Proc 8th Int Coral Reef Sym 1:839-842. 1997

COMPARISONS BETWEEN THE BENTHIC COMMUNITY STRUCTURE OF TWO TROPICAL LAGOONS

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ABSTRACT

Comparison is made between the invertebrate benthic infauna of the Great Astrolable Reef Lagoon (GAR), Fiji, situated 18°45'S and 178°30'E and the Tarawa Lagoon (TL), Kiribati sited to the north at 01°20'N and 173°30E. Twenty-five sampling stations from the GAR were compared to 20 stations from TL. The sampling methodology was different due to the differences in water depths. In both sites the fauna was dominated by polychaetes, molluscs and crustacea but in TL polychaetes increased their dominance to 53% of the species found. These results are discussed in relation to the known organic enrichment of the TL.

INTRODUCTION

The biodiversity of tropical soft sediment communities has been studied by Warwick and Ruswahyuni (1987), Chardy and Clavier (1988) and Newell et al. (1996). Warwick and Ruswahyuni were interested in challenging the accepted, but largely anecdotal view (Sanders, 1968), that species diversity was higher in tropical than temperate waters. They showed that the abundance and diversity of the macrobenthos was lower in the sediments off the N coast of Jarva than their reference area at Exmouth, UK. Tropical mangrove and soft sediment communities have been reviewed by Alongi (1989) in a very useful world-wide synthesis. He reviews the role of bioturbating organisms and it is clear that holothurians and thalassid shrimps are very important organisms in certain lagoons. Their role in the functioning of these lagoons has not been studied but it is clear that the S. Tarawa lagoon has large populations of both groups of animals whereas visual inspection during diving in the GAR indicates that it has relatively few thalassid shrimps.

The distribution of infaunal species is often considered to be strongly influenced by the granulometry of the sediments. Comparisons between different sites is thus likely to be strongly influenced by site differences between the sediments at the study areas. This is clearly shown for an intertidal estuary in North-West Spain (Junoy and Viéitez, 1990), for polychaetes in the St. Lawrence Estuary, Canada (Miron and Desrosiers, 1990) and for tropical lagoonal sediments in New Caledonia (Chardy and Clavier, 1988). This latter study showed that the high biomass of surface deposit feeding members of the benthic community are correlated to high levels of living organic matter in the surface sediments. The sediments with the highest living organic matter were those with white sand bottoms with a low proportion of fine sediments that compose the silt-clay fraction. When the fine deposits increase to above the 35% level the structure of the benthic community changes, with a marked decrease in the biomass of deposit feeders.

The nematode meiofauna of the sediments of the Great Barrier Reef have been studied by Alongi (1986) who showed that the observed densities were not related to either depth or granulometry. There were different communities developed across the reef, and those in the lagoons seem to be negatively affected by the burrowing activities of thalassinid ghost shrimps.

In another study of the GBR a series of transects across the reef showed that four different sediment types were to be found with those from the inner reef shelfs containing high levels of fine particulates (silt/clay) (Riddle 1988). There were different faunas from different sampling sites along the transects which were not correlated with sediment type. Different faunas seemed to be developed in relation to position on the reef with distinct communities being identified from the inner, middle and outer

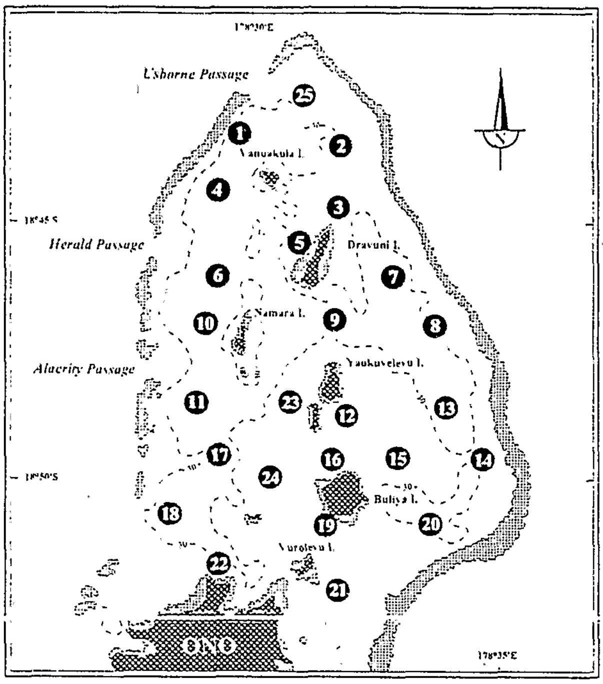

Fig. 1: Great Astrolabe Reef lagoon, showing the location of the sampling stations.

shelf reefs rather than in relation to depth zone or granulometry.

The soft sediment communities of coral reef lagoons have been the subject of a detailed programme of study by a team of biologists based in Noumea, New Caledonia (Chardy et al. 1987; Chardy and Clavier, 1988; Clavier and Garrigue, 1990; Clavier et al. 1992). The studies of the Noumea group (Chardy and Clavier, 1988) show that the zoobenthic biomass of 13 g AFDW m^{-2} is high for tropical sites but lower than the 17 g C m^{-2} reported from the Severn estuary, UK (Warwick et al. 1978). Their study on the lagoon to the SW of New Caledonia showed a dominance by weight of sponges, molluscs and cnidaria. The community is dominated by suspension feeders, which comprise 67% of the total zoobenthos AFDW. Newell and Clavier (1997) have shown that the abundance of animals from the GAR was lower than the SW Lagoon of New Caledonia yet the mean diversity of 4.12 (se 1.6) was higher than the values for New Caledonia (Chardy and Clavier 1988).

The two lagoons chosen for comparison in this paper are very different in a number of ways. The GAR lagoon would seem to be near pristine, with a high biodiversity, and with relatively low populations of people living on the islands within the lagoon. The lagoon to the north of the chain of atoll islands known as S. Tarawa, Kiribati, is well known for being contaminated by a variety of anthropogenic inputs (Kelly, 1993; Gangaiya, 1994). The overall population density of S. Tarawa of 1,596/km^2, with a maximum of 4,167/km^2 on Betio, is among the highest in the S. Pacific. There is no functional piped sewerage system and so the lagoon is polluted by sewage with high faecal coliform counts (Kelly, 1993) present in the shallow waters of the lagoon near villages.

Changes in benthic community structure in response to eutrophication has been studied by Beukema (1991) working in the Dutch Wadden Sea. This study, made over a 20 year period, showed that the total biomass of the animals in-

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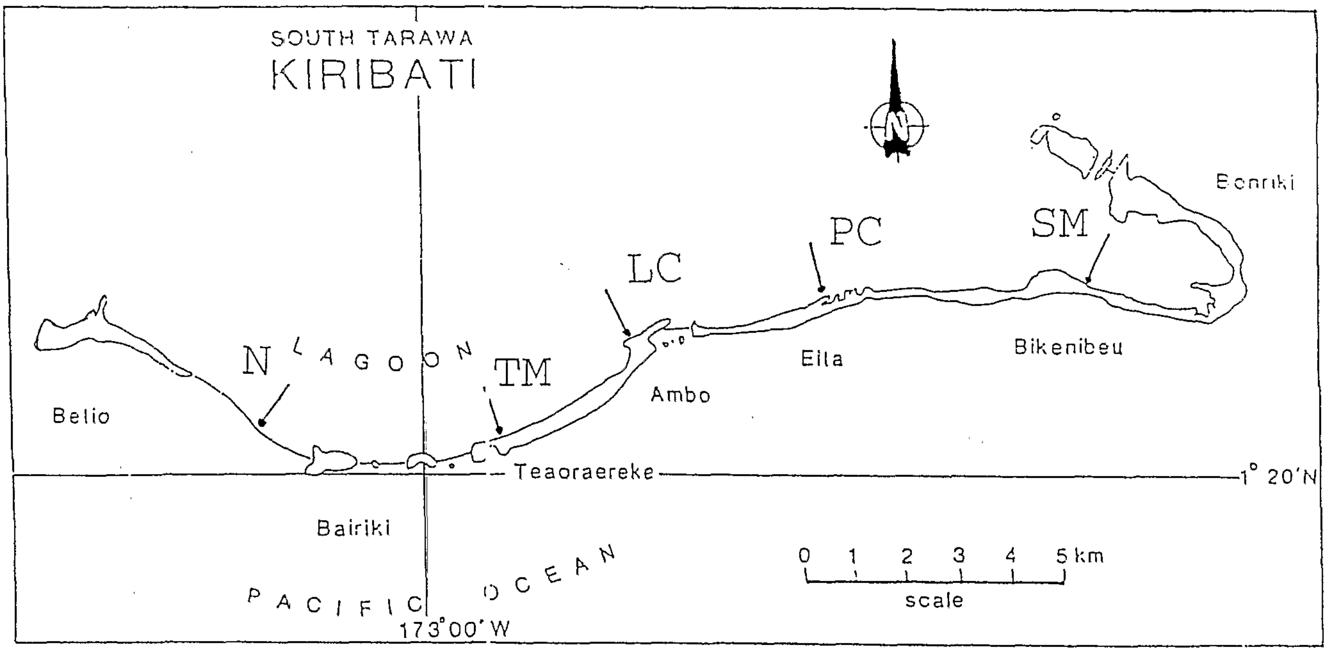

Fig. 2: South Tarawa showing the location of benthos sampling trasects. (Modified from Gagaiya (1994) and Riley (1994))

creased with increasing levels of N and P and that the polychaetes were differentially increased when compared to molluscs and crustaceans. The work also showed that the biomass of small species was increased and that the proportion of the biomass represented by carnivores declined and that deposit feeders increased. Suspension feeders showed no significant changes.

The zoobenthos of the GAR is dominated by suspension feeders (42%) with deposit swallowers (27%) and carnivores (21%) being of lesser significance (Newell and Clavier 1997).

MATERIALS AND METHODS

Two sampling areas were chosen for this study, the Great Astrolabe Reef lagoon, in the Kadavu Group of Islands, Fiji (sited around 18°45'S and 178°30'E, positions of sampling stations shown on the map, Fig. 1). This is a very deep and almost pristine lagoon with a good exchange of water between the lagoon and the surrounding ocean. The second lagoon was just north of the equator, the Tarawa Lagoon, in Kiribati (sited around 01°20'N and 173°30'E, positions of the transects are shown in Fig. 2). This is a shallow lagoon, where the exchange between the ocean and the lagoon is poor. Water exchange has been greatly slowed by the construction of non-culverted roads which join these atolls.

The macrobenthic fauna and flora of the GAR lagoon was sampled using ten replicate 0.1 m² Smith McIntyre grab samples, which sampled a total area of 1 m². the volume sampled was about 60 l. The grab was weighed down with an additional 60 kg of lead ballast and was deployed via a substantial "A" frame and hydraulic winch from the French research vessel the "ALIS". Due to the considerable depth of the GAR lagoon this was an entirely practicable way to arrange the sampling of the benthic infauna and flora.

The sediment samples were immediately sieved through a nest of three sieves with a mesh of 20, 5 and 2 mm. The animals were picked off the sieves and placed into labelled sample pots containing 10 % formalin neutralised with borax.

Tarawa Lagoon is entirely different from the GAR, it is shallow, with a considerable intertidal mudflat. The sediments were mostly sampled along 5 transects at low-tide. Each transect extended 1 km at right angles from the shore. Four sampling stations were established along each transect, each at 250 m apart. All sampling stations were < 2 m deep at high tide. At each sampling station the following samples were taken:

1) Three x 500 ml sediment samples which were immediately fixed in formalin for the extraction of the microfauna (defined as those animals retained on a 500 mm sieve).

2) One 100 ml of sediment for total organic carbon (TOC) and particle size analysis (PS), sampled by using a 50 mm diameter PVC sampling tube. A nested series of sieves was employed, 4.0 mm, 2.0 mm, 1.0 mm, 500 m, 250 m, 65 m and < 65 m, and the weighed, dried sediments passed through the sieves, the percentage distribution of each size fraction then calculated for each sample.

3) Three x 0.05 m² quadrat were then hand excavated down to 20 cm and sieved through a 2 mm square mesh sieve. All material retained on the sieve was fixed in formalin. These are termed the macrofauna samples, in fact, have some species in common with those of the microfauna.

Some samples were taken from a small boat using a remote Ponar grab, which sampled 0.05 m² of the sea bed. This procedure was used for samples N3, SM2 and SM4, but was abandoned due to the difficulty of operating the grab with a hand operated winch. Three sediment samples were taken for these stations, generally as described above. Duplicate grab samples were pooled from each station.

Sorting of the samples

Fauna in samples were identified to the least taxonomic unit (LTU), but verification of many identifications has not been done using recognised taxonomic experts. A collection of the animals obtained from both sites is being maintained at the University of the South Pacific. Where a reliable identification could not be made to species level the animals were grouped into what appeared to be different species and labelled accordingly.

RESULTS

All samples from Tarawa were sorted separately and the results presented by Riley (1994) are the pooled results from combining all samples. All species found in the 500 ml sediment samples were counted and included in the results. Those NOT present in the microfauna but present in the

Table 1: Percentage dominance of the major phyla within the infaunal assemblange in two tropical lagoons.

Phylum	Great Astrolabe Reef Lagoon (190 spp. of animals)	Tarawa lagoon (105 spp. of animals)
Annelida	27.9%	53.3%
Mollusca	25.8%	15.2%
Crustacea	22.1%	13.3%
Echinodermata	6.3%	5.7%
All Others	15.3%	10.4%

macrofauna samples have been used to produce Table 1. This gives a picture of the biodiversity of the species assemblage present, but even this may miss some of the larger and less abundant organisms.

Sediment analysis was made on the S. Tarawa lagoon samples which showed that the transect to the W, labelled N in Fig. 2 had more coarse material than any other of the transects, with up to 70% of the material being larger than 1 mm. The proportion of fine material, < 65 m in diameter, increased towards the E with the transect labelled SM having some samples composed of more than 40% of this fine material.

The results of the analysis of the macrofauna samples from the GAR are shown here only in a summary form (Table 1). Full identification of the animals taken from the microfauna samples is not yet complete.

Table 2 shows the numbers of families and species found at each of the two lagoons. What is clear is that the number of both phyla and species are all showing a reduction in faunal diversity at all taxonomic levels in the S.Tarawa when compared to the GAR lagoon. This is shown in Fig 3.

DISCUSSION

A comparison between the GAR and S Tarawa lagoons shows clear differences in the benthic fauna. The mean macrobenthic biomass of the GAR was 4.7 g AFDW (SE 1.64) of which 39% is plant material, dominated by *Halimeda* sp. The GAR has a fauna which is equally dominated at the 22.1-27.9% levels by three phyla, the Annelida, Mollusca and Crustacea. The weight of animal matter was 2.87 g AFDW (SE 0.10). The lagoon is clean, and deeper than most in the S. Pacific, and may provide a useful near pristine reference area for biodiversity studies elsewhere.

Table 2: Numbers of families and species of animals from the GAR and S. Tarawa Lagoons broken down into Phyla. *LTU = Least Taxonomic Unit; **Nematodes were not extracted as they are normally regarded as part of the meiofauna, and not the macrofauna. There could be as many as 200 species present from many families; ***Includes Oligochaetes.

	GAR Lagoon		South Tarawa	
Phylum	No. of Families	No. of Species /LTU*	No. of Families	No. of Species /LTU*
Porifera	1 or >1	6	1	1
Cnidaria	2	2	4	8
Platyhelmithes	1	1	-	-
Nemertea	1	1	1	1
Nematoda**	1 (or >1)	1	>1	>1
Annelida	18	53	19	56***
Sipuncula	1 (or >1)	5	1	1
Phoronida	1	1	-	-
Brachiopoda	1 (or >1)	2	-	-
Mollusca	12	49	11	16
Crustacea	26	47	11	14
Echinodermata	10	12	3	6
Hemichordata	1	1	-	-
Chordata	8	9	-	-
Echiura	-	-	1	1

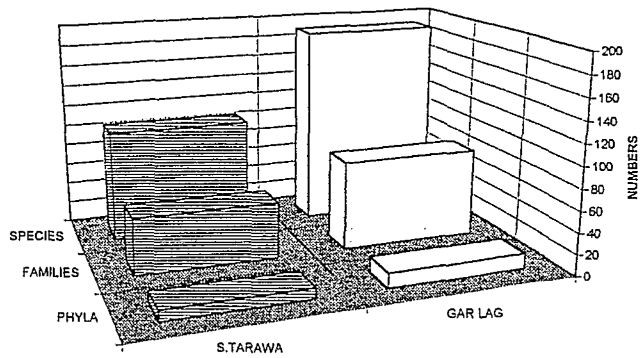

Fig. 3: Comparison between the faunal diversity of the GAR and S. Tarawa Lagoons at the Phylum, Family and species level. Note that the S. Tarawa lagoon is less diverse at all taxonomic levels than the GAR.

The S. Tarawa lagoon is shallow and a number of studies have identified it as suffering from the combined effects of a high population and an inadequate domestic sewage system. This study clearly shows that the fauna is less diverse than that of the GAR at all taxonomic levels. The fauna is modified such there are about the same number of annelids present as the GAR, but many fewer molluscs and Crustacea. Oligochaetes, the classical colonisers of organic enriched sites in temperate waters, (Pearson and Rosenberg, 1978) were also found in this lagoon. The percent dominance is shown in Table 1, with the annelids at 53.5%, molluscs at 15.2% and Crustacea at 13.3%. This finding is in agreement with that reported by Beukema (1991) from the Dutch Wadden Sea.

The sediments show a clear E-W trend, with the sediments from the E having few coarse particulates whereas those from the W, principally the N and TM transects, having at least 10% of their dry weight made up of particles > 1.0 mm. Polychaetes were found in all transects, with bivalves and zoanthid cnidaria only present in the E.

The granulometry was clearly different from the E transects, where there were fine deposits with few coarse particulates, to the W where a large fraction (> 40%) were greater than 1 mm. Whether this is as important in tropical systems as in temperate zones in determining the fauna that develops seems to be open to debate (Alongi 1986, Riddle 1988).

What is also interesting is that unlike many organically enriched sediments in temperate zones there does not seem to be an enrichment of the polychaete fauna by species belonging to the family Capitellidae. The GAR has 4 species and none were recorded from S. Tarawa. Perhaps the organic enrichment has not yet progressed far enough to produce these changes, or alternatively organic enrichment of tropical lagoons does not lead to an increase in the numbers of Capitellid species. Certainly it is not true that these are "indicator" species for pollution and organic enrichment as in many temperate habitats.

The organic enrichment of the S. Tarawa lagoon is currently at a relatively low level which is diffused along the entire northern shore from Betio to Bonriki, with highest inputs and faecal coliform counts near the settlements. The fauna has been modified, but not so reduced in diversity that if a proper sanitation system were to be introduced, then the lagoon would be likely to quickly restore itself to a clean condition and shellfish could once again be safely harvested and eaten.

If it is true that the organic enrichment of the S. Tarawa lagoon has led to changes in the community structure of the lagoon then these changes should be reversible, once the organic enrichment has ceased. As soon as a high proportion of the households in Kiribati have a functional sewage disposal system then it is proposed to return to resample

the lagoon and try and plot changes in the benthic community structure. The prediction then would be that once to organic enrichments cease then the dominance of the numbers of polychaete species should reduce with an increase in the relative numbers of species of crustacea and molluscs.

ACKNOWLEDGMENTS

The samples from the GAR were collected from the French research vessel "ALIS" and my thanks go to the excellent support from the crew and the French Embassy in Suva who funded the joint expedition. The samples have been analysed by Dr Jacques Clavier and a team of collaborators from the ORSTOM laboratories, both in France and New Caledonia. The S. Tarawa samples were collected by myself (PFN) and Ms. Jody Riley who was a student of the Biology Department, University of Victoria. I thank her for her resilience and dedication in completing the many hours of microscope work. I acknowledge the support of The University of the South Pacific and CIDA in funding and allowing me to present a workshop in Kiribati on "Infaunal Benthos Sample Processing" at the USP Atoll Research Centre from 31 Oct-4 Nov 1994. The sampling programme was greatly assisted by Mr. Temakei Tebano and the staff of the Atoll Research Centre.

My attendance at the 8th International Coral Reef Symposium has been made possible by the generous support of both the French Embassy in Suva and the USP.

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