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VARIATION IN SPONGE COMPOSITION AMONG SINGAPORE REEFS

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***ABSTRACT.* –** The coral reefs of the densely populated Republic of Singapore, present an interesting scenario to compare the effects of a particular form of human disturbance, namely land reclamation and related sedimentation processes. We present an exploratory study from a detailed survey where sponge assemblages were assessed at 21 sites associated with patch reefs at various distances from the city of Singapore. The variation in species composition across the study area was analysed with two multivariate techniques. We identified a total of 82 sponge species belonging to 43 genera and 27 families of which *Cinachyrella australiensis, Neopetrosia chaliniformis, Oceanapia sagittaria* and *Xestospongia testudinaria* were the most common species. The number of sponge species found in each of the 21 surveyed sites varied substantially, namely between 12 and 38 species. Sponge assemblages at the coral reefs of Singapore were not homogeneous, and were not structured according to an in- to offshore gradient as seen in other coral reefs. There does appear to be a tendency for more disturbance-adapted assemblages in sites to the east (around St John's island) and south (Raffles Lighthouse) and more diverse sponge assemblages in the west of the study area. The Singaporean sponge communities appear to be composed of sediment and low-light resistant species, however, it is expected that ongoing chronic stress of sedimentation will probably continue to alter sponge communities.

KEY WORDS. – Coral reef, disturbance, sedimentation, Singapore, South China Sea, sponge**.**

INTRODUCTION

Population growth and urbanization are predicted to be major determinants of species loss (McKinney, 2002; Miller & Hobbs, 2002). Relatively little is, however, known about the impact of human conurbations on coral reef ecosystems. At present very few coral reefs are located close enough to large cities to study the influence of large urban populations on reef assemblages. Exceptions include the Thousand Islands reef complex north of Jakarta (Cleary et al., 2006; Rachello-Dolmen & Cleary, 2007), the Spermonde Archipelago to the west of Makassar (Cleary et al., 2005; de Voogd et al., 2006), and Singapore (Chou et al., 2004; Dikou & Woesik, 2006). Studies in Jakarta and the Spermonde revealed a pronounced effect of the urban environment on coral reef assemblages with concomitant on-to-offshore gradients in the composition of various taxa and environmental variables (Cleary & Renema, 2007). These results indicate that human conurbations can have a pronounced effect on proximate marine assemblages, which should heighten the need for further research. Highly urbanized terrestrial environments, such as Singapore, have for example, already lost much of their original diversity (Corlett, 1992; Chua & Chou, 1994; Chou et al., 2004; Brook et al., 2006).

At present, Singapore's corals reefs are not subject to the unsustainable fishing practices that are pervasive throughout the rest of the region; fisheries and trade in aquarium fish are well controlled (Chua & Chou, 1994). Sewage and industrial waste treatment are also under control. However, the globally important port has taken a substantial toll on coral reefs (Chou, 1996). During the past four decades, Singapore has engaged in extensive land reclamation and coastal development projects. Around 60 percent of the total coral reef area has been lost due to land reclamation, and the accompanying sedimentation has triggered marked declines in coral cover since 1987 (Dikou & van Woesik, 2006).

The coral reefs of the Republic of Singapore, with more than 4 million inhabitants, therefore present an interesting scenario for the comparison of the effects of land reclamation and related sedimentation processes. The marine flora and fauna of Singapore have been studied to various degrees since the days of Stamford Raffles in the 19th century (Corlett, 1992). Significant economic and coastal development has reclaimed many natural marine habitats since then (Bird et al., 2004); in their place, concrete, artificial seawalls and lagoons now dominate the shoreline and few original marine habitats remain (Huang et al., 2006). Despite the relatively well-documented terrestrial and marine flora and fauna of Singapore (Goh & Chou, 1996; van Ofwegen et al., 2000; Hajisamae et al., 2004), the sponge fauna of the coral reefs of Singapore is poorly known (Gray, 1873; Carter, 1883; Dragnewitsch, 1905). Sponges, however, are an important component of coral reefs and provide substrate and shelter for a number of other invertebrate taxa (Arndt, 1933; Westinga & Hoetjes, 1981; de Voogd et al., 2006). They also compete with other benthic taxa for space and are important in reef dynamics (VanVeghel et al., 1996).

Currently no data exists on sponge biodiversity or community composition in Singapore. Here we present an exploratory study from a detailed survey where sponge assemblages were assessed at 21 sites associated with patch reefs at various distances from the city of Singapore. Variation in species composition across the study area was analyzed with two multivariate techniques namely nonmetric multidimensional scaling and principal components analysis (PCA).

MATERIAL AND METHODS

Study area. **–** The research sites are located in the Republic of Singapore, which is located at the southern tip of the Malayan Peninsula, approximately 135 km north of the Equator. The republic consists of a main island, which is separated from Malaysia by the narrow Johore Strait and approximately 54 smaller islands in the south where it is separated from the Riau Archipelago in Indonesia by the Singapore Strait. Singapore city has presently almost four million inhabitants on a total land area of 699 km^2 making it one of the most densely populated countries in the world. There are two major monsoonal periods; the Northeast Monsoon from November to March and SW monsoon from May to September. Annual precipitation averages 2,410 mm/yr which peaks during the Northeast Monsoon. The tidal amplitude is 2.5–3.0 m during high tide and 0.7–1.2 m during low tide.

In Singapore there is an ongoing land reclamation project which has resulted in land expansion from 581.5 km^2 in the 1960s to 699.3 km^2 today, and will probably grow by another 100 km^2 by 2030. Many of the smaller islands have lost their original geomorphology and have been joined together. This has had a large impact on the local coral reefs. Additional disturbances affecting coral resources include shipping activities, oil-related industries, dumping of solid waste and land-based waste.

The waters around Singapore have been heavily affected by an increased sediment load over the past 50 years; sedimentation rates ranged from 3–6 mg/cm^{-2} day^{1} in 1979 to 20–30 mg/cm^2/day at certain sites in 1994 (Lane, 1991). Consequently visibility has been drastically reduced from more than 10 m in the 1960s to less than 2 m presently at certain sites (Chou, 1996).

Data collection. **–** Sampling took place using SCUBA in March–April 2006 during a marine survey organized by The Tropical Marine Science Institute at 21 sites (including reef islands and channels; Fig. 1) at various distances from the mainland. Each site was visually surveyed during a one-hour dive from deep to shallow water. Smaller (cryptic, boring, and very thinly encrusting < 4 cm) specimens were excluded from this study. Species were photographed and visually identified in the field, and fragments of all species were collected for closer examination. Voucher specimens were preserved in 70% ethyl alcohol and deposited in the sponge collections of Naturalis (RMNH Porifera) and the Zoological Reference Collection of the Department of Zoology, National University of Singapore (ZRC).

Analyses. **–** Variation in species composition across the study area was analyzed with two multivariate techniques namely nonmetric Multi dimensional scaling (MDS) and Principal Components Analysis (PCA). For the MDS, using the CRAN package MASS within R (http://www.r-project.org/), the presence-absence species data matrix was used to generate a matrix of community similarity between samples using the Sørensen index (Sørensen, 1948). The Sørensen and its quantitative equivalent, the Bray-Curtis similarity index, are frequently used for ecological ordinations and have been shown to have good properties for ordination of species data (Legendre & Gallagher, 2001; Cleary, 2003; Cleary & Mooers, 2004). Again using MASS, an ordination of the matrix was then generated using PCA. MDS has been shown to be a robust technique for ordinating species abundance data, and it does not have such stringent model assumptions as alternatives such as Correspondence Analysis.

In addition to the MDS, we performed principal components analyses using the ADE4 CRAN package in R. Input for the PCA consisted of presence/absence data that were first ‘transformed’ within the Vegan CRAN package within R. Transformation consisted of modifying the species abundance data such that subsequent analyses preserved the chosen distance among objects (sample sites). The species abundance data were transformed because of the inherent problems of the Euclidean-based distance metric (in standard PCA) for community data (see Legendre & Gallagher, 2001). In the present case, the Hellinger distance was used, which gave good results in a comparison of various distance metrics (Legendre & Gallagher, 2001).

RESULTS

We identified a total of 82 sponge species belonging to 43 genera and 27 families (Table 1). The number of sponge

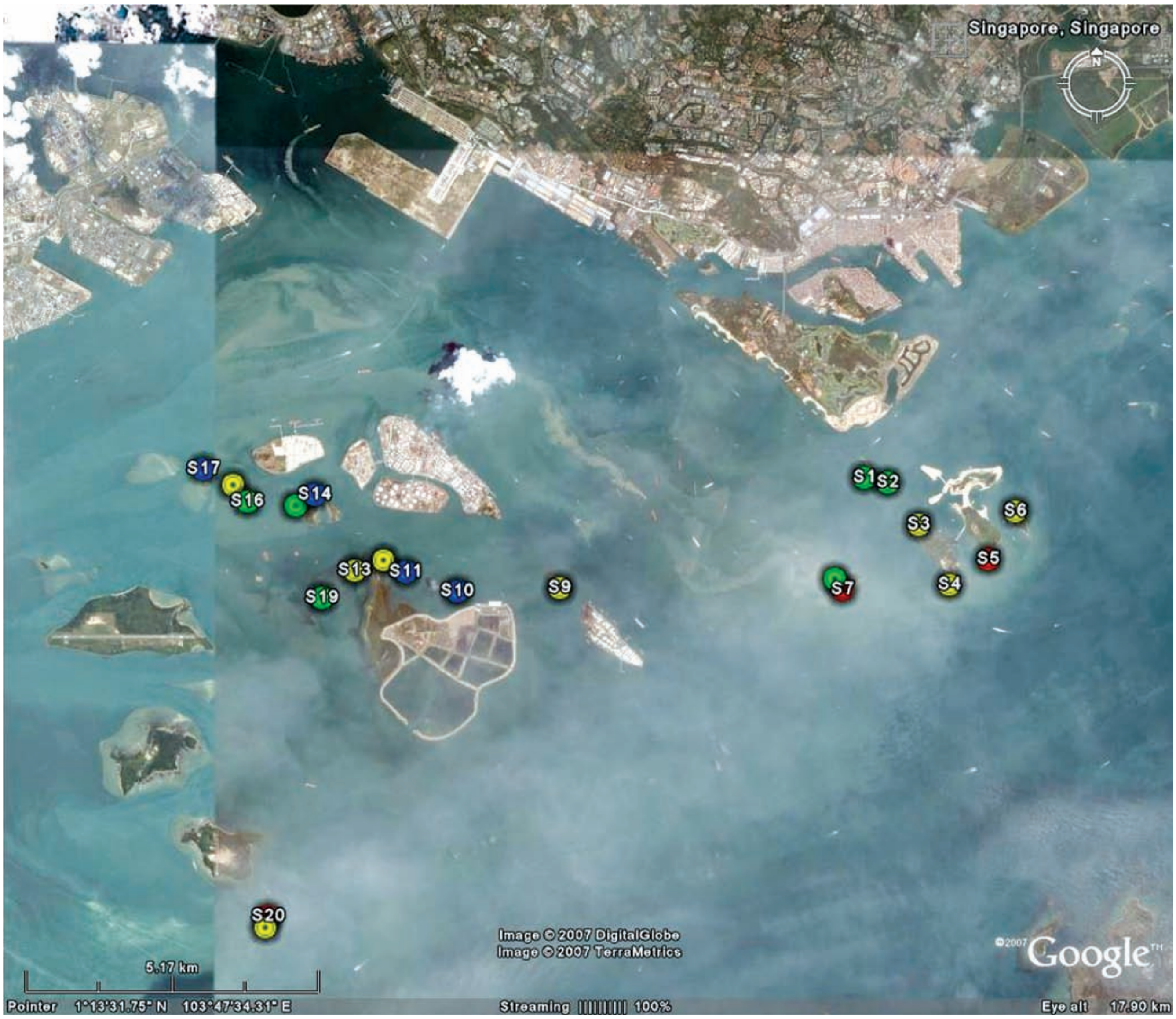

Fig. 1. Google Earth™ image of Singapore. Sites samples during this study are indicated. These include: (S1) Pulau Tekukor, northern side; (S2) Pulau Tekukor, south eastern side; (S3) Pulau Sakijang Bendera (St John's Island), northern side; (S4) Pulau Sakijang Bendera (St John's Island), south western side; (S5)- Pulau Sakijang Pelepah (Lazarus Island), south western side; (S6) Kusu Island (Pulau Tembakul), northern side; (S7) Pulau Subar Laut (Sisters) north western; (S8) Pulau Subar Darat (The Sisters), north western side; (S9) Pulau Jong, south western side; (S10) Terumbu Semakau, eastern side; (S11) Pulau Semakau, north eastern side; (S12) Pulau Semakau, northern side; (S13) Pulau Semakau, north western side; (S14) Pulua Hantu Kecil north eastern side; (S15) Pulau Hantu Besar, western side; (S16) Terumbu Pempang Darat, north eastern side; (S17) Terumbu Pempang Tengah western side; (S18) Terumbu Pempang Laut, western side; (S19) Beting Bemban Besar western; (S20) Pulau Satumu (Raffles Lighthouse), north eastern side and (S21) Pulau Satumu (Raffles Lighthouse), south eastern side. The colour of the symbols indicates the value of the sample site along the first PC-axis (see results). Red: PC1 < –1; yellow: –1 < PC1 < 0; green: 0 < PC1 < 1; blue: PC1 > 1.

species found in each of the 21 surveyed sites varied between 12 and 38. The highest number of species was found at the following sites: south eastern side of Pulau Tekukor (38 spp.), north eastern side of Terumbu Pempang Darat (37 spp.), north eastern side of Pulau Semakau (36 spp.), western side of Pulau Hantu Besar and the western side of Terumbu Pempang Tengah (35 spp. each). The lowest number of species was recorded at the northeastern side of Pulau Satumu and the south western side of Pulau Sakijang Pelepah (both 12 spp.). Only 13 species were common [i.e. co-occurred in > 13 different sites (66% level of sites) of which *Cinachyrella australiensis*, *Neopetrosia chaliniformis*, *Oceanapia sagittaria* and *Xestospongia testudinaria* were the most common species]. Table 2 lists the ten most common species. Of the 43 genera recorded at the 21 sites, only four genera, *Neopetrosia*, *Oceanapia*, *Petrosia* and *Xestospongia* were present at all sites. These genera all belong to the same family, Petrosiidae.

In Fig. 2 we present results of the multivariate analyses of species data. Fig. 2a is a two-dimensional representation that best approximates the observed distances between pairs of sites based on the Sørensen distance measure. In addition to this, we provide a plot of ordination distances against original dissimilarities and two measures of the goodness of fit of the two-dimensional representation namely the 'Stress' and the linear 'Fit' i.e., the correlation between fitted values and ordination distances (Fig. 2b). For the PCA the first four principal component axes are shown (variation explained: 37.6%) of site scores (Fig. 2c and 2e) and species scores (Fig. 2d and 2f). Both the MDS and PCA showed a similar distribution of sample sites along the first axis/dimension. The axis represents a synthetic gradient whereby sites with low (negative) PC1 scores were characterized by species such as *Axinyssa* sp. "2502", *Cinachyrella australiensis, Coscinoderma matthewsi Gelliodes fibulata*, *Neopetrosia chaliniformis*, *Paratetilla* aff. *bacca* and *Xestospongia testudinaria.* Species with high (positive) PC1 scores were characterized by species such as *Axinyssa* sp. "2567", *Axinyssa* sp. "2570", *Callyspongia diffusa, Dysidea* sp. "2563", *Euryspongia* sp., *Petrosia* cf. *microxea*, *Pseudoceratina purpurea* and *Stelletta clavosa.* There is less congruence between the MDS and PCA with respect to the second dimension/axis with the second PC axis primarily characterized by the marked PC2 score of the north western side of Pulau Semakau (S13). PC axis 3 represents variation in sites such as S13 and west side of Terumbu Pempang Tengah (S17) characterized by species such as *Dysidea frondosa* versus sites such as Pulau Hantu Besar (S15) and Pulau Tekukor (S2) characterized by *Coelocarteria singaporensis*. Axis 4 represents a gradient from site SE side of Raffles Lighthouse (S21) characterized by species such as *Theonella* sp. and *Jaspis splendens* versus sites Pulau Subar Laut (Sisters) north west (S7) and Terumbu Pempang Darat, north eastern side (S16) characterized by species such as *Chondrilla australiensis* and *Lamellodysidea herbacea*.

The distinct nature of S13 along PC2 is due to the presence of a number of unique species [i.e. species that were only recorded at this site]. These include *Acanthostrongylophora ingens*, *Biemna fortis*, *Mycale parishi* and *Xestospongia* sp. "2486". Twelve of the sample sites contained no unique species and six only contained a single unique. The north eastern side of Semakau (S11) contained two unique species and Terumbu Pempang Tengah western side (S17) three unique species. This indicates that expected species richness is higher for the western sites compared to the Eastern sites where most sites contained no unique species. In total we found 79 species in the 13 western sites (12 unique species) and 60 species in the 8 eastern sites (2 unique species). Both areas, however, showed a large variation in composition. Based on the PC scores of the first axis, we subdivided sites into four classes namely red (PC1 < –1), yellow (–1 < PC1 < 0), green (0 < PC1 < 1) and blue (PC1 > 1) (Fig 1). These were plotted onto a map of Google Earth™ in order to ascertain if there were any pronounced geographical gradients. There does appear to be a tendency for more red and yellow (negative PC1 values) sites to the east (around St. John's island) and south (Raffles lighthouse) of the study area whereas all the blue sites were located in the west of the study area (Pulau Semakau, Terumbu Pempang Tengah and Hantu Kecil).

DISCUSSION

In the present study, a relatively low number of sponge species (82 spp.) were found in comparison to other Indomalayan coral reef areas, e.g. 118 spp. in the Thousands Islands (north western Java) and 151 spp. in the Spermonde Achipelago (south western Sulawesi), although these studies covered a larger area compared to the present study (de Voogd et al., 2006; de Voogd & Cleary, 2008). Goh & Chou (1996) also remarked that the smaller number of gorgonians found in Singapore in comparison to other coral reefs is better explained in terms of the smaller sampling size and area rather than an inherently poor fauna. Interestingly, some of the ten most common sponge species of Singapore were shared with the reefs near the large cities of Jakarta and Makassar. *Hyrtios erectus* and *Petrosia hoeksemai* were shared with Jakarta and *Cinachyrella australiensis* and *Xestospongia testudinaria* with Makassar. The latter two species are known to have a circumtropical distribution and very broad ecological amplitude, from relatively pristine coral reefs (Wakatobi, Indonesia) to very disturbed habitats (Sydney harbour, Australia, Darwin Bay). We therefore hypothesize that they are stress-tolerant and dominant species analogous to massive corals such *Porites* spp., which are present in severely polluted reefs of Jakarta Bay (Rachello-Dolmen & Cleary, 2007). Interestingly, the reefs off Jakarta and Makassar also only share two of the 10 most common species. Van Soest (1989) already remarked that different geographic regions within the Indo-West Pacific all have some endemic species and in the complement of their common species are all very dissimilar. He also showed that the sponge fauna of Indonesia and the Central Indian Ocean are quite similar. Indeed most species found in Singapore were collected during the Dutch Snellius II and Siboga expeditions within Indonesian waters and more recent Indonesian expeditions, although some were described from other areas (for instance, *Clathria foraminifera* from India and *Petrosia microxeata* from the Seychelles).

Although the coral reefs of Singapore are situated within the triangle of highest biodiversity, chronic deposition of sediment due to land reclamation has drastically reduced scleractinian coral cover and presumably biodiversity in a relatively short period of time, i.e. 20 years (Dikou & van Woesik, 2006; Hoeksema & Koh, 2009). Even common species, such as the fragile *Seriatopora hystrix*, once abundant in Singapore, is now completely absent from Singaporean reefs. Unfortunately, no historical data exists on sponge diversity, although some of the early reported and described sponges of Singapore were observed during the present survey [e.g. *Coelocarteria singaporensis* (Carter, 1883) and *Callyspongia diffusa* (Ridley, 1884)]. However, in concordance with other coral reef studies from Singapore, we assume that sponge diversity has probably been reduced; particularly species that are sensitive to high sedimention rates and low-light conditions have probably disappeared. De Voogd & Cleary (2007) recently indicated

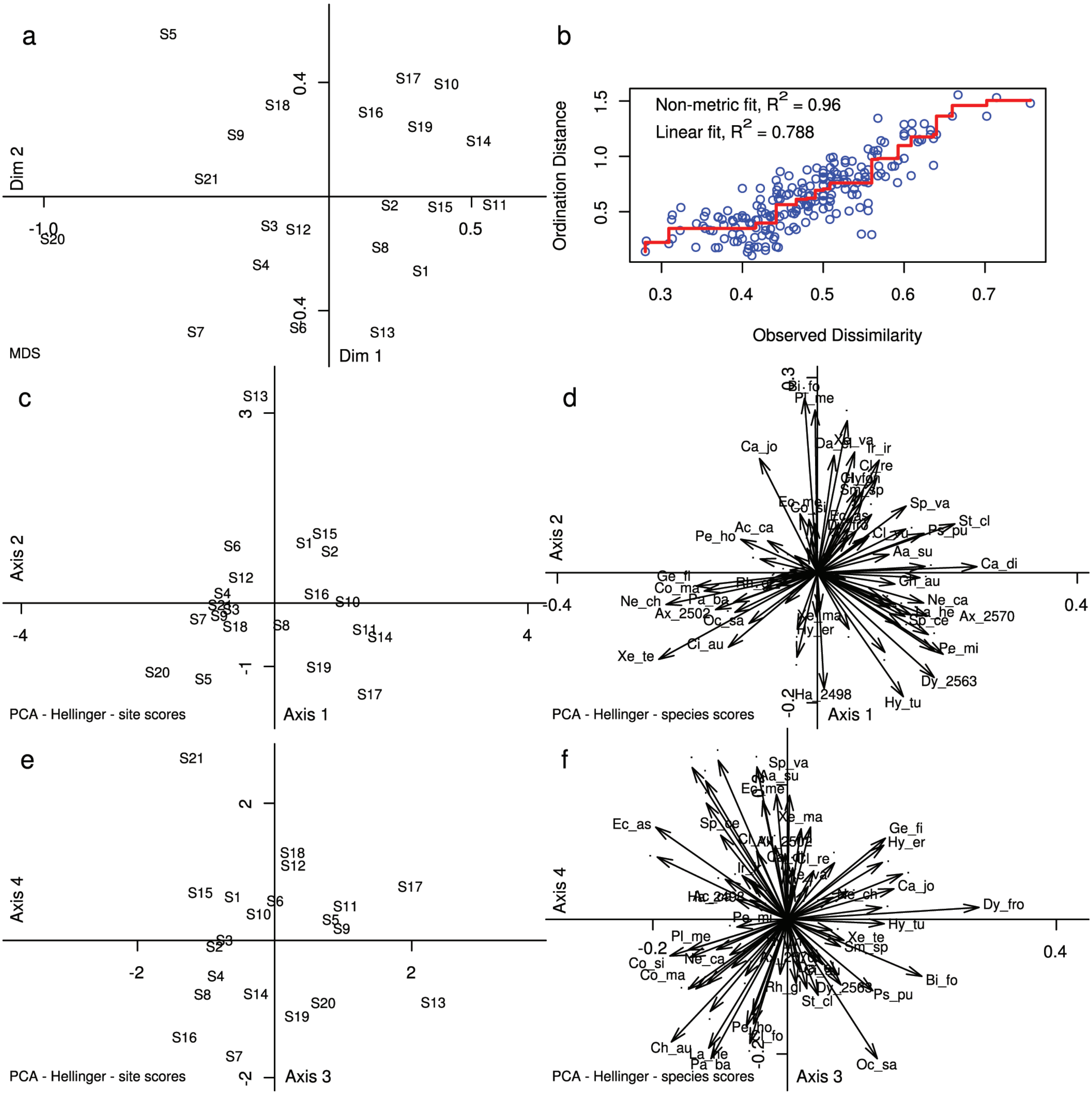

Fig. 2. Ordinations of sponge species-level data from the 21 sample sites: a, Multidimensional scaling ordination based on the Sørensen index; b, plot of ordination distances against original dissimilarities and two measures of the goodness of fit of the two-dimensional representation namely the 'Stress' and the linear 'Fit' i.e. the correlation between fitted values and ordination distances (c). Sample site scores of the PCA ordination based on the Hellinger distance, showing the first and second axes and (e) the third and fourth axes (for codes see Fig. 1). Species scores of the PCA ordination for (d) the first and second axes and (f) the third and fourth axes. Selected species are indicated by their respective codes: Aa_su, *Aaptos suberitoides*; Ac_ca, *Phakettia* cf. *cactoides*; Ax_2570, *Axinyssa* sp."2570"; Ax_2502, *Axinyssa* sp."2502"; Ca-jo, *Callyspongia joubini*; Ca_di, *Callyspongia diffusa*; Ch_au, *Chondrilla* cf. *mixta*; Ci_au, *Cinachyrella australiensis*; Cl_vu, *Clathria vulpina*; Cl_re, *Clathria reinwardti*; Cl_fo, *Clathria foraminifera*; Co_si, *Coelocarteria singaporensis*; Co_ma, *Coscinoderma matthewsi*; Da_el, *Dactylospongia elegans*; Dy_fr, *Dysidea* cf. *frondosa*; Dy_2563, *Dysidea* sp."2563", Ec_as, *Echinodictyum asperum*; Ec_me, *Echinodictyum mesenterinum*; Ge_fi, *Gelliodes fibulata*; Ha_2498, *Haliclona* sp. "2498"; Hy_tu, *Hyatella tubaria*; Hy_in, *Hyatella* cf. *intestinalis*; Hy_er, *Hyrtios erectus*; Ir_ir, *Ircinia* cf.*irregularis*; Ne_ca, *Neopetrosia* aff. *carbonaria*; Ne_ch, *Neopetrosia chaliniformis*; Oc_sa, *Oceanapia sagittaria*; Pa_ba, *Paratetilla* cf. *bacca*; Pe_mi, *Petrosia* cf. *microxeata*, Pe_ho, *Petrosia hoeksemai*; Pl_me, *Placospongia melobesioides*; Ps_pu, *Pseudoceratina purpurea*; Rh_gl, *Rhabdastrella globostellata*, Sm_sp, *Luffariella* cf. *variabilis* sp.; Sp_va, *Spheciospongia vagabunda*; Sp_ce, *Spongia ceylonensis*; St_cl, *Stelletta clavosa*; Xe_va, *Xestospongia vansoesti*; Xe_ma, *Xestospongia mammillata* and Xe_te, *Xestospongia testudinaria*

that associations between growth forms and environmental conditions can potentially be used as indicators in monitoring marine habitats. They found that globular, fan-shaped and fistulose growth forms were associated with sites with poor water transparency close to human settlement, while tubular and massive-incrusting growth forms were associated with sites with good transparency. Interestingly, sponges with a tubular growth form were completely absent from the reefs of Singapore.

Moreover, the most abundant species in Singapore had globular (e.g. *Paratetilla* aff. *bacca*, *Cinachyrella australiensis*), fistulose (*Coelocarteria singaporensis)*, fan-shaped (*Echinodictyum mesenterinum)* or ramose growth forms (e.g. *Gelliodes fibulata*, *Clathria reinwardti*). It is likely that certain growth forms are not able to cope with increased sedimentation, and that biodiversity loss can be even assessed using morphological data. For instance, the globular *C. australiensis* and fan-shaped *E. mesenterinum* are well adapted to perturbed sites and are common and abundant species inshore at other highly populated areas (de Voogd & Cleary, 2007). These species may easily be overlooked as they are often covered by a thin layer of sediment. Cup-shaped and phototrophic species, such as *Carteriospongia foliascens, Phyllospongia papyracea* and *Strepishordaia aliena*, which mainly rely on the translocation of nutrients from their symbiotic cyanobacteria were also absent from the shallow water coral reefs of Singapore. Whether they were present in the past is unknown. Only a few qualitative studies in the Indo-Pacific have compared sponge distributions at small and large spatial scales; all of these have shown that sponge assemblages are far from homogenous (Hooper & Kennedy, 2002; Hooper et al., 2002; de Voogd et al., 2006). Even fewer studies have related sponge composition to environmental conditions (de Voogd et al., 2006; de Voogd & Cleary, 2007; Cleary & de Voogd, 2007). Although this study only presents an exploratory study with qualitative data, these results suggest that the sponge assemblages at the coral reefs of Singapore are not homogeneous. However, sponge communities were not structured according to an in- to offshore gradient as seen in other coral reefs (de Voogd et al., 2006; de Voogd & Cleary, 2008). There does appear to be a tendency for more disturbance adapted assemblages as indicated by the presence of *Cinacharylla australiensis* and *Paratetilla* aff. *bacca* in sites to the east (around St John's island) and south (Raffles lighthouse) of the study area.

Dikou & van Woesik (2006) found that differences in coral community assemblages were explained by the ambient environment during non-monsoon conditions. As mentioned previously, the reefs of Singapore have been subjected to chronic stress and the reefs are not evenly affected by this; moreover, some reefs have been completely altered by land reclamation. Chou & Tun (2007) showed that conserving reefs next to a large marine landfill at Pulau Semakau can have a positive short term effect on coral reef rehabilitation. A large part of the reef at the eastern side of the island of Semakau was assigned for waste disposal in 1999. A total area of 350 ha (3.50 km^2) is presently enclosed by a 7 km rock wall to prevent contamination of the surrounding waters. Remarkably, the western side of the island has been monitored and preserved since and the extensive reef flat presently harbours average coral cover and 24 coral genera. In the present study, site 11 (north east of Pulau Semakau) was the closest to this landfill and was actually one of the most diverse sites with respect to the number of sponge species, whereas site 19 was the closest to the western part of Pulau Semakau. This site was still rich in species, but less diverse than the site adjacent to the landfill.

Although we did not measure any environmental variables, Chou et al., (2004) showed that sedimentation rate, sediment composition and ammonia concentration were the most important factors affecting the soft-bottom benthic communities at the reefs near Pulau Semakau. Furthermore, they concluded that these factors adversely affect faunal abundance and diversity in general; the most impacted sites were dominated by various polychaete families. Despite the high sedimentation rates, a relatively diverse coral reef community is still present (Goh & Chou, 1996; van Ofwegen, 2000), composed of species which are normally not found in such shallow waters. Interestingly, many gorgonians were found at depths less than 20 m, while these normally are found in deeper waters (Goh & Chou, 1996).

In conclusion, although human activities have altered the coral reef structure drastically in the past few decades and consequently have impacted the coral reefs of Singapore, the sponge community is reasonably diverse. The Singaporean sponge community appears to be composed of sediment and low-light resistant species. Also, some species appear to be quite abundant and thrive well under high sedimentation. However, it is expected that ongoing chronic stress from sedimentation will probably further alter sponge communities. Previous studies have shown that coral recruitment rates are dramatically low; some key coral reef species have already disappeared and most reefs are now dominated by silt and filamentous algae with the reef matrix literally falling apart (Dikou & van Woesik, 2006). The future of Singapore's coral reefs is uncertain with increasing population pressure and intensifying land reclamation and shipping traffic.

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Table 1. List of sponge species arranged to systematic order.

Demospongiae
Spirophorida Bergquist & Hogg, 1969
Tetillidae Sollas, 1886
Cinachyrella australiensis (Carter, 1886)
Paratetilla cf. *bacca* (Selenka, 1867)
Astrophorida Sollas, 1888
Ancorinidae Schmidt, 1870
Jaspis splendens (De Laubenfels, 1954)
Rhabdastrella globostellata (Carter, 1883)
Stelletta clavosa Ridley, 1884
Calthropellidae Lendenfeld, 1907
Pachastrissa sp.
Hadromerida Topsent, 1894
Clionaidae D'Orbigny, 1851
Spheciospongia vagabunda (Ridley, 1884)
Spheciospongia sp.
Placospongiidae Gray 1868
Placospongia melobesioides Gray, 1867
Suberitidae Schmidt, 1870
Aaptos suberitoides (Brønsted, 1934)
Chondrosida Bourny-Esnault, 1985
Chondrillidae Gray, 1872
Chondrilla australiensis Carter, 1875
'Lithistid' Demospongiae
Scleritodermidae Sollas, 1888
Aciculites sp.
Theonellidae Lendenfeld, 1903
Theonella sp.
Poecilosclerida Topsent 1928
Microcionina Hajdu, van Soest & Hooper, 1994
Microcionidae Carter, 1875
Clathria (*Thalysias*) *reinwardti* (Vosmaer, 1880)
Clathria (*Thalysias*) *vulpina* (Lamarck, 1813)
Clathria (*Wilsonella*) *foraminifera* (Burton & Rao, 1932)
Raspailiidae Hentschel, 1923
Echinodictyum asperum Ridley & Dendy, 1886
Echinodictyum mesenterinum (Lamarck, 1814)
Iotrochotidae Dendy, 1922
Iotrochota purpurea (Bowerbank, 1875)
Mycalina Hajdu, van Soest & Hooper, 1994
Desmacellidae
Biemna fortis (Topsent, 1897)
Mycalidae Lundbeck, 1905
Mycale (*Aegogropila*) *crassissima* (Dendy, 1905)
Mycale (Zygomycale) parishi (Bowerbank, 1875)
Isodictydidae Dendy, 1924
Coelocarteria singaporensis (Carter, 1883)
Halichondrida Gray, 1867
Dictyonellidae van Soest, Diaz & Pomponi, 1990
Acanthella cavernosa Dendy, 1922
Phakettia cf. *cactoides* (Burton, 1928)
Halichondriidae Gray, 1867
Axinyssa spp. (7 species)
Haplosclerida Topsent, 1928
Haplosclerina Topsent, 1928
Callyspongiidae De Laubenfels, 1936
Callyspongia (Cladochalina) diffusa (Ridley, 1884)
Callyspongia (Cladochalina) joubini (Topsent, 1897)
Callyspongia (Cladochalina) spinosissima (Dendy, 1887)
Callyspongia (*Toxochalina*) spp.
Chalinidae Gray 1867
Haliclona spp.
Niphatidae van Soest, 1980
Gelliodes fibulata Ridley, 1884
Gelliodes spp.
Niphates sp.
Petrosina Boury-Esnault & van Beveren, 1982
Phloeodictyidae Carter, 1882
Aka mucosa (Bergquist, 1965)
Oceanapia sagittaria (Sollas, 1902)
Oceanapia sp.
Petrosiidae van Soest 1980
Acanthostrongylophora ingens (Thiele, 1899)
Neopetrosia chaliniformis (Thiele, 1899)
Neopetrosia aff. *carbonaria* (Lamarck, 1814)
Neopetrosia spp.
Petrosia (*Petrosia*) *hoeksemai* de Voogd & van Soest, 2002
Petrosia (*Petrosia*) cf. *microxea* (Vacelet, Vasseur & Lévi, 1976)
Petrosia (Petrosia) spp.
Xestospongia aff. *mammillata* Pulitzer-Finali, 1982
Xestospongia vansoesti Bakus & Nishiyama, 2000
Xestospongia testudinaria (Lamarck, 1813)
Xestospongia spp. De Laubenfels, 1932
Dictyoceratida Minchin, 1900
Thorectinae Bergquist, 1978
Irciniidae Gray, 1867
Ircinia cf. *irregularis* (Polejaeff, 1884)
Ircinia ramosa (Keller, 1889)
Psammocinia sp.
Thorectidae Bergquist, 1978
Hyrtios erectus (Keller, 1889)
Dactylospongia elegans (Thiele, 1899)
Luffariella variabilis (Polejaeff, 1884)
Spongiidae Gray, 1867
Coscinoderma matthewsi (Lendenfeld, 1886)
Hyatella tubaria (Lamarck, 1814)
Hyatella intestinalis Lendenfeld, 1889
Hyatella sp.
Spongia (*Spongia*) *ceylonensis* Dendy, 1905
Dysideidae Gray, 1867
Dysidea frondosa Bergquist, 1995
Dysidea spp.
Eurospongia sp.
Lamellodysidea herbacea Keller, 1889
Verongida Bergquist, 1978
Aplysinellidae Bergquist, 1980
Suberea sp.
Pseudoceratinidae Carter, 1885
Pseudoceratina purpurea (Carter, 1880)

Table 2. Ten most common sponge species and their occurence at the 21 surveyed sites in Singapore.

Species	Family	No. of occurences
Cinachyrella australiensis (Carter, 1886)	Tetillidae	19
Clathria (*Wilsonella*) *foraminifera* (Wilson & Rao, 1934)	Microcionidae	16
Echinodictyum mesenterinum (Lamarck, 1814)	Raspailiidae	17
Gelliodes fibulata Carter, 1881	Niphatidae	18
*Hyrtios erectus (*Keller, 1889)	Thorectidae	17
Neopetrosia chaliniformis (Thiele, 1899)	Petrosiidae	20
Oceanapia sagittaria (Sollas, 1902)	Phloedictyidae	20
Petrosia (*Petrosia*) *hoeksemai* de Voogd & van Soest, 2002	Petrosiidae	16
Rhabdastrella globostellata (Carter, 1883)	Ancorinidae	18
Xestospongia testudinaria (Lamarck, 1814)	Petrosiidae	21

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