Macrofauna Associated with the Sponge *Neopetrosia exigua* (Kirkpatrick, 1900) in Mauritius

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Abstract — The macrofaunal community associated with the sponge *Neopetrosia exigua* (Kirkpatrick, 1900) was studied across a Mauritian lagoon. A total of 191 macrofauna belonging to 18 macro-invertebrate species were found in association with host sponges collected at depths of 1.4-2.7 m. Polychaetes and amphipods mostly inhabited the sponge canals whereas crabs and brittle stars were found at the base of the sponges. The most speciose taxon comprised Crustacea (61%, 11 spp.), followed by Polychaeta (33%, 6 spp.) and Echinodermata (6%, 1 sp.). The most dominant species was the polychaete *Haplosyllis djiboutiensis* (Gravier, 1900), comprising 71% of the specimens collected. There was, at best, moderately significant evidence that the number of macrofaunal species and individuals and their diversity index values were related to sponge volume and water depth. This sponge contributes to the maintenance of biodiversity in the lagoon by providing shelter and food for a number of invertebrates.

INTRODUCTION

Once described as "living hotels" by Pearse (1932), sponges are known to act as hosts for a number of micro and macro benthic organisms. They are an important source of biogenic structure for the settlement of epi-faunal and endo-faunal invertebrates in the marine ecosystem (Greene, 2008). According to Bascescu (1971), sponges constitute one of the richest and most interesting biotopes apart from tropical reefs.

The relationships between sponges and their endobionts can be of several types, including commensalism, predation, competition for space, mutualism and parasitism (Wulff, 2006). Past studies indicated that the most common macro-invertebrates associated with sponges included polychaetes, amphipods, decapods and molluscs (Wendt *et al*., 1985; Çinar *et al*., 2002; Schejter *et al*., 2012). Other studies

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also indicated the high dominance of brittle stars (Ophiuroidae) on marine sponges (Çinar *et al*., 2002; Henkel & Pawlik, 2011). Most of these organisms either live within the complex sponge canal system as endobionts or directly on the sponge surface as epibionts (Voultsiadou-Koukoura *et al*., 1987; Ribeiro *et al*., 2003). Sponges also provide reproduction sites for their endobionts, as well as nurseries for juvenile specimens, providing refuge from predators and a food supply for their associates (Westinga and Hoetjes, 1981; Wulff, 2006).

The endofaunal species composition and abundance can vary greatly relative to the characteristics of the host's environment (Greene, 2008). Klitgaard (1995) suggested that the majority of the fauna associated with sponges in temperate waters is composed of facultative species, while those in warm tropical waters are mostly obligate sponge associates. Size (Pearse, 1932), morphology (Koukouras *et al*., 1992), volume (Çinar *et al*., 2002; Ozcan & Katagan, 2011) and geographic location (Klitgaard, 1995) of the hosts can significantly influence the composition, diversity and abundance of their associated invertebrate fauna. Furthermore, environmental parameters such as depth (Pearse, 1950) and the habitat near sponges (Westinga and Hoetjes, 1981) can also affect the species composition of their associates.

Sponge-associated endofauna have been relatively well studied in temperate regions, e.g. in the Mediterranean Sea (Koukouras *et al*., 1985; Voultsiadou-Koukoura *et al*., 1987; Çinar *et al*., 2002), northeast Atlantic Ocean (Klitgaard, 1995) and northeast Pacific Ocean (Beaulieu, 2001). Fewer studies have been conducted to date in the tropical and subtropical regions, e.g. the Red Sea (Fishelson, 1962), the Caribbean region (Pearse, 1950; Westinga & Hoetjes, 1981) and the Great Barrier Reef (Skilleter *et al*., 2005). In the Indian Ocean, Abdo (2007) recorded some macrofaunal species on sponges in southwest Australia but these fauna have not been studied thus far in Mauritius.

Previously known as *Xestospongia exigua*, *Neopetrosia exigua* (Kirkpatrick, 1900) is a branched, chocolate brown sponge commonly distributed in the Indo-Pacific region (Levi, 1998). The present study aimed to evaluate macrofauna inhabiting this sponge in a northern lagoon of Mauritius and to assess the relationship between this community, host size and depth.

METHODS

Study Site

The lagoon of Trou aux Biches is located on the north-west coast of Mauritius and is known for its recreational activities. It is one of the biggest lagoons in the country and has discontinuous fringing reefs. Its shoreline is partially rocky but it has an elongated sandy beach about 3 km long. The depth in the lagoon varies from 1.5-6 m at low tide and is shallowest in the south. The sponge *Neopetrosia exigua* is widely distributed within the lagoon and even dominates the benthos at some locations (Appadoo *et al*., 2011).

Sampling and sorting

Ten sponge samples were collected by free diving at ten stations within the lagoon at 1–2.7 m depth (Table 1). GPS coordinates as well as the depths of stations were recorded. A zip-lock bag was carefully placed over targeted sponges to avoid escape of motile macrofauna, closed and the sponge was detached from its base with a knife. Samples were kept in their respective bags for a few hours to allow the associates to emerge with the progressive reduction of oxygen levels. The sponges were then cut into small sections of about 1–2 cm along the sponge canals and the fauna remaining inside were removed and sieved through a mesh of 1.0 mm. Water from the zip-lock bags was also filtered. Sponge volumes were determined using the water displacement method described by Schejter *et al*. (2012). The endobionts were fixed in 10% formal-saline, sorted under a stereomicroscope and preserved in 70% ethanol. All endobionts were identified to the lowest taxonomic level possible and counted.

Table 1. Location of sampling sites (Stations) for *Neopetrosia exigua* (Kirkpatrick, 1900) in Trou aux Biches, Mauritius, and the Shannon Diversity Index (*H'*), Pielou's evenness index (*J'*) and total number of the associated macrofaunal species (N) obtained from the samples.

Station	Latitude (S)	Longitude (E)	Depth (m)	Sponge volume (ml)	Total species (N)	Shannon Diversity Index (*H'*)	Pielou's evenness (*J'*)
1	20°02'10.8"	57°32'36.9"	1.40	55	2	0,5623	0,8113
2	20°02'08.3"	57°32'37.5"	1.70	30	2	0,5297	0,7642
3	20°02'05.7"	57°32'37.6"	1.70	47	3	0,3805	0,3464
4	20°02'03.4"	57°32'39.0"	1.60	28	3	0,2771	0,2522
5	20°01'59.6"	57°32'38.8"	1.50	33	2	0,6365	0,9183
6	20°01'52.8"	57°32'39.8"	2.00	65	2	0,1391	0,2006
7	20°01'48.2"	57°32'41.4"	1.80	10	4	1,3210	0,9528
8	20°01'44.8"	57°32'41.5"	2.10	30	3	0,3944	0,3590
9	20°01'42.0"	57°32'42.4"	2.30	60	6	1,6430	0,9172
10	20°01'37.4"	57°32'43.8"	2.70	70	11	1,2870	0,5367

Data analysis

Statistical analyses were performed using STATISTICA 10 and PRIMER 6. Shapiro-Wilk tests were performed to ensure that all raw data were normally or near to normally distributed. Non-normal data were log(x)-transformed prior to parametric analyses. Shannon-Weaver's (*H'*) Diversity and Pielou's (*J'*) Evenness indices were estimated to assess the level of species diversity in the samples. The relationship between the macrofaunal communities (number of individuals and species, and the diversity and evenness indices) and sponge volume and depth were assessed using Pearson's correlation analysis. Multiple regressions (quadratic polynomial fit) were performed to assess the combined influence of depth and volume on the number of associates (species and individuals). Species associations in the area were determined using Bray-Curtis similarity analysis. Multi-Dimensional Scaling was performed to assess the macrofaunal species similarity between stations relative to environmental parameters (depth and sponge volume).

RESULTS

Faunistic analysis macrofaunal associates of *Neopetrosia exigua* in Trou aux Biches yielded a total of 191 specimens, belonging to 18 species in three taxa (Table 2). The most speciose taxon comprised Crustacea (11 species), followed by Polychaeta (six species) and Echinodermata (one species). The diversity and evenness indices of all samples irrespective of station were H'=1.29 and J'=0.44.

Polychaeta were the most individuals to the macrofauna (79%), followed by the Crustacea (16.3%) and Echinodermata (4.7%). The most abundant species was *Haplosyllis djiboutiensis* (Gravier, 1900), accounting for 71% of all the macrofauna collected. The other dominant species were a *Balanus* sp. and *Ophiactis savignyi* (Müller & Troschel, 1842).

The canal networks of the host sponges were inhabited by various organisms. Polychaetes (mostly *H. djiboutiensis*) were densely abundant in small canals, whereas the larger canals were mostly inhabited by Crustacea (several *Maera* spp.). Crabs (*Dromia dormia* and *Thalamitoides tridens*) and a brittle star (*O. savignyi*) were prevalent in the bases of the sponges.

The number of macrofaunal species and individuals associated with *N. exigua* were positively but weakly correlated (r = 0.45, p = 0.187 and r = 0.48, p = 0.160) with sponge volume (Fig. 1A, B) but the macrofaunal diversity and evenness indices were very weakly correlated (r = 0.10, p = 0.775 and r = -0.23, p = 0.518) with this parameter (Fig. 1C, D). The number of macrofaunal species yielded a relatively strong positive correlation (r = 0.85, p = 0.002) with water depth, and the number of macrofaunal individuals a

Table 2. Species associated with the Neopetrosia exigua and their abundance on this sponge in Trou aux Biches, Mauritius. ND – Not determined.

Taxa/Station No	1	2	3	4	5	6	7	8	9	10
Crustacea										
Maera serratipalma (Nagata, 1965)	-	-	-	-	-	-	-	-	1	-
Ampithoe sp.	-	-	1	-	-	-	-	-	-	1
Maera sp. 1	-	-	-	-	-	-	-	-	-	1
Maera sp. 2	-	-	-	-	-	-	3	-	-	1
Elasmopus sp.	-	-	-	-	-	-	-	1	-	-
Copepoda ND	-	-	-	-	-	-	-	-	-	1
Leptochelidae ND	-	2	-	-	-	-	2	-	1	-
Balanus sp.	2	7	-	-	2	-	-	1	-	-
Thalamitoides tridens (A Milne Edwards, 1869) (D)	-	-	-	-	-	1	-	-	-	1
Dromia dormia (Linnaeus, 1763)	-	2	-	-	-	-	2	-	1	-
Diogenes sp.	-	-	-	-	-	-	-	-	-	1
Polychaeta										
Polynoidae sp.	-	-	-	1	-	-	-	-	1	-
Haplosyllis djiboutiensis (Gravier, 1900)	-	-	19	30	4	31	1	18	3	31
Opisthosyllis brunnea (Langerhans, 1879)	-	-	1	-	-	-	2	-	-	2
Eunice sp.	-	-	-	-	-	-	-	-	-	1
Eunice antennata (Savigny in Lamark, 1818)	-	-	-	1	-	-	-	-	-	4
Dorvilleidae ND	-	-	-	-	-	-	-	-	-	1
Echinodermata										
Ophiactis savignyi (Müller and Troschel, 1842)	6	-	-	-	-	-	-	-	3	-
Total	8	9	21	32	6	32	8	20	10	45

moderately positive correlation (r = 0.57, p = 0.075) with this parameter (Fig. 1E, F). The macrofaunal diversity index was positively and moderately correlated (r = 0.54, p = 0.109) with water depth but the evenness index showed a very weak negative correlation (r = -0.15, p = 0.688) with this parameter (Fig. 1G, H).

The quadratic polynomial fit based on multiple regressions (Fig. 2) revealed a degree of interaction between the number of macrofaunal species and individuals with sponge depth and volume. The number of species was very variable at low depths where fewer species, on average, were present but their number was clearly higher in the larger sponges at greater depth. Conversely, small sponges (below 30-40 ml, irrespective of depth) and those at shallow depths (below ~1.6 m, irrespective of sponge size) had fewer associated fauna and these were less diverse. Thus, depth seemed more important than sponge volume in the regulation of the number of sponge-associated species.

Cluster analysis revealed that three major species associations occur in the area (Fig. 3). The first group comprised Stations 1 and 2 were not significantly distinguishable from each other but were characterised by a high abundance of the brittle star *Ophiactis savignyi* and the barnacle *Balanus* sp. The second group comprised five stations (3, 4, 5, 6 and 8) which manifested a high abundance of the polychaete *Haplosyllis djiboutiensis*. The last group comprised Stations 7 and 10 and was characterized by the presence of the crab *Dromia dormia* and the amphipod *Maera* sp. 2. MDS analysis (Fig. 4) revealed no influence of host size or depth on the groups of species associated with the host sponge. Thus, in spite of some evidence that total number of species and total number of individuals were influenced by sponge size and depth, the taxonomic composition of the associated communities did not appear to be related to these variables

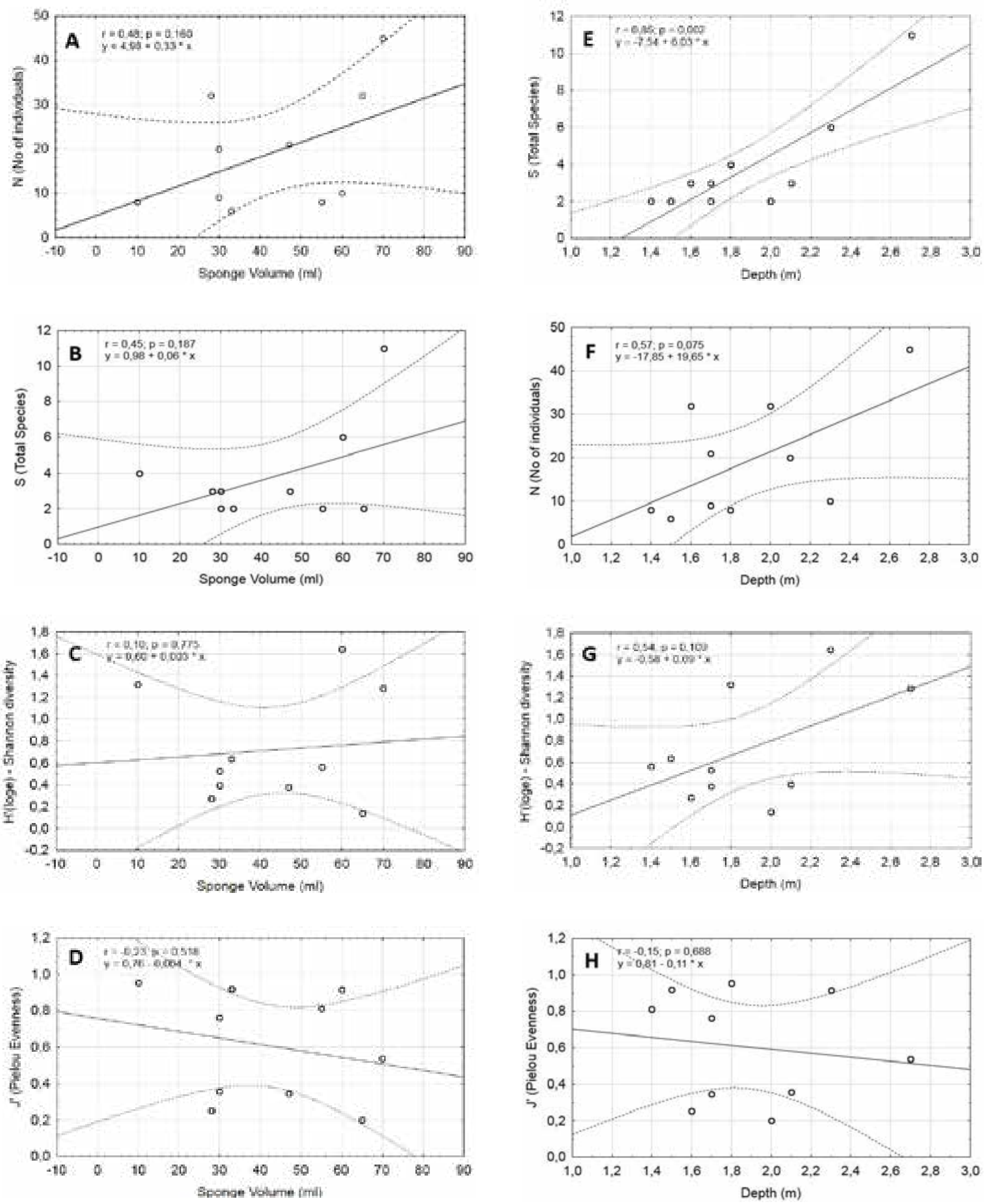

Figure 1. Correlations between the number of associated macrofaunal species, individuals, and their diversity and evenness indices versus *Neopetrosia exigua* size (A, B, C and D) and depth (E, F, G and H) in Trou aux Biches, Mauritius.

DISCUSSION

The sponge *Neopetrosia exigua* hosts a relatively low number of species of associated macrofauna in Trou aux Biches; only 18 species belonging to three invertebrate taxa were recorded. The endofauna associated with sponges in the family Petrosiidae are known to be impoverished (Koukouras *et al*., 1992) and a relatively low number of species were recorded associated with the sponge *Petrosia ficiformis* (Poirel, 1789). Crustaceans and polycheates were the most abundant groups associated with *N. exigua* in the present study.

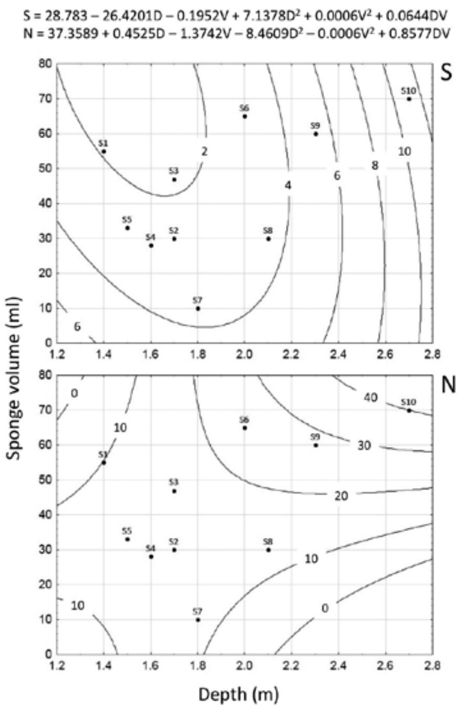

Figure 2. Response contours of quadratic polynomial fits of the number of associated macrofaunal species (S) and number of individuals (N) relative to *Neopetrosia exigua* size and depth. Collecting stations in Trou aux Biches, Mauritius, are marked as S1 - S10.

This observation is corroborated by several similar studies, since these taxa are known to be dominant associates in several sponge species, for example *Mycale microsigmatosa* (Ribeiro *et al*., 2003), *Sarcotragus foetidus* (Çinar *et al*., 2002), *M. magellanica* (Schejter *et al*., 2012) and *Spheciospongia vesparia* (Westinga & Hoetjes, 1981). Both crustaceans and polychaetes appear to favour the internal canals of sponges as refugia (Wulff, 2006) and detritus accumulated within the base of sponges provide these organisms with a source of food (Westinga & Hoetjes, 1981). The diversity of endofauna in sponges has been reported to be influenced by the host morphology (Koukouras *et al*., 1985; Skilleter *et al*., 2005). For instance, the small sponge *Clathria (Thalysias) schoemus* (de Laubenfels, 1936) harboured only five species in the Bahamas (Pearse, 1950), whereas large sponges with a complex canal system, such as *Sarcotragus foetidus* (Schmidt, 1862) (cited as *S.muscarum*; Çinar *et al*., 2002) and *Mycale (Aegogropila) magellanica* (Ridley, 1881) (Schejter *et al*., 2012) were reported to have a rich associated fauna. *Neopetrosia exigua* has mostly small oscules <0.2 cm in diameter (Levi, 1998) and thus its morphological structure enables the ingress of only small organisms.

There was evidence that the number of species and individuals associated with the sponge was, to a degree, positively correlated with sponge volume, a finding that parallels those of Koukouras *et al*. (1992), Çinar *et al*. (2002) and Ribeiro *et al*. (2003). The volume of an individual sponge is generally an indication of the amount of space available within its canal systems, an important factor for its occupation by associated organisms (Duarte & Nalesso, 1996). A larger sponge thus usually has more space for these fauna.

Sponges are reported to have higher endobiont richness in shallow and warm water (Schejter *et al*., 2012). However, the number of species and individuals associated with *N. exigua* was found to be slightly higher at increased depth. This observation may be due to the greater size (Appadoo *et al*., 2011) and complexity of the sponges within the depths of the lagoon as they are known to exhibit more complex morphology in deeper environments (Bell *et al*., 2013). Moreover, the presence of corals and seagrasses (Daby, 2003) in slightly deeper water in the lagoon may also enhance the abundance and diversity of the associated macrofauna. Lower and more variable numbers of associated macrofauna at shallow depths in Trou aux Biches may reflect marginal and more stochastic settlement by these fauna in a less stable environment.

The high abundance of *Haplosyllis djiboutiensis* associated with the host sponge is notable as this species has been described as a parasite by Magino and Gaino (1998). With regard to the other polychaetes, previous work has suggested that those in the family Syllidae prefer cryptic habitats, creeping actively through canals and crevices of sponges and corals (Uebelacker, 1978). Syllids have also been reported to be the most diverse and abundant

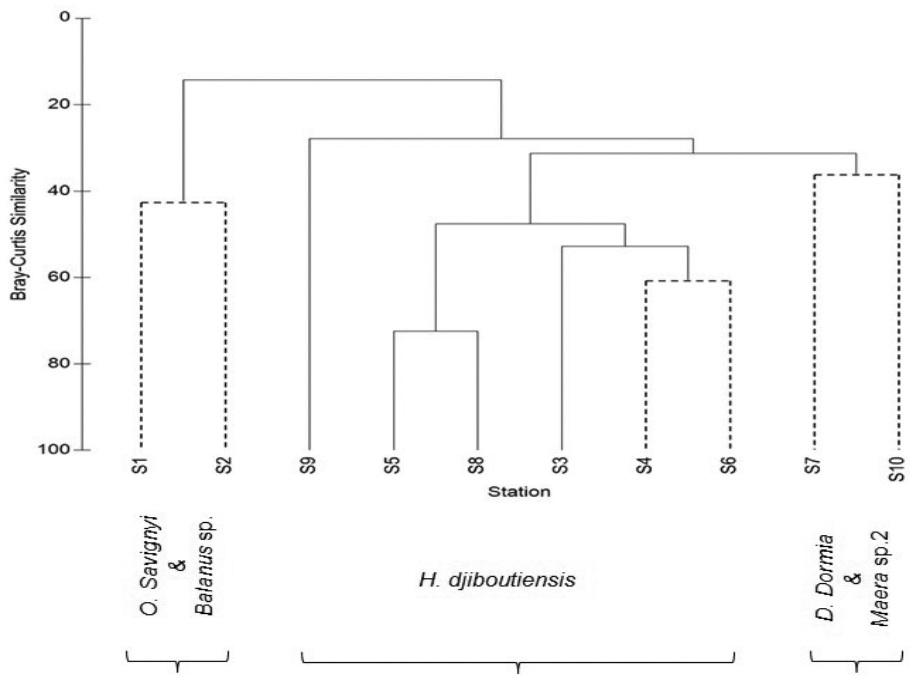

Figure 3. Similarity dendrogram of macrofaunal communities associated with *Neopetrosia exigua* at the sampling stations in Trou aux Biches, Mauritius (dashed lines indicate significantly similar groups).

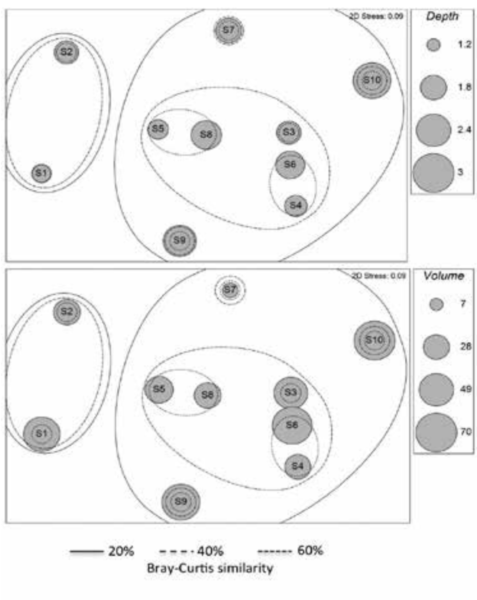

Figure 4. MDS of the macrofaunal communities associated with *Neopetrosia exigua* at the sampling stations in Trou aux Biches, Mauritius, relative to sponge size (volume, ml) and depth (m).

polychaetes in association with marine hosts such as sponges and corals (Çinar & Ergen, 1998). However, predation by the brittle star *Ophiactis savignyi* may explain the absence of polychaetes (including *H. djiboutiensis*) and amphipods at Station 1; despite it being detritivorous, many brittle stars usually feed on small organisms including polychaetes and crustaceans (Çinar *et al*., 2002). It is a common associate of marine sponges (Mladenov & Emson, 1988) and has also been found within the sponges *S. foetidus* (Cinar *et al*., 2002) and *M. microsigmatosa* (Ribeiro *et al*., 2003). It usually occupies sponges for shelter, feeding and reproduction (Mladenov & Emson, 1988).

Similarly, the crab *Dromia dormia* may feed on polychaetes within sponges at Station 2, resulting in the absence of any polychaetes at this station. The same observation was made at Station 7, where only a few polychaetes were present in the sample containing *D. dormia*. This crab, also known as the sponge crab, usually carries sponges on its carapace for camouflage (McLay, 1993) and the relationship between the two organisms can be considered mutualistic.

A relatively low number of polychaetes and crustaceans were recorded in sponges containing specimens of the *Balanus* sp. (Stations 1, 2 and 5). All these barnacles were located at the external pores of the sponge canals, blocking internal access to the hosts. Westinga and Hoejtes (1981) suggested the likelihood that they use the waterflow in the sponge as a feeding aid, being filter feeders.

No clearly significant relationships emerged between the sponge macrofaunal asociations and the environmental variables measured in this study, i.e. sponge size and depth. Other factors must therefore also contribute to the heterogeneity of associated communities. Current patterns in the lagoon may influence the settlement of these organisms, as well as other factors such as the distribution of the different sediment types, detritus and the surrounding biodiversity. Notwithstanding the relatively low macrofaunal diversity found associated with *N. exigua* in the study, this sponge does contribute to the maintenance of some species such as the *H. djiboutiensis* within the region and constitutes an important benthic community within the lagoon of Trou aux Biches.

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