
PRELIMINARY REPORT OF A TERRESTRIAL COMPONENT IN THE DIETS OF
BARRIER REEF CORALS: IMPLICATIONS FOR REEF DESTRUCTION AND REEF
MANAGEMENT

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INTRODUCTION

The authors are involved in a variety of research projects, some of which bear on the ecology of coral reefs. Some of the preliminary results are very intriguing, and seem to point the way to new techniques and principles that may be applied to long-standing questions of reef metabolism and stability. We have presented these results here in the hope that they might contribute to the larger purposes of the Workshop, but we do so with the admonition that the trends we herein describe are based on preliminary data only.

The use of stable isotopes to decipher diets and **paleodiets** of vertebrates is an active field of research at **McMaster** (Lovell et al., 1986; **Schwarcz** et al., 1985; Chisholm et al., 1982). The general principle is that the isotopic signature of the food source will be reflected in the tissue of the consumer, particularly in the structural proteins. Much of our modern and archaeological research has involved measurement of isotopic ratios of C, H and N in the collagen of humans and their prey, and in their vegetable food sources. Recently, this research has been applied to marine invertebrates. We have been able to relate the isotopic signature of the flesh of bivalves to their major food sources in Arctic (Magwood et al., 1985) and temperate (Leblanc and Risk, 1985) estuaries. In addition, the organic matrix in bivalve shells may be extracted by dialyzing in EDTA (Leblanc et al., 1985). This matrix also reflects the diet, and leads to the possibility of reconstructing fossil food webs. Coral skeletons also contain organic matter, although there is some question whether this is a true "organic matrix". It is therefore possible to analyze the change in coral diet through time (Risk and Tomascik, research in progress). We have recently begun a program designed to ascertain the possible terrestrial contribution to the diet of corals. Col laborative research between two of us (MJR and PWS) has

~~sulted in a series of papers on bioerosion of corals. Risk and~~
Sammarco, 1982; Sammarco et al., 1986, and Sammarco et al., in press. We were able to show that grazing affects the rate of internal bioerosion and the makeup of the bioeroding community, and that grazing itself removes significant amounts of dead coral substrate. We have recently extended this work to a major study of cross-shelf trends in bioerosion. These research projects were initiated independently, and some preliminary and very interesting results are available. It now seems likely that, as often happens, these processes are interrelated. This paper will briefly describe results to date, discuss the interrelationships, and draw possible conclusions re. management of reef ecosystems.

MATERIALS AND METHODS

Samples were taken in November, 1986. Several reefs were visited, along an onshore-offshore gradient in the Central Region, from Magnetic Island to Myrmidon Reef. At each reef, about 6 colonies each of Acropora formosa and Porites lobata were collected within as small an area as possible (generally a radius of a few tens of metres).

For the bioerosion study, heads were slabbed in the laboratory, photographed, and the amount of material removed by the various bioeroding groups digitized from the photographs, as in other studies (Hein & Risk, 1975; Risk & Sammarco, 1982).

Samples for isotopic analysis were frozen immediately after collection, and transported to James Cook University, where the coral tissue was separated from the zooxanthellae. Freeze-dried residues were sent to McMaster University. Samples were combusted with cupric oxide in evacuated tubes in a muffle furnace at 550°C, and the CO₂ and N₂ liberated were analyzed with a Micromass 602D mass spectrometer. Carbon isotope ratios are reported relative to the Chicago PDB carbonate standard. Nitrogen isotope ratios are reported relative to atmospheric nitrogen. Only a few $\delta^{15}\text{N}$ values are reported here.

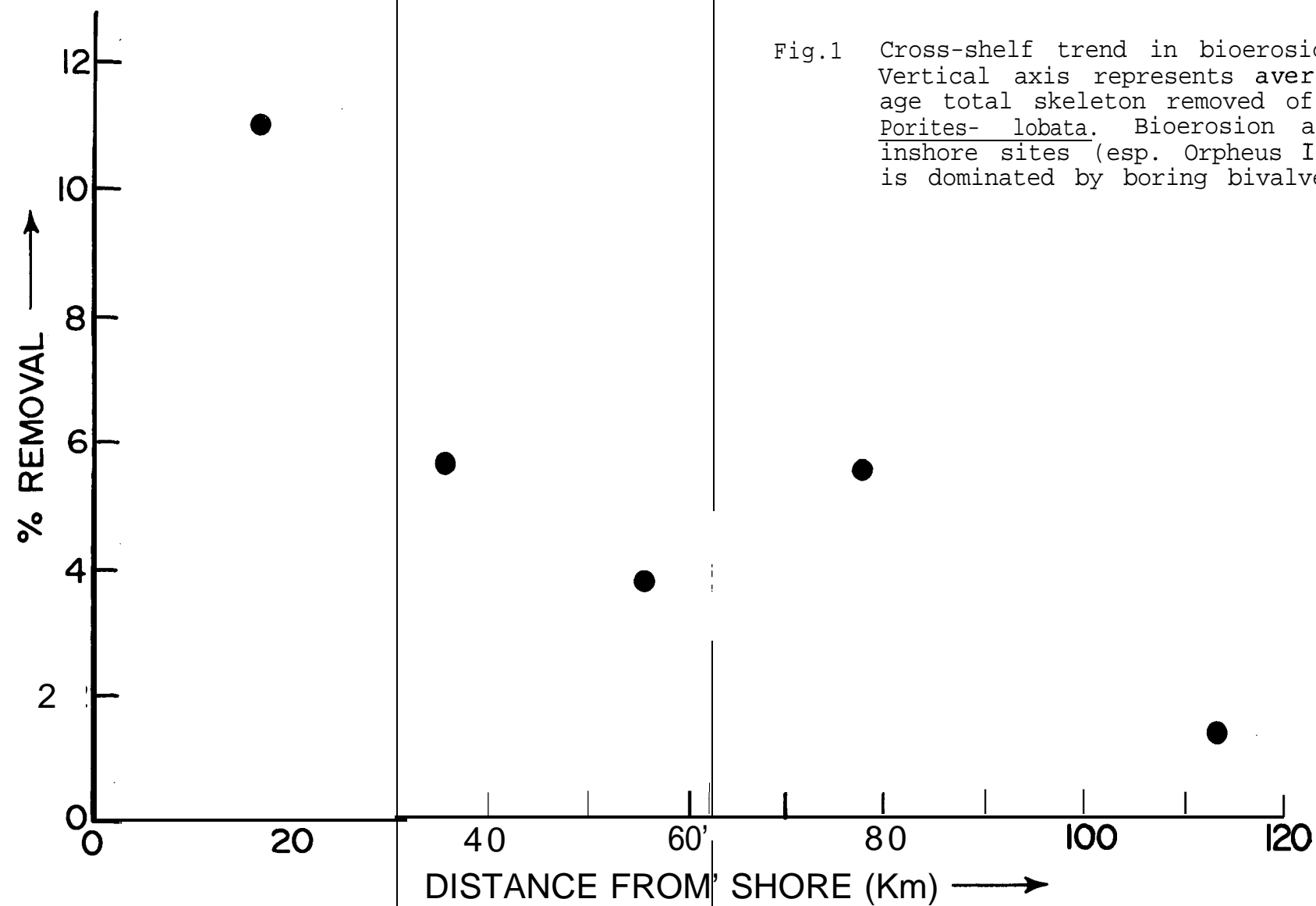
RESULTS AND DISCUSSION

1. Bioerosion

At present, only the Porites results are available. The data show that there is a pronounced shift in makeup of the bioeroder community with distance from shore. Nearshore sites are dominated by the boring bivalve, Lithophaga (some coral heads are completely riddled) with lesser amounts of boring sponge. Bioerosion on midshelf reefs is mostly by boring sponges, particularly Clithosa hancocki and Cliona viridis. Overall, there is a striking increase in bioerosion on nearshore reefs (Fig. 1). An average of 11% of the total volume of Porites heads on nearshore reefs has been removed by bioecision, whereas on Myrmidon Reef the figure is only 1%.

Bioerosion is one of the major processes by which corals are weakened and killed (Hein & Risk, 1977, Tunnicliffe, 1982). Boring by Lithophaga makes the already-weak Porites skeleton more susceptible to biological disturbance, such as predation by triggerfish (Guzman, 1986). These fish bite off large chunks of Porites in order to feed on the Lithophaga.

Some of the boring sponges occurring here are capable of overgrowing and killing corals in a short time (Acker & Risk, 1985). High bioerosion rates on ins'hore reefs are believed to be due to increased productivity, as the major bioeroders are filter feeders. Any increase in nutrient loading or, productivity in coastal waters will result in an increase in rate of coral destruction by bioeroders, as predicted by Risk & McGeachy (1978) and verified by Rose & Risk (1985).



2. Stable isotopes

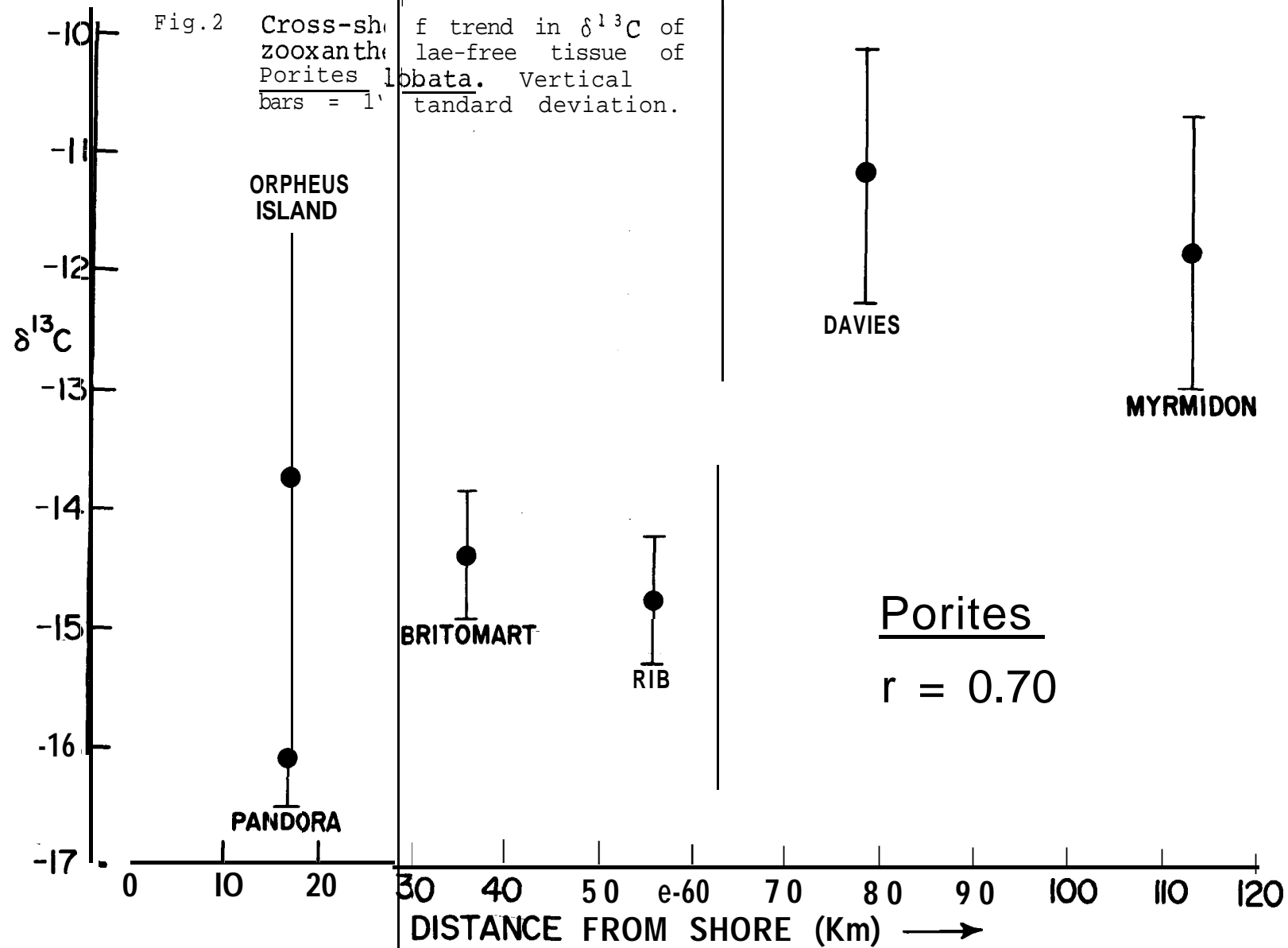
The results to date are presented in Table 1. Most of the tissue analyses for $\delta^{13}\text{C}$ have been completed for both species of corals at each site. Some $\delta^{15}\text{N}$ analyses have also been done for coral flesh. Zooxanthellae preparations will be analyzed in the near future.

Several interesting trends may be observed in the data in Table 1. First, there is a significant trend, in both corals, 'towards ^{13}C enrichment offshore (Figs. 2, 3). The trend is **stronger**, and the slope of the line steeper, in Porites. Evidently, Porites is more dependent on terrestrial carbon, at least on inshore reefs, than is Acropora.

The terrestrial carbon pool in this region of the Barrier Reef Lagoon has a $\delta^{13}\text{C}$ value of about -27‰ (Chivas et al., 1983; MJR, research in progress) while the oceanic carbon reservoir is -19‰ (Torgersen et al., 1983). Our results show significant uptake of terrestrial carbon by corals in nearshore environments, with a large ^{13}C enrichment relative to the terrestrial carbon pool. The cause of this enrichment is unknown, and intriguing. Somehow, large amounts of the light isotope, ^{12}C , have been lost. In dietary studies using isotopes, the fractionation between food source and animal flesh is generally less than or equal to 2‰, and is attributed to respiratory loss of ^{12}C . This enrichment may be due to fractionation in a partially-closed system, accompanied by repeated recycling of respiratory CO_2 between the coral host and the zooxanthellae. The degree of fractionation could be used to measure the extent to which the coral-zooxanthellae system is closed in any given coral species.

Some of the light CO_2 produced is used in building the coral skeleton, which is depleted in ^{13}C relative to normal marine carbonates (Weber and Woodhead, 1970). Such closed-system carbon recycling could explain $\delta^{13}\text{C}$ values of -10‰, rising well above those of any known food source.

Another intriguing aspect of these data is the high intra-site variance. In studies of the diet of bivalves, one normally encounters values at a site that differ, at most, by about 0.5‰. In this case, for example, Acropora values at Davies Reef differ by almost 4‰. Most of these values have been replicated, so there is little possibility they simply represent poor analytical precision. It is possible that this variance, in fact, is recording the degree of autotrophy, or the dependence on carnivory, of individual coral heads. Values of $\delta^{13}\text{C}$ are sensitive to trophic shifts, and generally become enriched in ^{13}C at higher trophic levels (as shown by Rodelli et al., 1984, for a mangrove-dominated Malaysian ecosystem). Values of $\delta^{15}\text{N}$ are even more sensitive to trophic level shifts, and although few data are yet available it seems that values of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ for individual corals are correlated (Fig. 4). That is, individual coral heads from the same area of a reef are capable of having quite different metabolic strategies, with differing degrees of dependence on their zooxanthellae.



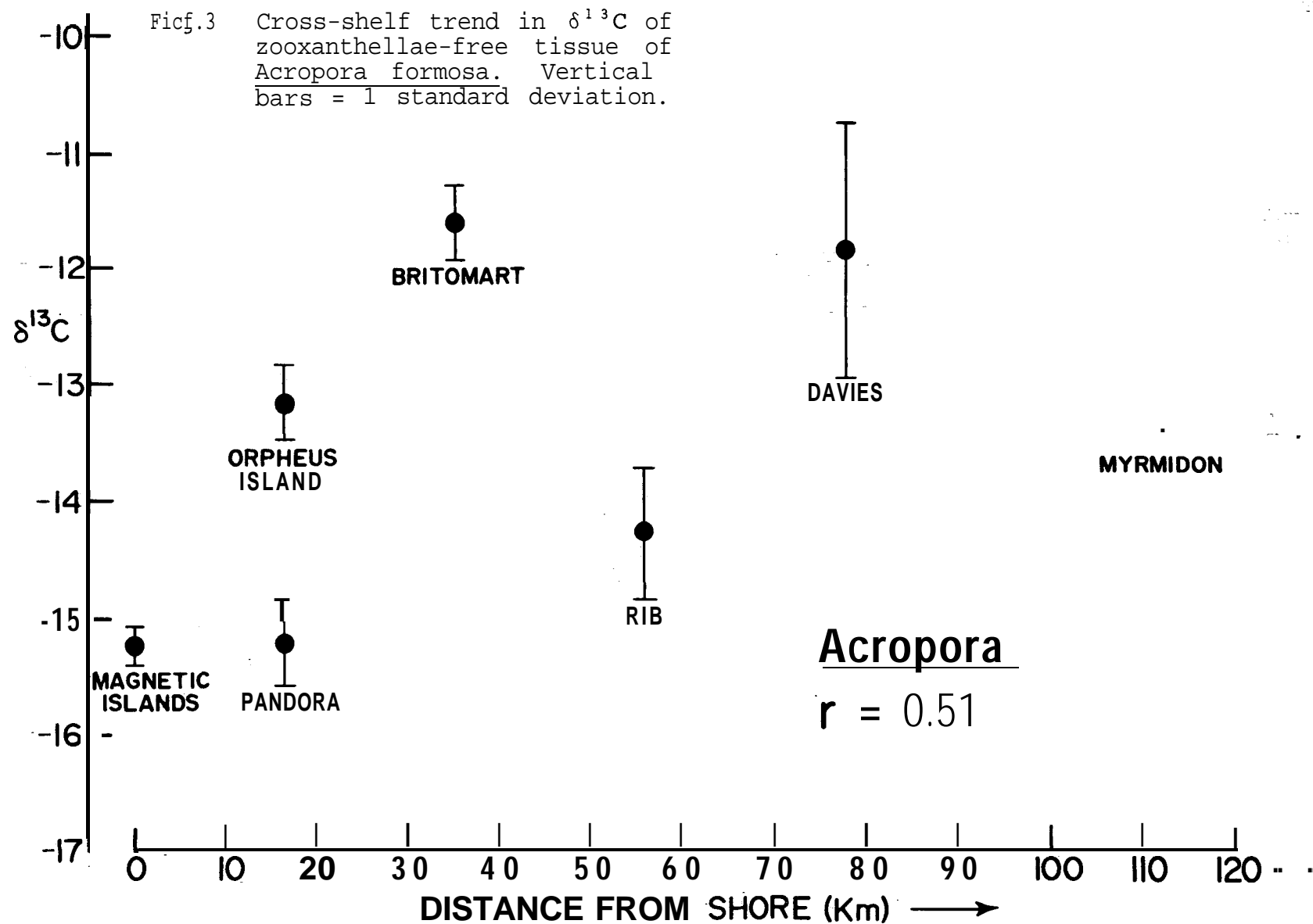
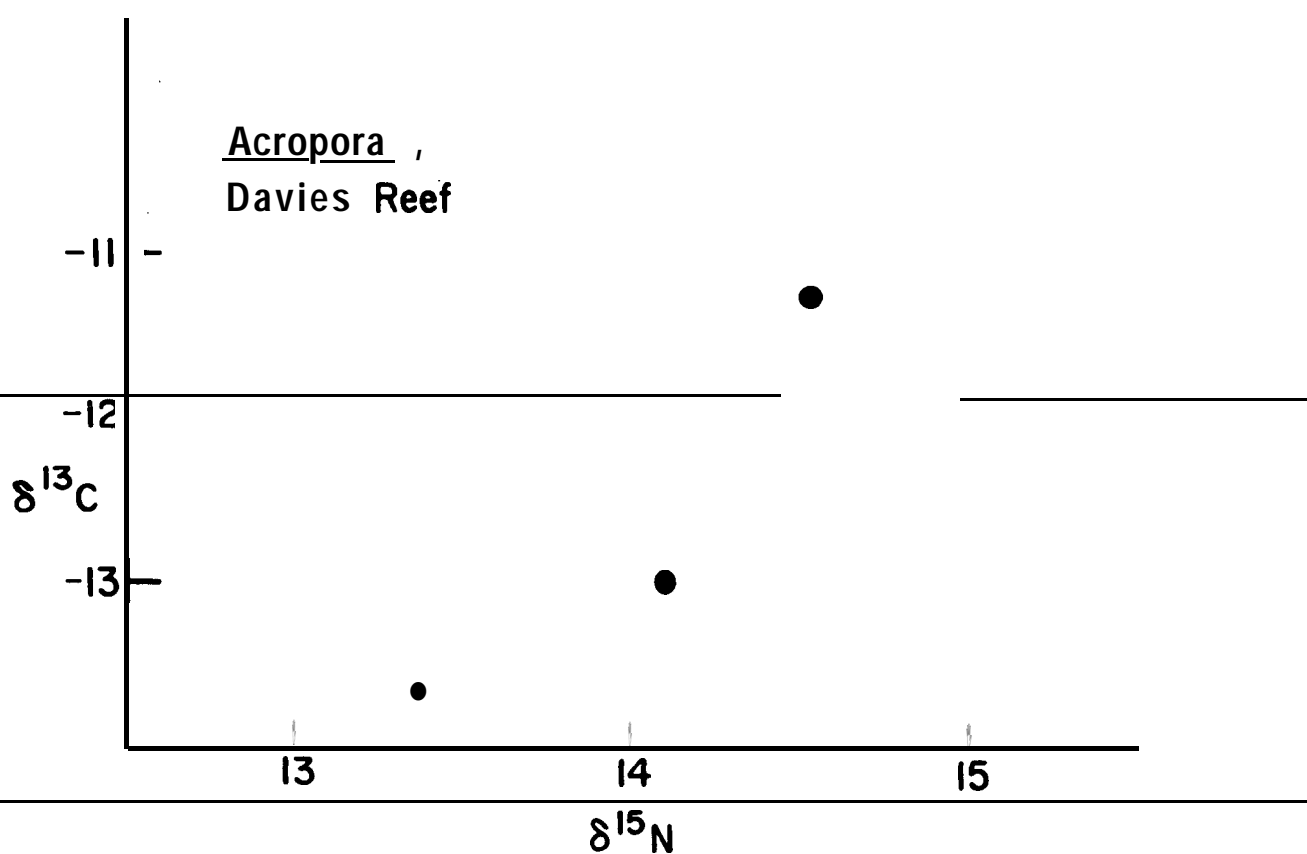


Fig.4 Relationship between $\delta^{13}\text{C}$
and $\delta^{15}\text{N}$ for Acropora
formosa at Davies Reef.



3. Synergistic effects.

The results of the bioerosion study suggest that nearshore reefs are very vulnerable to **accelerated** bioerosion caused by increased nutrient input, leading to higher productivity in coastal waters. The results would be increased sediment **production**, coral weakening and coral death. Inshore reefs would become much more susceptible to cyclone damage, because of the weakening and undermining that takes place between cyclones.

The main thrust of the initial isotope study was to determine whether there was any **uptake** of terrestrial carbon by reef corals. The results show that there is a clear link between terrestrial **runoff** and the diet of corals, and that the degree of linkage is **quantifiable**. The extent to which accelerated bioerosion may threaten inshore corals may be monitored using isotopic **tracers**.

Bioerosion is a major ordering process on coral reefs, **especially** in nearshore environments. The principle bioeroders, Lithophaga and the sponges, are filter feeders, and their destructive capabilities will be enhanced by any increase in coastal productivity. The link between the two studies is the unique potential of stable isotopic analyses to assess the importance of terrestrial input to the diets of both the corals and the bioeroding organisms.

OVERVIEW: IMPLICATIONS FOR REEF MANAGEMENT

1) The process of bioerosion has now been identified as a significant factor in the state of nearshore reefs. Changes in the rate of bioerosion can be detected via a program in which coral heads are censused at regular intervals, the growth of boring sponge colonies is monitored, and the population dynamics of Lithophaga studied. It is important that, as soon as possible, baseline values of terrestrial contribution to the diets of Lithophaga and the boring sponges be assessed.

2) Input of terrigenous **material** may be as **clastic sediments** (**siltation**) and dissolved and particulate organic matter. The effect of siltation on reefs is well known, and a technique is available to monitor these effects throughout the life of an individual coral head (Cortes and Risk, 1985). **Increased** nutrient input may result in accelerated growth of algae, which can out-compete corals for space, and may also cause increased rates of biological (and hence physical) destruction of reefs. Uptake of terrestrial organic matter by marine organisms can be monitored using stable isotope **tracers**. In addition, by analyzing the organic matrix of coral skeletons, we can detect historical changes in the rate of input of terrestrial material.

3. Agricultural activities may result in increased runoff of nitrogen-rich organic matter. **Uptake** of this anthropogenic nitrogen may be monitored using $\delta^{15}\text{N}$ ratios (Sweeney and Kaplan, 1980). Living organisms may be sampled, and also the progress of eutrophication through time, via coral skeleton studies.

4. Isotopic tracer methods appear to be very powerful tools in the study of coral metabolism, allowing us to evaluate the degree of **carnivory** of an individual coral head, and the relative dependence on terrestrial **organic** matter.

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TABLE 1. Stable carbon isotope ratios for Acropora formosa and Porites labata from reefs of the Central Region, Great Barrier Reef.

$\delta^{13}C$

Location	<u>Acropora</u>	<u>Porites</u>
Magnetic Island	-15.09 -15.36	not obtained
Pandora Reef	-14.91 - 15.53 :	-16.42 - 15.87
Orpheus Island	-12.94 -13.43	-12.27 -15.24
Britomart Reef	-11.92 -11.32	-14.62 -14.13
Rib Reef	-13.58 -14.11	-14.29 - 15.23
Davies Reef	- 12.97 - 10.71 <hr/> -11.23 -13.66	- 10.22 - 12.06 <hr/> -10.77
Myrmidon Reef	- 13.44	-10.84 - 12.80