The Sabellariid worm colonies of Suva Lagoon, Fiji

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ABSTRACT
The nearshore area between USP's Lower Campus and the Suva Bowling Club was investigated with regard to sabellariid worm colonies which are common on exposed bedrock, boulders and mangrove roots along that coastline. Polychaetous worms of the family SABELLARIIDAE build reef-like structures made of clusters of vertically oriented tubes composed of sand grains and cemented together by a proteinaceous substance. The structures reach considerable sizes of up to 1 m across and 30 cm height. They are indicative of sites along the coast where erosion is occurring and a combination of exposed bedrock and minor sand provides the worms with hard substrate to attach themselves and building material to construct their tubes. Their original habitat are the roots of mangroves most of which have been cleared from this stretch of the coast. Some findings about the habitat, morphology and biology of the sandbuilder worms are documented. Their regional significance and contribution to coast line development is investigated and the need for their preservation is highlighted.
Keywords: *Sabellariid worm colonies, sandbuilder worms, intertidal reefs, Laucala Bay, Suva, Viti Levu, Fiji.*

1 INTRODUCTION

The nearshore area between USP's Marine Campus (University of the South Pacific, Lower Campus) and the Q.E.D. Park (Umaria Park next to Suva Bowling Club) is characterized by numerous sabellariid worm buildups (Figure 2). These structures, termed reefs by Gosner (1978) are constructed by colonies of polychaetous worms, which live in individual tubes made from cemented sand grains. The worms attach their tubes to their neighbor's tubes forming large colonies which grow into massive mounding reefs uniquely adapted to intertidal conditions. Because of this characteristic behaviour they are also called sand builder worms. These sand-tube building annelids belong to the family SABELLARIIDAE Johnston, 1865 which contains two sub-families and 12 genera. More than 100 species of sabellariids are known to date (Kirtley, 1994). The worm colonies in the Suva area were previously mentioned by Morton and Raj (1979) as *Sabellaria* sp. and by Bailey-Brocks (1985) who noticed a "honeycomb that encrusted the boulders in the intertidal region adjacent to Suva Harbour" (p. 203) which she thought was formed by *Sabellaria alcocki* Gravier 1906, *S. spinulosa* Leuckart 1849 or related species. Because both are European species she concluded that the Fijian worms must belong to a different species. Indeed, preliminary investigation of the worms send to Dr. E. Nishi (Yokohama National University, Japan) suggests that the worms belong to a species of *Neosabellaria* Kirtley 1994 (Nishi *et al*. in prep.)

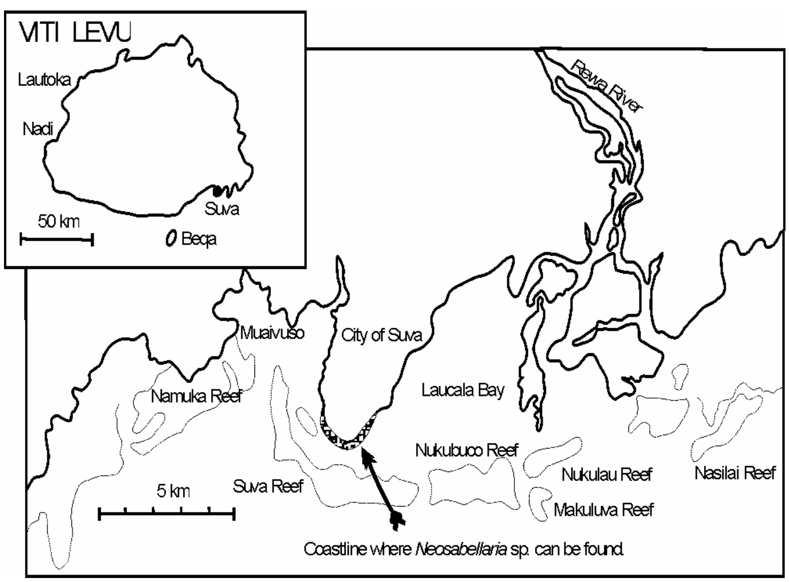

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Figure 1. Location of worm colonies in Suva's nearshore zone. See Figure 2 for details

Worm reefs are found in temperate as well as tropical waters and are common in nearshore zones. They have a wide distribution in modern seas but their existence can be traced back to the early Quaternary. Arenaceous bioconstructed tubes can be found in rocks as old as Cambrian (more than 550 million years old) suggesting that tube-dwelling worms may have also changed seashores in the geological past as they do today, although the precise nature of the fossil forms cannot be reconstructed anymore.

In the Suva region extensive worm buildups occur in the nearshore inter-tidal zone, growing on exposed hard substrates such as the Suva Marl, riprap embankment, the seawall or mangrove roots. A survey of colonies in locations other than Fiji shows that sand builder reefs are commonly associated with rocks, cobbles and gravel at the tidal level (Miller, 2001).

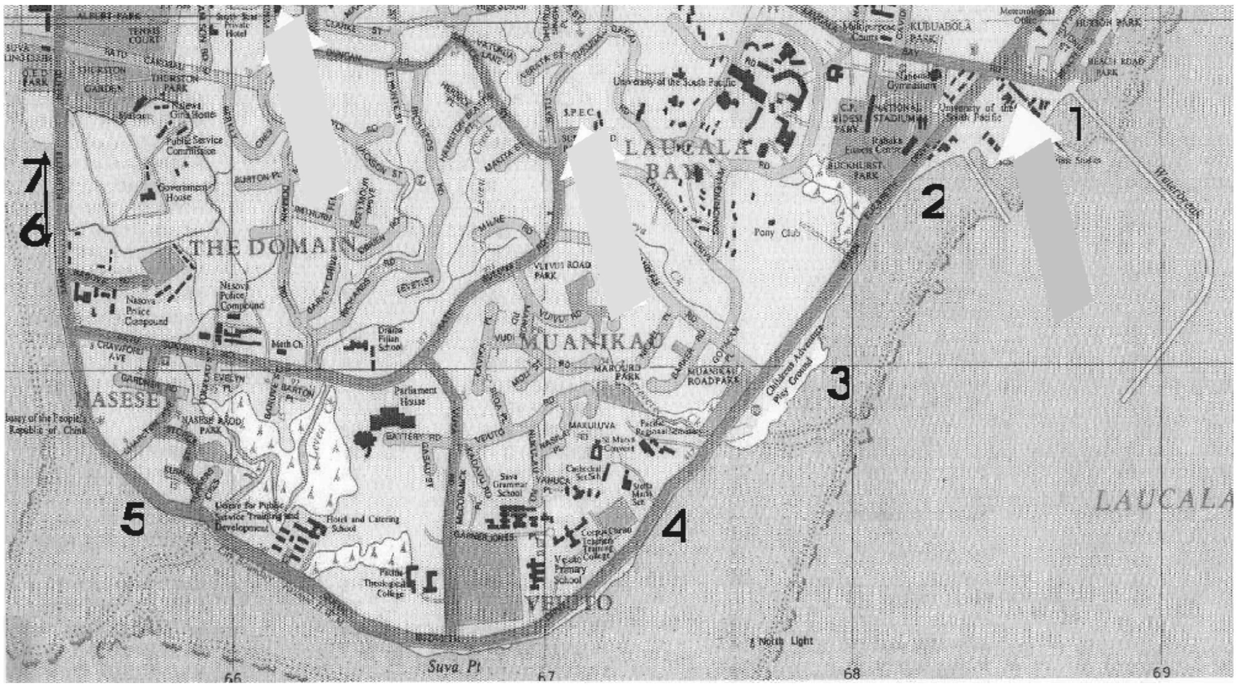


Figure 2. Map of Suva shoreline with stations 1-7.

The sabellariids can withstand several hours of exposure during low tide. They are filter feeders and need some water turbulence because suspended matter could foul their ciliary mechanism under stagnant conditions (Wells, 1970).

Sabellariid worm reefs probably offer feeding grounds to a diverse community of marine organisms. Kirtley (1994) noted a high attrition rate for sabellariids and concluded that they must make a large contribution to the local trophic web. They also provide a home for attaching plants, sponges and algae and they help in the stabilization of sediments along coastal shores. Sabellariid worm reefs may be affected by salinity and temperature variations, physical stress from wave and storm surges and also destructive activities of man.

Extensive research on sabellariid worm reefs has been carried out in other parts of the world including culturing of worm colonies in the laboratory. They are an important component of the marine benthic environment and their study has attracted the attention of numerous scientists and organizations (*e.g.*, Kirtley , 1966; Miller, 2001; National Rivers Authority, 1994; Wells, 1970; Zale and Merrifield, 1989). Because of their importance and vulnerability these reefs are protected in many parts of the world.

So far no study of these buildups is published from Fiji nor is their protection being contemplated.

It is the purpose of this paper to investigate and document these intertidal reefs to help understanding their regional significance and to highlight the need for preservation of these unique structures.

2 METHODS AND MATERIALS

A study of the sabellarid worm colonies was conducted along the tidal flats between the MSP Jetty and the Suva Bowling Club (Figures 1 and 2). The inter-tidal flats are located within Laucala Bay and Suva Harbour and are protected by the Suva barrier reefs. There are river outlets within the study area which could affect salinity concentration along the flat. The locations of the stations of the presence of the worm colonies are as follows:

- Station 1- within MSP jetty. The sabellariid worms are found attached to some rocks and parts of the seawall.
- Station 2- This station is out on the tidal flat opposite the Rabuka Fitness Club. Sabellariids are found attached to base of mangrove trunks and roots (Figure 3).
- Station 3- Mangroves at the Children Adventure Playground along Queen Elizabeth Drive; the colonies are found attached to the roots of mangroves on the seaward side of the stand.
- Station 4- Colonies found attached to the base of the seawall opposite the Corpus Christi College.
- Station 5- Colonies along the seawall near the China Club.
- Stations 6 and 7- Colonies all along the inter-tidal flat beginning 500m away from the Q.E.D. Playground

(Umaria Park) and up to the groyne that is formed by the reclaimed playground. Colonies are attached to boulders and seawall.

Miller (2001) used the term “reef” for aggregations > 1m across and “colonies” for aggregations < 1m across. According to his classification all Fijian buildups are colonies rather than reefs. Salinity of the water in the vicinity of the worm colonies was measured with the use of a refractometer, and temperature with a thermometer. Sediment samples of the tubes and also the sediments of the surrounding substrate were collected in equal amounts. Using a set of sieves ranging from 500µm, 250µm,125µm and 60µm, wet and dry sieving were carried out in order to separate the different sediment compositions. Histograms were plotted with the help of Excel. The presence of any associated living faunas and the description of the buildups in general were obtained through visual observation. The diameters of 50 tubes in one colony were measured with a Vernier caliper. About 50 of the tubes were measured randomly from both, margin and center of the colony. Samples of the worms were send to Dr. Eijiroh Nishi (Yokohama National University, Japan) for determination. His results on the taxonomy of the Fijian sabellariids will be published separately (Nishi *et al*. in prep.).

3 RESULTS AND DISCUSSION

3.1 DESCRIPTION OF BUILDUPS AND TUBES

The worm colonies are found attached to four different substrates: (1) At the base of mangroves up to 30 cm high and 60 cm wide colonies are found attached to trunks and roots (Stations 2 and 3). (2) Colonies attached to boulders strewn along the beach are found at Stations 6 and 7. These buildups attain up to 30 cm in height and 40 cm in width. (3) Colonies attached to the sea wall at Stations 1, 4 – 7 are usually small in size (up to 20 cm high and wide or smaller). (4) Colonies attached to exposed Suva Marl at Station 1 are also of small size similar to those attached to the sea wall mentioned before.

Figure 3. “Pillow-shaped” colonies of sabellariid worms at the base of mangrove roots. Location is Station 2 opposite Rabuka Fitness Club.

The maximum total length of the tubes is about 40mm but there are variations at the different sites. The mean diameter of 50 tubes from the center of the colony is about 2 mm and from the margin about 1.07 mm. On the seawall there is evidence of zonation, with the worm colonies right at the base having the largest tubes and light colored sand grains, the diameter of the tubes decreases up the wall (Figure 4). Zale and Merrifield (1989) observed that the larger diameter tubes were inhabited by adult worms, the smaller sized tubes were inhabited by the juveniles that are new additions to the colony. Settlement of larvae is induced by the presence of conspecific tubes. Where an adult colony is already present, the larvae select peripheral sites and avoid settling on top of other tubes. Kirtley (1966) and Eckelbarger (1976) observed that metamorphosing larvae begin building tubes by using heavy mineral grains, whereas adult worms use larger, lighter-coloured sand grains and shell fragments. The same behaviour is exhibited by the Fijian worms. The orientation of the tubes is vertical at the centre of the colonies and oblique changing to vertical at the margins. This is probably a function of the age of the tube, with later added tubes being the oblique ones. The size, shape and orientation of *Phragmatopoma* tubes (a sabellariid genus common on the southeastern North American coast) was observed to be variable and depending on hydrodynamic and sedimentary regimes (Kirtley, 1966). Possibly a more in depth study of the Fijian build-ups would reveal such adaptations as well.

3.2 SALINITY AND TEMPERATURE OF SURROUNDING WATER

The salinity ranged from 26-37 ppt at the various locations. Sabellariid worm reefs are known to grow best within the salinity range of 28-39 ppt thus most of the salinity values were within the range in which sabellariid colonies thrive. Along the flat, particularly on the Nasese side are numerous drainage pipes and creek outlets which are responsible for lower salinities commonly measured on that side (Figure 2). Few saballariids were found near creek outlets. Sabellariid worms in Florida are reported to survive salinities as low as 10 ppm for several days, but this is considered an adaptation unique to the region (Zale and Merrifield, 1989).

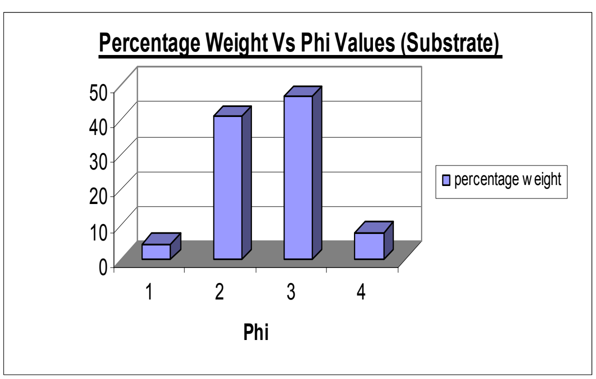
Figure 4. Close-up of some worm tubes showing the light coloured shell fragments and grey intertidal sand that the sabellariid worms used to build their tubes.

Temperatures were measured on May 21, 2003 on an overcast day with values around 27ºand 30ºC. The ideal temperature for worm growth ranges from 18-27ºC (Zale and Merrifield, 1989). The temperature readings probably exceed 30ºC through direct exposure to sunlight at low tide, however, it was found that the colonies are commonly found at sheltered sites where trees provide shade almost all day (either on mangrove roots or below large street trees at the Umaria Park sites). Studies of *Sabellaria alveolata* (Linnaeus, 1767) suggest that the growth is rapid and is promoted by high water temperatures (>20^{o}C) and high levels of suspended sand sized sediment. Growth rates in tube length between 10-15 cm have been reported in the first year of settlement slowing to 6 cm/year in the second year (Gruet, 1982; Wilson, 1971).

3.3 SEDIMENT COMPOSITION

The percentage weight of the sediment composition of Phi value 2 was the highest for the sediment samples of the tubes. However there was more % weight from Phi value 3 for the substrate sample. Obviously the worms have opted to use the coarser grains to build their tubes, thus modifying the sediment. In addition, the worms use tiny particles of shell fragments. Multer and Milliman (1967) observed a similar size preference by the sabellariid worms in Florida. They found that grain size increases with the age (size) of the worms and that a significant amount of sediment finer than 62 µm diameter (Phi- <4) was incorporated into the structure serving as a "mortar" to fill cracks between large grains. Sabellariid worms require a stable settlement substrate such as rock outcrops, sea walls, boulders, mangrove roots or dead worm reefs. In addition, sediments surrounding the colonization site must be composed of sand or other particles suitable for tube construction (Multer and Milliman, 1967). In the Suva nearshore region these requirements are fulfilled at sites where erosion is occurring such as the Suva Point (Figure 2) or in front of seawalls and riprap embankments

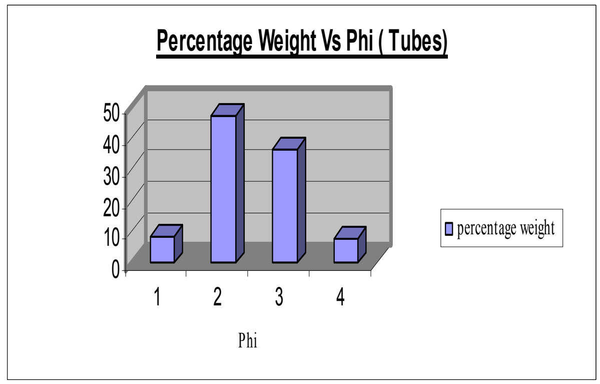
Table 1. Results of sieve analysis of substrate collected from Station 1 adjacent to a sabellariid colony attached to mangrove roots.



3.4 ECOLOGY OF THE WORM COLONIES

Most studies of sabellariid worm reefs suggest that they are not very diverse communities (Wilson, 1971; Cunningham *et al*. 1984) and are able to out-compete all other littoral species for space. Particularly young colonies (around 2 years old) reduce the number of crevices which could provide shelter for littoral fish, small crabs and mollusks. As the reefs get older they break up and provide habitats for various organisms. Apparently the diversity of the worm reefs community increases with the size and age of the buildups and in fact exerts some control on the community structure (Gruet, 1982).

Table 2. Results of sieve analysis of disintegrated worm tubes collected from Station 1, a sabellariid colony attached to mangrove roots. The comparison with table 1 shows that the worms prefer to use the coarser sand (1 and 2 Phi fraction) to build their tubes.



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Cunningham *et al.* (1984) suggested that there is a *Sabellaria/Mytilus* succession which, depending on sedimentary and other factors could shift the community structure to favor one or the other group. This can also be seen at Station 1 (MSP) where mussels of the genus *Septifer* (Johnson Seeto, pers. comm., 2003) and colonies of sabellariids are competing for space. Currently an increase in worm colonies can be observed. Barnacles and oysters also compete for space with sabellariids (Zale and Merrifield, 1989). Some crabs (e.g., *Pachycheles monilifer*, a species observed in SE Florida) may feed on the same plankton and materials as the worms and may be competitors for food (Gore *et al*. 1978).

The most detailed account of worm food is by Zale and Merrifield (1989) for *Phragmatopoma lapidosa* in southeast Florida. The worms are filter feeders and feed on algae and other organisms encrusting sand and shell fragments and planktonic microorganisms such as diatoms and foraminiferans.

Some of the organisms found to live in association with the worm colonies of Suva are the oysters *Saccostrea*, sea-anemones, *Nerita* sp., limpets, mussels, small crabs in the crevices of the tubes and also algae. The crevices of the tubes also provide habitat to amphipods and nereid worms (Nishi, pers. comm., 2004). In southeast Florida crustaceans make up the largest component of associated fauna (Gore *et al*. 1978). Although such a survey has not yet been conducted in Fiji, numerous crustaceans (decapods and stomatopods) can be seen in the vicinity of the larger (melon-sized) worm-build structures. The survey in Florida showed that at least two species of crabs are restricted to worm reef habitats.

A benthic survey conducted in the vicinity of *S. spinulosa* reefs in England found that *S. spinulosa* sites have twice as many different species and almost three times as many individuals (excluding the worms) than areas without *S. spinulosa*. This suggests that the presence of the worm reefs strongly affects community structure (National Rivers Authority, 1994). Worm reefs appear to also attract various fish species and the report by Zale and Merrifield (1989) concluded that the presence of sandbuilder worms substantially enhances the diversity and abundance of certain food fishes in the beach zone.

No predators were observed preying on the Fijian worms, however, study of the colonies when submerged or at night might show activity of predators. Zale and Merrifield (1989) noted that crabs that live on or near *Phragmatopoma* reefs are the principal predators of the worms and numerous crabs are seen on the Fijian colonies as well. Some gastropods are also thought to feed on sabellariids. In Cumbria the shore crab (*Carcinus* sp.) and the blenny (*Blennius pholis*) were found to have worm remains in their stomachs (Taylor *et al*. 1962).

The life span of the Fijian sandbuilder worms is to date not known. Other species of Sabellariidae mature in the first year, spawning in the second summer following settlement (Wilson, 1971) unless conditions are adverse. A typical life span observed was 4-5 years but a maximum of 9 years is inferred (Gruet, 1982).

Observation of the colonies near Q.E.D. Park in Suva suggest a high turn-over. Intermittent episodes of burial by debris were seen which led to smothering of the worms. Resettlement occurred within a few weeks of the killing event. Miller (2001) who surveyed sandbuilder worm colonies in Delaware Bay (USA) noted a nearly complete kill of sandbuilder worm adults in the intertidal zone each winter. Recruitment of new spring larvae is presumably from the more stable subtidal colonies. So far no subtidal colonies of sand builder worms were seen anywhere in the Suva lagoon probably due to the lack of attachment sites offshore. New recruitment must be from other intertidal locations to the east from where larvae can travel with the longshore drift to locations down current.

3.5 INFLUENCE OF THE WORM BUILDUPS ON THE COAST LINE AND COASTAL WATER

The colonial worms are capable of thriving under relatively high energy conditions in the nearshore zone where they form wave-resistant structures. These reef-like structures reach a fair size and aid in dissipitating wave energy. At the Suva seawall the effect of the worm buildups is twofold. (1) The structures interfere with the incoming waves thus reducing the force the wave exerts onto the base of the seawall. (2) Upon reflection of the waves they also reduce the wave energy back towards the lagoon. Wave reflection is a major cause of coastal erosion which is why seawalls are often problematic structures which aggravate erosion problems rather than alleviate them. Further habitat modification includes the stabilization of mobile sand, shingles, pebbles and small boulders (Cunningham *et al.* 1984). The sabellariid worms extract and agglutinate littoral drift materials which makes them important agents of coastline development. By impounding sand on their landward side they provide for progradation of beaches. The tube-dwelling worms sort out the larger grain sizes of sand and shell fragments which aids retention of beach sediments. Cracks and crevices in the reefs aid as natural sediment traps further contributing to sand retention. It has been shown that worm reefs in southern Florida play a key role in formation and maintenance of beaches and barrier islands (Multer and Milliman, 1967).

A large number of worms can potentially create a strong feeding current and filter the water mass. Similar to *Sabellaria* the serpulid tube worm *Ficopomatus enigmaticus* forms reefs albeit of calcareous tubes. Davies *et al.* (1989) reported that a substantial population of *F. enigmaticus* that had colonized a large marina could completely filter the marina water in 26 hours. The serpulid worm also has an influence on oxygen and nutrient levels within subtropical lagoons (Keene, 1980). The filter-feeding sabellariid worms may have a similar influence on water quality.

3.6 DISTRIBUTION

Most genera and species of Sabellariidae are known from their occurrence and distribution in shallow intertidal nearshore regions in water less than 10 m deep. Some forms are reported from intermediate depth on continental shelves, from the continental slope and even from abyssal plains (Kirtley, 1994). Kirtley (1966) noted that at depth > 2 m wave action is insufficient to provide enough turbulence for worm feeding and capturing sand grains for tube building. Colonies reported from > 100 m depth are probably located where strong submarine currents occur (Kirtley and Tanner, 1968). Few species are cosmopolitan, typically the Sabellariidae are stenotopic, stenobathic and endemic. Requirements of certain temperatures, water mass circulation, sedimentological and substrate conditions and probably other factors limit sabellariid worms in their distribution. This seems to apply also to the Fijian species which was seen so far only in intertidal waters around Suva Peninsula but not in the extensive mangrove forests east of the Rewa River nor along the coral coast. However, further investigations are needed.

3.7 THREATS TO THE WORM COLONIES AND THEIR HABITATS

Upon observation of the densities of the colonies at each station, it was noticed that at station 3 (mangrove patch at the Children's Adventure Playground) the colonies seemed deteriorated. On some of the colonies overgrowth of algae has occurred, which could be due to:

1. Location of the habitat close to a park where evidence of pollution was seen (Figure 2).
2. There was also the evidence of the cutting down of mangroves, which could have affected the density of the colonies at this particular station. Where no sabellariid colonies grow around the roots, depression in the surrounding sediment shows that sediment is being carried away where sand is not impounded by the worms.

Near the Bowling Club site, which is located on the leeward side of the Suva Peninsula high turbidity is common in the nearshore water. The amount of suspended solids in the water column could affect the colonies, because smothering of the worms could occur. High concentrations of silt may result in damaged feeding tentacles and worm mortality (Miller *et al.* 1992, 2002). Previous studies have indicated a high level of pollution in the waters of the bay and research has shown that sabellariid worms are affected by pollution such as refined fuel oils, cadmium and toxicant sodium sulfate (reference in Zale and Merrifield, 1989). Extreme weather conditions may stress the reef-building tube worms thus El Niño effects may adversely affect colonies. A particularly devastating effect have the tropical depressions and storms that wash up large amounts of seaweeds and garbage, smothering the worm colonies in the nearshore zone. Such an event was observed at the Bowling Club site where all sandbuilder colonies were killed following a tropical depression which caused a pile up of garbage on the windward side of the groyne that is formed by land reclamation.

4 CONCLUSIONS AND RECOMMENDATIONS

The extent of sabellariid worms in Fiji is not known, neither in the intertidal nor in the subtidal regions. The role they may play in coastal stabilization for the whole region is also not known but it can be seen in the Suva area that they help in stabilizing sand at the roots of mangrove trees and that they dissipate wave energy received by the seawall at the Suva Bowling Club site. Considering that southern Viti Levu is an eroding coastline it would be worth while to investigate the possible role of the sabellariid worms further. If the worm colonies turn out to be limited to the vicinity of Suva Harbour it raises the question whether the worms are endemic to Fiji or are imports from another, as yet unknown location. The colonies are affected by various natural factors, such as temperature, salinity and wave action and human activities such as building of sea walls, clearing of mangroves and pollution. The reefal structures and associated invertebrates represent a productive nearshore marine habitat and factors affecting them, as well as the colonies themselves, should be monitored in order to further elucidate the role sabellariid worm buildups play in Fiji. It is essential to obtain a thorough knowledge of the colonies along the inter-tidal flats to help in the preservation of such vulnerable marine communities which play an important role both, geologically and biologically.

Potential strategies to attract sandbuilder worms were suggested by Miller (2001) and include:

1. Establishment of new colonies by emplacement of colonized rocks at another location where erosion is occurring.
2. Placement of suitable substrate such as large rocks, cobble sized gravel on the sand beaches in the intertidal zone to facilitate new settlement.
3. Emplacement of large boulders in the deep intertidal zone to provide settling sites for the worms in a relatively stable but high energy environment and to reduce wave impact and associated erosion to the coastline.

These strategies could help to protect the Queen Elizabeth Drive opposite Veiuto Primary School and adjacent sites where the road is in imminent danger of undercutting by the sea. Because larval settlement in most sabellariids is stimulated by cement secretions of adult and newly settled young worms they should be provided with the boulders.

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