

# Effects of multiple perturbations on the survivorship of fragments of three coral species

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## Abstract

Fist-sized fragments of *Porites cylindrica*, *Porites rus* and *Pavona frondifera* were deployed in single-species (*P. cylindrica*) and mixed-species (all three) plots in a shallow reef area in the northwestern Philippines. After 6 months, the corals in half of the plots were broken into smaller pieces to simulate an episodic physical disturbance. The survival of all corals was monitored from March 2000 to July 2001 during which the corals experienced 2 typhoons and episodes of algal overgrowth. For both intact and broken treatments, there was significantly higher survival in the mixed-species plots than in the single-species treatments. Fragment mortality varied between disturbances of varying frequencies and magnitudes, namely: one-time fragmentation stress, seasonal overgrowth by cyanobacteria and macroalgae, short-term (1 day) and long-term (more than 1 week) burial. The mixed-species assemblages had higher fragment survivorship than the monospecific assemblages during small-scale perturbations (e.g., algal overgrowth), but not in the face of subsequent, larger scale disturbances. This study emphasizes that coral responses to disturbance are both species- and context-specific.

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## 1. Introduction

Natural disturbances are an essential part in the structuring and maintenance of ecosystems (Karlson and Hurd, 1993; Nott and Hayne, 2001). In turn, the structure of a system (e.g., species diversity, landscape patterns) determines the extent to which it can withstand an environmental fluctuation or disturbance (e.g., Yachi and Loreau, 1999; Peterson, 2002). High species numbers provide a wide array of responses to various perturbations that help ensure continued functioning at the community or ecosystem level.

Episodic disturbances in coral reefs, such as anchor damage, storm surges or tourism- and fishery-related activities (e.g., coral treading, dynamite fishing) result in the

breakage of hard corals into non-stabilized fragments of various sizes (e.g., Bruno, 1998; Bruckner and Bruckner, 2001; Fox et al., 2003). Although the initial impact of these perturbations (i.e., fragmentation) is instantaneous, the timing and trajectory of survival and recovery of the affected corals become unpredictable as other factors come into play, such as species-specific susceptibilities to the disturbance (Bythell et al., 1993), prior disturbance experience (Hughes, 1989; Lirman and Fong, 1995; Fukami, 2001) and the presence and influence of other stresses (i.e., Paine et al., 1998; Nordemar et al., 2003).

This paper presents the results of a 16-month field experiment on coral fragments that were transplanted to field plots and exposed to natural and induced, episodic disturbances. Specific objectives of the study are to: (1) determine if transplant survival is species-specific, (2) compare coral fragment survival between single- and mixed-species assemblages, and (3) assess if coral fragments in frequently disturbed areas are able to survive into established colonies over time.

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## 2. Methods

### 2.1. Experimental plots

The study was conducted in a shallow rubble zone within the Carót Marine Sanctuary in Pangasinan, north-western Luzon, Philippines (16°22'42.56" N, 119°59'33.3" E). Three sets of 1 m<sup>2</sup> plots (5 plots per set) were demarcated in the area (average depth = 3.8 m). Steel stakes were driven into the substrate to mark the corners of each plot, after which strips of steel matting (10 × 100 cm, coated with white epoxy paint to prevent corrosion) were tied to the stakes using coated tie wire to serve as the borders of each plot and to fence in the coral transplants.

The experimental layout followed a complete randomized block design with each set of plots serving as a block. There were 4 treatments within each block representing combinations of 2 factors: species number ("single-species"/"mixed-species") and breakage treatment ("intact"/"broken"). The fifth plot in each block did not contain coral transplants and served as a control. Thus, plots within each block were systematically designated as (1) intact, mixed-species, (2) intact, single-species, (3) broken, mixed-species, (4) broken, single-species, and (5) control (no transplants). Each treatment was replicated 3 times, as indicated above.

On 9 March 2000, fist-sized coral colonies were collected from the vicinity of the experimental set-up but outside the marine sanctuary. Three species were represented, namely: *Porites cylindrica* (branching), *Porites rus* (encrusting/submassive), and *Pavona frondifera* (foliaceous). The coral fragments were held in place inside each plot by tying them to metal rods that were equidistantly spaced on the bottom. They were further stabilized by tying them to thin metal stakes driven vertically into the substratum. Each of the single-species plots contained 21 *P. cylindrica* colonies, while 7 transplants of each of the three species (*P. cylindrica*, *P. rus*, and *P. frondifera*) were placed in an interspersed manner in the mixed-species plots (21 transplants per plot).

### 2.2. Breakage treatment

Six months after transplantation (September 2000), a physical form of disturbance was applied to the transplants in the "breakage plots" (single- and mixed-species). Using

a mallet and a chisel, the transplants were broken into several pieces ( $\leq 30\%$  of original colony size) and were left unanchored to the substrate. This was meant to simulate the immediate impact of a strong episodic disturbance such as a storm, dynamite fishing activities, anchor damage or a ship grounding. After breakage, the live fragments were tagged with plastic-coated wire to distinguish them from rubble. Periodic visits of the plots were made thereafter, noting the number of surviving fragments and colonies, as well as other organisms that were found inside the plots.

### 2.3. Subsequent perturbations

Following this experimental treatment, other physical and biological perturbations that occurred in the area were recorded until the end of the study in July 2001. At about the same time as the breakage was performed in September 2000, filamentous cyanobacterial mats appeared in the study area, growing over coral rubble, the wire grids and every available substrate. A month later, Typhoon Bebinca (local name: Seniang) crossed the main island of Luzon in November 2000 and buried the set-up with dead and live coral rubble. However, the corals were immediately dug up a day after the storm to expose the transplants. Afterwards, the coralline green alga *Halimeda* sp. proliferated in the area beginning in December 2000 until May 2001. Multispecific algal assemblages gradually replaced the *Halimeda* mats from April to June 2001. In July 2001, Typhoon Utor (local name: Feria) buried the entire set-up with coral rubble and this resulted in the death of almost all the transplants (Fig. 1). During this time, it was not possible to dig up the plots as the after-effects of the typhoon caused suspension of all visits to the field site for over a week.

### 2.4. Statistical analyses

The survival probability functions of the different treatment groups were estimated using the non-parametric Kaplan–Meier product-limit method (Lee, 1992) which makes use of exact survival times (time until a fragment is recorded as dead) as well as the survival times of "censored observations" (i.e., fragments that were still alive at the end of the experiment). A fragment was recorded as 'dead' when there was  $<5\%$  living tissue remaining on the coral skeleton. Survival functions between 2 treatments (single-species ver-

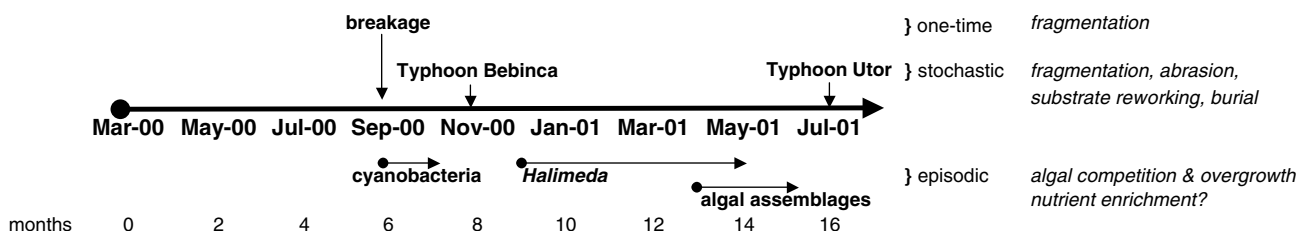


Fig. 1. Timeline of induced and natural disturbances experienced by the coral transplants from March 2000 to July 2001.

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