APPENDIX VIII

CORAL BLEACHING IN PANAMA AND CONSIDERATIONS FOR THE FUTURE

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EVIDENCE FOR BLEACHING AND TEMPERATURE ANOMALIES IN PANAMA. Preliminary examination of our temperature data indicates no unusually high temperatures for Panamanian waters. There is no evidence of bleaching on reefs fringing the mainland. However, on reefs in the San Blas (Holandes, Limones) some bleaching was seen during visits in mid-November, primarily in shallow water (1-2 m) colonies of Montastrea annularis. Although no quantitative measures were taken, bleached coral was certainly less than 5% of total coral cover.

RECOMMENDATIONS FOR IMMEDIATE ACTION. We need quantitative information on the extent of bleaching (preferably expressed as percent cover), and the impact of bleaching (best studied by monitoring bleached and healthy corals in areas where both occur). These data should be collected from a range of sites throughout the Caribbean and from a variety of reef types at each site.

CONSIDERATIONS FOR THE FUTURE. Our strategies for future actions depend upon our goals, the possibilities for which we are best outlined as a sets of alternatives.

1) If we are interested in major, unusual "events", are we interested in only catastrophic events, or all unusual occurrences (e.g. recruitment pulses)?

2) Are we also interested in long-term trends, that is a series of minor events all working in the same direction? Such trends could include both reef deterioration and reef recovery.

3) Do we want to collect data that would permit assessment of causation and the ability to make predictions? If so, we are facing a very complex set of problems.

4) What species are we interested in? Possibilities include all (e.g. % cover, species diversity) or a subset. Subsets could be defined by community (sessile vs. mobile, benthic vs. water column) or by importance (defined as spatial dominants, such as Montastrea, Agaricia, or as ecological "keystones" such as coral predators and herbivores).

5) What macro and micro-geographic scales are we interested in? Choices to be made include the number of sites in the Caribbean, and at each site, the number of reef types as defined by depth, exposure, slope, etc., and the number of replicates.

6) What temporal scales are we interested in? This involves not only choices about sampling intervals for the future, but also the extent to which we make use of data for the past, particularly as recorded by the corals themselves in their skeletons. The latter will be essential to put into perspective any future changes observed, particularly in assessing the likely impact of man's activities.

7) What kind of methods will be use? These obviously depend on the goals, but should regardless be relatively simple, relatively cheap, quickly analyzed, and standardized.

8) What kind of communication network will be set up, and how will this data be collected and published?

LESSONS FROM PREVIOUS EVENTS FOR UNDERSTANDING CURRENT BLEACHING. This is not the first example of rapid, substantial mortality detected in marine or terrestrial environments, and some previous findings are applicable here.

1) Assigning cause can be extremely complex. The best parallel is the forest die-backs observed in Europe and the U.S. over the decade (see BioScience 37 (8)). Like the coral bleaching, enormous variation in the species, timing and environments affected have been observed. Studies have concluded that a complex of causes are probably involved, the identity of which varies from region to region and even within regions. The historical record as provided by tree cores has provided critical evidence of long-term stress preceding the die-back.

2) Initial mortality can have substantial ecological after effects which include he role of predators following El Nino mortality in the eastern Pacific and following hurricane mortality in Jamaica.

3) We really have little idea of what levels of mortality could be a normal part of the life cycles of reefs, whose constituents have life-spans greatly exceeding those of scientific studies. The *Acanthaster* explosion was initially considered to be dramatic evidence of the effects of man, but more recent analyses suggest potential natural causes, and rapid recovery (see Colgan in Ecology 68:1592-1605). Again, coring studies

could provide invaluable insights into past mortality patterns. For the moment, one troubling feature of Caribbean reefs (in comparison to those of the Indo-Pacific) is their frequent domination by species whose life histories make rapid recovery unlikely, suggesting that such reefs are not normally subjected to frequent catastrophic mortality.