

The Effects of Storms and Cyclones on Coral Reefs: A Review

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ABSTRACT: Cyclones (hurricanes, typhoons) are one of the major natural disturbances on coral reefs, and they affect coral reef structure and functioning at different spatial and temporal scales. This paper reviews the types and mechanisms of damage induced by cyclones and tropical storms, their effects on coral reef organisms and communities, and their short- and long-term consequences on reef functioning through succession and recovery processes.

Cyclones generate various kinds of damage by mechanical destruction, change in sedimentation, increase in turbidity, lowering of salinity, and change in sea level. Reef surface morphology and sedimentation are modified by both erosional and depositional effects. All levels of reef organization are affected by cyclones, from primary production (planktonic and benthic) to hard corals and other reef invertebrates and fish assemblages. Cyclone-induced damage to reef communities is highly variable and is related to numerous factors, including cyclone characteristics, location of the reef to the storm path, reef topography, shape, size and biological attributes of reef organisms, characters of the pre-storm communities, their location and depth on the reef, as well as the time elapsed since the previous disturbance. Recovery processes are complex and vary in space and time. A succession of benthic algal blooms generally develops just after the storm. Depending on the level of cyclone-induced damage and on history, recovery of coral reef communities may take from a few years to centuries. In some circumstances, a shift to algal-dominated communities may occur. Though short-term events, cyclones have long-lasting consequences on coral reef communities, evolution and growth.

INTRODUCTION

Hydrodynamic factors have long been recognized as major agents in determining geomorphology, and community structure and distribution on coral reefs (GOREAU, 1959; WIENS, 1962; BRADBURY and YOUNG, 1981). Extreme disturbances, especially tropical storms and cyclones (hurricanes, typhoons) may drastically affect coral reefs at various spatial and temporal scales, inducing massive mortalities of reef organisms and changes in reef organization. Catastrophic disturbance, firstly considered as anecdotic, is now recognized as a controlling parameter in community dynamics, as are biological interactions such as competition and predation (CONNELL, 1983; SOUSA, 1984; RAPPORT *et al.*, 1985; HUBBARD, 1988). The growing realization that disturbance may play a great role in structuring coral reef communities has led to an expanding literature on the effects of natural and man-induced disturbances on coral reefs (review in STODDART, 1971; JOHANNES, 1975; ENDEAN, 1976; BROWN and HOWARD, 1985; SALVAT, 1987; GRIGG and DOLLAR, 1990; GLYNN, 1990). So, why a review on the effects of cyclones on coral reefs?

Since the last review paper specifically devoted to cyclones (STODDART, 1971), a number of case studies was published, particularly in the last few years (Table 1), bringing information on a wider range of geographic locations, depths, reef communities and types of organisms. Monitoring studies and re-surveys of specific reefs affected by cyclones provided data pertaining to situations observed before, 'during' and after events of known magni-

tude, and enable us to better comprehend the succession and recovery processes of coral reef communities. As expected changes in global climate may result in an increased frequency of hydrographic disturbances and cyclones (EL-DIN and DONGUY, 1983; PHILANDER, 1983; REVELL and GOULTER, 1986), the assessment of the long-term impact of such catastrophic events is of prime importance for the future of coral reefs and coral reef islands (ROY and CONNELL, 1991; SALVAT, 1992a; SMITH and BUDDEMEIER, 1992). The aim of this paper is to review the various types of damage provoked by cyclones, their direct and indirect effects on reef morphology, sedimentation, community structure and metabolism, and to discuss their short- and long-term significance in reef ecology, dynamics and growth in the light of the recent data.

The effects of cyclones on coral reefs are characterized by the following (DONE *et al.*, 1986; DONE, 1992b; ROGERS, 1992):

- (1) Diversity of the disturbing parameters (waves and currents, turbidity, salinity, temperature);
- (2) Diversity of their duration and mechanisms (mechanical or not, direct or indirect, immediate or delayed, short- or long-termed);
- (3) Diversity of the levels of reef organization affected (from individual organisms, populations, communities, to whole reef structure);
- (4) Diversity of the spatial scales at which damage occurred (denuded areas of 10's to 100's of square meters