Spatial Variability of Sponge Assemblages on the Wellington South Coast, New Zealand

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Abstract: The aim of this study was to provide baseline data for sponge biodiversity on the Wellington South Coast, New Zealand. Eighteen sites were qualitatively sampled resulting in the identification of 65 different sponge taxa. Forty-three of these species were also reported from a quantitative survey of three vertical wall sites in 8-10m depth conducted as part of a long-term monitoring study. All three sites had a similar mean number of species per quadrat, however, the percentage cover of sponges and sponge density varied significantly between sites. ANOSIM showed that all three sites were significantly different from each other ($P<0.001$), which is likely the result of differences in environmental conditions. The Wellington South Coast has a diverse sponge assemblage, which is atypically dominated by calcareous species of the genus *Clathrina*. This appears to be unusual for New Zealand, and although the reasons for this situation are unknown, we hypothesise that this situation is explained by the low levels of nutrients on the Wellington South Coast, allowing calcareous sponges to proliferate at the expense of the demosponges.

Keywords: Porifera, sponge assemblages, spatial variability, New Zealand.

INTRODUCTION

Sponges have been a major element of the benthic marine fauna from the early Cambrian to the present day and are found across the world's benthic environments [1-10]. Although algae dominates the biomass of shallow subtidal (<12m deep) reef communities around mainland New Zealand, amongst the encrusting invertebrate groups, sponges have been reported as the largest contributor to total biomass in many locations. For example, at Raglan on the North-west coast of the North Island and Chalmers near Dunedin on the South Island [11]. Typical habitats that have rich sponge assemblages in New Zealand are rocky subtidal reefs, underneath rocks and boulders, and on vertical and overhanging bedrock, especially in channels, crevices, caves and gulleys [12, 13].

Spatial diversity describes how organisms are distributed at different distance scales. There have been many studies on sponges describing spatial variability in genetic structure [14-19]; biochemical composition [20, 21]; morphology [22]; and distribution patterns of specific species [23-25]. Spatial variation in abundance and diversity have also been reported at different levels: within a particular habitat – alpha diversity [26-29]; variation within geographic areas – beta diversity [3, 5, 30-32]; and variability across different geographic regions – gamma diversity [33-36]. Variation in sponge diversity, distribution and abundance is likely to influence other benthic organisms due to the important functional roles that sponges fulfil [27, 37-42]. Sponge assemblages are influenced by a number of physical factors including: depth [43-45]; water flow [44, 46]; temperature [26, 47]; light intensity [48]; sedimentation [49-52] and salinity [26, 53, 54]. Biological factors influencing sponge assemblages include: predation [55-58]; mutualistic and symbiotic associations [59-61]; concentration and plankton diversity [62-64]; spatial competition [65-67]; and disease [68-71]. There has been some discussion regarding the relative roles of biological and physical factors in controlling sponge assemblages in different geographic regions. Biological factors may be more important than physical factors in determining tropical sponge assemblage structure in the Caribbean, however, physical factors have been found to be most important in the NE Atlantic and Eastern Pacific [2, 57, 58, 72, 73].

The sponge fauna of New Zealand is reasonably well known [74-79], however, the majority of sponge biodiversity work in has been concentrated in the waters around the north of the North Island (particularly north of Auckland) [80-82], and at deep sea mounts and offshore islands [79, 83]. There are large areas around New Zealand, which have not yet been fully surveyed for sponges. For example, at Pariokariwa reef, North Taranaki, a preliminary survey reported 57 sponges species, of which only 17 were given likely or confirmed species names [84]. Despite this earlier research, there have been no peer reviewed publications about Pariokariwa reef even though it is designated a Marine Reserve partially because it is considered one of the 'top sponge hotspots' in the world (*Battershill pers. com*).

Some of the sponge species and typical sponge habitats on the Wellington South Coast (WSC) have recently been described, although work focused on relatively few common species from only a few sites [12, 44, 85]. The aim of our study was to provide baseline data for the sponge biodiversity of the Wellington South Coast, and use this information to identify suitable sites for permanent quantitative quadrats that are representative of sponge biodiversity and abundance on the Wellington South Coast;

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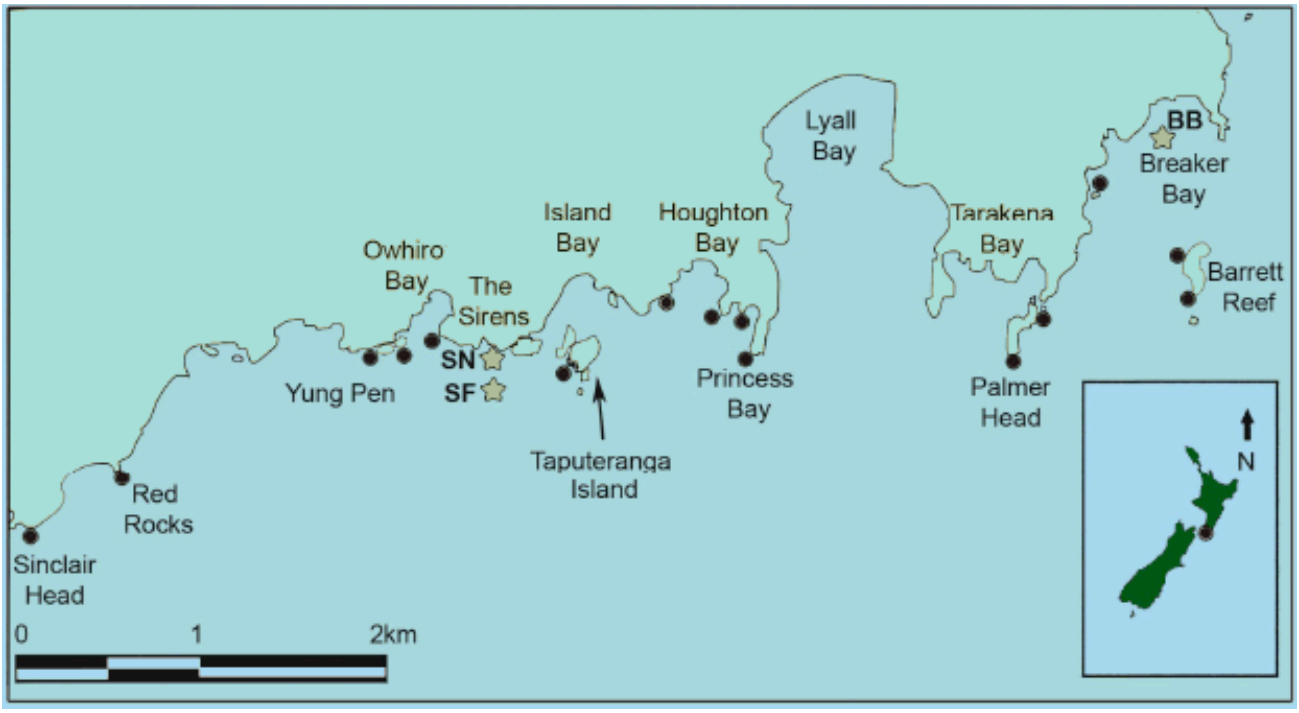


Fig. (1). The circles mark the positions of the fifteen sites surveyed for qualitative sponge biodiversity survey. The stars mark the three sites where the sponge assemblages were quantitative surveyed along the Wellington South Coast, New Zealand. These sites are: SN → Near Sirens; SF → Far Sirens; and BB →Breaker Bay.

these sites will be used to investigate temporal variation in sponge assemblages in the future.

MATERIALS AND METHODOLOGY

Study Site

Sponge assemblages were qualitatively sampled at eighteen sites along the south coast of Wellington, New Zealand (41" 21'S, 174" 45'E) (Fig. **1**). Three sites were chosen from the eighteen sites for quantitative analysis after the preliminary biodiversity survey. These were: Near Sirens (41°20'56.43"S, 174°45'52.46"E); Far Sirens (41°20'58.89"S, 174°45'54.26"E); and Breaker Bay (.41°19'58.28"S, 174°49'52.98"E). These sites were chosen as they were the most easily accessible sponge-dominated sites with continuous similar vertical bedrock habitat at a similar depth (8-10m) along the Wellington South Coast (WSC).

The study area has a south to south-east aspect, and is exposed to frequent high-energy south-easterly swells and storm episodes interspersed by north-westerly winds from which the shores are afforded relative protection by high cliffs. There are three separate water bodies that combine to form the Cook Strait current that flows past the study sites: the Southland Current (a mix of subtropical and sub-Antarctic water) that flows northward up the east coast of the South Island and westward into the Cook Strait, the East Cape Current (subtropical water) that flows south along the east coast of the North Island and then westwards into Cook Strait and the D'Urville Current (warm subtropical water) that flows from north to south from the Tasman sea [86]. Tidal currents in the region can reach speeds of up to 360 cms^{-1} [87]. Maximum wave heights can exceed 13 m during large storm events, while wave height (the highest one-third of the waves) can exceed 8 m [88]. This type of wave regime inevitably influences intertidal and subtidal community structure. The monthly mean sea temperature (**±SE**) between May 2008 and May 2009 was 15.67°C ± 0.03.

Qualitative Biodiversity Survey

Specimens were collected by SCUBA along 12 km of the WSC and at a depth of up to 18m between September 2007 and April 2009. Small specimens (approximately 1 cm^3) were collected from each sponge. Photographs of the sponges were taken *in situ* using an Olympus 5060 camera on the macro setting in an Olympus housing. Tissue preparations were prepared by sectioning. Sections were taken horizontally from the surface of the sponge and also vertically at a 90° angle through the specimen. The sections were dehydrated in absolute alcohol and then placed in Histoclear to clarify the tissue before being mounted on a microscopic slide using DePeX mounting medium. Spicule preparations were prepared directly on microscope slides by dissolving a small tissue sample (1 mm^3) in a few drops of concentrated nitric acid, which was gently heated by repeatedly pulling the slide across the flame of a Bunsen burner in a fume cupboard. Additional drops of acid were added to replace evaporated acid until the remaining spicules were clean. The slide was then rinsed with a few drops of absolute ethanol, dried and mounted using DePeX mounting medium.

Quantitative Survey

Six 0.5m^2 random quadrats (within the available vertical bedrock) were taken at three of the sites used for quantitative analyses (see above) in April 2008. All sponges were

surveyed in the same month to prevent temporal variation influencing the sponge assemblage patterns. Each quadrat was divided into 25 x 10 cm^2 sections and each section was photographed. Within each section the number of patches and the percentage cover of each species were recorded from the pictures. If a sponge overlapped two sections the patch was only counted once, however, the percentage cover was recorded for all sections it covered. Percentage cover was calculated using an overlaying grid of 100 dots for each separate photograph. The sponge density, percentage cover, mean species richness and Shannon index were calculated for each site.

The statistical package Plymouth Routines in Multivariate Ecological Research [PRIMER 6] was used to analyse the sponge assemblage data. Species accumulation curves in PRIMER were plotted for each site using UGE from DIVERSE [89, 90]. A one-way ANOVA was used to determine if there were any significant differences in sponge abundance and sponge percentage cover between sites. The abundance data from each site was pre-treated using a dispersion factor to down-weigh the impact of clumping of highly abundant species in relation to more evenly dispersed species. The three conditions that have to be met in order to use a dispersion factor are: that the data for each species are genuine counts not densities that have been standardised; replicates need to be independent within the sample groups; and that each replicate is of uniform size. The percentage cover data was log(X+1) transformed to down-weigh the influence of highly abundant species.

'Site' and 'Quadrat' were considered as a *priori* factors for the data analysis. A similarity matrix was then created using a zero adjusted Bray-Curtis similarity analysis to identify any similarities and differences between the sites and quadrats within sites. A dummy variable of one was used in a zero-adjusted Bray-Curtis analysis to prevent Bray-Curtis behaving erratically as values in some samples approached zero [91, 92].

Ordination was carried out using non-Metric Multi-Dimensional Scaling (nMDS) to determine the relationships between the replicates at the different sites, and between sites. Clusters identified by the SIMPROF test elucidated any significant similarities between replicates without the bias of the *a priori* groupings at the site level and were presented using MDS plots.

ANOSIM was used to determine if any differences in assemblage structure existed between sites. Where ANOSIM R=1, the groups are completely different and where ANOSIM R=0, they are exactly the same. Permutation tests are used to determine if significant differences exist between sites. Finally, SIMPER analysis was used on the dispersion-weighted data, and the square root transformed percentage cover data, to elucidate which sponge species were contributing to the similarities between and within sites and which species characterised each site.

To investigate how well the multivariate pattern based on sponge abundances (densities) reflected the multivariate pattern of sponge percentage cover, we used the RELATE routine within PRIMER, which compared the matrices using a Spearman rank correlation test. The significance level of the test was determined by 1000 permutations under the null hypothesis of no relationship between the similarity matrices.

RESULTS

Biodiversity Survey

We reported 65 sponge taxa from the WSC from 27 families and eleven orders of demosponges and four families and three orders of calcareous sponges (Table **1**). Of the species found, 38 have been identified to species-level with the remaining 26 identified to genus level, apart from one species that could only be identified to order (a Poecilisclerid). There were nine calcareous sponge species recorded, four species of *Clathrina*, two each of *Leucetta* and *Leucosolenia* and a *Sycon* species. The current status of the taxonomy of calcareous sponges combines many species together [93, 94], however, the species we have listed here as distinct, differ in combinations of colour (*in situ* and also when air dried), external morphology, spicule complement and skeletal structure. Also they coexisted in the same habitat type of vertical bedrock and under overhangs, therefore we are satisfied they are distinct enough to be considered separate species (even for those only identified to genus level).

Table 1. Sponge Taxa Listed in Alphabetical Order Recorded from the Wellington South Coast

Genus	Subgenus	Species	Authority
*Ancorina**		*alata*	Dendy, 1924
Ancorina	*c.f.*	*novazelandiae*	Dendy, 1924
*Callyspongia**		*bathami*	Bergquist & Warne, 1980
Callyspongia	*c.f.*	*ramosa*	Gray, 1843
*Callyspongia**		*spp.*	Bergquist, 1961
*Chelonaplysilla**		*violacea*	Lendenfeld, 1883
Chondropsis		*sp.*	
*Chondropsis**		*topsenti*	Dendy, 1895
*Cinachyra**		*sp.*	

(Table 1) Contd…..

Genus	Subgenus	Species	Authority
*Clathria**		*sp.*	
*Clathrina**		*sp. 1*	
*Clathrina**		*sp. 2*	
*Clathrina**		*sp. 3*	
*Clathrina**		*sp. 4*	
*Cliona**		*sp.*	
Crella	*Pytheas*	*incrustans*	Carter, 1885
*Crella**		*sp.*	
*Darwinella**		*oxeata*	Bergquist, 1961
*Dendrilla **		*rosea*	Lendenfeld, 1883
*Dysidea **		*sp. 1*	
*Dysidea**		*sp. 2*	
*Halichondria**	*Halichondria*	*moorei*	Bergquist, 1961
*Haliclona**	*c.f.*	*venustina*	Bergquist, 1961
*Haliclona**		*sp.*	
*Haliclona**	*Haliclona*	*sp.*	
Halisarca		*dujardini*	Johnston, 1842
*Halisarca**		*sp.*	
Hamigera		*macrostrongyla*	Bergquist & Fromont, 1988
*Hymeniacidon**		*perlevis*	Montagu, 1818
*Iophon**		*sp.*	
Iophon		*minor*	Brøndsted, 1924
Iophon		*proximum*	Ridley, 1881
Latrunculia	*Biannulata*	*wellingtonensis*	Alvarez *et al*., 2002
*Leucetta**		*sp. 1*	
*Leucetta**		*sp. 2*	
*Leucosolenia**		*echinata*	Kirk, 1896
*Leucosolenia**		*sp.*	
*Mycale**		*sp.*	
*Oscarella**		*lobularis*	Schmidt, 1862
*Oscarella**		*sp.*	
Plakina		*monolopha*	Schulze, 1880
*Plakina**		*trilopha*	Schulze, 1880
Polymastia	*c.f.*	*lorum*	Kelly-Borges & Bergquist, 1997
*Polymastia**		*granulosa*	Brøndsted, 1924
Polymastia		*hirsuta*	Bergquist, 1968
Polymastia	*c.f.*	*massilis*	Carter, 1886
Polymastia		*fusca*	Bergquist, 1961
Polymastia	*c.f.*	*aurantium*	Kelly-Borges & Bergquist, 1997
Polymastia		*croceus*	Kelly-Borges & Bergquist, 1997
Psammocinia		*sp.*	Cook & Bergquist, 1996
Raspailia	*Raspailia*	*topsenti*	Dendy, 1924

(Table 1) Contd…..

Genus	Subgenus	Species	Authority
*Stelletta**		*sp.*	
Stelletta	*c.f.*	*purpurea*	Ridley, 1884
Stelletta	*c.f.*	*arenaria*	Bergquist, 1968
*Strongylacidon**		*conulosa*	Bergquist & Fromont, 1988
Suberites		*cupuloides*	Bergquist, 1961
*Sycon **		*sp.*	Grace & Grace, 1976
*Tedania **		*diversirhaphidophora*	Brøndsted, 1923
*Tethya**		*aurantium*	Pallas, 1766
*Tethya**		*berquistae*	Hooper, 1994
*Tethya **		*burtoni*	Sarà & Sarà, 2004
*Thorecta**		*reticulata*	Cook & Bergquist, 1996
Thymosia		*sp.*	
*Unidentified Poecilisclerid**			
*Xestospongia**		*sp.*	Lawson *et al*., 1984

* Indicates taxa was also found during the quantitative survey.

Quantitative Survey

Forty-three species of sponge species were found across the three quantitative sites. Results of species accumulation plots predicted that eighteen quadrats were sufficient to record the majority of species from the three sites combined and that the six quadrats were sufficient for each of the sites separately (Figs. **2** and **3**). All three sites had a similar mean number of species per quadrat (± SE); Breaker Bay 19.5 ± 0.99; Far Sirens 19.17 ± 1.40 and Near Sirens 18 ± 1.37. The Shannon diversity indices (H) were also similar between sites; Breaker Bay 2.49 ± 0.05; Far Sirens 2.34 ± 0.09 and Near Sirens 1.92 ± 0.06.

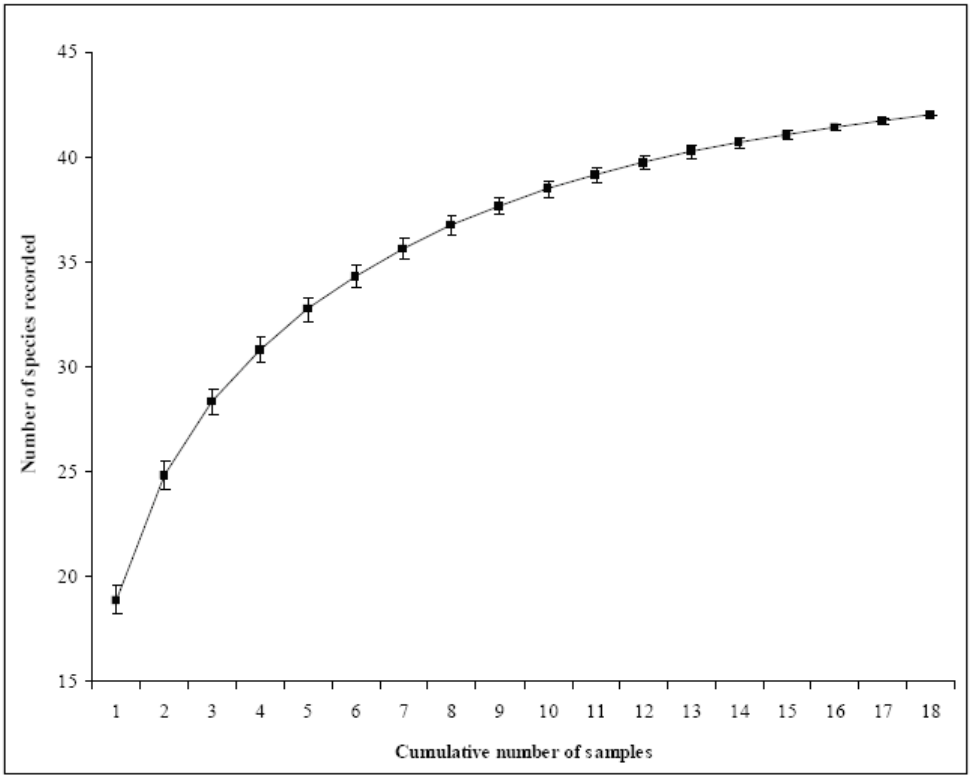


Fig. (2). Species accumulation curves (using the UGE method [90]) for the Wellington South Coast combining data from Breaker Bay, Far Sirens and Near Sirens replicates.

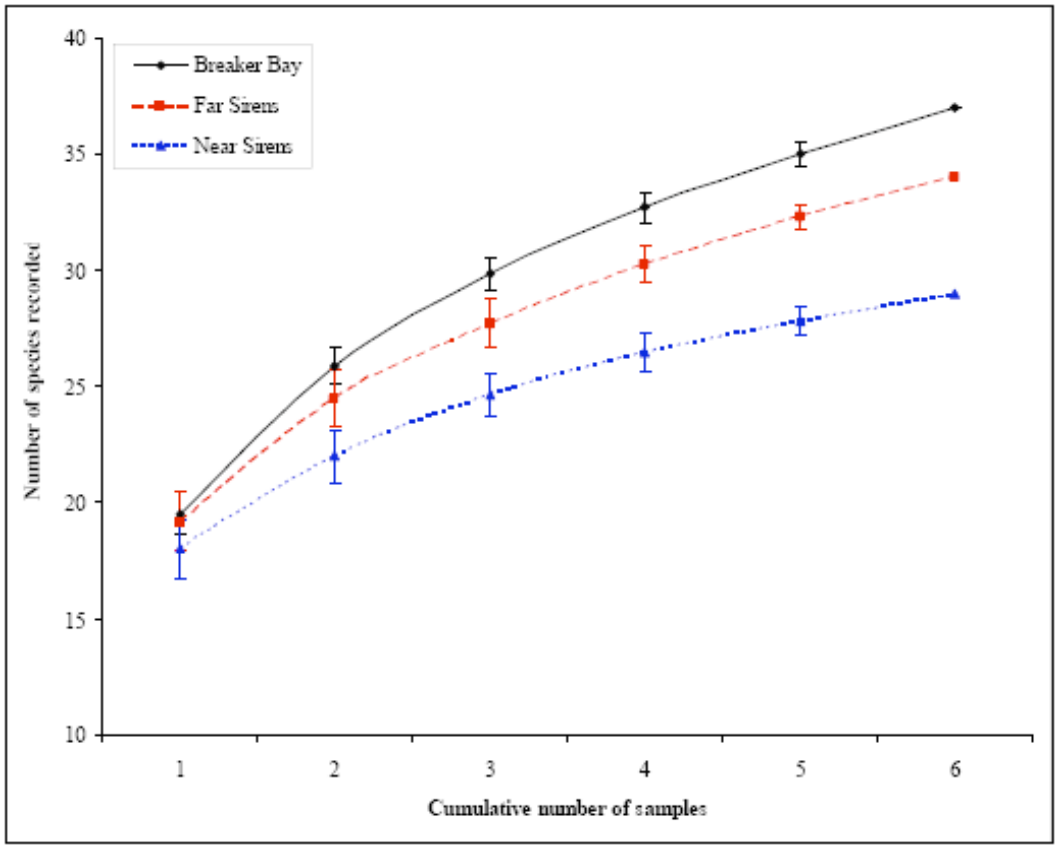


Fig. (3). Species accumulation curve (UGE method [90]) comparing Breaker Bay, the Far Sirens and the Near Sirens sites.

The calcareous sponges of the genus *Clathrina* were the most abundant sponges, particularly at the Near Sirens site. *Oscarella* sp. and *Halisarca* sp. were also abundant, in particular at both Sirens sites (Fig. **4**). *Ancorina alata* and *Stelletta* sp. dominated the sites in terms of percentage cover (Fig. **5**), while *Clathrina* sp. *Halisarca* sp., *Leucosolenia* sp. and *Plakina trilopha* also had high percentage cover, particularly at the Near Sirens site.

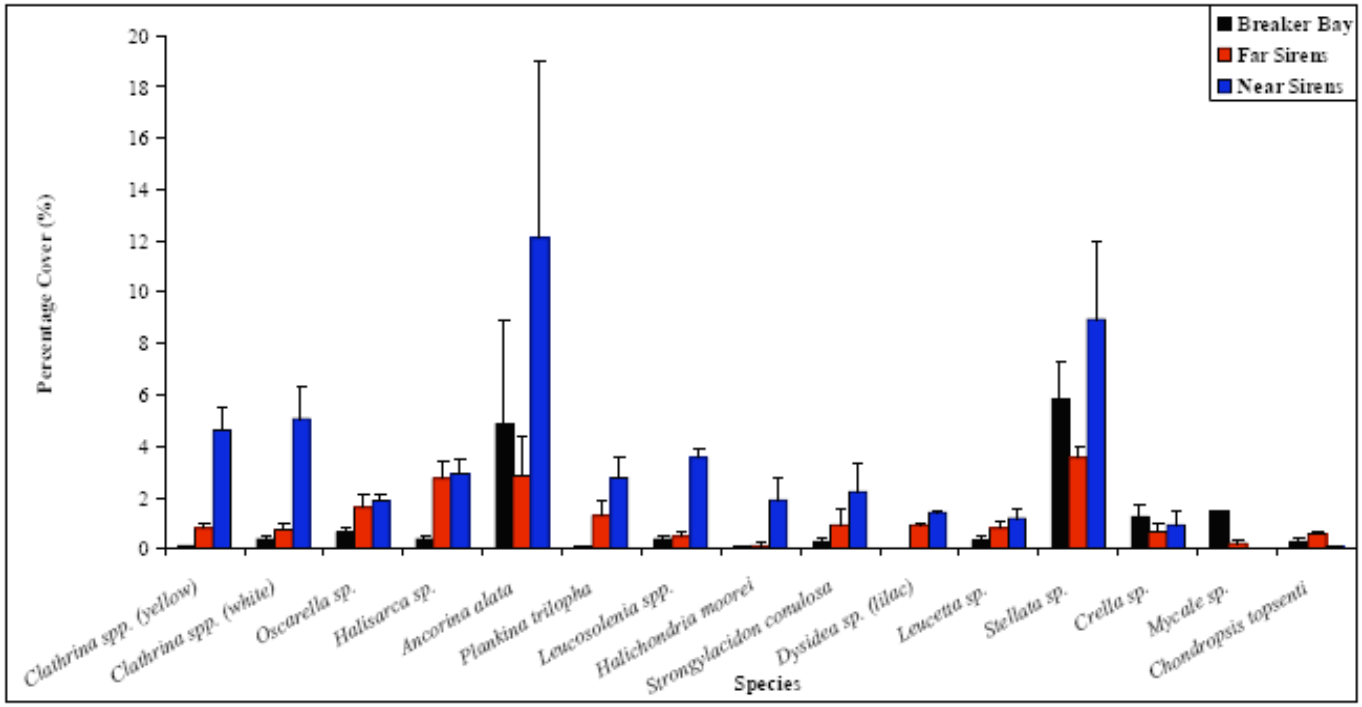


Fig. (4). Sponge density (m^{-2}) at Breaker Bay, the Far Sirens and the Near Sirens sites for the fifteen most abundant sponge species.

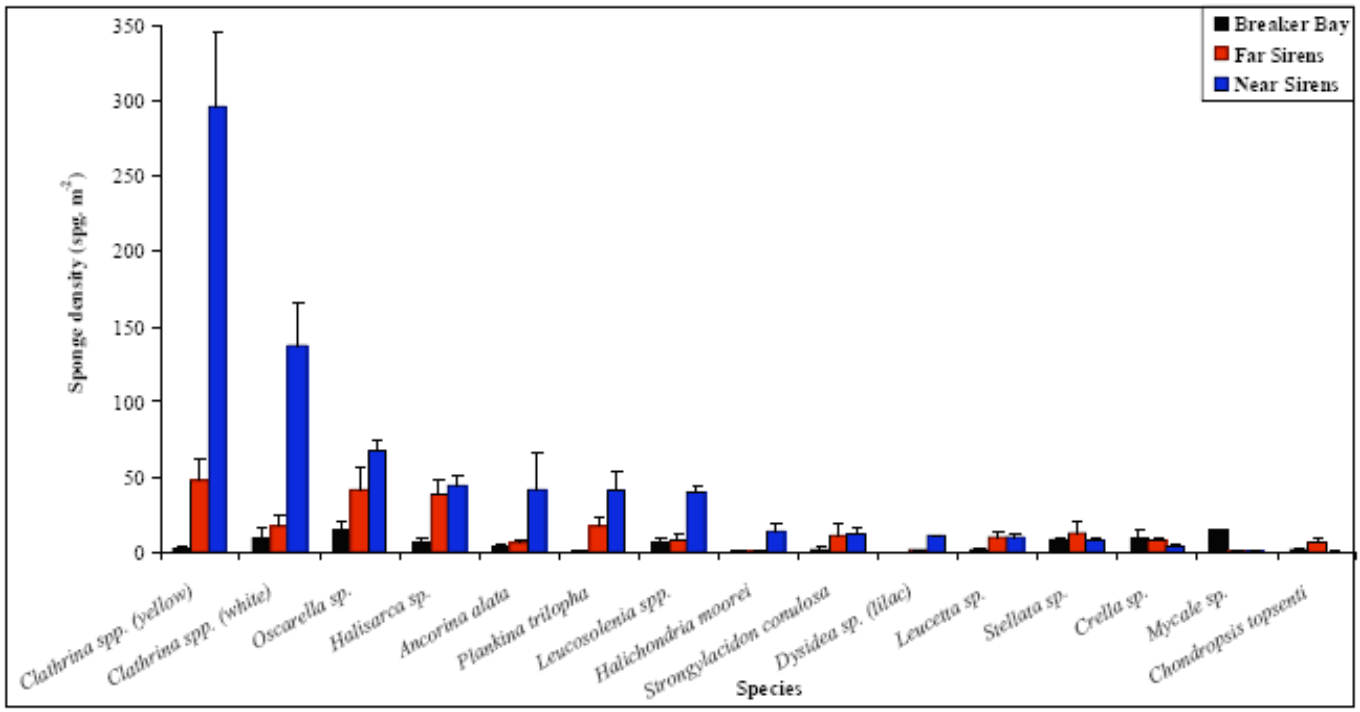
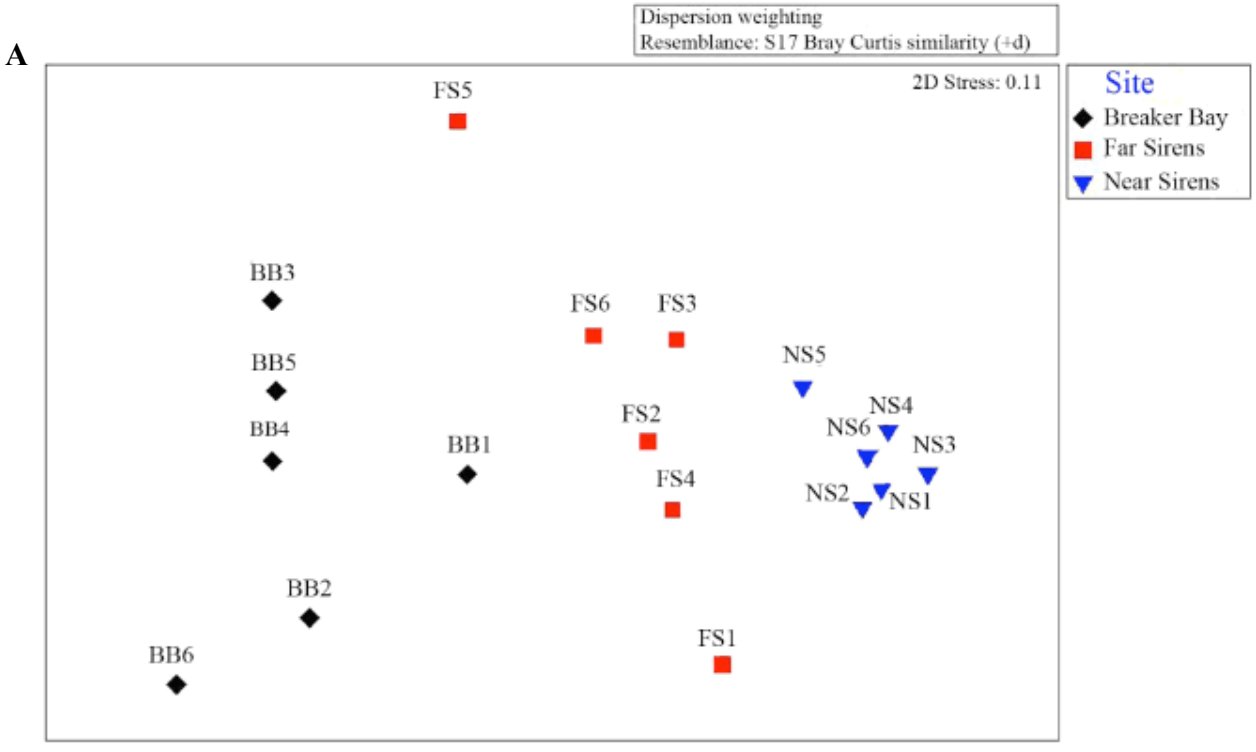


Fig. (5). Percentage Cover for the fifteen most abundant sponge species at Breaker Bay, the Far Sirens and the Near Sirens sites.

The results of the MDS plots for percentage cover and density separates the sites, and significant (P<0.005) clusters were identified using SIMPROF. Clusters overlaid from the density data that had been down-weighted using a Dispersion Index indicated that the Near Sirens quadrats, and all but one of each of the Far Sirens quadrats, formed a Sirens group, while the Breaker Bay replicates plus one of the Far Sirens replicates also formed a significantly differentiated cluster (P<0.05) (Fig. **6**).

The percentage cover data, which were log(X+1) transformed, were significantly grouped by SIMPROF, with the Breaker Bay replicates, together with one replicate form the Far Sirens, forming one cluster, and the Near Sirens



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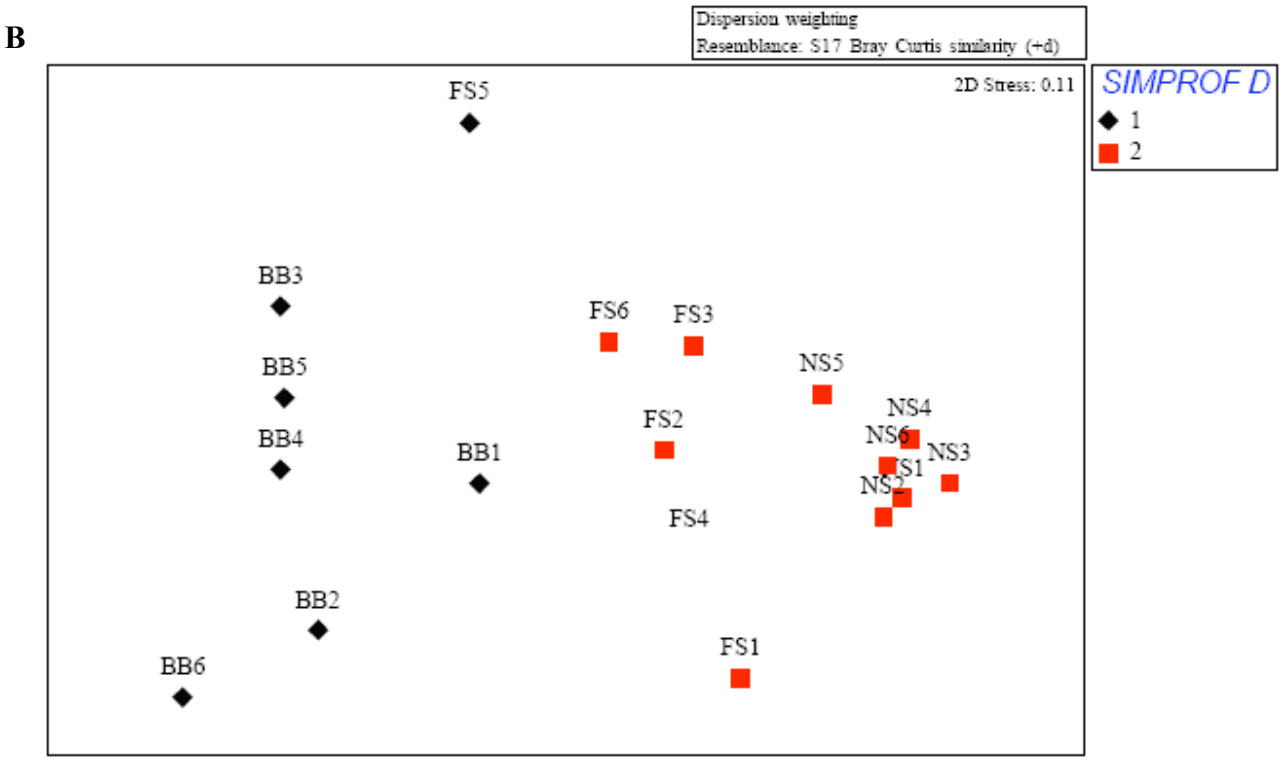
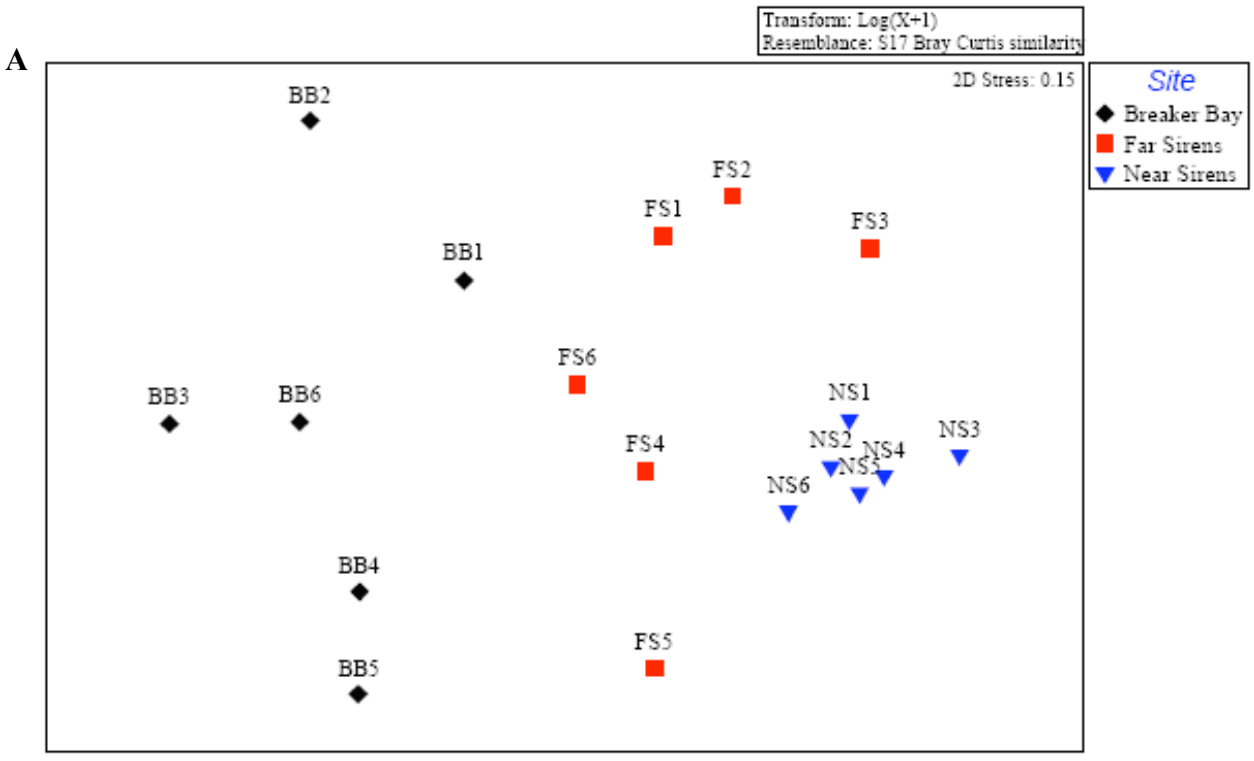


Fig. (6). Non-metric multidimensional scaling ordinations (nMDS plots in PRIMER) of the sponge assemblages using zero adjusted Bray-Curtis matrices from the Far Sirens (FS), Near Sirens (NS) and Breaker Bay (BB) based on abundance (**A**) and **B**) with SIMPROF significant clusters (P<0.05; 1000 Random permutations).

replicates forming another cluster. The Far Sirens data was split into two further significant subgroups (P<0.05) (Fig. **7**). There were large differences between the replicates at the Far Sirens quadrats (they were spread over three significant clusters), while the quadrats for the Near Sirens site were more similar to each other.



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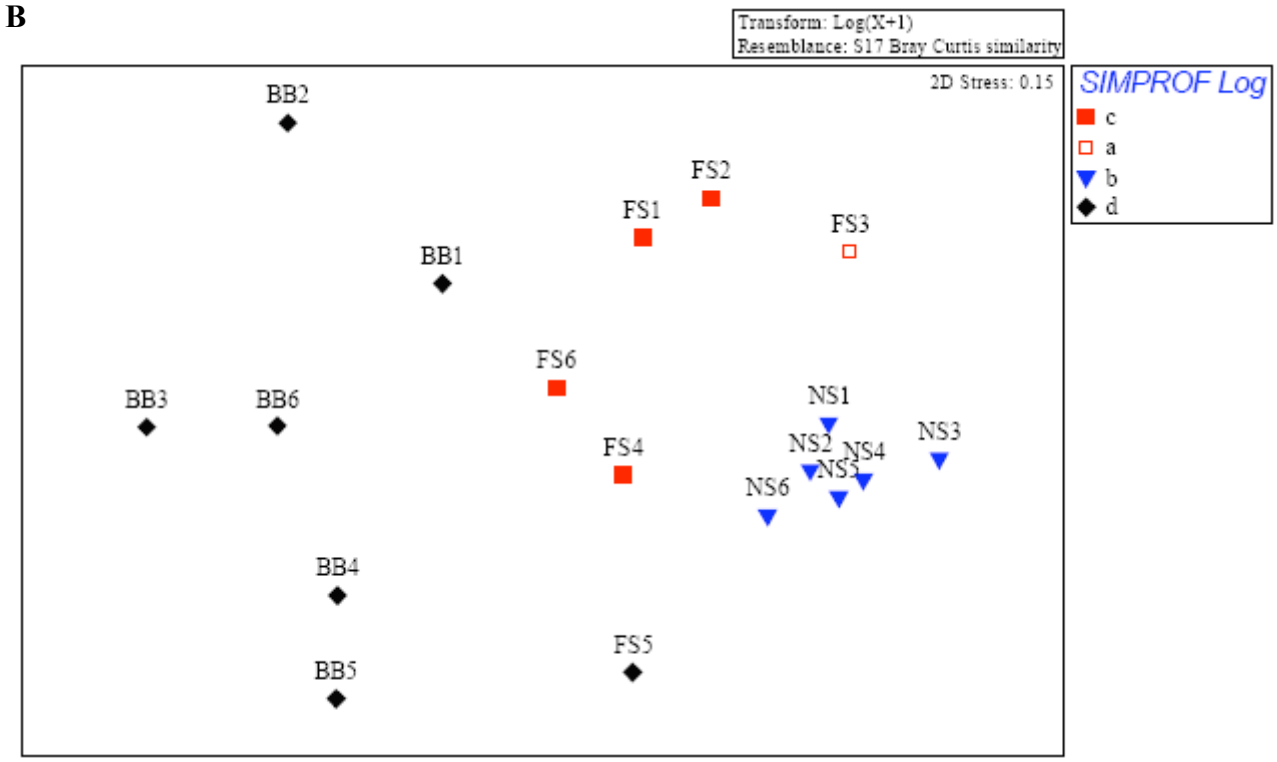

Fig. (7). Non-metric multidimensional scaling ordinations (nMDS plots in PRIMER) of the sponge percentage cover transformed using square root transformation and a Bray Curtis similarity matrix (**A**) showing groups and then (**B**) showing the significant clustering ($P<0.05$) using SIMPROF.

ANOSIM showed that there were significant differences between all three sites based on the abundance dispersion-weighted data (Global test R=0.765 P=0.001 with 9999 permutations). Breaker Bay and the Near Sirens sites were very different (R= 0.985 P=0.002). Far Sirens and Near Sirens (R=0.626 P-=0.002) were significantly different, but had higher similarity than the other pairwise site comparisons; the Breaker Bay and Far Sirens were significantly different (R=0.733 P=0.002).

Table 2. SIMPER Analysis of the Percentage Similarity within and between Sites in Relation to Sponge Abundance (Log Transformed)

% Similarity	Far Sirens	Near Sirens	Breaker Bay
Far Sirens	59.51		
Near Sirens	56.04	75.1	
Breaker Bay	47.45	36.42	55.07

The log(X+1) transformed percentage cover data used for the ANOSIM test showed that there were significant differences between all three sites (Global Test R= 0.589 P=0.001 with 9999 permutations). Breaker Bay and the Near Sirens were very different (R= 0.937, P=0.002). The differences between the assemblage percentage cover at the Far Sirens site was significantly different from the Near Sirens and the Breaker Bay site (R= 0.457 and R=0.478 respectively both at P=0.002). There was less difference identified from the percentage cover data than from the sponge density data, however, the differences in all cases were significant.

SIMPER analysis showed a similar pattern for both the percentage cover and density data (Tables **2-4**). The Near Sirens sponge density replicates were most similar to other replicates at this site (62-75% similarity) and least similar to Breaker Bay replicates (18-36%) (Tables **2** and **3**). SIMPER analysis, using the percentage cover data, showed less variability within and between sites, however, the Breaker Bay site was less similar (40.99 Near Sirens and 49.36 Far Sirens) to the Sirens sites than the variation between the Breaker Bay replicates (Table **4**). *Stelletta* sp. and *Ancorina alata* were the main species driving the differences in percentage cover of sponges within and between sites. As shown previously (Fig. **6**), when the data is not down-weighed with a Dispersion Index, the calcareous sponges dominate the abundances, particularly at the Near Sirens

Table 3. SIMPER Analysis of the Percentage Similarity within and between Sites in Relation to Sponge Abundance (Dispersion Index Down-Weighted)

% Similarity	Far Sirens	Near Sirens	Breaker Bay
Far Sirens	41.33		
Near Sirens	32.08	62.83	
Breaker Bay	26.55	17.59	38.65

sites. When the abundance values are adjusted using down-weighting, the calcareous sponges (especially the *Clathrina spp*.) are the main contributors to the differences between the Near Sirens and the other two sites. *Halisarca* sp. and *Mycale* sp. were the main contributors to the differences between Breaker Bay and the Far Sirens sites with *Halisarca* sp. being the main species present across all the replicates at the Far Sirens and *Mycale* sp. being the characterising species for the Far Sirens replicates.

Table 4. SIMPER Analysis of the Percentage Similarity within and between Sites in Relation to Sponge Percentage Cover

% Similarity	Far Sirens	Near Sirens	Breaker Bay
Far Sirens	56.55		
Near Sirens	53.96	69.73	
Breaker Bay	49.36	40.99	54.25

RELATE was used to compare the rank correlations between the similarity matrices (which the MDS plots are a visual representation of) for abundance and percentage cover. There was a highly significant correlation ($R=0.816$ and $P<0.001$) between the percentage cover and density data therefore the patterns they show are very similar.

DISCUSSION

This work provides the first quantitative survey of sponge assemblages on the Wellington South Coast, New Zealand. We reported sixty-five different sponge species from 27 families and eleven orders of demosponges and four families and three orders of calcareous sponges, which is relatively high in comparison with other similar-sized sampling areas from temperate regions including the few areas sampled quantitatively in New Zealand (Table **5**). Forty-three of the species were found within the quantitative survey with a mean of 18.89 ± 1.25 species per quadrat across all three sites, with no significant differences in number of species present between sites. Percentage cover and sponge density were significantly different between all sites, as was assemblage structure between some site pairs.

Sponge Biodiversity

There are over 700 known sponge species from the New Zealand biogeographic region [95]. This is high in relation to other well-known temperate areas of similar size, such as the UK and Ireland where approximately 400 species have been described (8, 95), and these areas have been much more extensively studied. Within the 700 known species in New Zealand waters over 95% are considered to be endemic at the national level [95]. There have been few intensive regional surveys and most reports of sponge diversity are in grey literature. Examples of these include: 57 species recorded from the Pariokariwa reef, North Taranaki [84]; 215 species recorded between North Cape and Cape Reinga at the very tip of the North Island [96]; and 84-170 species recorded from the Cape Rodney to Okari Point Marine Reserve (about 90 km north of Auckland) [80, 97]. It is hard to compare these other New Zealand values with the values from the WSC directly, as they sampled different habitat types with variable levels of sampling effort, however, these results combined with our study suggests that there are multiple areas of high sponge richness around the North Island of New Zealand. Currently, there are no known regional data sets for sponge richness from the South Island of New Zealand for comparison.

The sponge species present on the WSC are likely to be a mixture of North and South Island species as the WSC is an area where three currents meet [86]. The dynamic high-energy current environment may result in a sponge assem-

Table 5. Temperate Sponge Species Richness. All Values Shown are taken from a Depth of 12-18m Over Similar Sized Sampling Areas on Bedrock (Updated from (2)). Although other Sponge Richness Figures are Available they are not Directly Comparable due to Varying Sampling Effort and Habitat Type

Location	Species Richness	Source
New South Wales (Australia)	82	Roberts *et al.* (2006) [116]
Lough Hyne (Ireland)	77	Bell & Barnes (2000) [2]
Skomer Island (Wales, UK)	57	Bell *et al.* (2006) [117]
Wellington (New Zealand)	46	This study
Pariokariwa Reef, Taranaki (New Zealand)	35	Berman (unpublished)
Goat Island, Auckland (New Zealand)	34	Ayling (1976) [118]
Goat Island, Auckland (New Zealand)	33	Battershill (1987) [119]
Perth (Australia)	33	McQuillan (2006) [120]
Fiordland (New Zealand)	21	Smith (unpublished)
Cork (Ireland)	13	Bell & Barnes (2000) [2]
Sussex (England, UK)	12	Bell & Barnes (2000) [2]
Cornwall (England, UK)	6	Bell & Barnes (2000) [2]

blage composed of species at the northern and southern limits of their distributions, such as has been reported for macroalgae species [98]. The sponge species pool on the Wellington South Coast may be linked to the biographic transition zone for cold (South Island) and warm (North Island) species, although further comparisons between regional species composition data is required to confirm this.

Quantitative Sponge Survey

The sites used for quantitative analysis were chosen as they appeared to be similar to each other (similar depths and substrata), such that they could be considered replicates for the Wellington region for a larger temporal investigation. Despite looking similar on first examination, the MDS plots and the ANOSIM for both density and percentage cover data indicated clear differences between all three sites. This difference is also supported by the univariate data as the Near Sirens had significantly higher density of sponges and percentage cover than the other two sites. The other two sites also had less overlap in assemblage composition, which was shown by the SIMPROF cluster analysis placing one of the replicates from Breaker Bay within the Far Sirens Group and one of the Far Sirens quadrats into a separate group of its own. This can be explained by the high levels of within site variability, particularly at Breaker Bay, shown in the MDS plot, compared to the other sites. However, the SIMPROF grouped all the Breaker Bay replicates together, and they were significantly different from the Sirens sites. The down-weighted abundance data reduces the 'error' variance attributable to highly variable species and reduces the noise caused by species that have clumped distributions. There was a significant difference in the percentage cover of sponges between Breaker Bay and the two Sirens sites, while the two Siren's sites had similar percentage cover.

The RELATE test showed that the data for percentage cover and density were highly correlated across the three sites. The similarities between replicates (irrespective of measurement type) are likely to be driven by a common set of environmental drivers, therefore explaining the similar site patterns obtained for species with higher densities as for species with higher percentage cover as they both appear to respond in a similar way.

All sites had higher between site variability than within site variability according to the SIMPER analysis. Breaker Bay had the highest within site variability, while the Near Sirens site had the lowest within site variability for both percentage cover and sponge density data. Both of the Siren's sites were also more similar to each other than to the Breaker Bay site. The Sirens sites are approximately 200 m apart, while the Breaker Bay site is about 6 km away from the other two sites, so this result is perhaps not surprising. The environmental drivers are likely to be different in terms of the nutrient content of the water between the Sirens sites and Breaker Bay, particularly as there is low organic water content in the waters along the WSC extending from the Wellington Harbour, which is closest to Breaker Bay. The WSC waters have low levels of organic matter including total particulate and dissolved organic matter, when compared with other temperate regions, however, seston values are particularly low compared to other similar temperate areas. These low levels of seston are thought to limit the number of other suspension feeders such as mussels, which are very rare on the WSC [99-101]. Sponges can phagocytise the smallest fractions of the nano- and picoplankton (particles <2 μm) including bacteria and possibly viruses [64, 102, 103]. Therefore even though the waters on the WSC may have low levels of organic material, particularly its seston content, the sponges may be able to exploit the low levels of nutritional content in the form of viruses and bacteria and proliferate where other suspension feeders cannot survive.

Other studies of sponge assemblage spatial variation in temperate waters have also shown considerable spatial variation between locations [104, 105]. The factors likely to be responsible for this variation include larval supply, recruitment, physical disturbance and biological interactions [106]. The South coast is a very active hydrodynamic area and variations in the energy reaching the sites and scouring away near shore sponge assemblages is likely to be high. The reasons for spatial variation in sponge species could be due the naturally patchy distribution of sponge species and their short range dispersal patterns that result in the formation of local clusters of specific species. For example, the budding of *Stelletta sp.* and *Ancorina alata* would explain their local high percentage cover at some of the sites [107].

The most abundant sponges by density and percentage cover were encrusting species of the genus *Clathrina*. *Clathrina spp.* are calcareous sponges that are found all over the world, however, they are difficult to identify [108]. Other calcareous sponges were also among the top fifteen most abundant species including *Leucosolenia spp.* and *Leucetta sp*. These species are also found in other sites with high sponge richness on the North Island of New Zealand including the Pariokariwa reef off North Taranaki, White Island and Volkner Rocks in the Eastern Bay of Plenty and the Poor Knights off the East coast of Northland, but they are much rarer than those found on the WSC, where they dominate the sponge assemblages.

Calcareous sponges, which dominate by abundance on the WSC, have been reported to increase in abundance and percentage cover in winter, with a die-off in the summer in other temperate locations, which is the opposite pattern to many of the demosponges [109-112]. Our survey was carried out in April, which is the autumn in New Zealand, and therefore the waters are just starting to cool. It will be interesting to see if calcareous sponges dominate the assemblages throughout the year or if they have seasonal changes in abundance as has been reported from other locations. Calcareous sponges are thought to be short-lived (less then one year in some cases) in comparison with demosponges that can live much longer, some up to hundred of years [110, 113, 114]. *Clathrina clathrus* has been shown to have a hypo-active phase over winter allowing it to control its metabolism and maintain biochemical homeostasis over the winter months [115].

CONCLUSION

The Wellington South Coast supports a diverse sponge assemblage with up to 500 sponges per m^2, covering over 50% of the substratum at some sites. Although the species density is similar across the three sites the species com-

position, their abundances and percentage coverage vary significantly. All the sites are atypically dominated by calcareous species, in particular of the genus *Clathrina*, which appears to be unusual for the North Island or New Zealand generally. Reasons for the high abundance and density of *Clathrina spp.* could be due to their ability to be hypo-active during the winter months and therefore be spatially dominant at a time when other demosponges and other filter feeders might be regressing due to less food in the water and colder temperatures.

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