TAPHONOMY OF MODERN CORALS FROM MADANG LAGOON, PAPUA NEW GUINEA

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INTRODUCTION AND EXPERIMENTAL DESIGN

Taphonomy is the study of the different processes that affect biological organisms in the post-mortem stage (thanatocoenosis), and it includes the history of events that leads to preservation of such organisms in the fossil record (taphocoenosis). The potential for preservation of any given organism depends on the various processes it undergoes after its death, and whether it has a hard skeleton or not. The extent to which information is lost in this process, affects our understanding of ancient, biologically diverse, systems that readily changed with their surrounding environment (Pandolfi, 1996; Pandolfi, 2001; Pandolfi and Greenstein, 1997a).

If an organism is buried quickly after death, its chances of preservation increase once it is out of the taphonomically active zone (TAZ) (Brenchley and Harper, 1998; Pandolfi and Greenstein, 1997b). Once buried, the preservation potential of such an organism is solely influenced by its surrounding sedimentary environment (Brenchley and Harper, 1998).

A taphonomy experiment on modern corals was carried out from 1992 to 1993 in Madang Lagoon, Papua New Guinea. The purpose of this project was to assess the effects of burial, growth form, productivity, and wave exposure on the degree and nature of taphonomic alteration experienced by corals over 1 year.

The taphonomic processes considered in this project were: encrustation and internal bioerosion (biological alteration), and discolouration, abrasion and weight change (physical/chemical alteration). Massive (*Goniastrea retiformis*, branching (*Acropora* cf. *pulchra*), and free-living (*Fungia* spp.) corals were deployed at three reefs ranging from a protected lagoon to an exposed patch reef (Fig. 1). At each site, one group of tethered corals was buried 25 cm below the sediment-water interface and the other was left exposed on the sea floor (Fig. 2). Sixty-three of 72 specimens were recovered, 9 were lost on the reef. A parallel experiment was run on bivalves (see Best et al., this volume).

Figure 1**.** Map of study area. Madang Lagoon, Papua New Guinea. The three sites chosen are Nagada Harbour (a protected lagoon, with the highest nutrient levels), Gosem Island (a fringing reef, intermediate conditions), and Paddoz reef (an exposed patch reef, with the lowest nutrient level). Modified from. Pandolfi and Minchin (1995) Fig. 1.

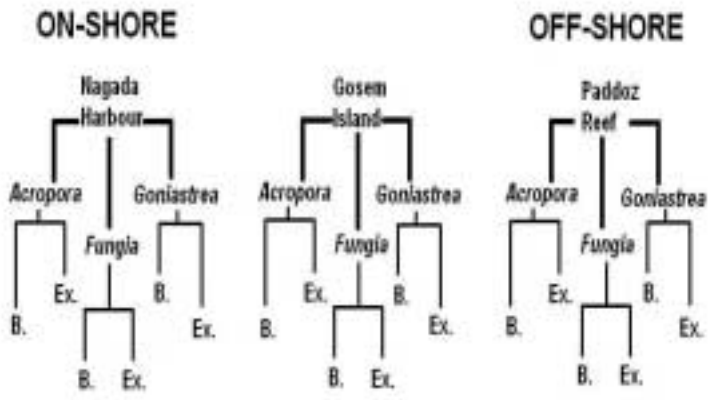
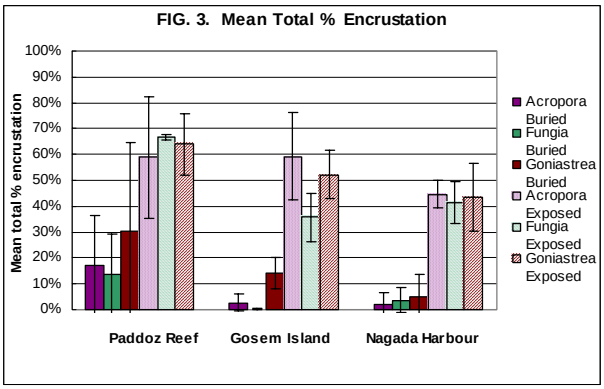


Figure 2**.** Experimental design. Each site (Nagada Harbour, Gosem Island, Paddoz Reef) has a representative group of 3 growth forms (*Acropora, Fungia, Goniastrea*) and 2 treatments per growth form. Each test (buried vs. exposed, and growth forms) was replicated 4 times at each site. A total of 72 specimens. **Note: B.** = Buried, **Ex.** = Exposed.

RESULTS AND DISCUSSION



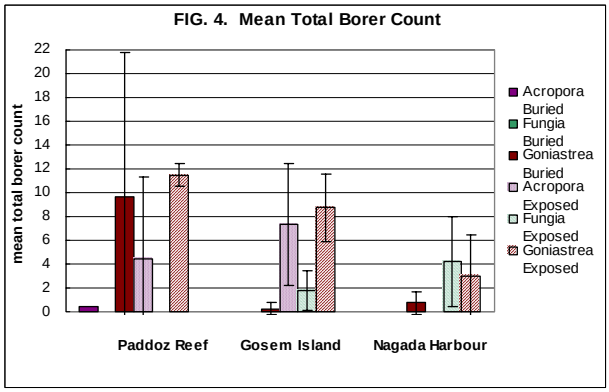


Figure 3. Mean Total % Encrustation for all treatments. Estimate of % cover was done by hand/eye, because the technology to use computer image analysis was not available at the time. Figure 4. Mean Total Borer Count for all treatments. Macroborers were counted and total means were calculated from the data collected. Error bars in all graphs represent the 95% ci. The 95% ci was calculated for each variable but was restricted to only those that had 3 or more replicates per test.

The effect of burial on the taphonomic variables was strong. Exposed specimens, as expected, showed significantly higher amounts of all types of biological and physical alteration than buried ones (Figs.3-6), except for discolouration, which was higher in buried specimens (Fig.7). Weight change (as %) was dominated by weight loss and was generally higher in exposed specimens (Fig.5). With respect to sites, the effect of productivity and energy levels on the taphonomic variables was also strong. Encrustation and internal bioerosion were always highest at Paddoz Reef -PR-(lowest nutrient level, highest exposure (energy) level), and lowest at Nagada Harbour-NG- (highest nutrient level, lowest exposure (energy) level). The biological alteration was higher in the buried specimens of PR than in any other site (Figs.3&4); this was probably due to higher frequency of exhumation at PR. The effect of sedimentation and wave energy (burial-exhumation cycles) largely overprinted any effect primary productivity might have on the biological activity (Best and Kidwell, 2000a; Lescinsky *et al.*, 2002).

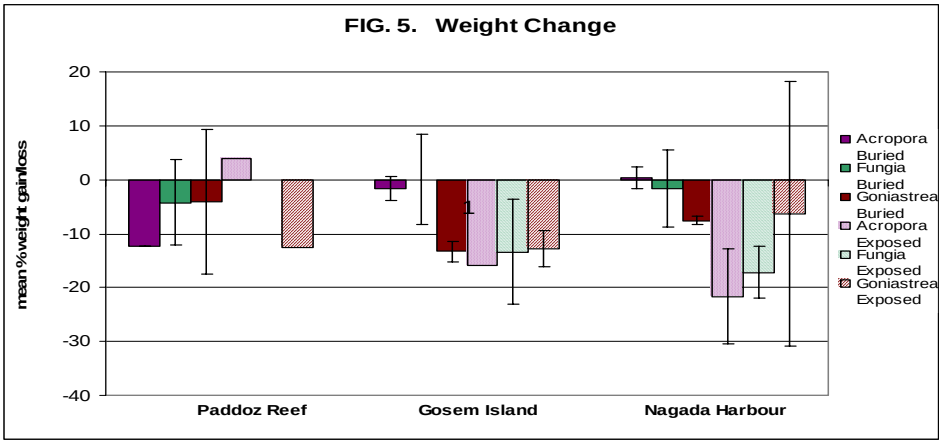
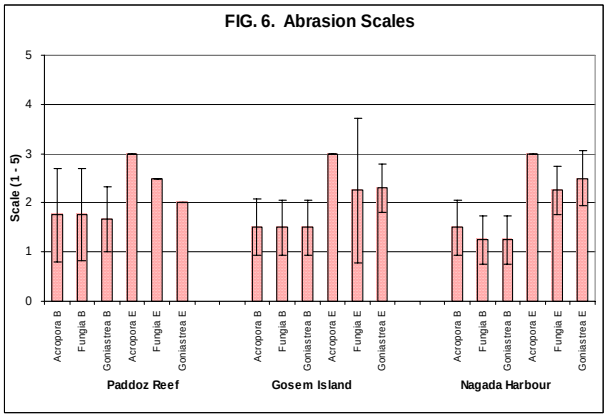
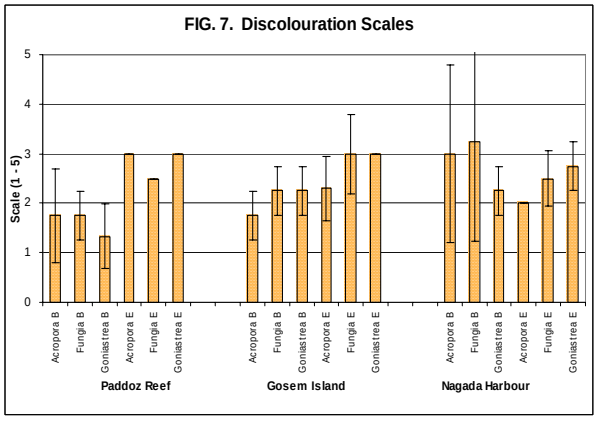


Figure 5. Weight Change was calculated as mean % weight gain/loss.

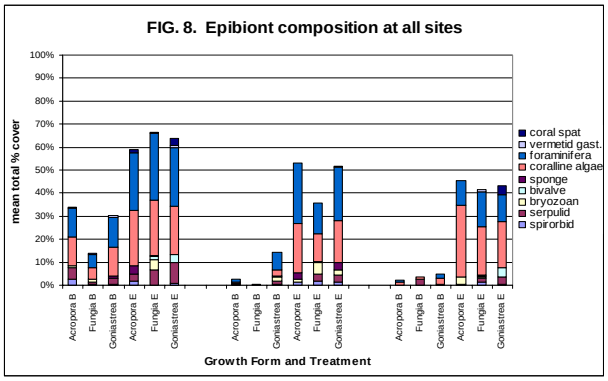




Figures 6 and 7**.** Abrasion and Discolouration scales were designed specifically for this project and were modelled after the scales used by Pandolfi and Greenstein 1997a. Scales range from 1 (lowest amount of alteration) to 5 (highest amount of alteration). Error bars in all graphs represent the 95% ci. The 95% ci was calculated for each variable but was restricted to only those that had 3 or more replicates per test.

Abrasion varied very slightly with respect to site, but no significant pattern was observed (Fig.6). Discolouration also varied slightly with site, (only significant in buried specimens) and was lowest at PR (exposed area) and highest at NH (mangrove area) (Fig.7). This is probably a result of organic-rich siliciclastic influence (Langer and Lipps, 2003). Weight change was highly variable with respect to site and growth forms (Fig.5) and no clear pattern was found.

The effect of growth form on the taphonomic variables was minimal; only weak patterns were observed. Massive corals (highest skeletal density) had the most macroborers. The least dense growth form (branching) showed the highest degrees of abrasion, probably because these were more easily transported and reworked.



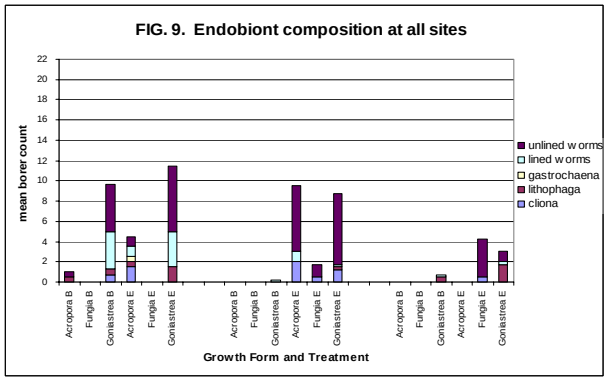


Figure 8. Epibiont composition for all treatments. Shown as % cover.
Figure 9. Endobiont composition for all treatments. Shown as macroborer count.

The occurrence of epibionts was dominated by coralline algae and foraminifera, and, to a lesser extent, by serpulid and spirorbid worms (Fig.8). Endobiont composition was limited, but it was dominated by lined and unlined worms (Fig.9).

SIGNIFICANCE FOR THE FOSSIL RECORD

It is tempting to present biological activity as a measure of paleoproductivity, but the results of many studies, including this one, emphasize the importance of considering the role of burial when addressing this concept. This may present a problem when interpreting paleoenvironments, since it becomes more complicated when trying to explain the effect of productivity and the effect of burial-exhumation cycles at the same time (Edinger and Risk, 1997; Lescinsky *et al.*, 2002). These cycles are almost impossible to determine from the ancient records, since alteration is not continuous and is restarted every time a new cycle starts. Therefore the time of exposure of the coral to any type of taphonomic alteration would be difficult to predict (Greenstein and Moffat, 1996; Edinger and Risk, 1997).

Wave energy is usually related to physical alteration, so it may be expected that interpreted ancient high energy environments would have had more physical degradation. (Lescinsky *et a*l, 2002; Pandolfi, 1996). However, abrasion in this study is not significant (probably due to the short length of the experiment). Interestingly, opposite effects were found by Pandolfi and Greenstein (1997a), where lower energy settings showed higher physical degradation. This finding strongly emphasizes the importance of the extra attention that should be given to the interpretation of ancient environments when relating wave energy to physical degradation.

Patterns of both physical and biological alteration on the different coral growth forms might help recognize the potential for preservation of individual coral morphologies (Brenchley and Harper, 1998). This can lead to a better interpretation of ancient population diversity and richness, and to

determine how accurate the fossil record really is (Behrensmeyer and Kidwell, 1985; Brett and Baird, 1986).

CONCLUSION

(1) The specimens that were exposed or otherwise exhumed always showed a higher degree of taphonomic alteration in all aspects, except for discolouration.

(2) The effect of burial on taphonomic alteration among the different sites was largely affected by burial-exhumation cycles. The effect of sedimentation entirely overprinted the influence of nutrients and primary productivity on biological alteration (Lescinsky *et al.*, 2002).

(3) Lower biological and physical alteration (with the exception of discolouration) was experienced in the less exposed areas (nearshore, organich-rich siliciclastic influence -Nagada Harbour). Higher taphonomic alteration (but lower discolouration) was displayed in the more exposed, carbonate-rich environment (Paddoz Reef). Similar patterns were observed in studies done with mollusks, such as Best and Kidwell (2000a) and Lescinsky *et al.* (2002).

(4) In this study, growth forms played a less important role in taphonomic alteration, only having minor effects on bioerosion and abrasion.

(5) Encrustation was the predominant form of biological alteration. Initial colonization by macroborers is usually slow, and might become more important over a longer period of time. Burial also plays a crucial role in determining the amount of bioerosion since bioerosion can be terminated by early burial (Bromley and Asgaard, 1993; Chazottes *et al.*, 1995; Perry, 1998; Lescinsky *et al.*, 2002; Tapanila et al., 2004).

(6) Both bioerosion and abrasion were potentially affected by the short length of the experiment, and may have become more important if the specimens experienced a longer exposure time.

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AN ENIGMATIC PACHYCEPHALOSAURID (ORNITHISCHIA: MARGINOCEPHALIA) FROM THE DINOSAUR PARK FORMATION, SOUTHERN ALBERTA

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In 2002, the Royal Tyrrell Museum Field Experience Program collected a nearly complete squamosal of a pachycephalosaurid dinosaur from the uppermost Dinosaur Park Formation. The specimen (TMP 2002.12.63) represents the most derived pachycephalosaurid known from the Dinosaur Park Formation, and may represent a new taxon.

In posterior view the squamosal bar maintains a constant depth laterally, and slopes at a significant ventrolateral angle. No supratemporal fenestra is present. Squamosal ornamentation resembles that of *Prenocephale* and *Sphaerotholus* in that it has of a linear row of large, subconical nodes along its caudal margin. It differs from these taxa in the presence of second linear row of smaller nodes medial to the corner node. The arrangement of nodes into two separated linear rows is unique among derived pachycephalosaurids.

Preliminary phylogenetic analysis indicates that the specimen represents the most derived pachycephalosaurid taxon known from the Dinosaur Park Formation. The specimen was recovered from the poorly documented Lethbridge Coal Zone, and may be stratigraphically and ecologically distinct from other pachycephalosaurids in the formation. Morphological and stratigraphic considerations argue for taxonomic distinction of the new material. However, intrataxic variation in cranial ornamentation of closely related forms is poorly understood, and pachcephalosaurid phylogeny is inadequately resolved. It is also possible that TMP 2002.12.63 represents a variant of the essentially coeval *Sphaerotholus goodwini* from New Mexico.