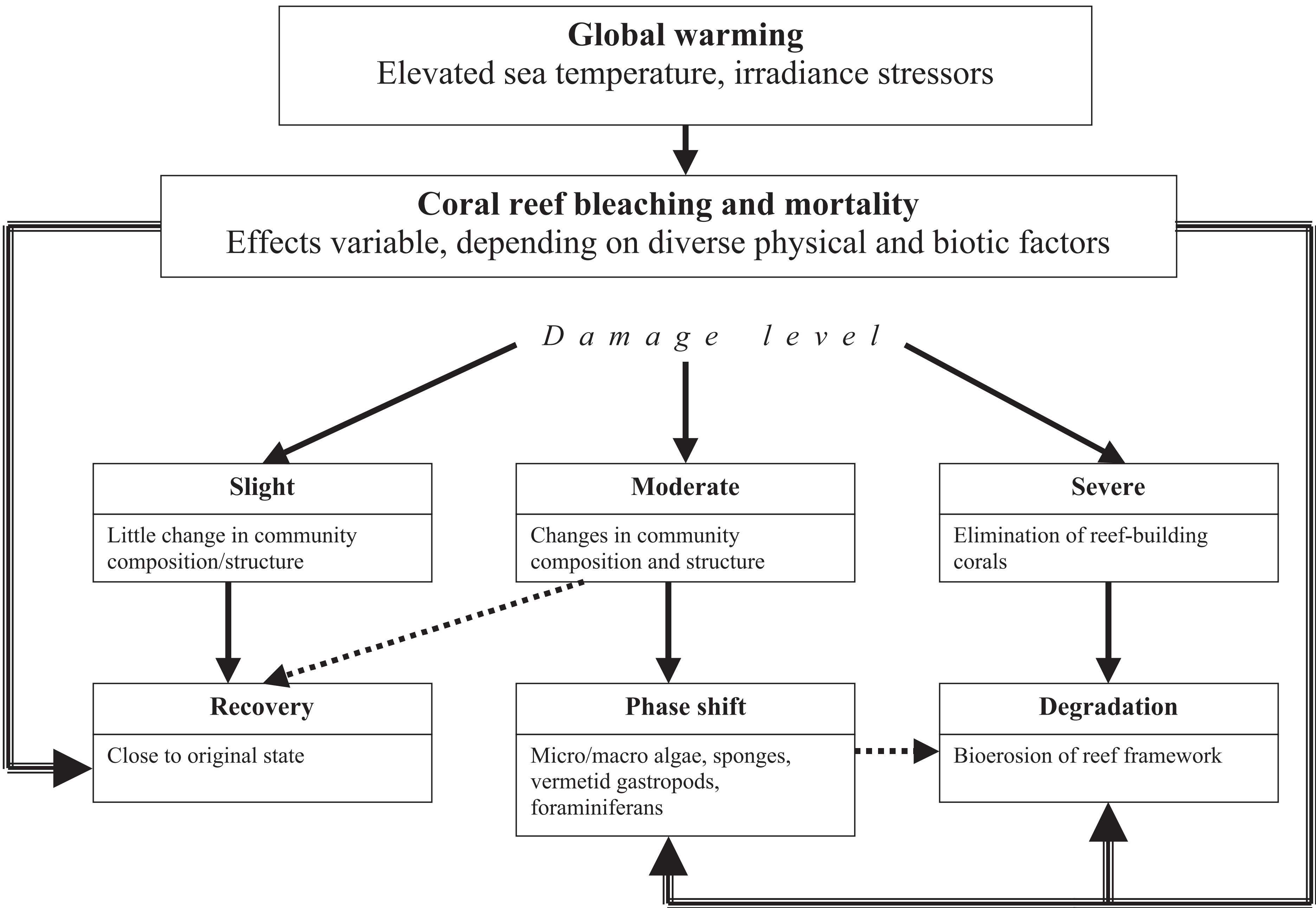
Attempts to define bleaching thresholds, such as "degree-heating-weeks" or "days", and more recently methods that take into account both the magnitude and duration of thermal stress (R. Berkelmans, in press), are advancing our understanding of coral responses to sea warming events. Because bleaching is so variable in space and time, it is imperative to continue studies of critical thermal thresholds, as well as species specific coral host and algal symbiont susceptibilities, not discounting the likely interactions of solar radiation, salinity, pollutants, and other stressors. While numerous population and community-level responses to bleaching events have been reported, these observations are often of disparate species and from different habitats and regions, making it difficult to develop a sense of generality, if such exists.

Even if bleached species survive and eventually recover, their populations will experience changes, often negative, relating to reproductive activities, fecundity, spawning rhythms, dispersal, settlement and recruitment. Such perturbations will inevitably result in changes to coral community composition and structure with alterations to interspecific and interphyletic patterns of competition, predation, symbiosis and disease. Such shifting community-level interactions will affect rates of calcification, framework building and carbonate accumulation. Bioeroder activities usually accelerate on reefs that have undergone large reductions in live coral cover, and carbonate erosion in the extreme can cause the fragmentation of reef structures, resulting in the loss of habitat complexity and reductions in biodiversity.

(See figure 1, next page)

With the likelihood that coral bleaching and mortality will increase on a global scale, it seems worth considering some special conditions under which corals are least impacted during periods of elevated sea warming. If some areas or habitats of relatively high coral survival exist, it would be useful to identify these and perhaps consider using this information in the design of marine proected areas (MPAs) to help mitigate the impact of bleaching events (Salm et al., 2000). A workshop

DECADAL SCENARIO OF WARMING EFFECTS ON CORAL REEFS



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convened at the Bishop Museum in Honolulu (29–31 May 2001), co-hosted by S. Coles, R. Salm and G. Llewellyn, identified several factors that seem to contribute to bleaching resistance and resilience. For example, some physical factors that appear to temper bleaching impacts are (1) water exchange, (2) upwelling, (3) location near deep water, (4) high current velocity, (5) shading, (6) turbidity, and (7) cloud cover. Resilience, or the ability of a disturbed coral reef ecosystem to return to its pre-disturbance structure and function, may be facilitated, for example, by (1) its connectivity with other coral reefs, (2) the availability and abundance of recruits and recruitment success, (3) diversity of symbionts and herbivores, and (4) low abundances of corallivores, diseases and bioeroders. By continuing to investigate such factors and their interactions, I am hopeful that present-day bleaching disturbances can be better understood, thus leading to effective conservation measures that could significantly minimize sea warming disturbances to some coral reef ecosystems.

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Graphics

1. *Changing views on the causes of coral reef degredation.*
   A 1994 report on the Implications of Global Climate Change on Coral Reefs "...concluded that the major problems for coral reefs were direct anthropogenic stresses of nutrient pollution, excessive sediments and over-exploitation acting at many local sites near concentrations of people, and that global climate change was not yet an issue."

   "Climate change by itself is unlikely to eliminate coral reefs...".

   "Yet within 4 years of that report (1998), both authors have become convinced that evidence points to global climate change posing an equal or even greater threat to coral reefs than direct anthropogenic impacts."

   C. Wilkinson,
   Status of Coral Reefs of the World: 2000

2. *Factors Influencing Bleaching Resistance and Resilience*

   Physical factors
   - water exchange
   - upwelling
   - location near deep water
   - high current velocity
   - shading
   - turbidity
   - cloud cover

   Biotic factors
   - connectivity with other coral reefs
   - availability and abudance of larvae
   - recruitment success
   - diversity of symbionts and herbivores
   - low abundances of corallivores, diseases and bioeroders