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# Bioerosion of Corals and the Influence of Damselfish Territoriality: A Preliminary Study

Michael J. Risk* and Paul W. Sammarco

Australian Institute of Marine Science, P.M.B. No. 3, Townsville M.S.O., Qld. 4810, Australia

**Summary.** Samples of the staghorn coral *Acropora* were taken from within territories defended by damselfish (Pisces: Pomacentridae) and from undefended areas. The fish utilized in this experiment were *Hemiglyphidodon plagiometopon* Bleeker and *Pomacentrus bankanensis* Bleeker. The extent of bioerosion was determined by randomly selecting pieces of coral substrate from treatment and control areas, cutting transverse sections, and determining total eroded area with the aid of enlarged photographs. Boreholes within the photos were traced with a digitizing sensor and area was integrated with the aid of a computer.

Corals inside territories were significantly more bioeroded ($p < 0.001$) than corals outside areas. Most of the destruction was caused by boring sponges (*Cliona* sp.) and sipunculids (*Cleosiphon*). It is suggested that bioerosion is accelerated within territories as a result of reduction in grazing by fish.

## Introduction

Bioerosion is ubiquitous on tropical and subtropical reefs. Organisms considered to be the most destructive are generally the algae (Kobluk and Risk 1977) and sponges (Hein and Risk 1975; MacGeachy and Stearn 1977). A wide variety of other organisms is also involved, including bacteria (Di Salvo 1969), fungi (Kobluk and Risk 1974), sipunculids (Williams and Margolis 1974), polychaetes (MacGeachy and Stern 1976), and bivalves (Hamner and Jones 1976; Hamner 1978; see Carriker et al. 1969 for general coverage of this topic). The process of bioerosion on modern Caribbean reefs has recently been summarized by Risk and MacGeachy (1978). Much of the previous work on boring sponges has been geologically oriented, tending to emphasize production of sediments (Futterer 1974; Moore and Shedd 1977) and weakening and removal of the substrate (Neumann 1966; Hein and Risk 1975). Estimates of rates have been calculated for borers, including some for the algae (Kobluk and Risk 1977) and sponges (Rutzler 1975).

Hein and Risk (1975) suggested that bioerosion might control the maximum size of a coral colony by reducing the strength of the base and decreasing the colony's ability to withstand wave shock. More recently, experimentation in Jamaica has shown that boring by sponges is an important factor influencing the strength of colonies of the staghorn coral, *Acropora cervicornis* (Tunnicliffe 1979). A healthy colony can withstand the shear stress exerted by normal storm waves, whereas colonies which have been heavily bored are quite weak. The ability of any coral to withstand wave shock is in part determined by the extent to which it is bioeroded.

Pomacentrids (damselfish) which are among the most common fish on coral reefs in the Indo-Pacific (Allen 1975) are also known to affect coral survival. Some are known to kill adult corals, removing tissue and promoting colonization by algae (Kaufman 1977; Potts 1977). Many are territorial, defending small areas against conspecifics and other grazing fish (e.g., scarids and acanthurids). Algal turfs commonly found within their territories are a direct result of reduced fish grazing (Myrberg and Thresher 1974; Thresher 1976), and algal biomass in the territories can be, in species such as *Eupomacentrus planifrons*, significantly higher than outside (Brawley and Adey 1977).

During a study of the damselfish *Hemiglyphidodon plagiometopon* Bleeker, one of us (PWS) noticed that dead coral within the territories of this fish was markedly fragile, particularly in older territories. The substrate was riddled with boring sponges. Independently, the other investigator (MJR) noted a striking contrast between relative levels of crypticity in these same sponges versus those in the Caribbean. The papillae of those sponges observed on the Great Barrier Reef were generally small and inconspicuous; large colonies could only be discovered by randomly opening coral heads. In Caribbean sponges, the papillae are generally much larger, facilitating detection of large colonies.

Here we present evidence supporting the hypothesis that bioerosion is accelerated under conditions of reduced grazing by fishes. We also suggest that the crypticity exhibited by boring sponges on the Great Barrier Reef may be an ultimate result of such grazing.

## Materials and Methods

### *A. Study Site*

Studies were carried out on Britomart Reef (18° 15′ S, 146° 45′ E) in the central region of the Great Barrier Reef. The physical oceanography of this reef has been described in part by Wolanski and Jones (1980). An area composed of depressions immediately behind the reef front (Hole 1) on the southern border of the reef served as the study site. The area measures approximately 100 × 150 m, has a maximum depth of 11 m, and possesses a well-developed coral community.

### *B. Sampling Procedure*

Territories of damselfish were identified in branching thickets of *Acropora grandis* (Brook) which occurred close to and at the same depth as undefended *Acropora* stands. Two areas were

* Present address: Department of Geology, McMaster University, Hamilton, Ontario, CANADA L8S4M1

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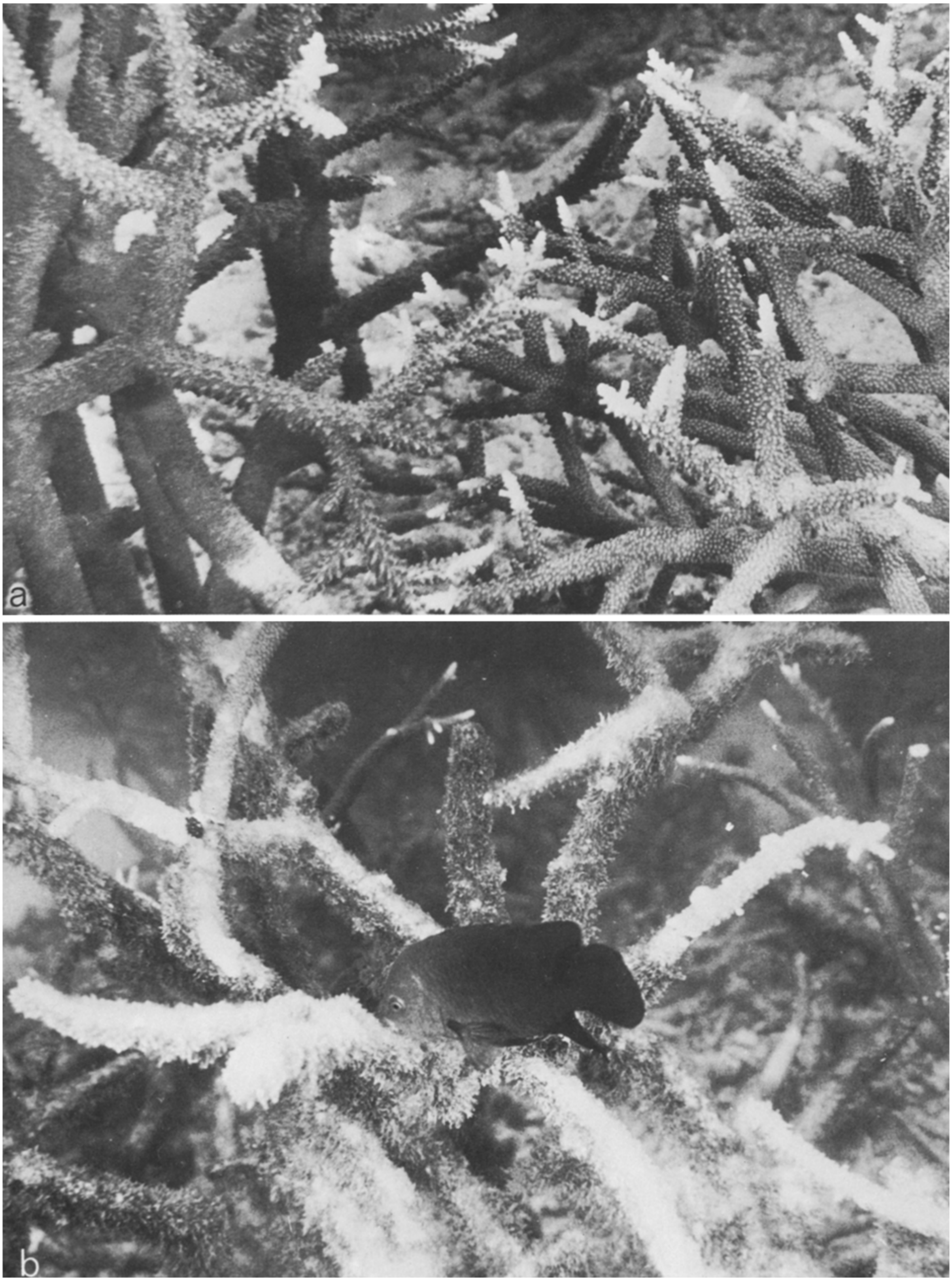


**Fig. 1 a, b.** Areas of *Acropora grandis* (**a**) outside and (**b**) within territories of the damselfish *Hemiglyphidodon plagiometopon.* Territories are characterized by dense algal turfs and extensive amounts of dead coral examined: one where *Hemiglyphidodon plagiometopon* (Bleeker) was defending territorities (areas A1 and A2; see Fig. 1) and one where *Pomacentrus bankanensis* (Bleeker) was defending (area B).

In each area, samples of coral were taken both from within and outside the defended territories. A coral branch bearing a live tip was located, and pieces of coral approximately 10 cm long were broken out of the branch from an older, dead area 60 cm behind the tip. It appears that arborescent, staghorn *Acropora's* in general grow at an average rate of approximately 12 cm/yr. on the Great Barrier Reef (J.K. Oliver, pers. comm.; Oliver 1979) and 10 cm/yr. in the Caribbean (Gladfelter et al. 1978). It was thus estimated that these samples of coral were approximately five years old. Several dozen pieces 2 cm in diameter were collected from each area. Pieces were returned to the laboratory where macroborers were collected and identified. The coral was then bleached in sodium hypochlorite, dried and bagged.

### *C. Analytical Techniques*

Ten pieces of coral were randomly chosen from each treatment and control (total=60 pieces). A point along the length of each stick was located with the aid of a random numbers table, and a transverse disc 2 mm in thickness was sawn from it. The discs were photographed with black-and-white film and enlarged prints were made.

Sample discs were examined under a binocular dissecting microscope, and corresponding individual boreholes were outlined on the photographs. The outline of each hole was coded by a colour assigned to each group of macroborers. Boreholes of sponges were easily identified by their morphology and by the characteristic scalloped appearance of their walls. Cylindrical vermiform borings were simply classed under the category of worms (mostly sipunculids, although polychaetes were also observed). Borings of bivalves were elliptical in cross-section, frequently bearing remnants of shell, while those of barnacles were easily recognized by their characteristic striations (Seilacher 1969).

Photographs were then mounted on a digitizing board (Summagraphics TD) interfaced with a PDP-11 computer, and the area removed by each group of bioeroders was integrated. Total disc area was also calculated.

The precision of these estimates was high. Variation between operators was about 1%, and areas read by an operator were reproducable to within $\pm 1\%$ of the average. Since the average borehole is only several mm$^2$, total error in calculations of area was negligible.

## Results and Discussion

A summary of comparative extents of erosion and the groups of organisms responsible for them under the two main treatments is presented in Table 1. As with other studies of bioerosion in corals (Hein and Risk 1975; MacGeachy and Stearn 1977), boring sponges caused most of the destruction. The dominant sponge involved here was a species of *Cliona,* as yet undescribed. It is ubiquitous in branching corals of all types within the study area and is characterized in the field by its creamy-orange papillae. Worms were responsible for removing the next largest area, and the dominant species in this group was the sipunculid *Cleosiphon aspergillum.* Borings caused by barnacles and bivalves were considerably less abundant.

Differences between the extent of bioerosion within and outside territories were immediately apparent and highly significant ($p < 0.001$, two-way ANOVA). The maximum figure for area removed within a territory was 48% while many of the control samples lacked any sign of bioerosion whatsoever (Fig. 2). This represents a dramatic difference in rates of coral destruction.

**Table 1.** Summary of percent of area removed by various groups of macroborers both within and outside territories of damselfish. Highly significant difference in extent of erosion between the two treatments ($p < 0.001$, two-way ANOVA). No significant difference between pomacentrids or areas ($p > 0.05$). Significant interaction between area and presence or absence of territory ($p < 0.01$). See text for explanation. Data are homoscedastic ($p > 0.05$, Bartlett's test). (Data representing average and standard deviations arcsine-transformed for purposes of normalization; see Sokal and Rohlf 1969.)

| Treatment | Pomacentrid species | Area | % of Coral removed by bioeroders | | | | Average total area removed | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Sponge | Worms | Bivalve | Barnacle | | Percent | Arcsine transform |
| Territory | *Hemiglyphidodon plagiometopon* Bleeker | A1 | 19.6% | 8.4 | 0.05 | 0 | x̄ | 28.15% | 30.1 |
| | | | | | | | s | | 12.58 |
| | | | | | | | n | | 10 |
| | | A2 | 16.2 | 0.7 | 5.7 | 3.0 | x̄ | 25.6 | 28.6 |
| | | | | | | | s | | 11.05 |
| | | | | | | | n | | 8 |
| | *Pomacentrus bankanensis* Bleeker | B | 9.6 | 10.5 | 3.0 | 1.8 | x̄ | 24.8 | 27.2 |
| | | | | | | | s | | 9.4 |
| | | | | | | | n | | 10 |
| Control | | A1 | 0.4 | 0.4 | 0 | 0.5 | x̄ | 1.3 | 3.0 |
| | | | | | | | s | | 5.50 |
| | | | | | | | n | | 9 |
| | | A2 | 0.2 | 0.4 | 0 | 0.6 | x̄ | 1.2 | 3.6 |
| | | | | | | | s | | 4.53 |
| | | | | | | | n | | 10 |
| | | B | 0.9 | 4.8 | 0 | 4.0 | x̄ | 9.7 | 17.2 |
| | | | | | | | s | | 5.12 |
| | | | | | | | n | | 10 |

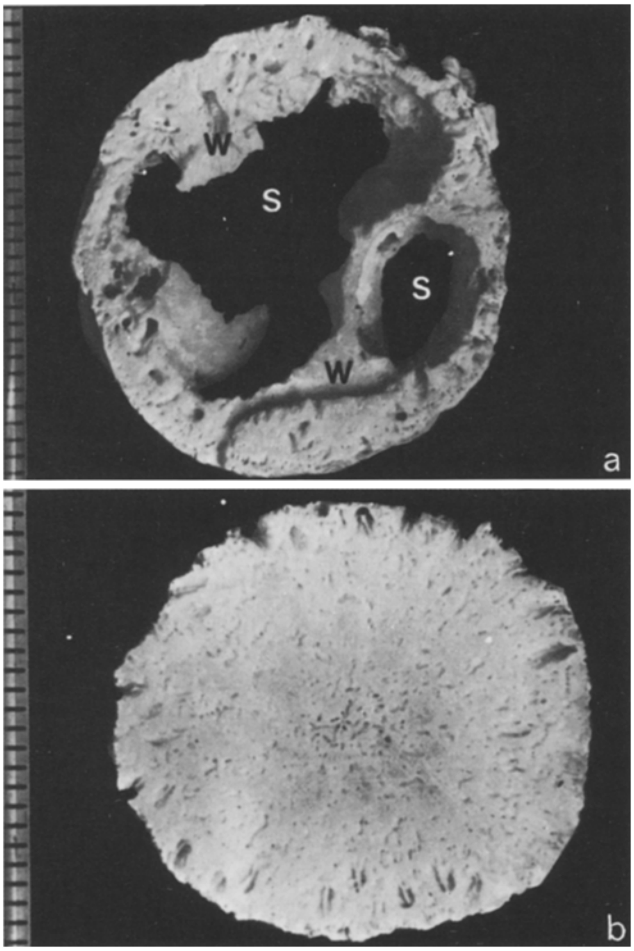


**Fig. 2 a, b.** Transverse discs cut from *Acropora grandis* from (**a**) within ("S" – sponge boring; "W" – worm boring) and (**b**) outside a damselfish territory. Lines represent mm

There was no significant difference between the two different species of pomacentrids or between the areas sampled ($p > 0.05$). There was, however, a somewhat higher degree of bioerosion in the B-control, yielding a significant two-way interaction term as revealed by ANOVA ($p < 0.05$). Although this control still possessed a significantly lower degree of bioerosion than its corresponding treatment area, this variance suggests that biological and physical factors other than intensity of grazing may also be influencing rates of bioerosion.

It is possible that the branches of coral had been dead for different periods of time and this could have influenced the extent of bioerosion. Preliminary results from controlled experiments initiated in 1979, however, support the hypothesis that reduction in grazing plays an important role in determining rate of bioerosion. Experiments are continuing to examine this problem further.

The observed phenomenon may be explained by two possible hypotheses: either some factor is retarding bioerosion outside the territories or another factor is accelerating it inside. With respect to the first hypothesis, the dead coral sampled was often encrusted with coralline algae and a light cover of *Spyridia filamentosa, Jania capillacea, Centroceras clavulatum,* and *Gelidium crinale*. It seems unlikely, however, that encrusting corallines serve to protect the substrate. Most boring sponges and sipunculids observed thus far on the Great Barrier Reef, and particularly those encountered here, can readily penetrate corallines (MJR, pers. obs.).

Acceleration of bioerosion within territories appears to be the more likely of the two hypotheses. Reduction in grazing would carry with it a concommitant reduction in biological disturbance by grazers (see Sammarco 1975, 1977, 1980a). It is possible that the density of newly-settled larvae are reduced outside territories as a result of disturbance. This positive relationship between reduction of grazing and success of settlement in sessile invertebrates within damselfish territories has already been demonstrated for spirorbid polychaetes (Vine 1974) and coral spat (Sammarco 1980b; Lawrence and Sammarco, in press; Sammarco and Carleton, in press).

The presence of an algal turf within territories may indirectly affect bioerosion rates. Reduction in grazing causes a local increase in algal biomass and cover (Brawley and Adey 1977; Lassuy 1980; Hixon and Brostoff in press; Wilkinson and Sammarco in press). Older *Hemiglyphidodon* territories were often characterized by extensive stands of *Spyridia filamentosa, Roschera condensata* (?), *Halimeda opuntia,* and *Tydemania expeditionis.* Alg&! are known to trap sediment and particulate organics within damselfish territories (Lobel 1980) and this could enhance the rate of growth in boring suspension-feeders by indirectly providing food. More importantly, the algae could provide refuge for borers. Predators such as wrasses, which have commonly been observed to prey on boring sponges and sipunculids in this area (MJR, pers. obs.), would most likely have difficulty in detecting them. These observations suggest that predation pressure may be one selective factor contributing to the evolution of the cryptic habit of boring sponges on the Great Barrier Reef (also see Bakus 1964, 1966, 1972).

## Conclusions

1. Bioerosion of branching *Acropora* is significantly higher within territories of the damselfish *Hemiglyphidodon plagiometopon* and *Pomacentrus bankanensis* than in non-defended areas. An average of 26% of the coral was removed by macroborers within territories compared to 4% outside.

2. Sponges (particularly an undescribed species of *Cliona*) and sipunculids (*Cleosiphon aspergilum*) were responsible for most of the destruction.

3. Increased bioerosion within territories may be a result of one or more of the following:
   a) increased success of larval settlement,
   b) reduced grazing and predation on macroborers, and
   c) increased food supplies due to the algal turf.

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