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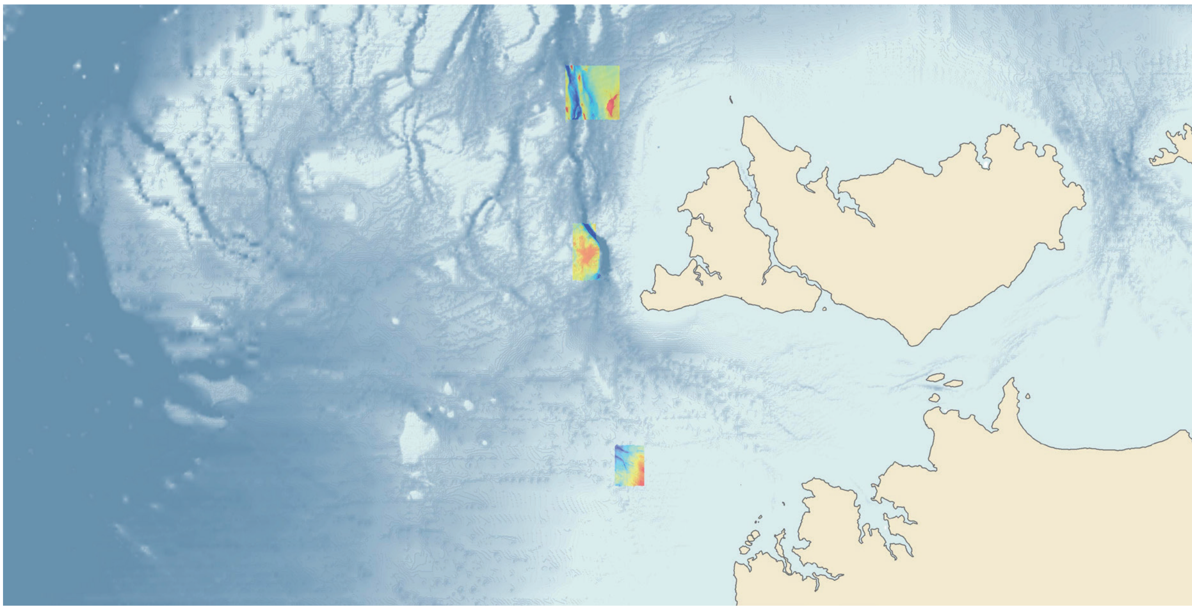

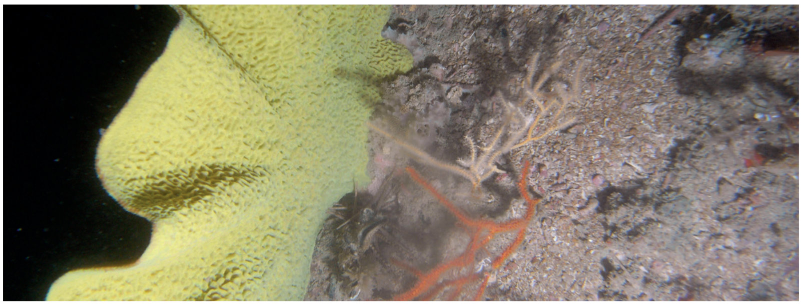

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The ecology and morphology of sponges and octocorals in the northeastern Joseph Bonaparte Gulf

Tegan Kelly & Rachel Przeslawski

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by

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Contents

Executive Summary

The Joseph Bonaparte Gulf (JBG) is an offshore area in northern Australia, with active petroleum exploration and infrastructure development. The Van Diemen Rise, an area of raised banks and channels in the northeastern region of the JBG, has been included for protection as part of the Oceanic Shoals Commonwealth Marine Reserve. However, baseline information for much of this area is lacking, including spatial and environmental patterns of biological communities. This study uses still imagery of the sea floor in four study areas across the Van Diemen Rise, collected during two seabed mapping surveys conducted by Geoscience Australia and the Australian Institute of Marine Science in 2009 and 2010. Based on these analyses benthic communities are characterised, and important species and morphological groups are compared with a number of abiotic variables. In so doing, a preliminary assessment is given as to which abiotic variables make the most appropriate surrogates for characterising benthic communities in the region. A number of variables are found to correlate significantly and strongly with some of the biological groups determined in this study. Pheophytin, Si/Al and mud content correlate with the large habitat forming species *Mopsella* sp., *Ianthella* sp. and *Xestospongia* sp. respectively. Backscatter signals from multibeam sonar surveys correlate very strongly with depth and also to some degree with a number of the functional growth forms of sponges. Based on the positive results of this preliminary data investigation, it is recommended that non-linear modelling and robust multivariate analyses be applied to the data set to investigate more complex relationships. This study provides baseline information on the ecology and morphology of key habitat-forming organisms in the northeastern Joseph Bonaparte Gulf which will contribute to marine monitoring programs for reserve management and environmental impact assessments for industry activity.

1. Introduction

The characterisation of Australia's marine biodiversity is important from both a conservation and industrial perspective. Despite the potential contradictory interests of these perspectives, both require knowledge of the distribution of key marine organisms and communities as well as an understanding of broad biodiversity patterns.

A network of Commonwealth Marine Reserves (CMRs) has been developed throughout Australia's Exclusive Economic Zone (EEZ) in order to manage Australia's marine environment as directed in an Oceans Policy by the Australian Government in 1998 (Harris et al. 2007). Marine protected areas such as the CMRs should abide by the CAR principle, i.e. they should exhibit the following:

- Comprehensiveness ("includes the full range of ecosystems recognised at an appropriate scale within and across each bioregion"),
- Adequacy ("the maintenance of the ecological viability and integrity of populations, species and communities"), and
- Representativeness (reasonably reflect the biotic diversity of the marine ecosystems from which they derive") (ANZECC 1999).

The CAR principle means it is necessary to characterise bioregions and benthic habitats throughout Australian waters, in order to select the appropriate locations for reserves

One of the key aspects of marine management after the establishment of a reserve is to implement monitoring programs. Such programs are useful to detect change in biological communities or physical environments so that management plans can be appropriately developed and updated. However, monitoring programs require baseline data which can then be compared with data collected from future sampling to detect change.

In addition, industrial or commercial activity in Commonwealth waters often requires an environmental impact statement (EIS). The need for an EIS is detailed in the *Environmental Protection and Biodiversity Conservation Act 1999* and depends on the proposed activity (e.g. seismic exploration, drilling) and the region. One of the main components of an EIS is to assess potential impacts to significant biological communities or species in the region. In order to do this, knowledge of the presence and distribution of benthic organisms is crucial.

Unfortunately, marine benthic systems are often difficult and expensive to study and have poor historical coverage compared to terrestrial equivalents (McArthur et al. 2010). For this reason, seafloor habitat studies are often conducted instead using abiotic surrogates that correlate with biodiversity or other community assessments (Huang et al. 2011, Przeslawski et al. 2011). When natural resource management decisions must be made based on minimal biological information, surrogacy becomes particularly important. It is therefore useful to understand the strength and direction of relationships between abiotic and biological variables, with strong relationships indicating potential surrogates. For example, Cleary et al. (2005) compared the diversity and community composition of benthic taxa in the reefs across the Spermonde Shelf, southwest Sulawesi, Indonesia and found that most of the variation in sponge and coral diversity could be explained by models using distance offshore, depth and exposure, with depth being revealed as the most important parameter.

1.1 STUDY AREA AND SURVEYS

The Joseph Bonaparte Gulf (JBG) is an area of active petroleum exploration and infrastructure development, with existing gas and oil fields and pipelines and an ongoing acreage release program (Geoscience Australia 2011). The area is also of interest for Carbon Capture and Storage (CCS) potential, and some of the first Australian acreage areas for CCS were released here in 2009. In addition to these interests, the Van Diemen Rise, an area of raised banks and channels in the north eastern region of the JBG, is part of the Oceanic Shoals Commonwealth Marine Reserve.

In collaboration with the Australian Institute of Marine Science, Geoscience Australia undertook intensive seabed mapping surveys in 2009 and 2010 across the Van Diemen Rise. Detailed geological and biological data and samples were collected from a range of habitats across four study areas in a north-south transect (Figure 1.1). These study areas are representative of the eastern JBG and broader north Australian shelf region. Detailed descriptions of the methods and techniques used for data collection and sampling can be found in the post-survey reports (Heap et al. 2010; Anderson et al. 2011). In brief, the study areas were mapped with multibeam sonar, and sub-surface data was collected using a sparker sub-bottom profiler. The high-resolution bathymetry, backscatter (seabed reflectance) and sub-bottom profiles facilitated the selection of priority stations for sampling. At each station, a suite of operations were conducted, typically including towed underwater video, sediment grabs, and benthic sleds. At several stations, CTD (conductivity, temperature, and depth), vibrocores, oceanographic moorings, and rotary cores were also deployed. As a result, a broad suite of geophysical, oceanographic, sedimentological, geochemical and biological data and samples were collected.

Some ecological work has been carried out on this survey data, comparing various biological measures with multiple environmental variables (Przeslawski et al. 2011). The biological measures included species richness, biomass, community structure, video-based habitat classification and the presence or absence of coral/sponge gardens. The environmental variables considered included:

- Grain-size (mud and gravel content)
- Pheophytin
- Total reactive chlorin
- Depth
- Nitrogen isotopes
- Iron
- Si/Al
- Al
- Mn
- %S
- FeSAl

These analyses found very weak, though sometimes statistically significant, correlations. The reasons for this are unclear but may be due to gradational or patchy species assemblages or masking by stronger environmental regulators (Przeslawski et al. 2011).

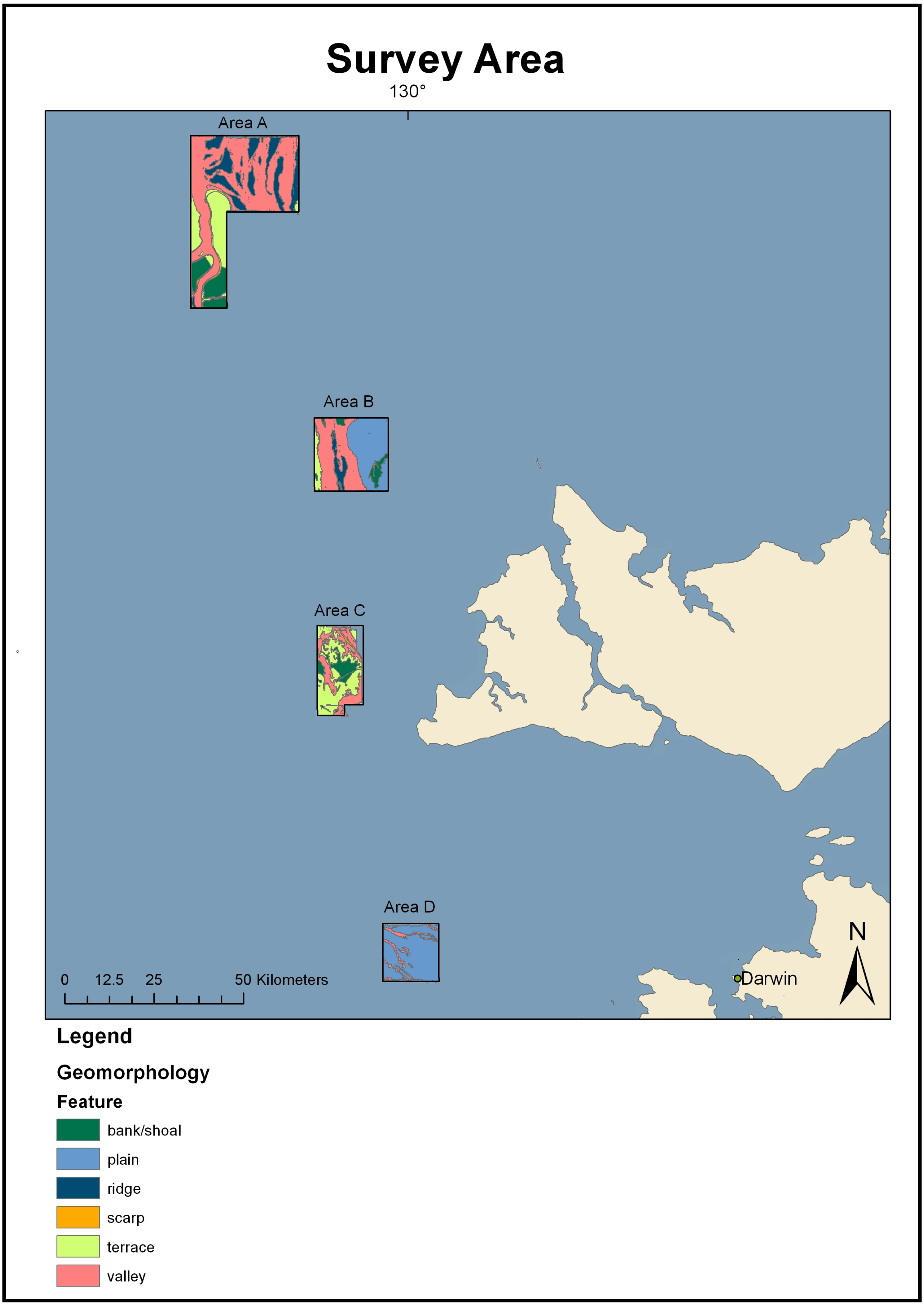

Figure 1.1: *Study region showing the location of the survey areas relative to the city of Darwin. Geomorphic features were identified from high-resolution bathymetry obtained from multibeam sonar collected on surveys GA-322 and 325 (Przeslawski et al. 2011).*

1.2 STUDY ORGANISMS

Traditional biological metrics such as species richness and community composition/structure can often be time-consuming to generate and require taxonomic expertise. As an alternative to these metrics, this study aims to determine whether abiotic factors correlate to morphological groups of octocorals and sponges. Two taxonomic groups are of particular interest in this study due to their abundance in the survey area and their ability to provide habitat to other organisms: octocorals (subclass Alyconaria in phylum Cnidaria) and sponges (phylum Porifera).

Octocorals include the soft corals and seapens, as well as gorgonians and sea whips. Octocorals form colonies of filter-feeding polyps with 8-fold symmetry. Gorgonians and sea whips secrete a skeleton made of a rigid but flexible substance called gorgonin (Edgar 2001) that can persist after mortality. It is this skeleton that classifies them as habitat-forming taxa and makes them a taxon of interest here. Gorgonians have an arborescent morphology, with often anastamosing branches forming in a single plane to produce a fan-like shape. In contrast, sea whips consist of only a single branchless stem.

Sponges are also sessile filter feeders, whose skeletal elements include a network of fibrous protein known as spongin plus small spicules of calcium carbonate or silica (Edgar 2001). Sponges grow in a variety of morphologies and have been classified in the following major forms (Schönberg unpublished):

- *Erect Laminar*: Sponges with a somewhat flattened erect body.
- *Erect Branching*: Sponges with branches which may be thick or thin, separate or joined, may vary in the location of origin on the stem, how they are distributed and how the tips end.
- *Simple Erect*: Sponges with noticeably higher than wide morphology and no branches.
- *Stalked erect*: Sponges consisting of a distinct stalk supporting a somewhat globular body.
- *Simple Massive*: Sponges that have a lumpy or amorphous shape with some sort of fleshy body.
- *Hollow Massive*: Sponges in the shape of a vase, cup or barrel with roughly radial symmetry with a central hollow of variable size and depth.
- *Encrusting*: Sponges that cover a substrate surface with no noticeably protruding parts.

Megabenthic taxa, such as sponges and corals, increase the structural complexity of the benthic environment and fulfil many roles in ecosystems. Bell (2008) lists many of the functional roles of sponges, including:

- Impacting substrate through processes such as bioerosion (detailed further in Schönberg 2008), reef creation, and substrate stabilisation and regeneration;
- Bentho-pelagic coupling, including contribution to carbon cycling and energy flow, silicon cycling, oxygen depletion, and nitrogen cycling; and
- Associations with other organisms, including facilitation of primary production, provision of microhabitat, protection from predation, provision of settlement substrate and cues, disruption of boundary flow regimes, and release of chemicals.

Octocorals can also fill similar functional roles to sponges, especially with regard to their associations with other organisms. Sea whips can be used as a platform for filter-feeding species from which they can escape the low current flow and plankton supply near the seabed (Edgar 2001). Goh et al. (1999) summarises from various authors the advantages that gorgonians provide to associated organisms:

- Arborescent morphology means that the branches of the gorgonian (or erect branching sponge) are held in faster moving water, away from the relatively still boundary layer immediately above the substrata;

- Orientation of the colony perpendicular to prevailing water currents increases the amount of water flowing by the polyps (Wainwright & Dillon 1969), maximising feeding for the gorgonian and also any filter-feeding associated organisms;
- A mucus layer commonly traps detritus, diatoms and bacteria from which other organisms can derive nutrients (Patton 1972); and
- Toxic and unpalatable metabolites provide a refuge for many organisms from predation.

Many organisms are associated with corals and sponges. In a study of gorgonian-associated fauna collected from a variety of reefs south of Singapore, Goh et al. (1999) recovered 7 phyla, 17 families, 23 genera and 23 identified and 7 unidentified species. Sponges also host a diverse range of associated organisms and can serve as proxies for overall megabenthic diversity (Schlacher et al. 2007, Przeslawski et al. 2011). Buhl-Mortensen et al. (2010) explain that variables such as the size, flexibility and architectural complexity of habitat-forming organisms are positively related to diversity for both sessile and mobile species. As such, it is hoped that investigating patterns related to growth morphology of habitat-forming species in the Joseph Bonaparte Gulf will contribute to an understanding of overall biodiversity in the region. Such results will then inform the management and monitoring of industrial activity, as well as the proposed MPA in the region, particularly in relation to the CAR principle.

1.3 STUDY AIMS

This study explores the spatial and ecological patterns related to the morphology of tropical invertebrates from two habitat-forming taxa (sponges and octocorals). In particular, we aim to do the following:

- Identify and analyse sponge/octocoral community types (e.g. hard coral-dominated, sponge-dominated, octocoral-dominated, mixed, sparse, none) based on still images;
- Identify and analyse body types based on still images; and
- Correlate community type and morphologies with oceanographic, geochemical, and geological factors.

2. Methods

2.1 STATION SELECTION

Sponge/octocoral gardens were identified from all stations from surveys GA-322 and 325, defined as locations at which >5kg of sponges or octocorals were collected in sled hauls, or where expanses of dense octocorals or sponges were observed in the video (Przeslawski et al. 2011). Sponge/octocoral gardens were recorded at 21 of the 124 stations, and a further five stations from non-garden locations were included in the study for comparative purposes (Table 2.1). For these 26 stations, the number of images available for each station varied from 72 – 200. Images which were greater than 25% obscured (out of focus, lack of light, overexposed, turbid etc) or repeat images of a location were excluded from analyses. Overall 31.5% of all images were excluded, ranging from 0.6% - 61.6% per station. Table 2.1 characterises each of the stations included in this study.

Table 2.1: List of analysed survey stations from marine surveys GA-322 (denoted by A on station number) and GA-325 (denoted by B on station number)

STATION	GEOMORPHOLOGY	DEPTH	GARDENS?	# IMAGES	# USABLE IMAGES (N)	% EXCLUDED
1A	Bank	21.0	Yes	153	143	6.5%
2A	Bank	34	Yes	166	157	5.4%
7B	Plain	41.5	No	113	44	61.1%
10A	Deep/hole/valley	107	Yes	145	109	24.8%
22A	Ridge	82	Yes	139	64	54.0%
23A	Ridge	71	Yes	165	62	62.4%
25A	Ridge	69	No	200	91	54.5%
30A	Terrace	47	No	175	166	5.1%
31A	Terrace	27	Yes	190	178	6.3%
32A	Terrace	63	Yes	179	167	6.7%
32B	Deep/hole/valley	124	Yes	195	95	51.3%
34A	Bank	27	Yes	146	138	5.5%
35B	Terrace	53	Yes	107	90	15.9%
38A	Deep/hole/valley	65	No	156	155	0.6%
41A	Bank	34	Yes	144	127	11.8%
44B	Terrace	58	Yes	108	58	46.3%
45B	Terrace	54	Yes	129	79	38.8%
49B	Deep/hole/valley	135	Yes	166	136	18.1%
51B	Bank	37	Yes	123	27	78.0%
52B	Bank	27	Yes	157	83	47.1%
55B	Bank	31	Yes	121	71	41.3%
56B	Bank	33	Yes	94	44	53.2%
64B	Bank	51	Yes	72	39	45.8%
65B	Bank	51	No	87	40	54.0%
72B	Bank	13	Yes	145	63	56.6%
73B	Bank	25	Yes	128	110	14.1%

2.2 BIOLOGICAL COUNTS AND CLASSIFICATIONS

Visible epifauna in each image were counted, and details were entered in a spreadsheet. Individuals were counted only when a characteristic or large enough portion of the individual was visible to facilitate a confident identification. If there were more than 20 individuals of a given species or morphological type, the count was simply recorded as >20. Three species groups were targeted due to their large size and associated capacity to provide habitat for other organisms (*Mopsella* sp., *Ianthella* sp., *Xestospongia* sp.). Abundances were recorded in the following categories:

- Broad taxonomic groups:
  - Gorgonians
  - Whips
  - Sponges

- Species:
  - *Mopsella* sp., a large gorgonian (Figure 2.1a)
  - *Ianthella* sp., a large erect laminar sponge (Figure 2.1b)
  - *Xestospongia* sp., a large hollow massive sponge (Figure 2.1c).

- Sponge morphologies (See Figure 2.2, Schönberg (unpublished report) and Section 1.2 for morphological descriptions):
  - Erect Laminar
  - Laminar Branching (new category, intermediate between erect laminar and erect branching, not included in Schönberg's scheme)
  - Erect Branching
  - Simple Erect
  - Stalked Erect
  - Simple Massive
  - Hollow Massive
  - Encrusting (recorded as percent cover where more than 20 individuals were present or where cover was greater than 25%)

For each of the above categories, the counts per image were averaged across each station to provide an average number of individuals per image for each station (Appendix A). Averaging for each station was necessary because much of the abiotic data is only available per station, not per image.

We also wanted to assess whether fan-shaped organisms are oriented to maximise ocean currents. Since there was no indication of direction (e.g. north, south) on our still images, we could not assess direction of orientation; however, we could quantify the number of organisms that had similar orientation and therefore test the null hypothesis that orientation is random. We did this in images that showed three or more fan-shaped organisms (gorgonians, erect laminar sponges, laminar branching sponges and erect branching sponges). For these images, the percentage oriented in roughly the same plane were recorded and averaged for each station.

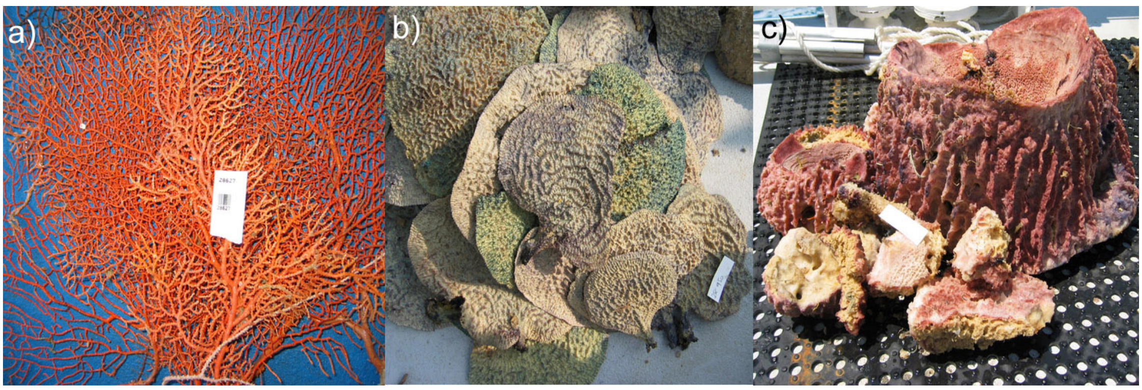

Figure 2.1: *Megabenthic species recorded from underwater still images collected from marine surveys GA-322 and GA-325: a) the fan-shaped gorgonian Mopsella sp., b) the fan-shaped sponge Ianthella sp., and c) the barrel sponge Xestospongia sp.*

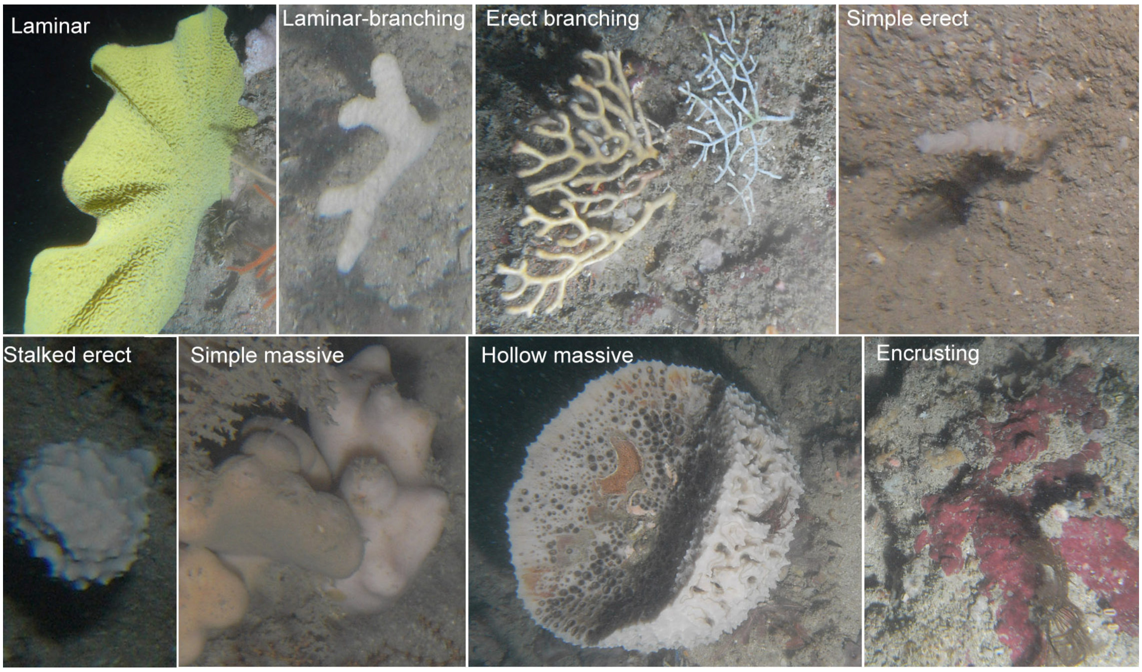

Figure 2.2: *Morphologies used to classify sponges in underwater still images collected from marine surveys GA-322 and GA-325, based on Schönberg, unpublished report.*

In addition to abundance of target taxa and groups mentioned above, the presence of non-target organisms was noted (e.g. holothurians, hydroids, algae, solitary corals). Where reef-forming hard corals were present, percent cover was estimated for each of the following categories:

- Branching
- Encrusting
- Tabular
- Other

Each analysed image was also classified into the following categories based on dominant biological community (Figure 2.3). For each station, the percent of images in each category was calculated:

- None: No organisms observed;
- Sparse: Less than 3 individuals observed (unless >50% cover);
- Other: Dominated by taxa other than octocorals, sponges or hard corals in which less than 3 octocorals/sponges/hard corals occur but 3 or more individuals of other taxa observed;
- Octocoral: Dominated by octocorals in which 3 or more individuals observed, with at least 2/3 of these octocorals;
- Sponge: Dominated by sponges in which 3 or more individuals observed, with at least 2/3 of these sponges;
- Hard Coral: Dominated by reef-forming hard corals in which 3 or more individuals observed, with at least 2/3 of these reef-forming hard corals;
- Mixed communities: Equally dominated by octocorals and sponges (in ratios between 1:2 to 2:1);
- Mixed (HC): Equally dominated by octocorals and sponges and at least 1/3 reef-forming hard corals.

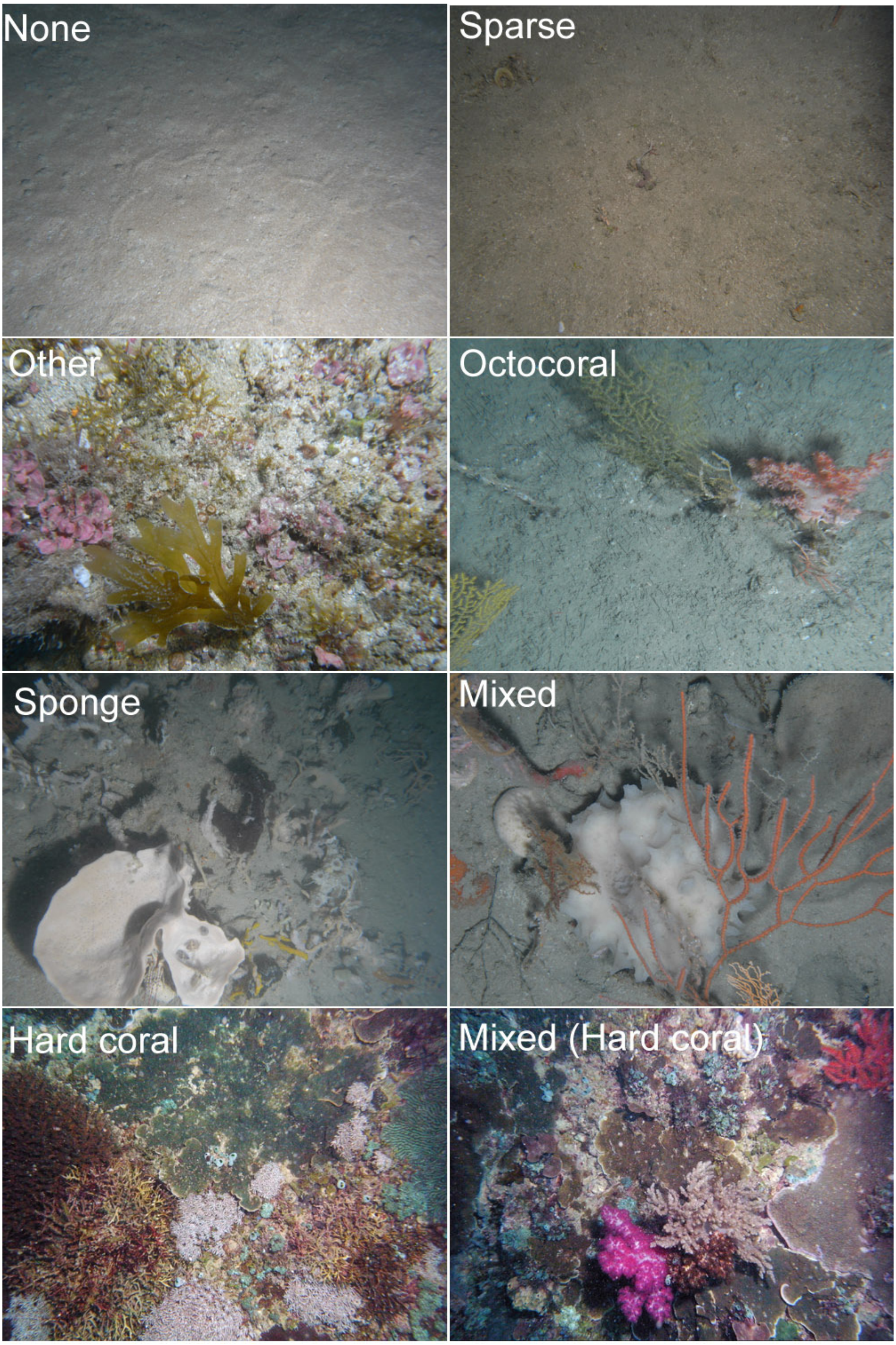

Figure 2.3: *Representative underwater still images for each category based on dominant biological community. Definitions of categories are provided in the text.*

2.3 ABIOTIC DATA

Data related to geomorphology, sedimentology, and geochemistry was available for each station as per methods detailed in Anderson et al. (2011) and Heap et al. (2010). The following abiotic variables were considered for comparison with biotic data:

- Geomorphology (bank, terrace, ridge, plain, valley as defined in Przeslawski et al. (2011) and Heap and Harris (2008))

- Depth (the average depth of the transect based on depth recorded from ship's echosounder at the start and end of each transect)

- Substrate parameters
  - Acoustic backscatter (dB)
  - Mud content
  - Gravel content
  - Sorting

- Geochemistry
  - $CaCO_3$
  - Pheophytin (ug g^{-1}dwt)
  - Total reactive chlorins (ug g^{-1})
  - $\delta^{15}N$ (‰)
  - Si/Al (mol)
  - Al (mg kg^{-1})
  - Mn (mg kg^{-1})

Geomorphic features were derived from high-resolution bathymetry obtained from multibeam sonar and were thus depth-related (Table 2.2). Acoustic backscatter gives an indication of seafloor hardness and roughness (Kloser et al. 2001), while mud content, gravel content and sorting may provide an indication of the hydrodynamic energy levels at a particular site. The geochemical variables were selected based on preliminary indications of patterns in the datasets from surveys GA-322 and 325 (Przeslawski et al. 2011; L Radke pers. com.).

Table 2.2: Mean, minimum and maximum depths of stations.

GEOMORPHOLOGY	MEAN	MINIMUM	MAXIMUM
Bank	32	13	51
Terrace	50	27	63
Ridge	74	69	82
Valley	108	65	135

2.4 DATA VISUALISATION AND STATISTICS

For each station, the percentage of images given each biological classification was calculated. A regional map was prepared showing each station represented as a pie chart of biological classifications, overlaying the geomorphology of the study areas. In order to further investigate the relationship between biological distributions and geomorphology, a series of column graphs were created, with stations grouped by their geomorphology and compared to the biological classifications of images and to the proportions resulting from counts for group abundance, species abundance and sponge morphologies.

Scatter plots were created comparing each of the biological variables (excluding hard coral cover) with each environmental variable. All variables were compared with depth, including environmental ones to check for covariance. An r^2 value was calculated for each comparison in order to determine the strength of any relationships. A correlation matrix was created to determine the significance of each relationship, highlighting those that are statistically significant at an alpha level of $p<0.05$. For statistical purposes, any count of >20 was considered as 20.

3. Results

3.1 RELATIONSHIPS WITH GEOMORPHOLOGY

Analysis comparing the biological categories with geomorphology revealed that sponge gardens tend to dominate on banks and terraces, while octocorals and mixed images are more common in valleys and ridges. This is illustrated in the following figures 3.1 – 3.3 in which geomorphology classifications are overlain by survey stations represented as pie-charts. Each pie chart indicates the proportion of each biological class identified at each station (none, sparse, octocoral dominated, sponge dominated, mixed, hard coral dominated, mixed with hard corals, other). Study area D is not shown (although it was included in all analyses), because it contains only one survey station analysed in this study and that station is not a garden location. Therefore all images at this station were classified as either none or sparse.

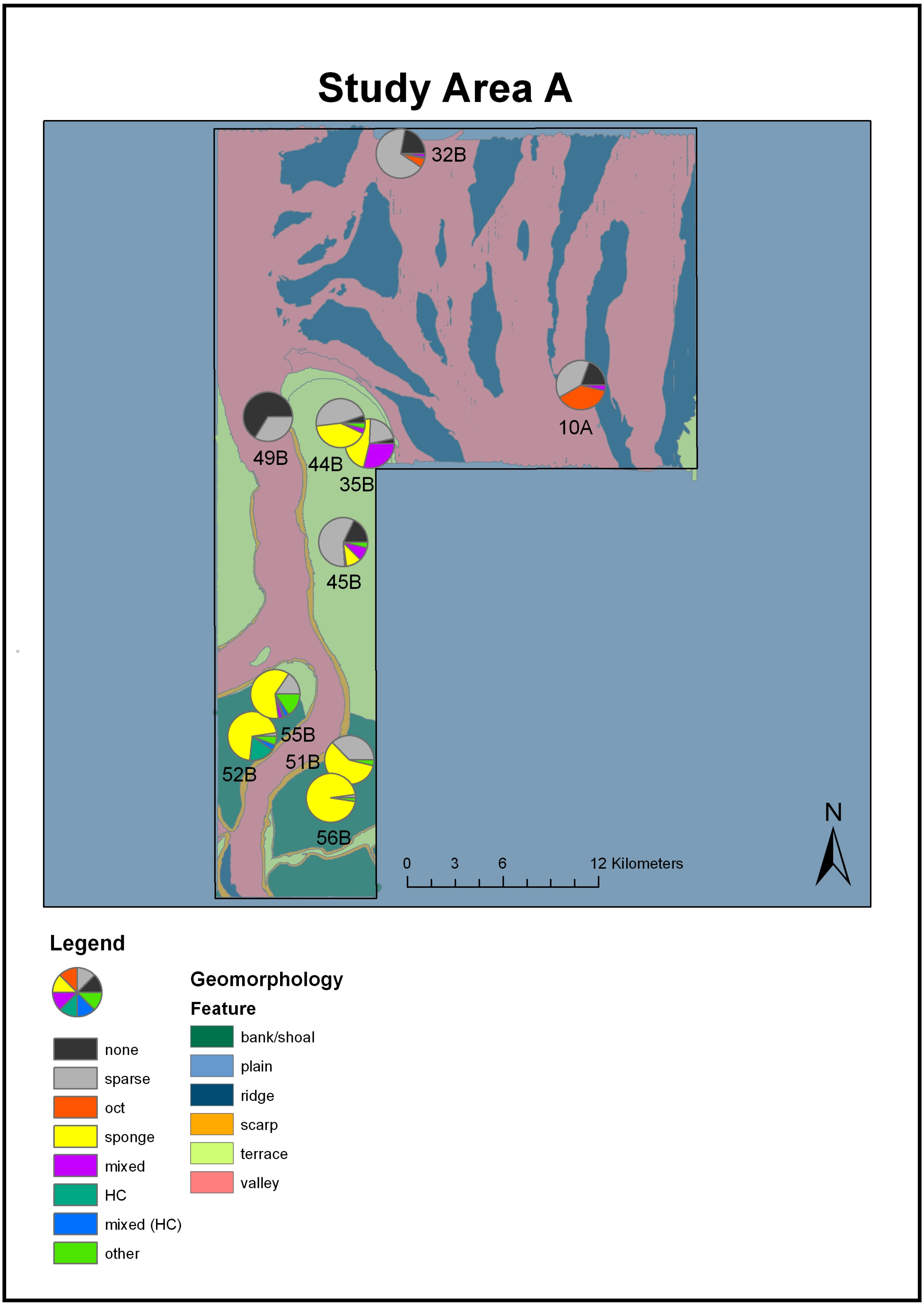

Figure 3.1: *Biological classifications and geomorphology of Study Area A. Each pie chart shows the location of a station from which still images were analysed, with each pie slice representing the proportion of images in each biological classification. HC = hard coral, Oct = octocoral, mixed = mixed patches as defined in text.*

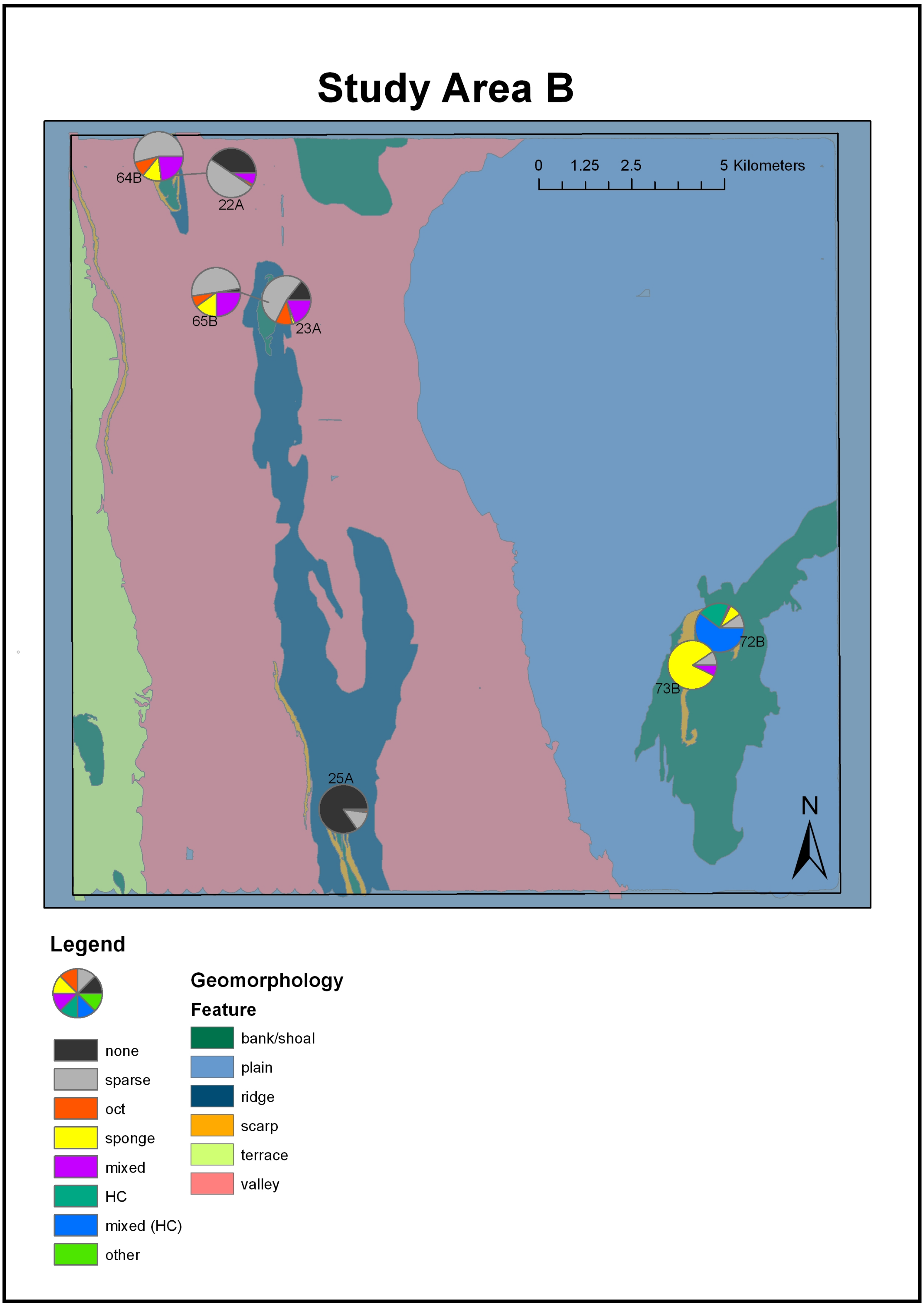

Figure 3.2: *Biological classifications and geomorphology of Study Area B. Each pie chart shows the location of a station from which still images were analysed, with each pie slice representing the proportion of images in each biological classification. HC = hard coral, Oct = octocoral, mixed = mixed patches as defined in text.*

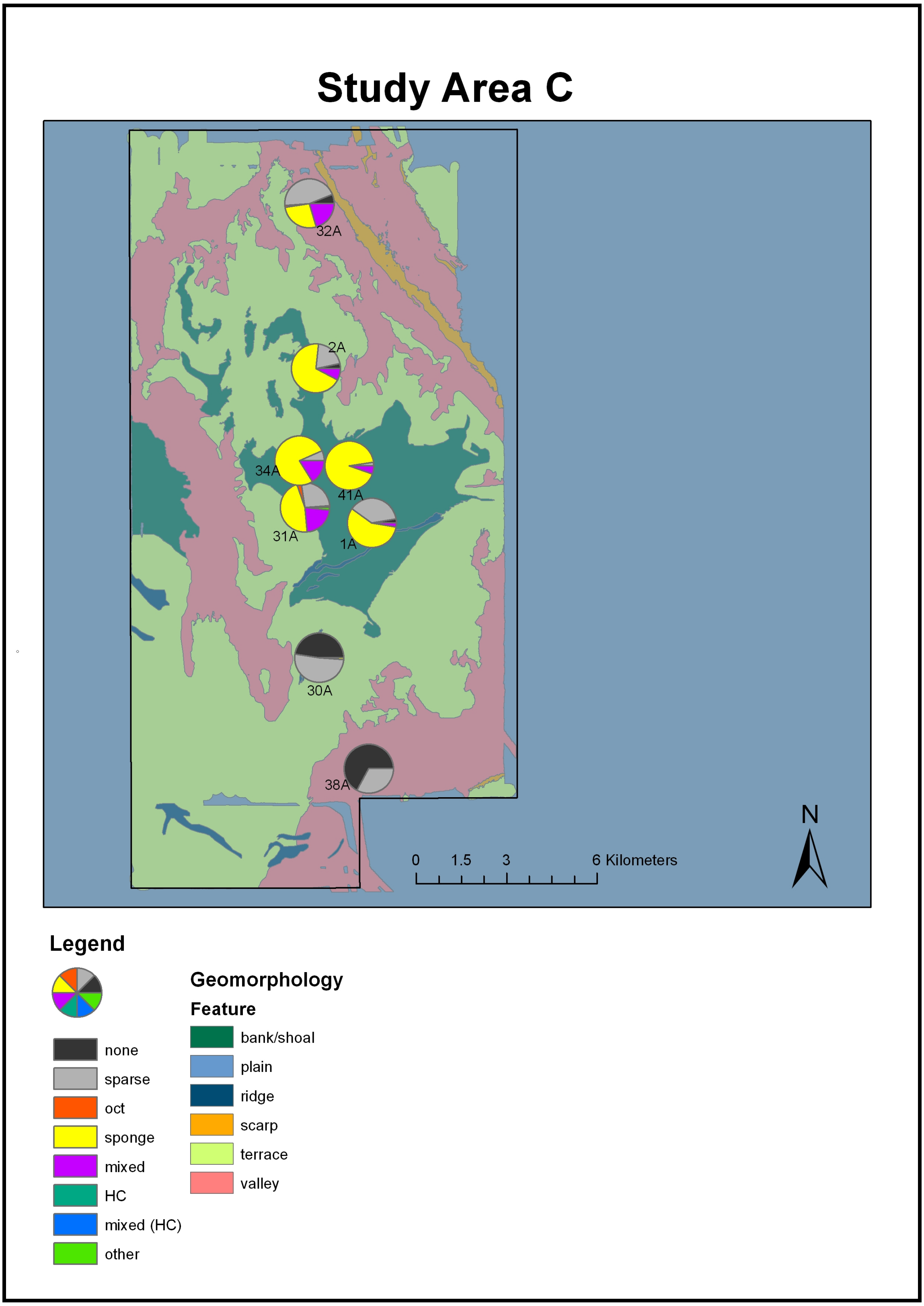

Figure 3.3: *Biological classifications and geomorphology of Study Area C. Each pie chart shows the location of a station from which still images were analysed, with each pie slice representing the proportion of images in each biological classification. HC = hard coral, Oct = octocoral, mixed = mixed patches as defined in text.*

Images classified as none or sparse occurred in all geomorphological regions. Figure 3.4 shows the biological classification as a proportion for each geomorphology type. Plains are comprised solely of none or sparse biological classes, although this is based on data from a single station only. Greater than 80% of ridge and valley images, and >50% of terrace images are dominated by none or sparse classifications (Figure 3.4). Banks showed the greatest coverage of biota, with a much lower (approximately 20%) of images classified as sparse or none. Banks also displayed the greatest diversity of biota according to this classification system, being the only geomorphology type to provide hard coral habitat in addition to octocorals and sponges (Figure 3.4). Banks and terraces included more sponge-dominated images than gorgonian images, while valley and ridge habitats were more octocoral-dominated (Figure 3.4).

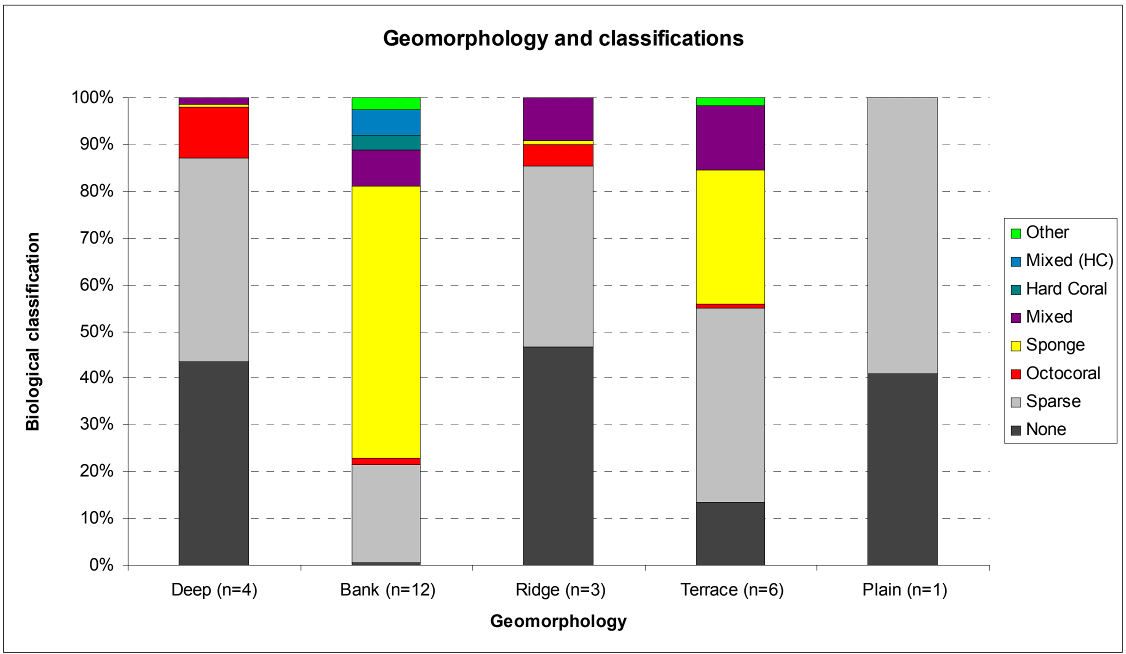

Figure 3.4: *The proportion of images given each classification, according to geomorphology type. n= the number of stations in that geomorphology type. HC = hard coral*

Based on the abundance of the three major groups assessed in this study (sponges, whips and gorgonians), sponges occurred in all environments, though much more commonly in banks and terraces (Figure 3.5). Gorgonians were more common than whips, though when abundance of gorgonians increased, so did that of whips (Figure 3.5).

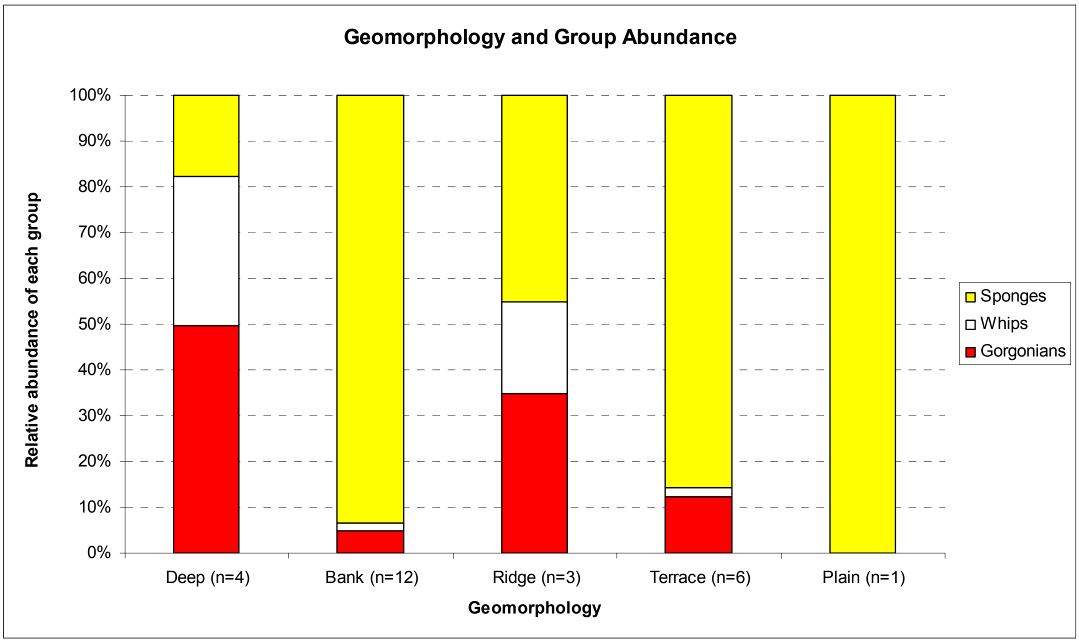

Figure 3.5: *The relative abundance of each major group (gorgonian, whip or sponge) for all images in each geomorphology type. n= the number of stations in that geomorphology type. Images from the single plain station were all classified as sparse or none (Figure 3.4).*

In relation to the three target taxa, (*Mopsella* sp., *Ianthella* sp., *Xestospongia* sp), *Mopsella* sp. was common in all geomorphologic features, except plains where none of the target taxa occurred (Figure 3.6). The valley areas contained no *Xestospongia* sp. and very few *Ianthella* sp., while the ridges did not include *Ianthella* sp. but had the highest abundance of *Xestospongia* sp. (though still far less common than *Mopsella* sp.). *Xestospongia* sp. also occurred infrequently in terraces and banks, though *Ianthella* sp. was much more common in these regions than others, outnumbering *Mopsella* sp. in bank areas (Figure 3.6).

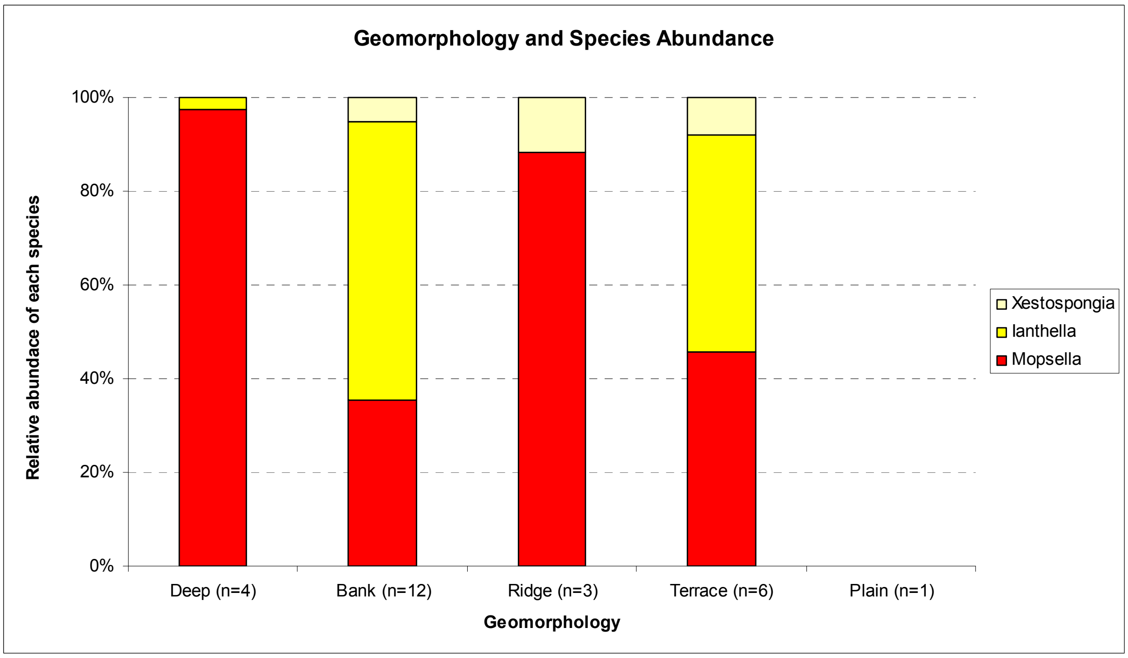

Figure 3.6: *The relative abundance of each species of interest (*Mopsella *sp.,* Ianthella *sp,* Xestospongia *sp.) for all images in each geomorphology type. n= the number of stations in that geomorphology type.*

In relation to sponge morphology, erect branching and simple massive sponges were ubiquitous across all geomorphic features (Figure 3.7). Simple massive sponges were more common than erect branching sponges at all stations, except those in plains and valleys. Most growth forms occur in all regions (disregarding the single plain station) except erect laminar and laminar branching, which don't occur in ridges and valley areas respectively, plus stalked erect, which only occur in ridges. Encrusting sponges are common in all areas (except plains), particularly in banks and ridges, where they are more abundant than simple massive and erect branching sponges combined (Figure 3.7).

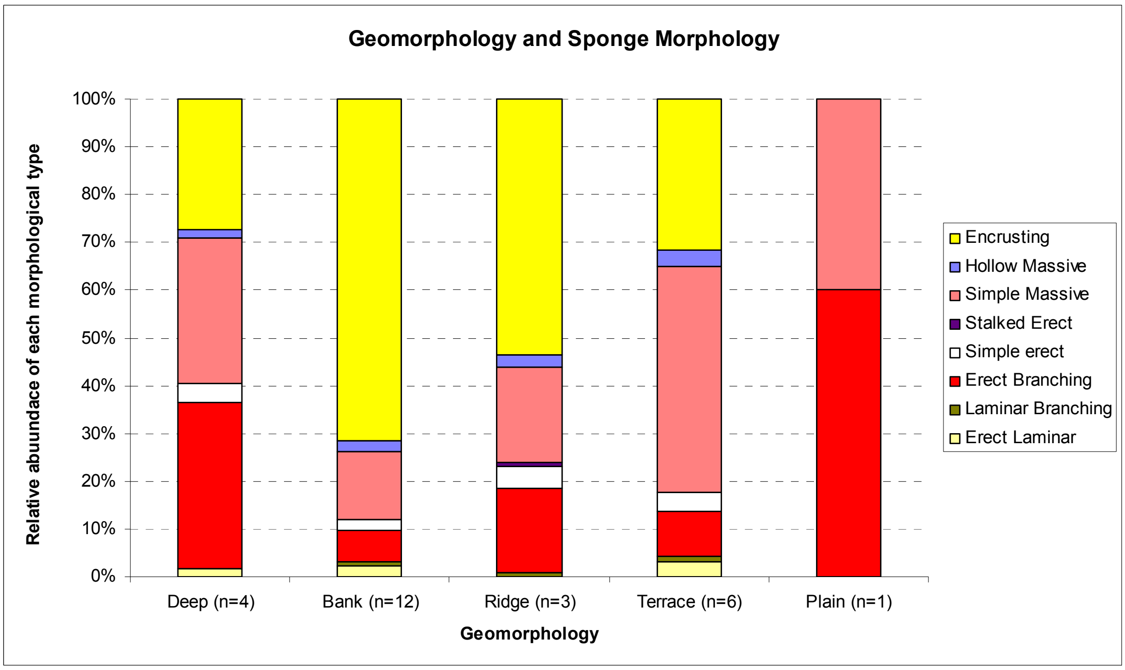

Figure 3.7: *The relative abundance of sponges in each morphological category for all images in each geomorphology type. n= the number of stations in that geomorphology type.*

All biological measures used in the current study (biological classification, group abundance, species abundance and sponge morphology) vary among geomorphic features (Figs 3.1 – 3.7). Banks and terraces are largely sponge dominated, as well as when comparing the number of sponges with the numbers of gorgonians and whips (Figs 3.4-3.5). Those sponges are mostly (>70%) encrusting on banks and simple massive or encrusting (together ~80%) on terraces (Figure 3.7). Although not dominant relative to other growth forms, erect laminar sponges are more common on banks and terraces than the other areas, and indeed, the erect laminar sponge species *Ianthella* sp. almost exclusively occurs in only these environments (occurring very infrequently in valleys and not at all on ridges). Hollow massive sponges occur infrequently in all environments except plains (which have no sponge/coral gardens), though *Xestospongia* sp. is more common on ridges than banks and terraces, and does not occur at all in valleys. Hard corals occur only on banks. In contrast, valleys and ridges are dominated by octocorals, and of these gorgonians are more abundant than whips. The gorgonian species, *Mopsella* sp., occurs in all environments (except plains), far outnumbering the sponges, *Ianthella* sp. and *Xestospongia* sp. in valleys and ridges (Figure 3.6). Approximately 45% of the count for ridges is sponges, of which just over half are encrusting. The remaining sponges are mostly simple massive and erect branching in equal parts (~20% each). The sponges in valleys (18% of the count) are roughly equal parts encrusting, simple massive and erect branching (~30% each).

3.2 CORRELATIONS WITH ENVIRONMENTAL VARIABLES

According to individual correlation analyses (Table 3.1), the following five linear relationships are both strong ($r^2>0.5$) and significant ($p<0.05$):

- Depth & backscatter ($r^2 = 0.77$)
- Mud & abundance of laminar branching sponges ($r^2 = 0.63$)
- Pheophytin & abundance of whips ($r^2 = 0.63$) and *Mopsella* sp. ($r^2 = 0.56$)
- Si/Al & abundance of *Ianthella* sp. ($r^2 = 0.52$)

Twelve relationships are moderate ($r^2 = 0.31$ to 0.5) and significant ($p<0.05$):

- Mud & abundance of *Xestospongia* sp. (r2 = 0.47)
- Sorting & abundance of *Mopsella* sp. ($r^2 = 0.42$)
- Si/Al & abundances of erect laminar sponges ($r^2 = 0.37$) and stalked erect sponges ($r^2 = 0.36$)
- Al & abundance of whips ($r^2 = 0.45$) and *Mopsella* sp. ($r^2 = 0.49$)
- Backscatter & overall abundance of sponges ($r^2 = 0.48$), as well as abundance of simple massive sponges ($r^2 = 0.43$), hollow massive sponges ($r^2 = 0.39$) and encrusting sponges ($r^2 = 0.50$)
- Depth & overall abundance of sponges ($r^2 = 0.39$), as well as abundance of hollow massive sponges ($r^2 = 0.32$)

A further 17 relationships were statistically significant but weak ($r^2 = 0.1$ to 0.3) or very weak ($r^2 <0.1$). Due to the high number of correlations performed and the associated risk of Type I errors (i.e. false positives), these relationships are not explored further in this report (see Moran 2003 for discussion of this topic). Scatter plots associated with each of the cells in Table 3.1 are available in Appendix B.

Table 3.1: Correlation matrix of r^2 values. R^2 values >0.5 (shaded dark grey) are considered to show a strong relationship, with one variable explaining at least 50% of the variation in the other. Values of 0.31-0.50 are considered to be of moderate strength (shaded medium grey), while those of 0.11-0.30 are weak (shaded light grey) and <0.1, very weak (white). Values in red are statistically significant at an alpha level of 0.05.

	GORGONIANS	WHIPS	SPONGES	MOPSELLA	IANTHELLA	XESTOSPONGIA	ERECT LAMINAR	LAMINAR BRANCHING	ERECT BRANCHING	SIMPLE ERECT	STALKED ERECT	SIMPLE MASSIVE*	HOLLOW MASSIVE	ENCRUSTING	ORIENTED	DEPTH
MUD	0.18	0.01	0.00	0.06	0.28	0.47	0.45	0.63	0.13	0.03	0.03	0.16	0.13	0.04	0.02	0.00
GRAVEL	0.05	0.00	0.04	0.02	0.08	0.07	0.14	0.18	0.04	0.02	0.08	0.01	0.01	0.26	0.09	0.01
CACO3	0.00	0.05	0.31	0.07	0.10	0.00	0.01	0.05	0.02	0.00	0.01	0.14	0.09	0.29	0.05	0.02
SORTING	0.10	0.33	0.13	0.42	0.00	0.01	0.01	0.04	0.02	0.01	0.03	0.06	0.02	0.12	0.00	0.05
PHEOPHYTIN (UG/G DWT)	0.14	0.63	0.11	0.56	0.00	0.00	0.00	0.01	0.01	0.00	0.02	0.06	0.03	0.10	0.02	0.09
TOTAL REACTIVE CHLORINS	0.21	0.02	0.17	0.02	0.00	0.01	0.06	0.08	0.16	0.04	0.25	0.43	0.25	0.19	0.02	0.12
$\Delta^{15}N$ ‰ AIR	0.03	0.01	0.04	0.01	0.00	0.03	0.01	0.13	0.04	0.01	0.05	0.01	0.01	0.04	0.05	0.00
SI/AL	0.00	0.01	0.11	0.00	0.52	0.28	0.37	0.01	0.09	0.03	0.36	0.03	0.00	0.22	0.07	0.00
AL (MG/KG)	0.21	0.45	0.27	0.49	0.03	0.08	0.08	0.08	0.07	0.00	0.00	0.24	0.19	0.22	0.08	0.20
MN (MG/KG)	0.01	0.05	0.35	0.11	0.03	0.00	0.00	0.05	0.02	0.01	0.02	0.22	0.21	0.46	0.01	0.16
BACKSCATTER_(DB)	0.00	0.09	0.48	0.09	0.10	0.07	0.24	0.33	0.27	0.12	0.02	0.43	0.39	0.50	0.01	0.77
DEPTH	0.00	0.03	0.39	0.03	0.08	0.03	0.13	0.07	0.25	0.22	0.04	0.17	0.32	0.31	0.00	1

* One station (56B) was excluded from the simple massive sponges category, because a small but abundant sponge occurred in very large numbers at this station, skewing the average no. of individuals per image for massive sponges and creating an outlier.

4. Discussion

Analysis of underwater still images collected from the JBG revealed that morphological and taxonomic groups of megabenthos vary across geomorphic features. Sponges dominate banks and terraces, while gorgonians are more common on ridges and in valleys. This may indicate that sponges prefer comparatively shallow waters, while gorgonians prefer relatively deeper areas, although other confounding factors such as substrata and currents associated with geomorphic features may also regulate the abundance of sponges and octocorals. However, depth does have a moderately strong, statistically significant relationship with sponges as well as with a number of sponge morphologies (Table 3.1).

Many other studies have found sponge communities to vary with depth. Depth was found to be the most important parameter for sponge and coral diversity in the Spermonde Archipelago (Cleary et al. 2005), and sponge species richness declines with depth in submarine canyons of southeastern Australia (Schlacher et al. 2007). McArthur et al. (2010) point out that when biological measures correlate with spatial variables such as depth, it is actually a depth-related factor driving the biological differences (e.g. temperature, light, pressure), as organisms do not respond to depth *per se.* The main impact of increasing depth is related to a reduction in light transparency. Buhl-Mortensen et al. (2010) summarise various authors to conclude that depth increase is related to a reduction in substrate variability, grain size, bottom current, food supply and the size of habitat-forming epibenthos, though they were referring to much deeper environments (200-4000 m) than those surveyed in this study.

A strong relationship between backscatter, depth, and sponge abundance may be due to rocky substrates in the shallows providing hardness, as well as abundant sponge and coral cover creating roughness. The direction of causation for the correlations between backscatter, depth and sponge abundance is difficult to determine. It may be that sponges grow in the shallower areas due to depth-related factors such as greater light penetration and food availability and in so doing, increase the roughness in these areas, resulting in the correlation with backscatter results. On the other hand, hydrodynamic energy also decreases with depth (Cleary et al. 2005) so perhaps the hard substrates created in the higher energy shallow areas cause both the observed backscatter values and increased sponge abundance by providing appropriate attachment sites for sponge fauna. Depth and overall sponge abundance show no clear correlations with any other variables in this study except with each other and backscatter. It seems likely that these three variables probably all correlate with some other factors not measured here. Encrusting sponges have a moderately strong ($r^2 = 0.50$) relationship with backscatter but not with depth, suggesting the relationship is, in this case, more closely related to the substrate, rather than other variables which might vary with depth. Alternatively, the encrusting sponges may influence the backscatter signal directly, by creating roughness on the ground surface. Encrusting sponges dominate in the shallow bank environments. This is in part because many of the images in these environments include numerous individuals of limited extent. Additionally, encrusting sponges may survive very high hydrodynamic energies, where erect sponges may be damaged by wave action.

Gorgonians in the JBG are proportionately more abundant than sponges in the deeper environments (valleys and ridges). In a study investigating the habitat of a Central Great Barrier Reef shelf margin across a depth range of 51-145 metres, octocorals dominated the seafloor community below 75 metres, while photosynthetic organisms, such as scleractinians corals, dominated at shallower depths (Bridge et al. 2011). However, no significant correlation is observed between gorgonians and depth in this study because the relative abundance of gorgonians at depth is actually due to the lack of sponges, not an increase in gorgonian numbers. In fact gorgonians are more abundant on terraces than on any of the other geomorphic features (an average of 0.62 individuals per image in terraces compared to 0.33, 0.47 and 0.37 for ridges, banks and valleys respectively; see Appendix C). Buhl-Mortensen et al. (2010) found that in deep ocean margins, gorgonians are mostly confined to hard bottoms, yet no relationship was observed between gorgonians and backscatter in this study. The terraces in the JBG are comprised of soft sediments interspersed with rocky outcrops (Przeslawski et al. 2011), and the abundance of images classified as none or sparse for both terraces and valleys indicates the patchiness of the coral gardens at these stations. It is likely that the octocorals grow on rocky outcrops where they are available, with relatively barren sandy areas between garden patches. This pattern was also observed in the JBG video footage previously analysed (Przeslawski et al. 2011) as well as in sponge distributions on the Carnarvon Shelf (Schönberg & Fromont 2011). In addition, other factors not considered in the current study may also be affecting the distribution and abundance of gorgonians (e.g. sediment accumulation in Bridge et al. 2011).

The abundances of whips and the gorgonian species *Mopsella* sp. correlate significantly and strongly with the presence of pheophytin (r^2 = 0.63 and 0.56, respectively) and moderately with aluminium (r^2 = 0.45 and 0.49, respectively). Pheophytin is a common degradation product of chlorophyll-a, which indicates a high rate of primary production and fast sinking rates in the water column (Stephens et al. 1997). Octocorals may preferentially settle and survive in productive areas where there is a source of fine particulate matter supplying organic detritus (along with aluminium). Alternatively octocorals could be responsible for the increased concentrations of pheophytin, as whips and gorgonians secrete a mucus layer that traps and accumulates detritus, diatoms and bacteria that degrade (Patton 1972). However, the lack of an apparent relationship with chlorins suggest that *Mopsella* are occurring in areas where aluminosilicate sediments are accumulating, and their distribution is not necessarily related to primary productivity (L. Radke, pers. comm.).

The gorgonian *Mopsella* sp. is an important habitat-former and is the most common octocoral along the Van Diemen Rise (Przeslawski et al. 2011). Pheophytin may be a useful surrogate for determining the locations of *Mopsella*-dominated communities in the JBG. It is important to include octocoral gardens in protected areas, as gorgonians host a diverse range of associated organisms (e.g. Goh et al. 1999) and many of these associations are often obligate. Buhl-Mortensen et al. (2010) explain that although the species richness of associated fauna is lower in tropical gorgonians than in the deep sea, the number of obligate symbiont species is higher. In fact obligate associations are more common with octocorals than scleractinian corals, though the reason for this is unknown (Buhl-Mortensen et al. 2010).

Sponges also provide a number of functional services to the benthic ecosystem (Bell 2008), and both major species investigated in this study have significant correlations with at least one abiotic variable. *Ianthella* sp. correlates strongly with Si/Al (r^2 = 0.52) which provides an indication of the ratio of quartz to clay in the sampled sediments. Total erect laminar sponges and stalked erect sponges have a moderate correlation with it too (r^2 = 0.37 and 0.36 respectively). These correlations indicate a preference for a clay-poor environment, suggesting a higher energy hydrodynamic regime. These groups may prefer to live where the current is a little stronger, providing suspended organics for filter feeding.

Xestospongia sp. shows a moderate correlation with mud content (r^2 = 0.47), and laminar branching sponges are strongly correlated with mud content (r^2 = 0.63). The laminar branching sponges were a small group, consisting primarily of what appeared to be a single morphospecies. The strong correlation is based on relatively few data points and unlikely to be important. *Xestospongia* sp., on the other hand, is a long-lived, prominent, habitat providing species. The correlation with muddy environments suggests a preference for lower energy hydrodynamic regimes. This species was not observed at any of the valley stations, so also appears to prefer the relatively shallow sites.

5. Conclusions and Recommendations

There are differences in the epibenthic communities between different geomorphologic features in the northeastern Joseph Bonaparte Gulf. The most notable difference is the dominance of sponges in the shallower areas (banks and terraces) relative to gorgonians which are relatively more abundant in the deeper locations (ridges and valleys). Nevertheless, gorgonians, whips and most of the sponge morphology classifications occur on all of the geomorphologic features, with the only exception possibly being the relatively barren plains.

Some abiotic measures analysed in this study may potentially be useful as coarse surrogates. Moderate to strong predictors were identified for all three species selected for inclusion in this study (pheophytin with *Mopsella* sp., Si/Al with *Ianthella* sp. and mud content with *Xestospongia* sp.). These species are all large, prevalent, habitat-providing organisms, which may help to support local biodiversity. Backscatter was also revealed as a potentially important surrogate, with more moderate to strong correlations amongst the biological variables than any other abiotic measure. It also strongly correlated with depth, however, indicating that these variables are likely to be confounded.

The data exploration in this study consisted almost exclusively of analysing linear relationships in a series of univariate scatter plots. Such an approach may fail to detect more complex relationships. For example, the relationship between backscatter and several biological metrics (sponge abundance, *Ianthella, Xestospongia,* erect branching sponges, erect laminar sponges, encrusting sponge) suggest a threshold in which the response of biological measures to the abiotic factor slows, stops, or reverses (Appendix 2). In such cases, linear modelling may simplify logarithmic or parabolic relationships.

The number of moderate to strong relationships gathered from this preliminary investigation bodes well for the success of multivariate and non-linear analyses if they were to be conducted on this dataset. It is recommended that more robust and sophisticated statistical techniques be applied to these data, to draw out the information missed by these preliminary analyses and determine the suites of abiotic variables that can be best used for characterising sponge and coral communities in the Joseph Bonaparte Gulf.

A large amount of data was extracted from images for this study, much of which remains unexplored. Information about the hard coral communities on the banks of Van Diemen Rise can be gathered from the percent cover estimates made for various hard cover growth forms. Additionally, knowledge of currents throughout the area may be derived from the orientation data for fan-shaped organisms.

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Appendices

APPENDIX A: IMAGE CLASSIFICATIONS, AVERAGE NO. INDIVIDUALS PER IMAGE, PER STATION AND PERCENT OF FAN SHAPED ORGANISMS ORIENTATED

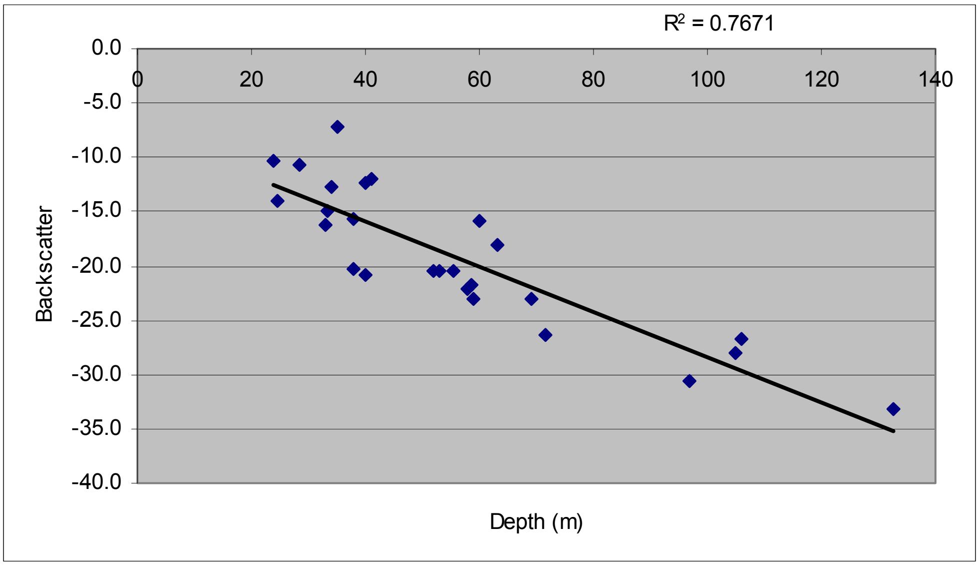
	Classification								
Station	Dominant Classification	%none	% sparse	% oct	%sponge	%mixed	%HC	%mixed (HC)	%other
10A	Sparse	19.3%	38.5%	37.6%	0.9%	3.7%	0.0%	0.0%	0.0%
1A	Sponge	2.8%	41.3%	0.0%	62.9%	2.8%	0.0%	0.0%	0.0%
22A	Sparse	40.6%	50.0%	1.6%	0.0%	7.8%	0.0%	0.0%	0.0%
23A	Sparse	14.5%	53.2%	11.3%	1.6%	19.4%	0.0%	0.0%	0.0%
25A	None	84.6%	13.2%	1.1%	1.1%	0.0%	0.0%	0.0%	0.0%
2A	Sponge	3.2%	19.7%	0.6%	68.2%	7.6%	0.0%	0.0%	0.6%
30A	Sparse	47.6%	51.2%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%
31A	Sponge	1.1%	26.4%	2.8%	46.1%	21.9%	0.0%	0.0%	1.7%
32A	Sparse	6.0%	44.9%	1.2%	26.9%	20.4%	0.0%	0.0%	0.6%
32B	Sparse	22.1%	68.4%	6.3%	1.1%	2.1%	0.0%	0.0%	0.0%
34A	Sponge	0.0%	6.5%	0.0%	76.8%	15.9%	0.0%	0.0%	0.7%
35B	Sponge	3.3%	21.1%	0.0%	46.7%	28.9%	0.0%	0.0%	0.0%
38A	None	67.1%	32.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
41A	Sponge	0.0%	2.4%	0.0%	91.3%	5.5%	0.0%	0.0%	0.8%
44B	Sparse	5.2%	46.6%	0.0%	41.4%	3.4%	0.0%	0.0%	3.4%
45B	Sparse	17.7%	58.2%	1.3%	10.1%	8.9%	0.0%	0.0%	3.8%
49B	None	66.2%	33.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
51B	Sponge	0.0%	37.0%	0.0%	59.3%	0.0%	0.0%	0.0%	3.7%
52B	Sponge	0.0%	2.4%	0.0%	71.1%	0.0%	16.9%	3.6%	6.0%
55B	Sponge	0.0%	15.5%	0.0%	60.6%	2.8%	1.4%	2.8%	15.5%
56B	Sponge	0.0%	2.3%	0.0%	95.5%	0.0%	0.0%	0.0%	2.3%
64B	Sparse	0.0%	53.8%	10.3%	12.8%	23.1%	0.0%	0.0%	0.0%
65B	Sparse	2.5%	50.0%	7.5%	15.0%	25.0%	0.0%	0.0%	0.0%
72B	Mixed (HC)	0.0%	9.5%	0.0%	7.9%	1.6%	20.6%	60.3%	0.0%
73B	Sponge	0.0%	9.1%	0.0%	82.7%	7.3%	0.9%	0.0%	0.0%
7B	Sparse	40.9%	59.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

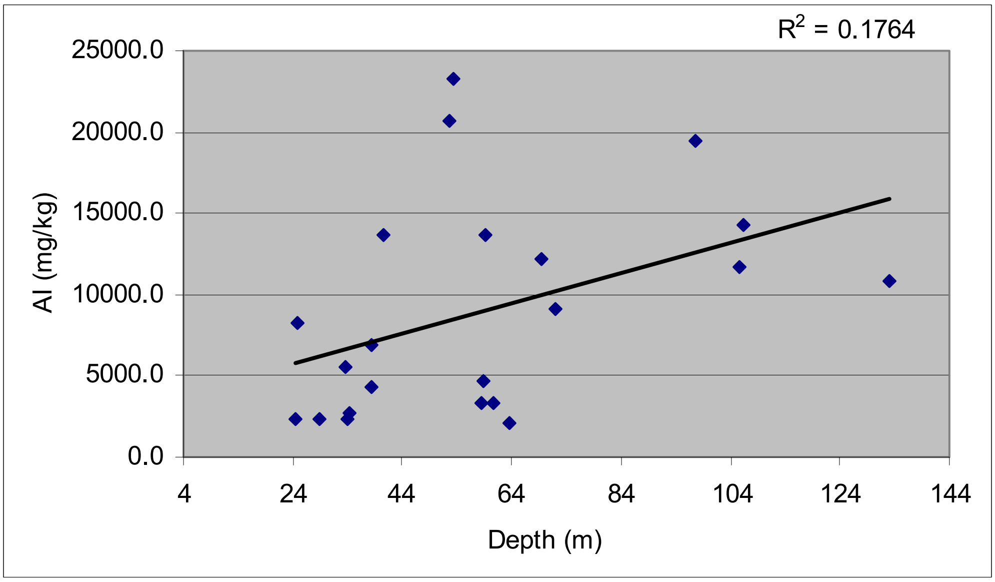
	Group Abundance			Species Abundance			
Station	Gorgonians	Whips	Sponges	Mopsella	Ianthella	Xestospongia	% fan shaped orgs oriented
10A	1.15	0.79	0.30	0.31	0.01	0.00	78%
1A	0.10	0.04	3.69	0.00	0.03	0.02	87%
22A	0.27	0.17	0.38	0.13	0.00	0.02	67%
23A	0.69	0.35	0.81	0.11	0.00	0.02	57%
25A	0.03	0.04	0.11	0.00	0.00	0.00	na
2A	0.48	0.16	5.44	0.05	0.50	0.04	60%
30A	0.00	0.00	0.09	0.00	0.00	0.00	na
31A	1.02	0.05	4.49	0.06	0.19	0.06	94%
32A	0.48	0.10	2.40	0.09	0.18	0.01	71%
32B	0.32	0.16	0.21	0.03	0.00	0.00	85%
34A	1.27	0.09	10.17	0.14	0.35	0.01	78%
35B	1.53	0.29	6.72	0.18	0.02	0.00	49%
38A	0.00	0.01	0.01	0.00	0.00	0.00	na
41A	0.69	0.06	10.49	0.02	0.21	0.03	62%
44B	0.26	0.07	10.59	0.02	0.00	0.00	na
45B	0.41	0.09	1.58	0.04	0.00	0.00	68%
49B	0.01	0.01	0.01	0.00	0.00	0.00	na
51B	0.00	0.00	6.33	0.00	0.00	0.00	na
52B	0.06	0.07	14.64	0.00	0.01	0.00	na
55B	0.31	0.03	12.93	0.00	0.00	0.00	na
56B	0.07	0.05	15.09	0.00	0.00	0.00	na
64B	1.00	0.64	1.98	0.26	0.03	0.00	77%
65B	0.85	0.33	2.10	0.21	0.03	0.00	70%
72B	0.16	0.11	12.03	0.03	0.03	0.00	na
73B	0.65	0.29	11.43	0.00	0.00	0.00	59%
7B	0.00	0.00	0.11	0.00	0.00	0.00	na

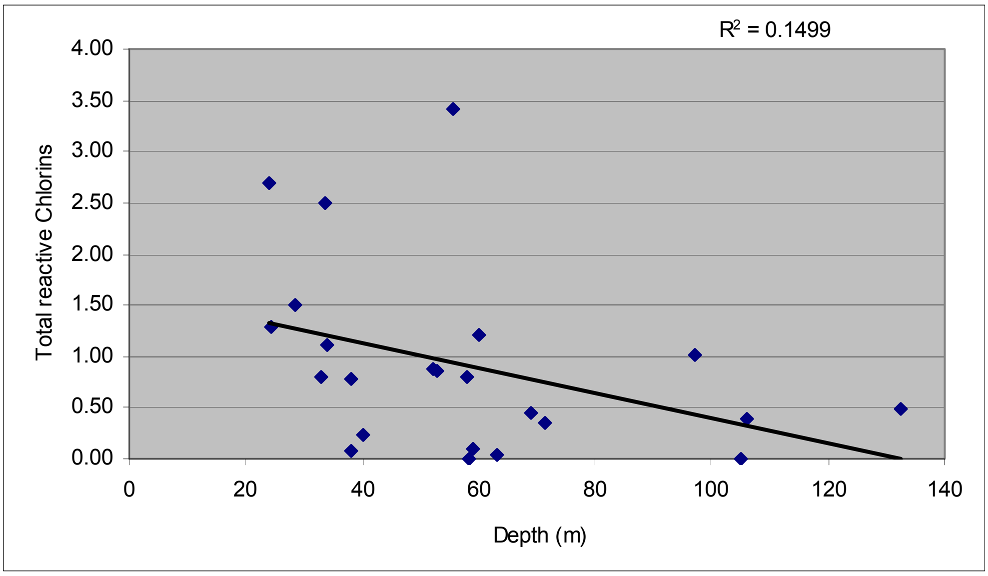
	Growth Forms - Sponges								
Station	Erect Laminar	Laminar Branching	Erect branching	Simple erect	Stalked erect	Simple massive	Simple massive (no outlier)	Hollow massive	Encrusting
10A	0.01	0.00	0.12	0.00	0.00	0.06	0.06	0.01	0.11
1A	0.19	0.14	0.27	0.10	0.00	1.51	1.51	0.17	1.34
22A	0.00	0.00	0.06	0.00	0.00	0.06	0.06	0.02	0.23
23A	0.00	0.00	0.15	0.05	0.00	0.19	0.19	0.02	0.40
25A	0.00	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.05
2A	0.61	0.03	1.25	0.39	0.01	2.01	2.01	0.27	0.88
30A	0.01	0.00	0.02	0.00	0.00	0.03	0.03	0.01	0.03
31A	0.47	0.29	0.31	0.08	0.00	1.38	1.38	0.31	1.65
32A	0.26	0.00	0.38	0.40	0.01	0.77	0.77	0.25	0.34
32B	0.00	0.00	0.05	0.02	0.00	0.09	0.09	0.00	0.03
34A	0.68	0.17	1.12	0.28	0.01	2.30	2.30	0.32	5.30
35B	0.11	0.00	0.84	0.22	0.03	1.69	1.69	0.19	3.63
38A	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
41A	0.46	0.16	1.25	0.31	0.02	1.87	1.87	0.35	6.07
44B	0.02	0.00	0.62	0.28	0.00	8.52		0.07	1.88
45B	0.00	0.01	0.30	0.06	0.00	0.25	0.25	0.05	0.91
49B	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
51B	0.00	0.00	0.26	0.07	0.00	0.89	0.89	0.00	5.11
52B	0.02	0.00	0.43	0.11	0.00	0.79	0.79	0.18	13.12
55B	0.03	0.01	0.28	0.03	0.00	1.10	1.10	0.19	11.29
56B	0.00	0.00	0.27	0.00	0.00	1.66	1.66	0.50	12.66
64B	0.03	0.03	0.36	0.21	0.00	0.59	0.59	0.08	0.92
65B	0.03	0.00	0.28	0.23	0.00	0.54	0.54	0.10	0.97
72B	0.19	0.30	0.43	0.10	0.00	0.35	0.35	0.08	10.62
73B	0.21	0.05	0.73	0.68	0.01	1.50	1.50	0.27	7.98
7B	0.00	0.00	0.07	0.00	0.00	0.05	0.05	0.00	0.00

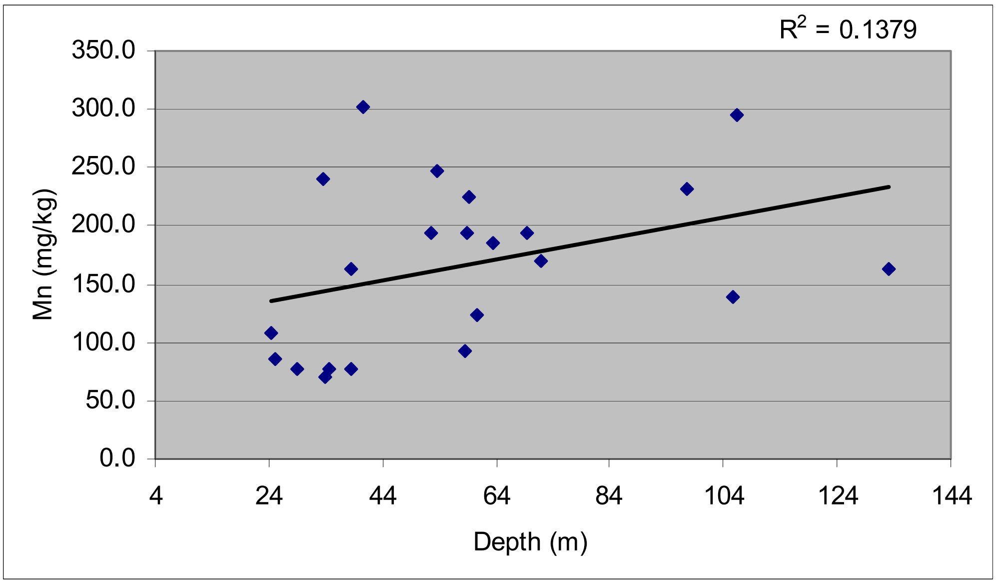
APPENDIX B: SCATTER PLOTS OF BIOTIC AND ABIOTIC RELATIONSHIPS

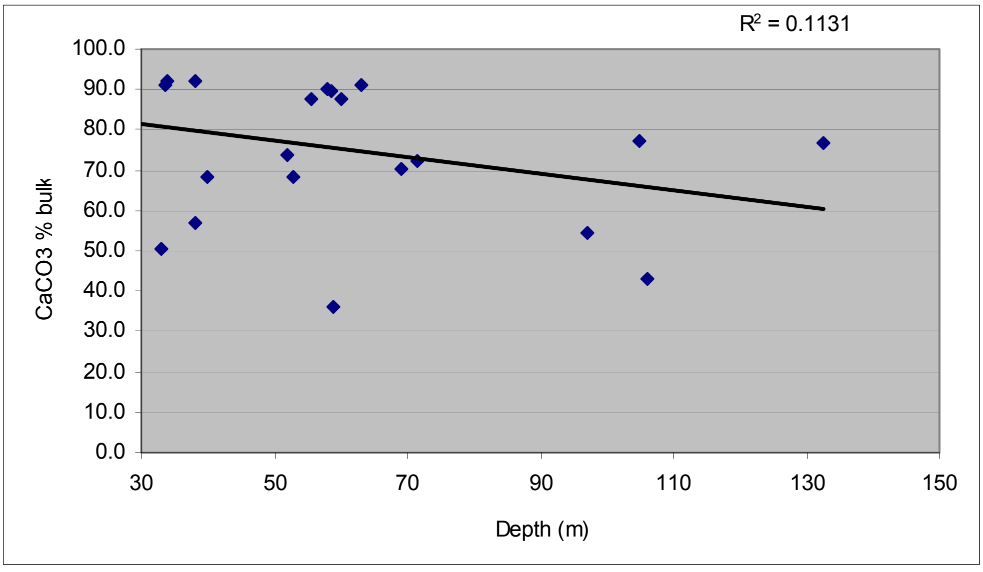
Depth

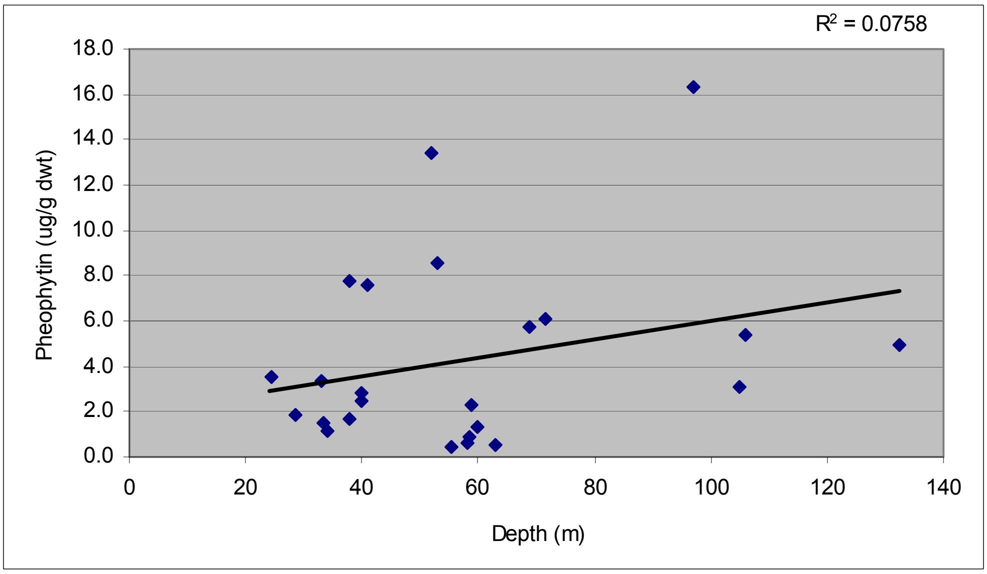


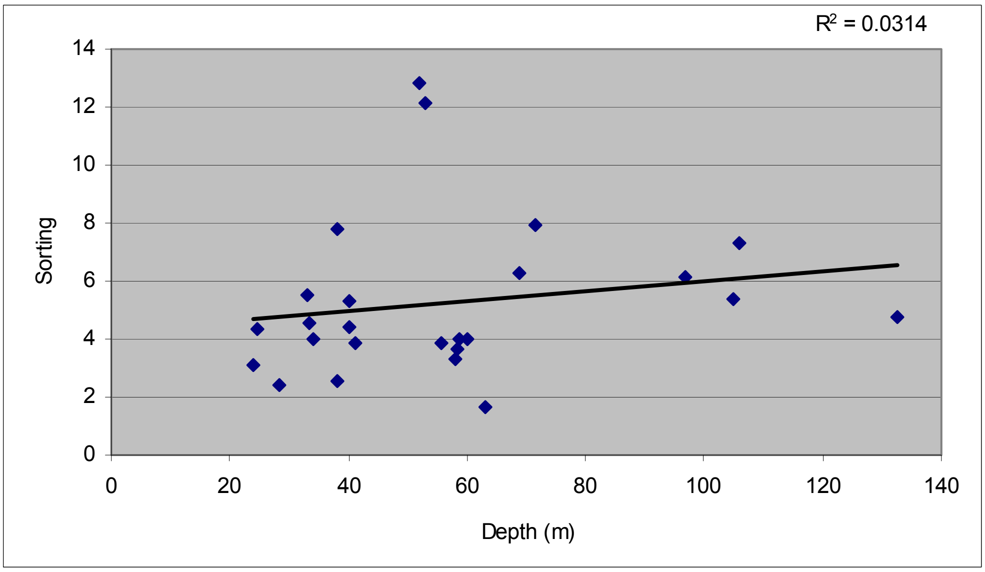


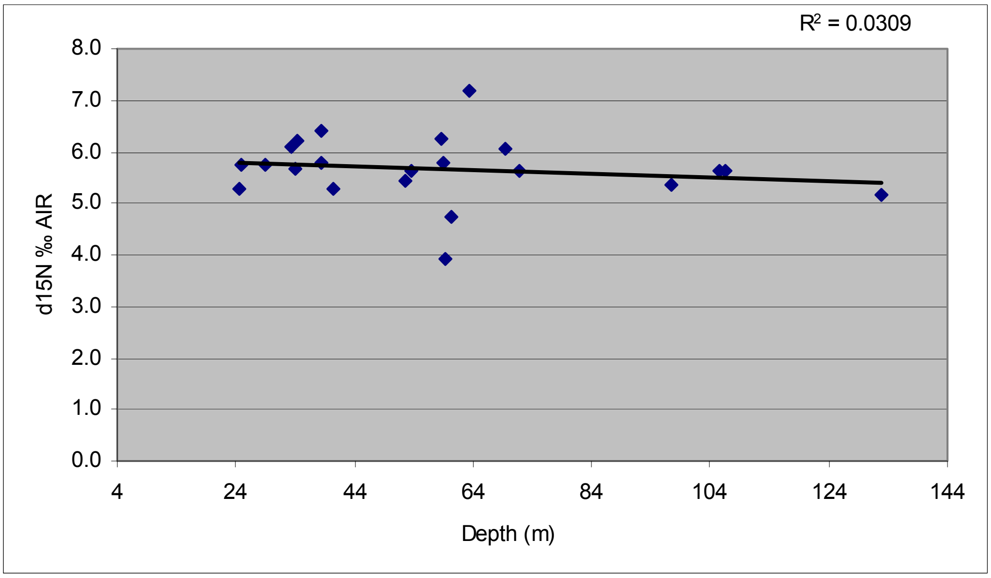

R² = 0.1499
Total reactive Chlorins
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
20
40
60
80
100
120
140
Depth (m)

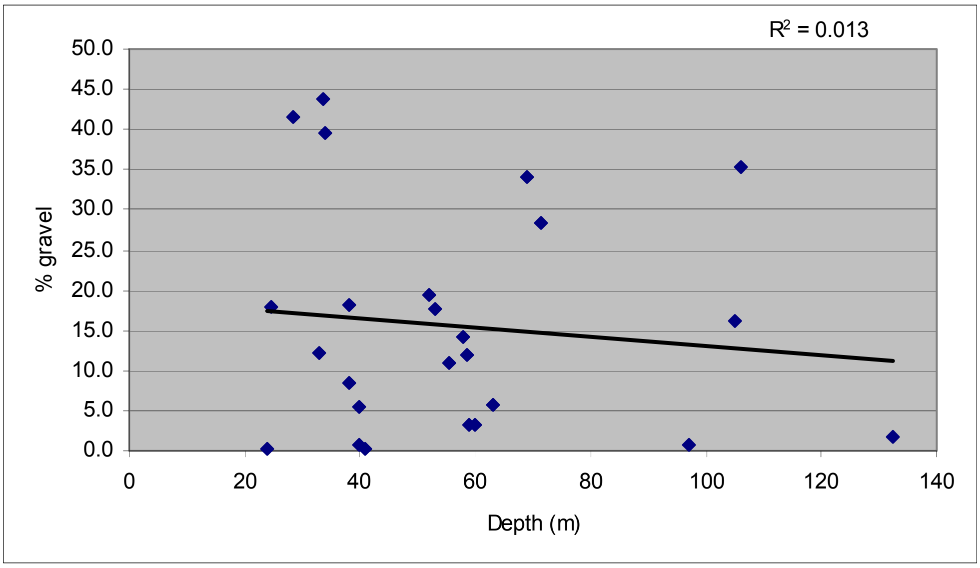

R² = 0.1379
Mn (mg/kg)
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
4
24
44
64
84
104
124
144
Depth (m)

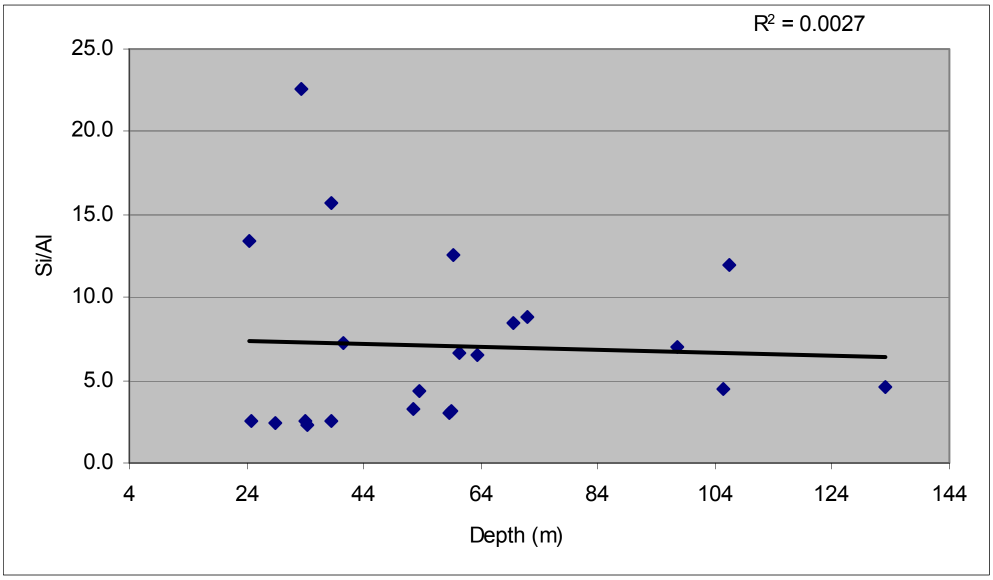

R² = 0.1131
CaCO3 % bulk
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
30
50
70
90
110
130
150
Depth (m)

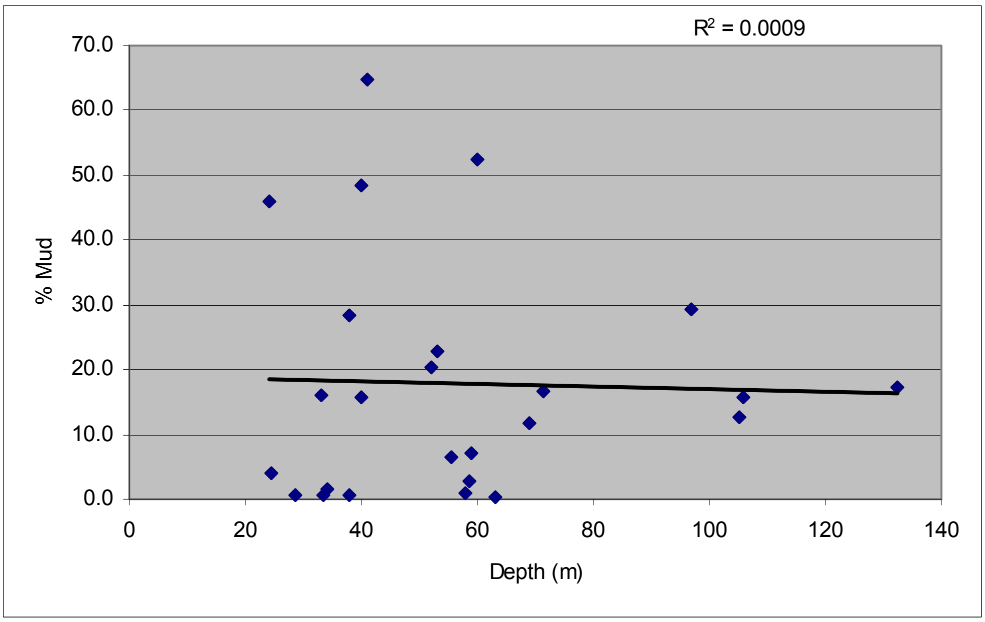

R² = 0.0758
Pheophytin (ug/g dwt)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
20
40
60
80
100
120
140
Depth (m)


R² = 0.0314
Sorting
14
12
10
8
6
4
2
0
0
20
40
60
80
100
120
140
Depth (m)

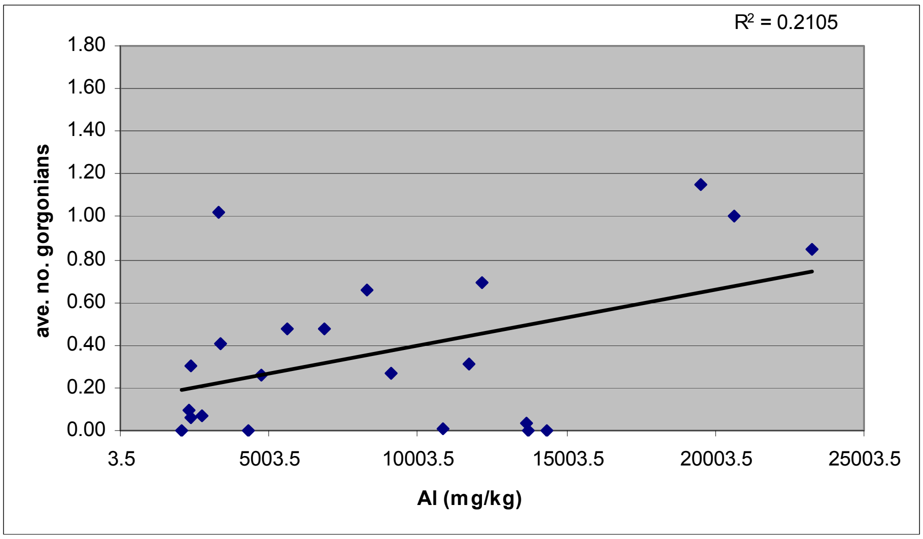

R² = 0.0309
d15N ‰ AIR
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
4
24
44
64
84
104
124
144
Depth (m)

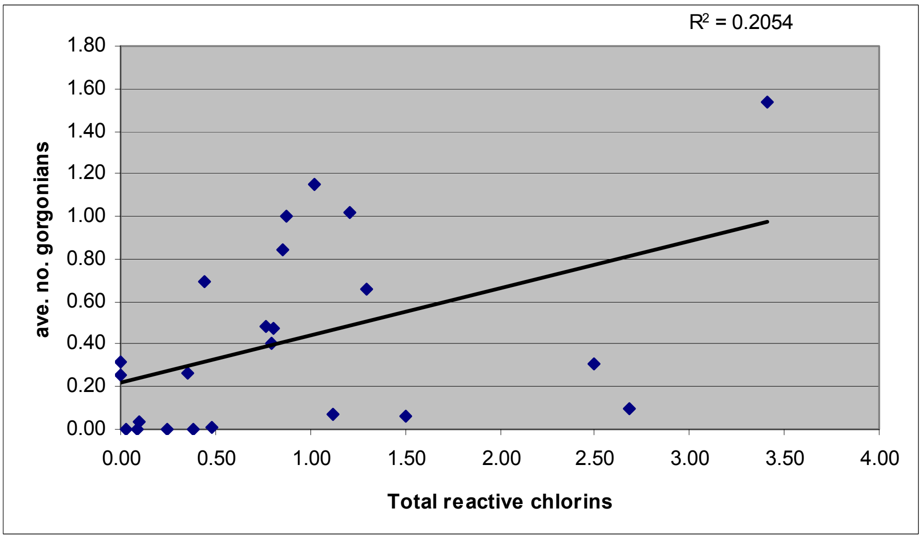

R² = 0.013
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
% gravel
0
20
40
60
80
100
120
140
Depth (m)

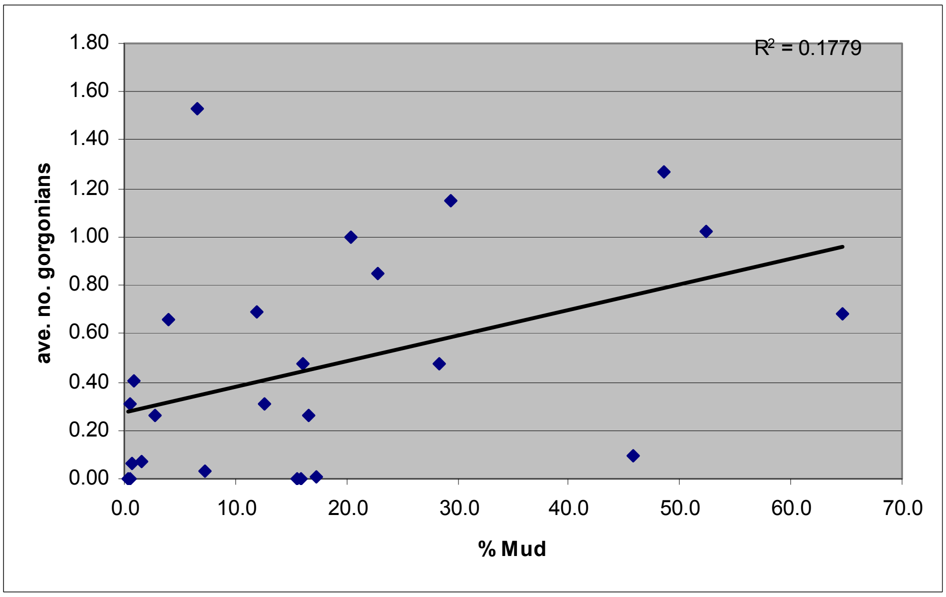

R² = 0.0027
25.0
20.0
15.0
10.0
5.0
0.0
Si/Al
4
24
44
64
84
104
124
144
Depth (m)

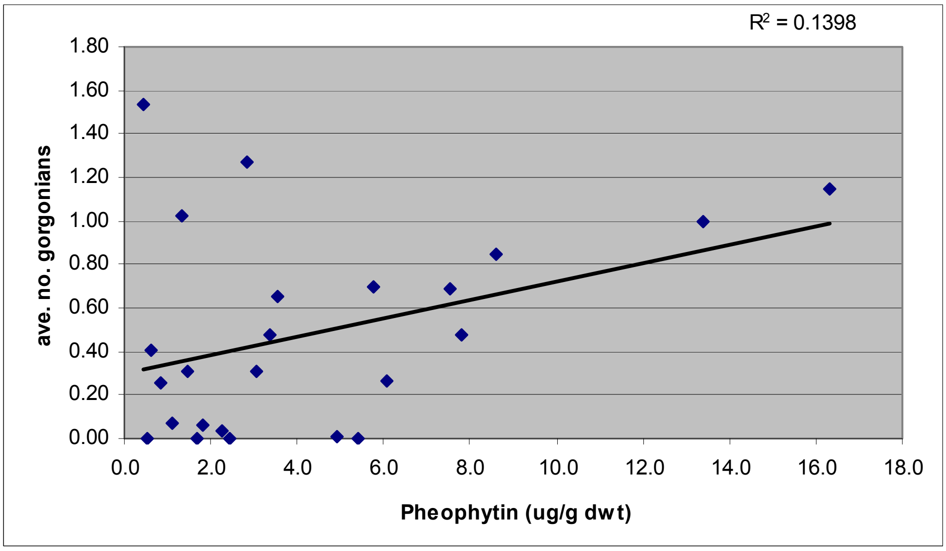

R² = 0.0009
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
% Mud
0
20
40
60
80
100
120
140
Depth (m)

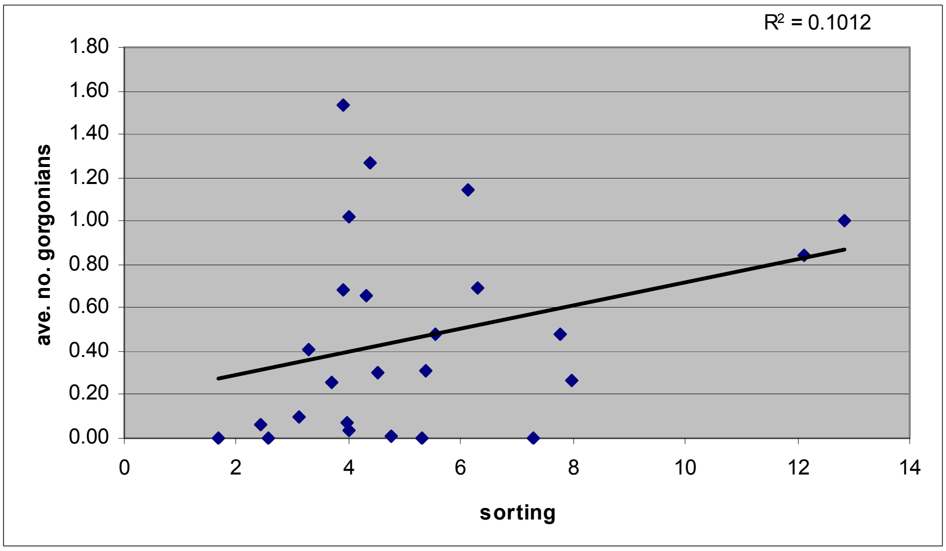
Gorgonians

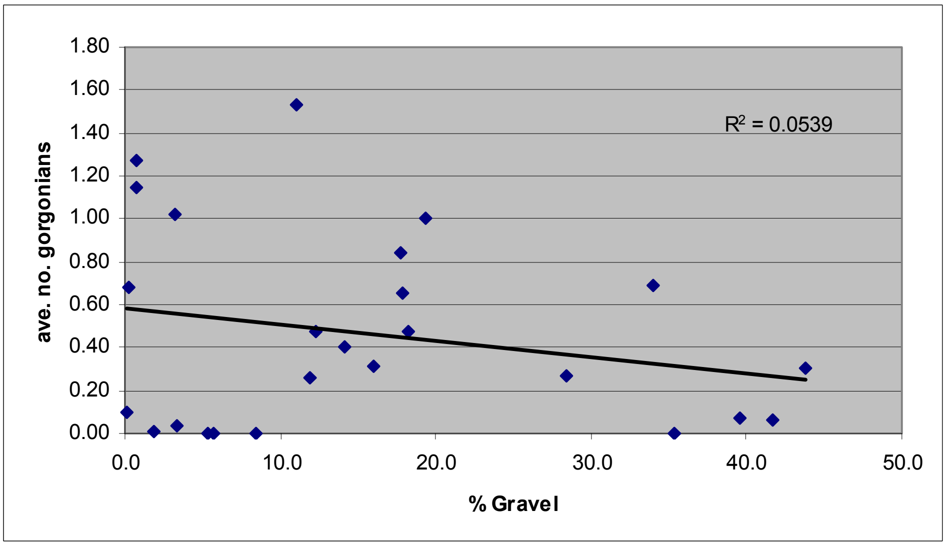

R² = 0.2105
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
ave. no. gorgonians
3.5
5003.5
10003.5
15003.5
20003.5
25003.5
Al (mg/kg)

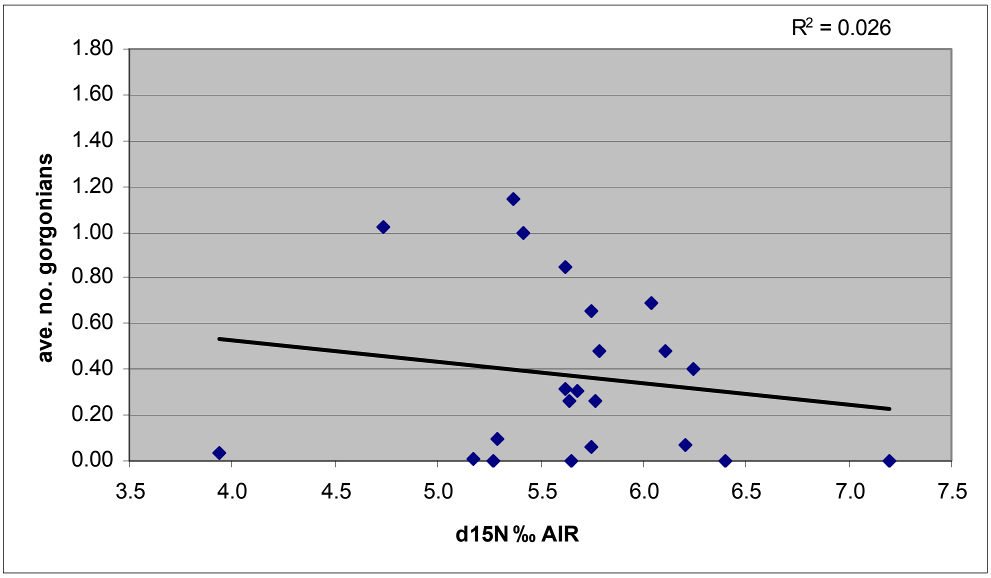

R² = 0.2054
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
ave. no. gorgonians
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Total reactive chlorins

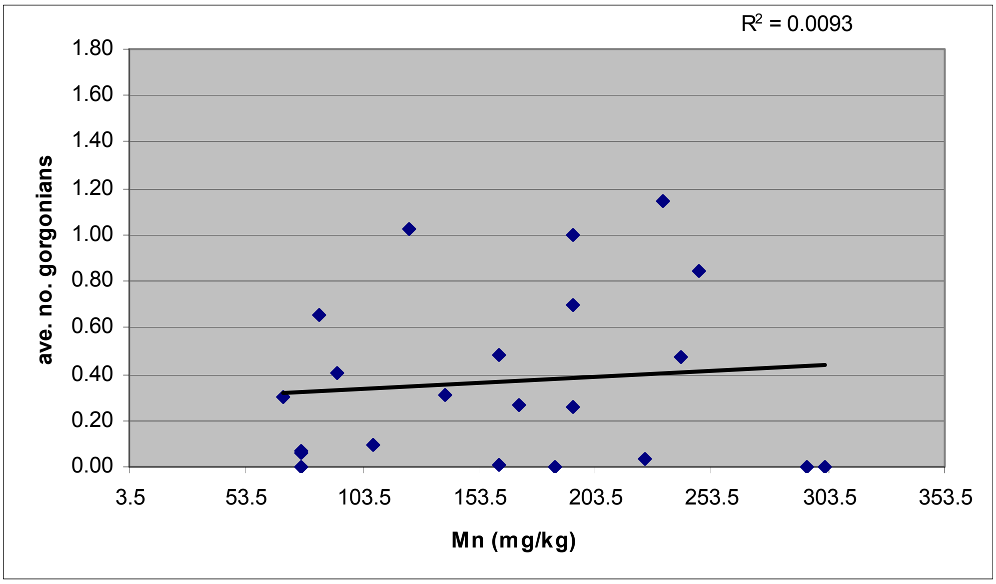

R² = 0.1779
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
ave. no. gorgonians
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
% Mud

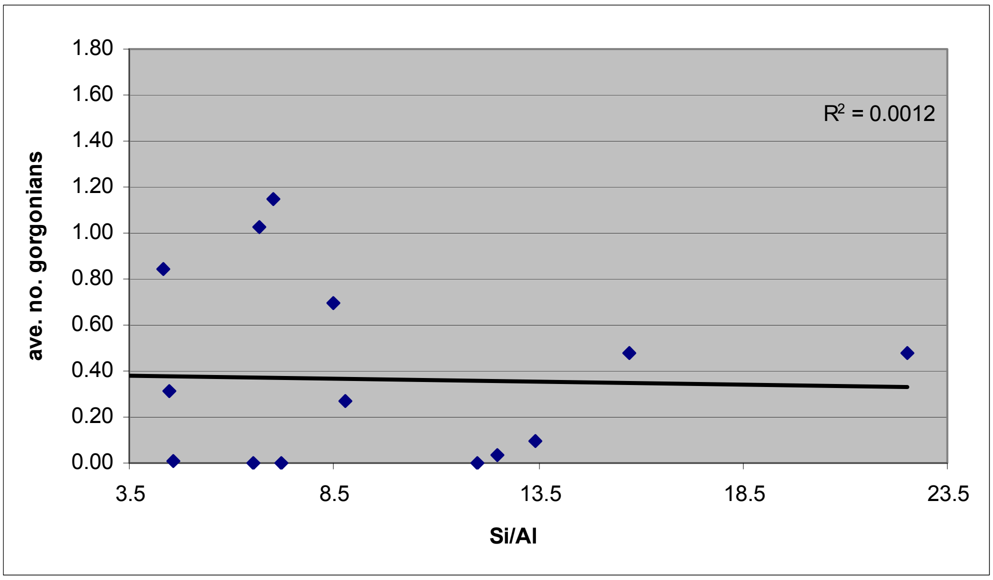

R² = 0.1398
ave. no. gorgonians
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Pheophytin (ug/g dwt)

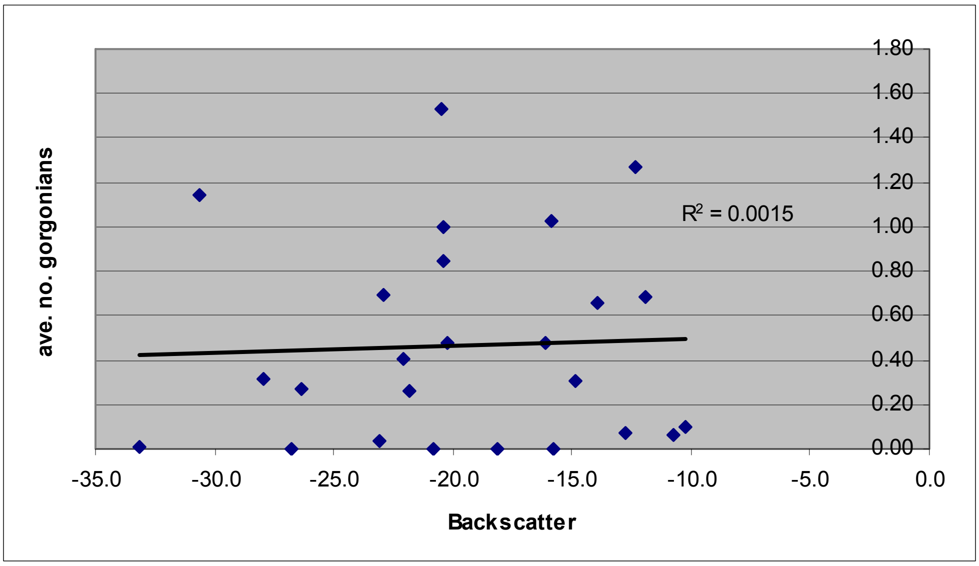

R² = 0.1012
ave. no. gorgonians
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
2
4
6
8
10
12
14
sorting

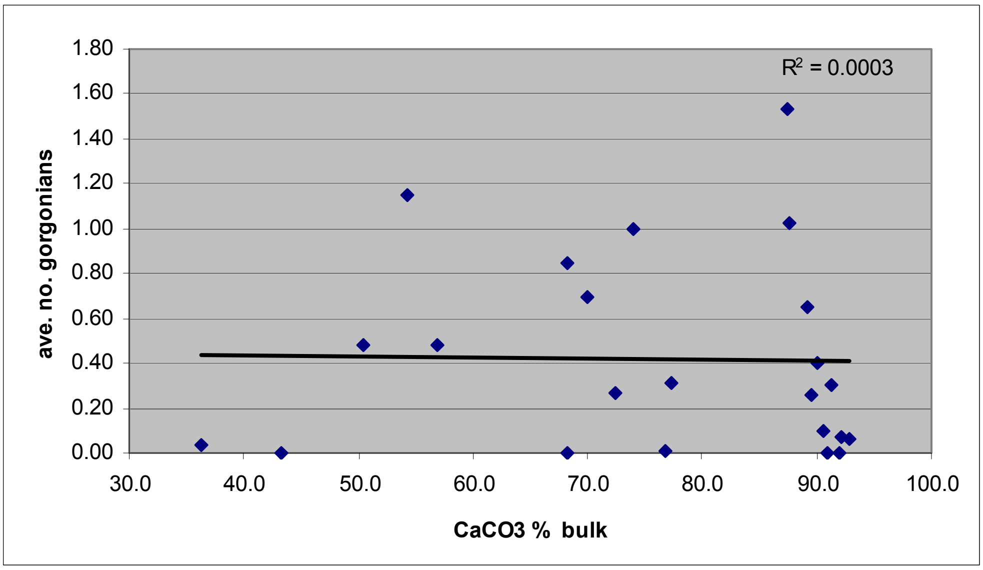

R² = 0.0539
ave. no. gorgonians
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.0
10.0
20.0
30.0
40.0
50.0
% Gravel


R² = 0.026
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
ave. no. gorgonians
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
d15N ‰ AIR

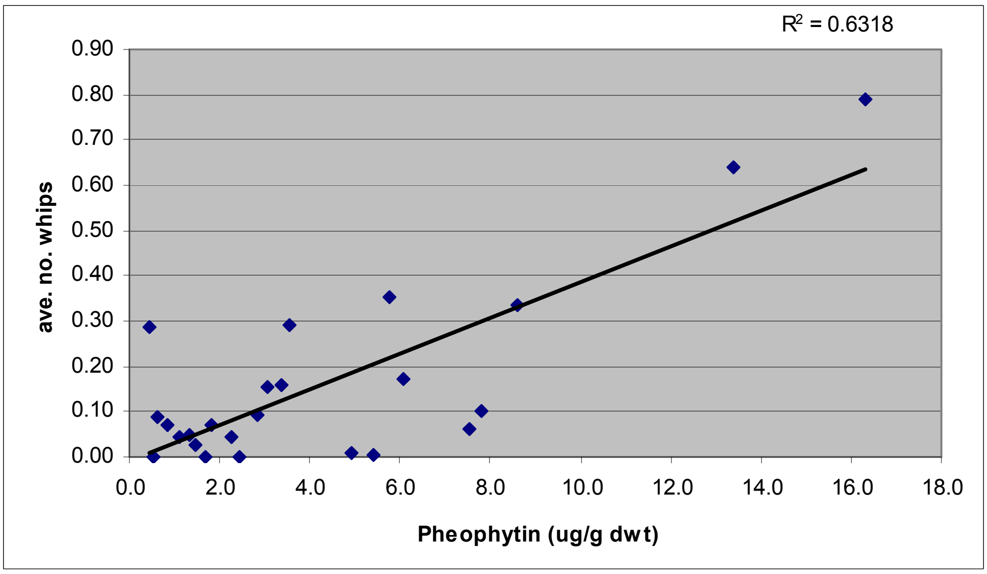

R² = 0.0093
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
ave. no. gorgonians
3.5
53.5
103.5
153.5
203.5
253.5
303.5
353.5
Mn (mg/kg)

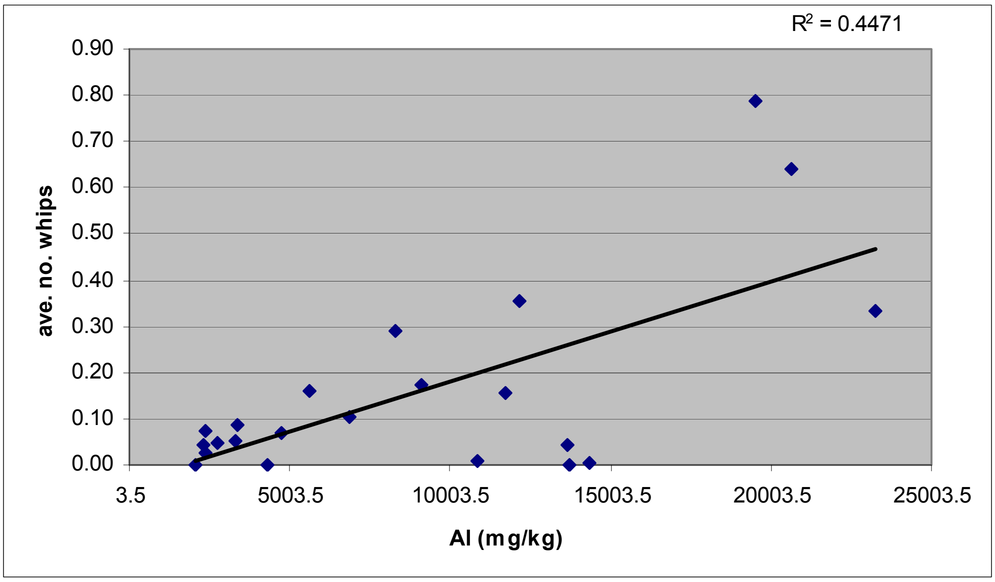

R² = 0.0012
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
ave. no. gorgonians
3.5
8.5
13.5
18.5
23.5
Si/Al

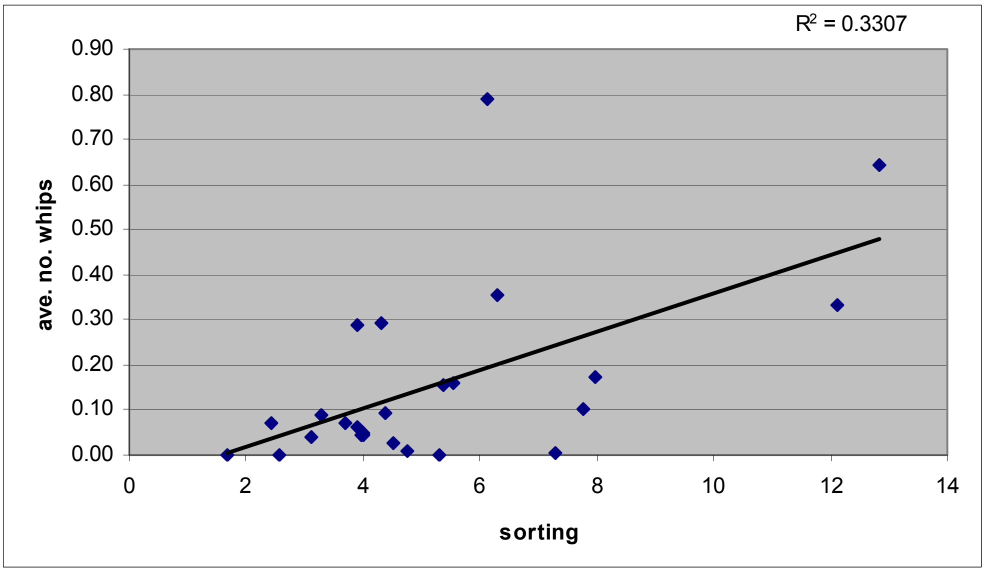

ave. no. gorgonians
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
R² = 0.0015
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0
Backscatter

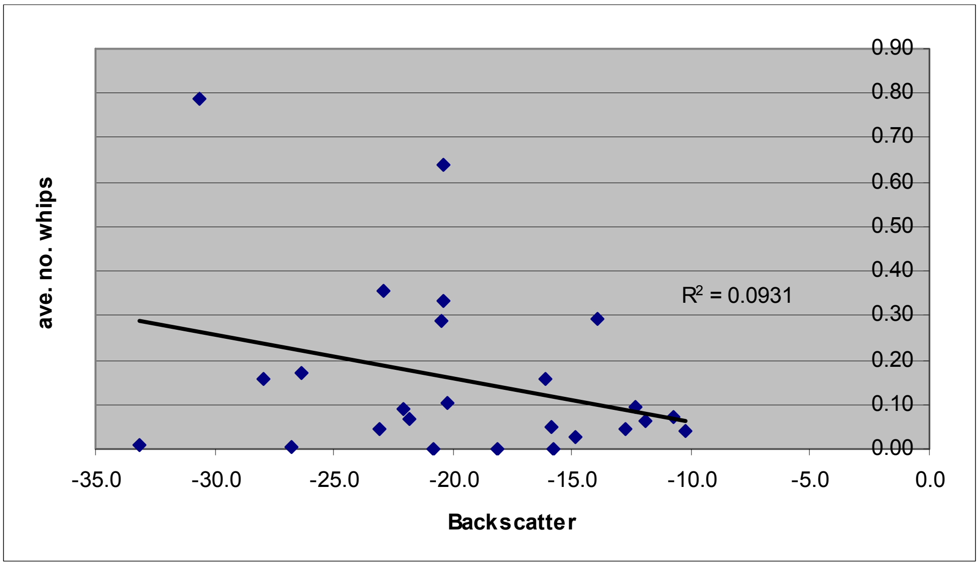

ave. no. gorgonians
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
R² = 0.0003
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
CaCO3 % bulk

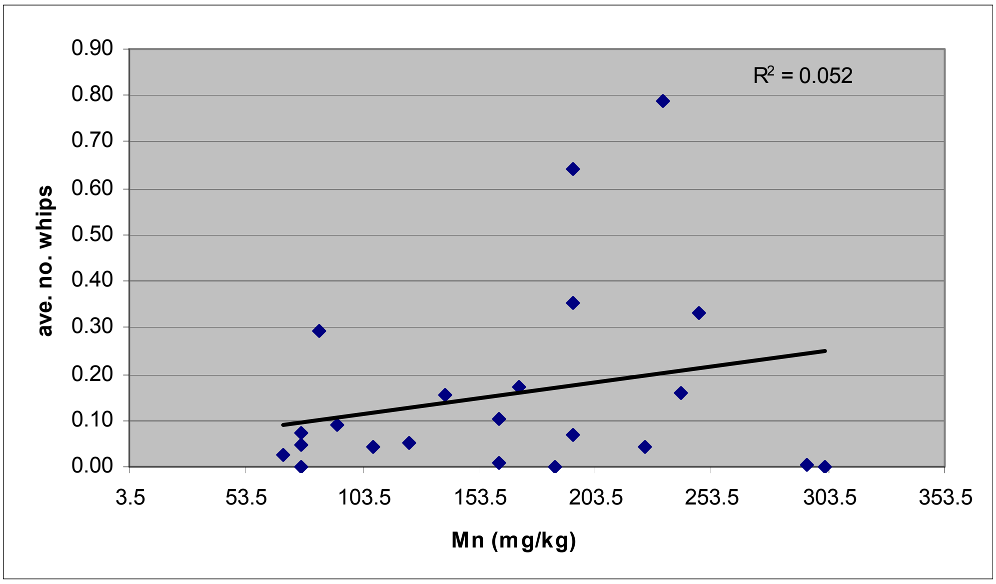
Whips

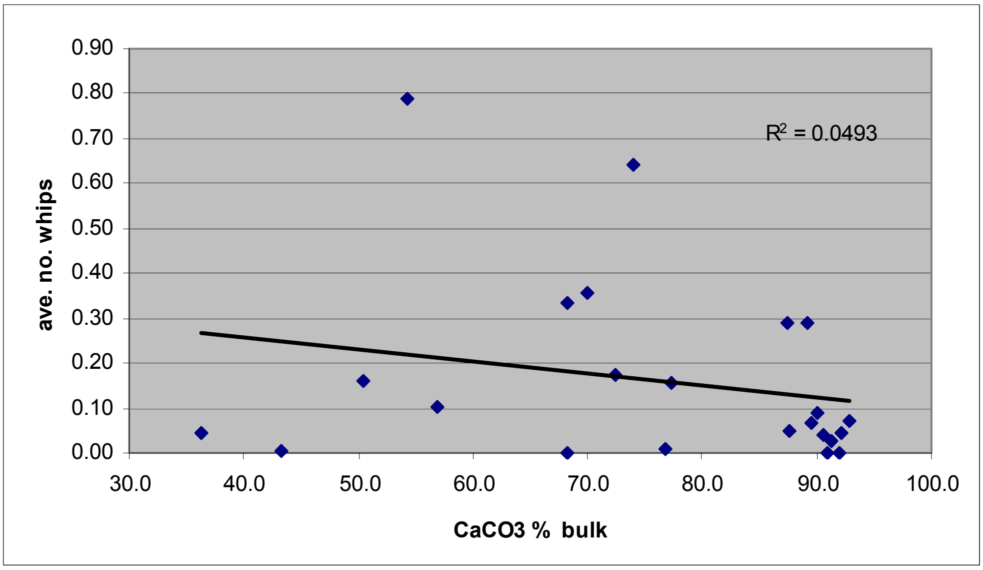

ave. no. whips
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
R² = 0.6318
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Pheophytin (ug/g dwt)

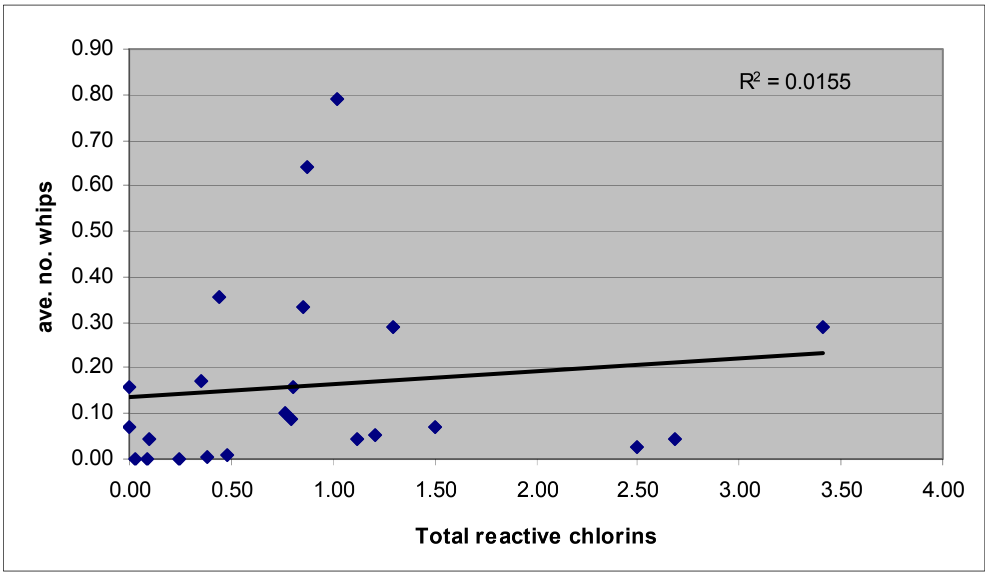

R² = 0.4471
ave. no. whips
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3.5
5003.5
10003.5
15003.5
20003.5
25003.5
Al (mg/kg)

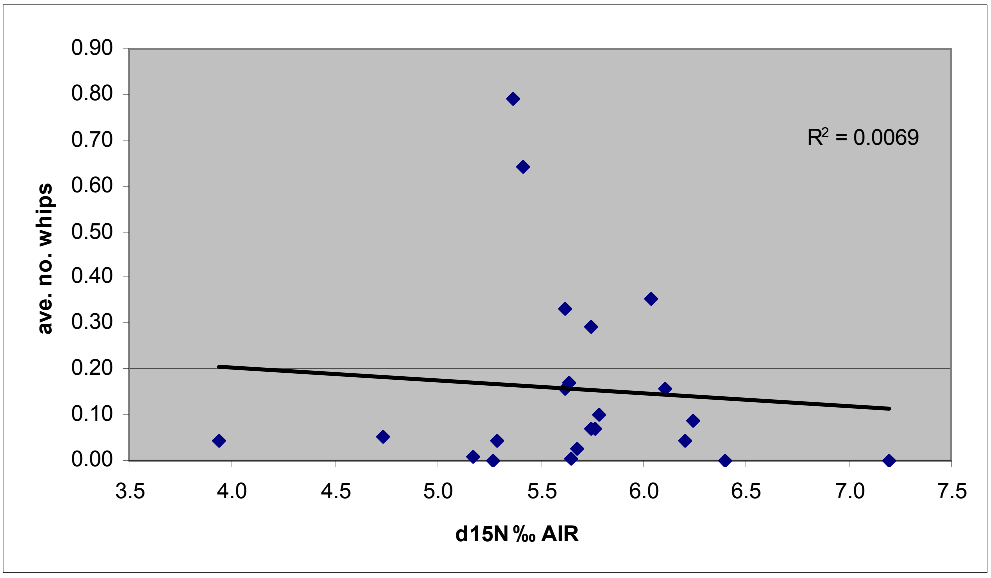

R² = 0.3307
ave. no. whips
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
2
4
6
8
10
12
14
sorting

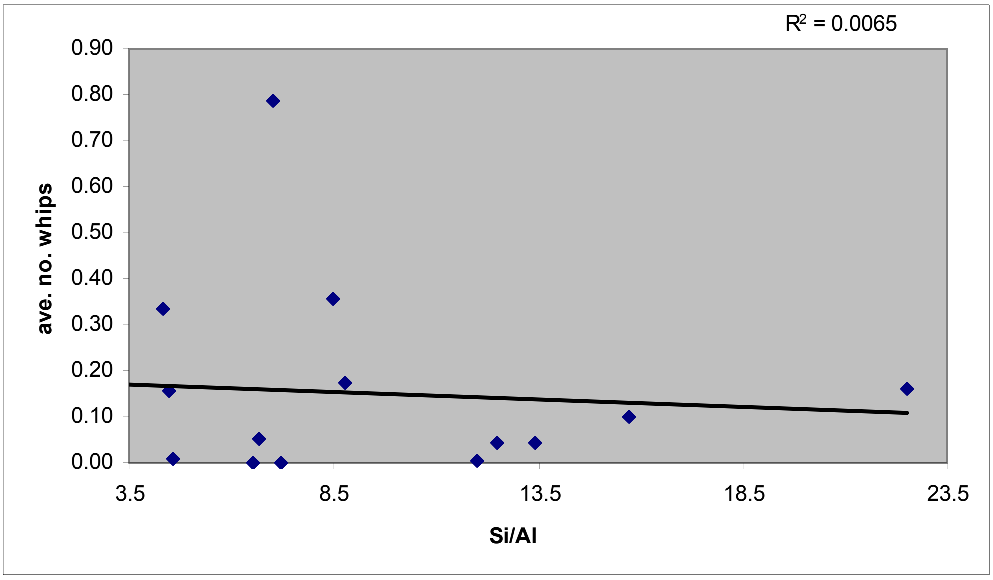

ave. no. whips
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
R² = 0.0931
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0
Backscatter

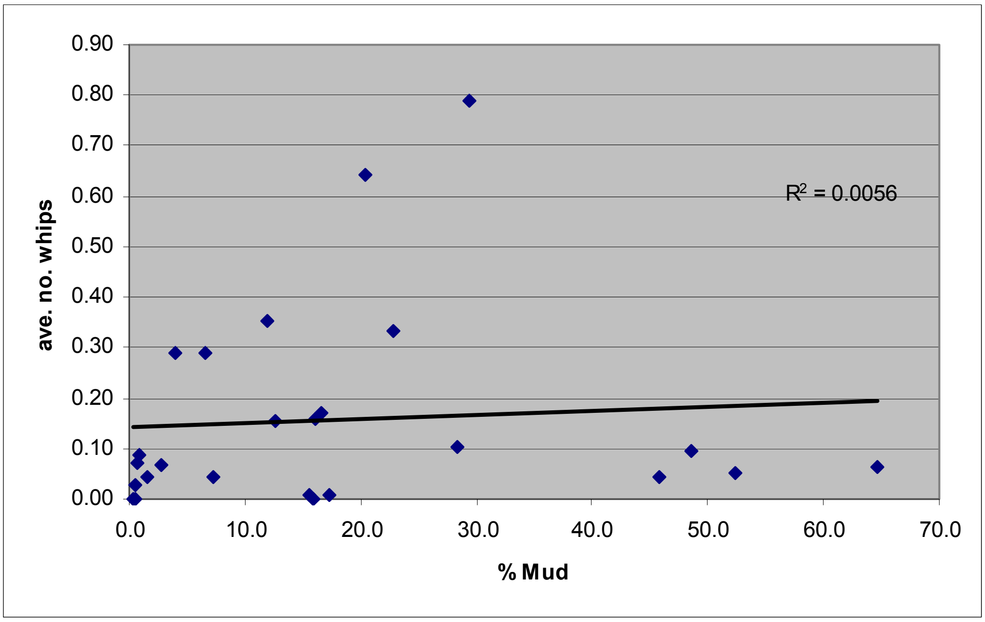

R² = 0.052
ave. no. whips
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3.5
53.5
103.5
153.5
203.5
253.5
303.5
353.5
Mn (mg/kg)

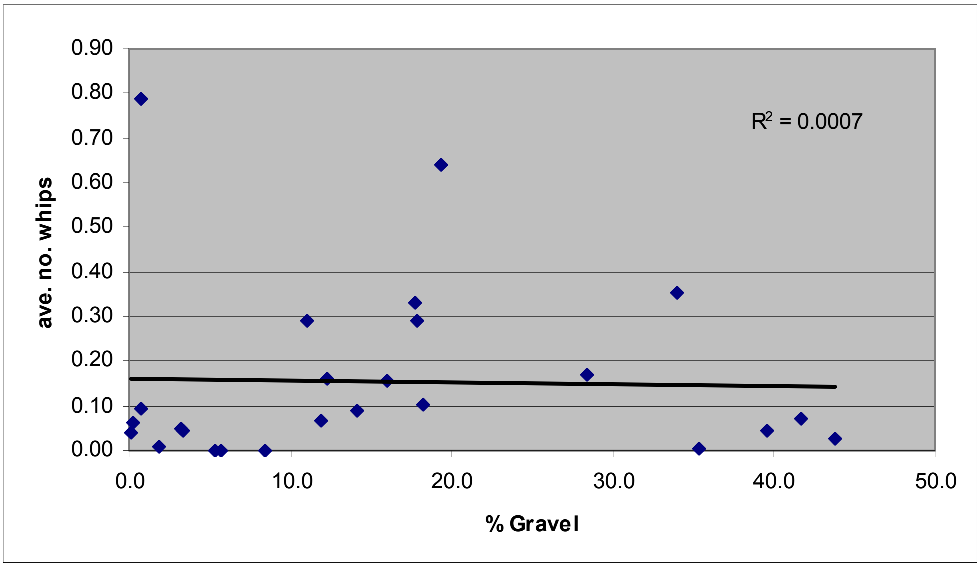

R² = 0.0493
ave. no. whips
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
CaCO3 % bulk


R² = 0.0155
ave. no. whips
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Total reactive chlorins

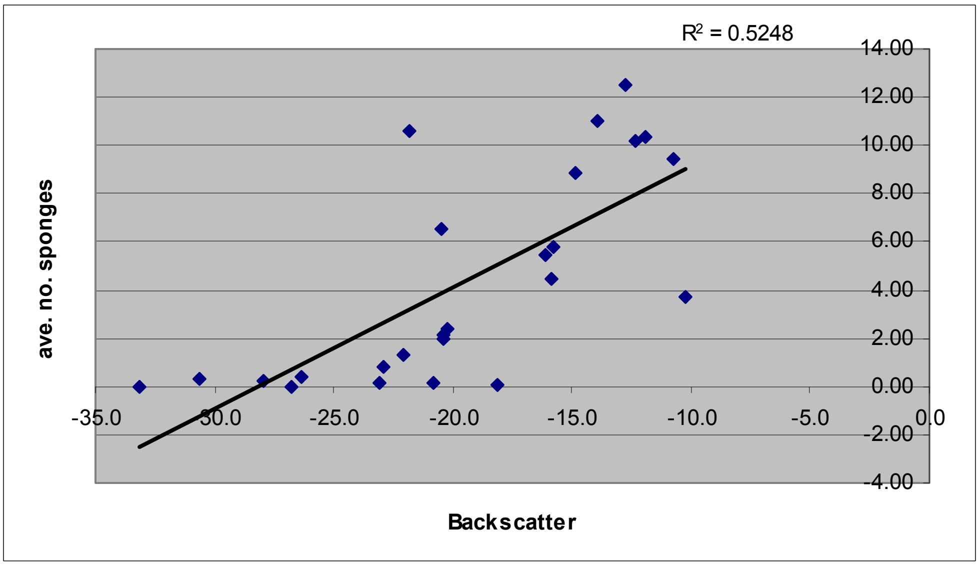

ave. no. whips
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
R² = 0.0069
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
d15N ‰ AIR

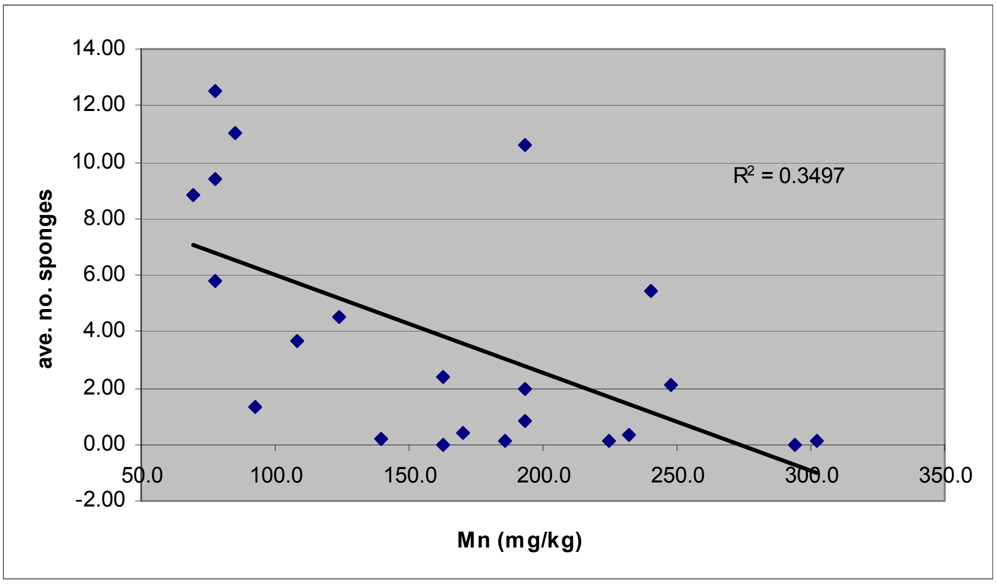

R² = 0.0065
ave. no. whips
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3.5
8.5
13.5
18.5
23.5
Si/Al

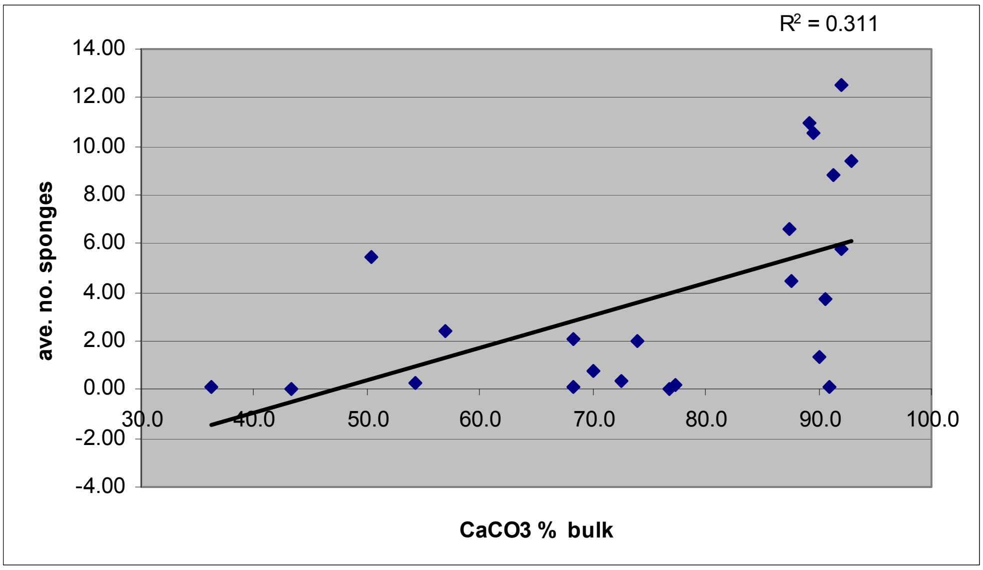

ave. no. whips
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
R² = 0.0056
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
% Mud

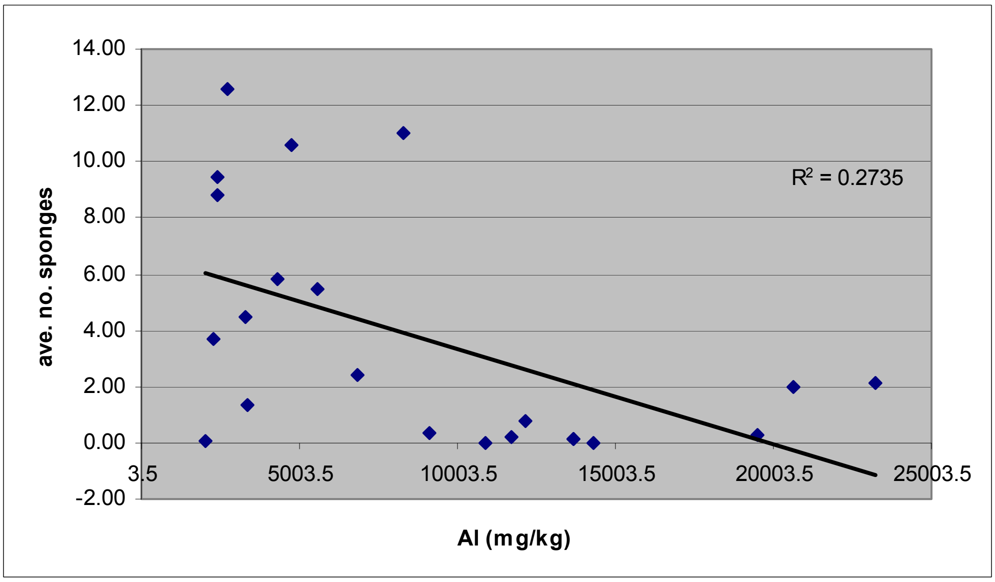


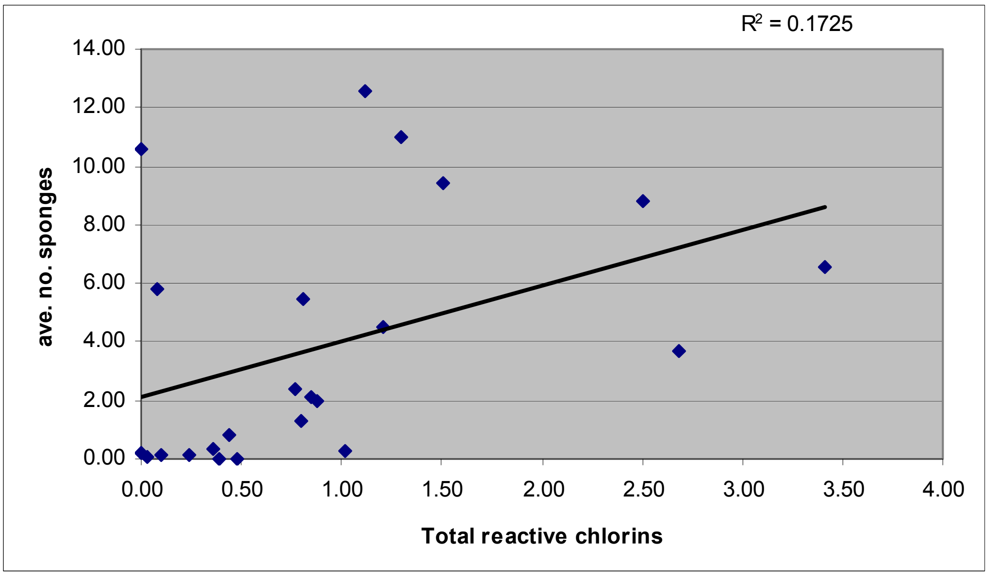
Total Sponges

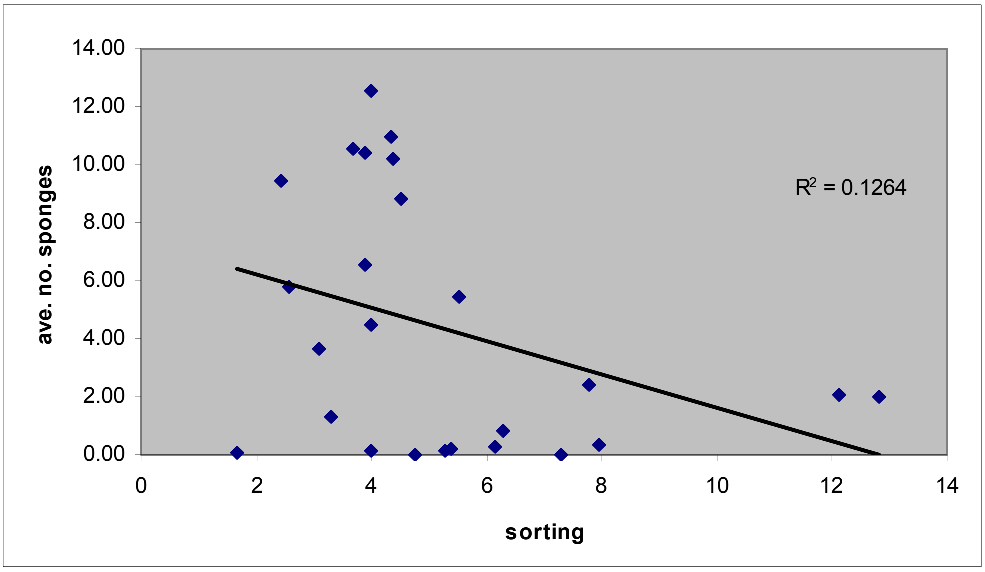




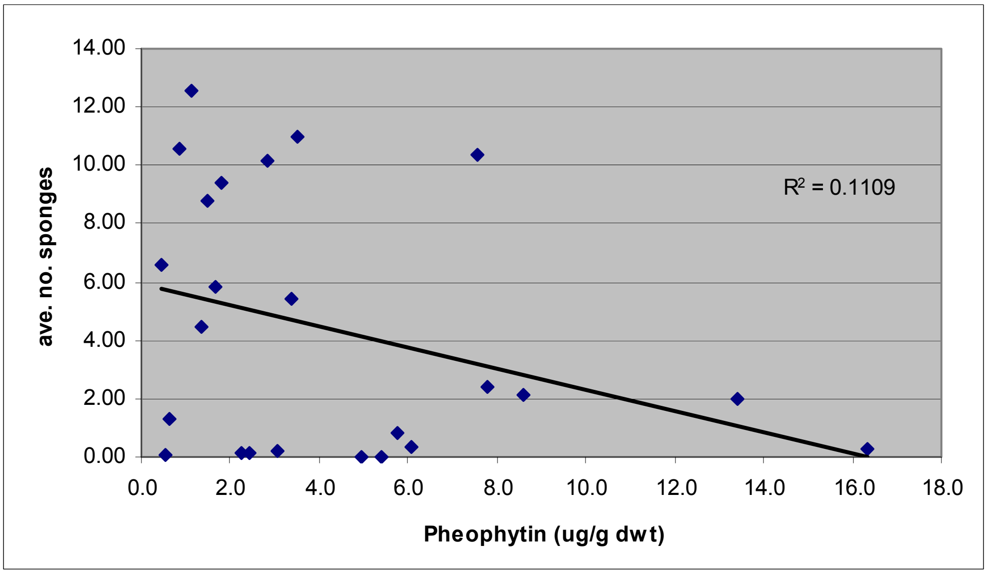

R² = 0.311
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
ave. no. sponges
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
CaCO3 % bulk


R² = 0.2735
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
ave. no. sponges
3.5
5003.5
10003.5
15003.5
20003.5
25003.5
Al (mg/kg)

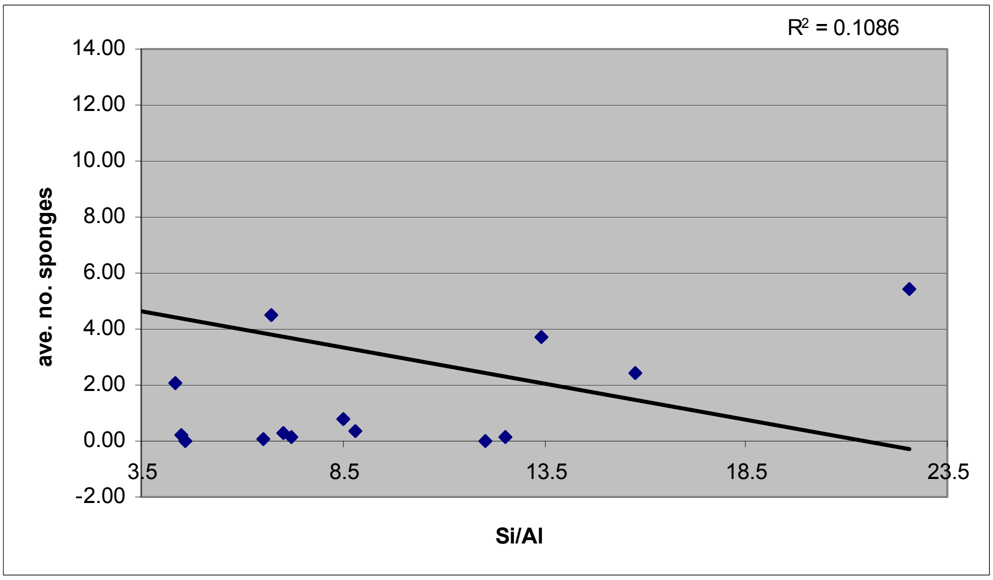

R² = 0.1725
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
ave. no. sponges
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Total reactive chlorins



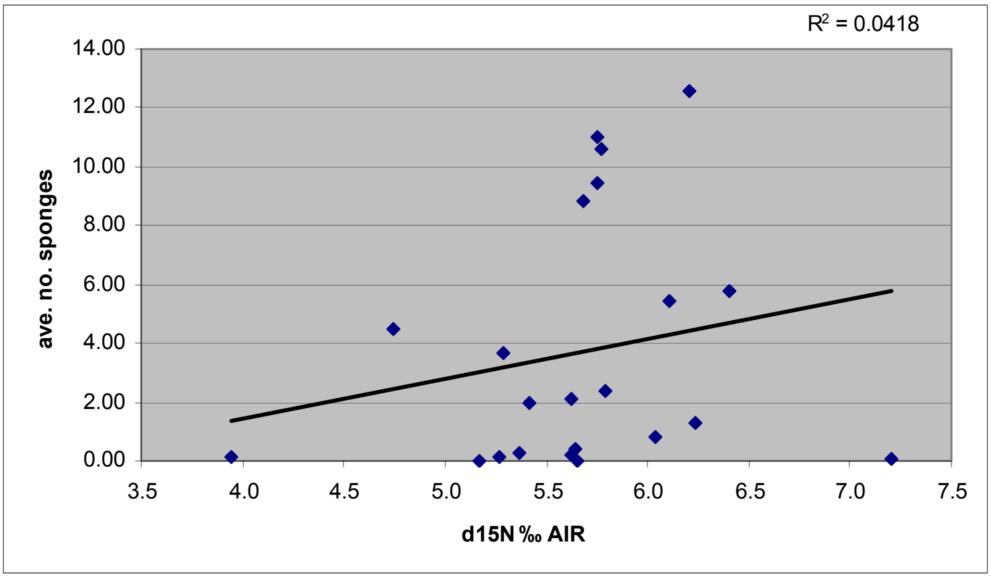
ave. no. sponges
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
2
4
6
8
10
12
14
sorting
R^2 = 0.1264

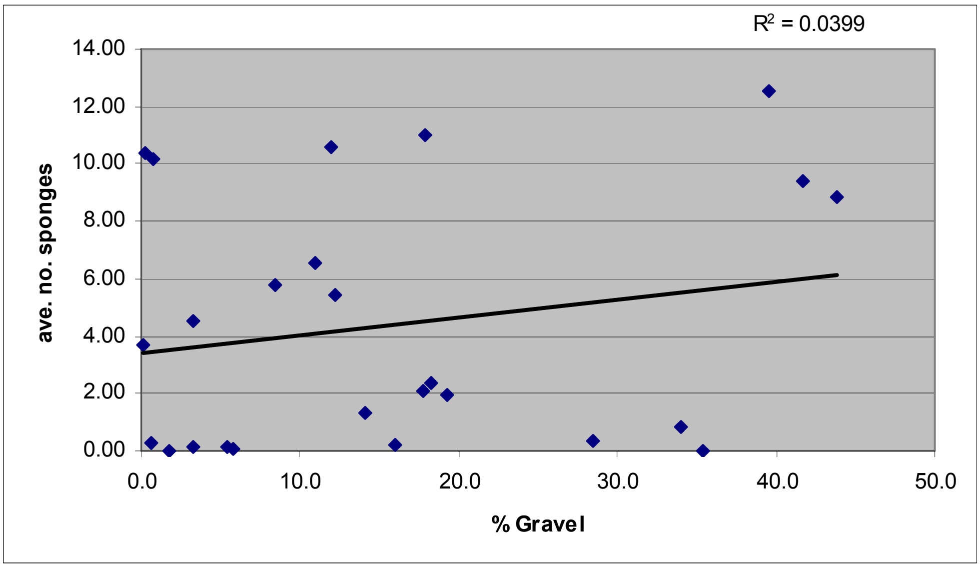


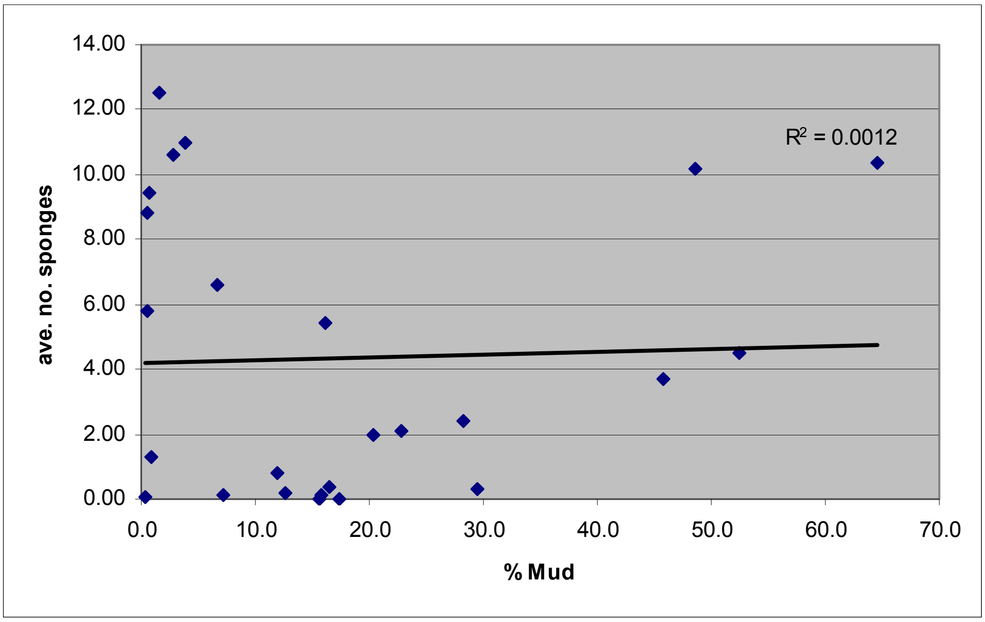
ave. no. sponges
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Pheophytin (ug/g dwt)
R^2 = 0.1109



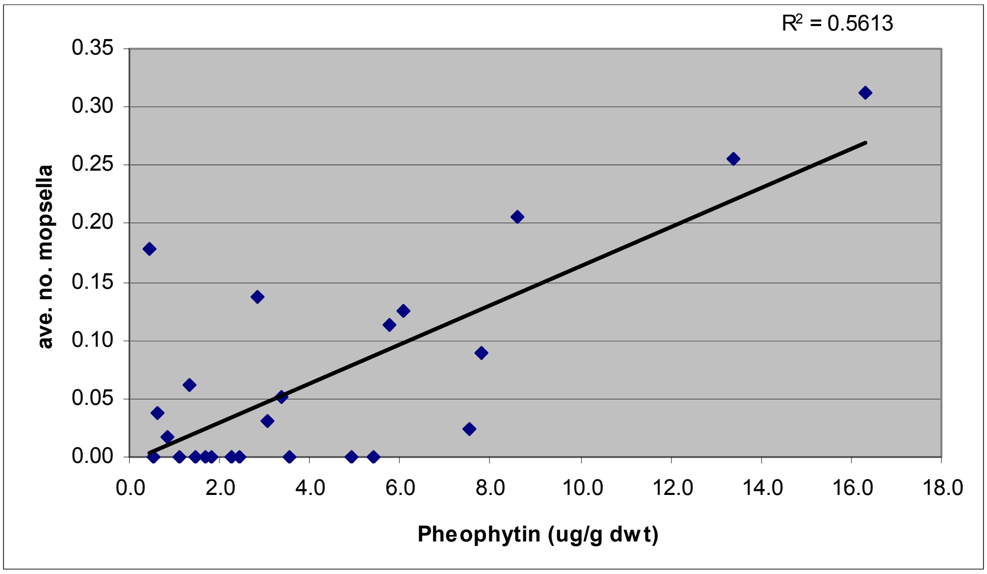
R^2 = 0.1086
ave. no. sponges
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
3.5
8.5
13.5
18.5
23.5
Si/Al

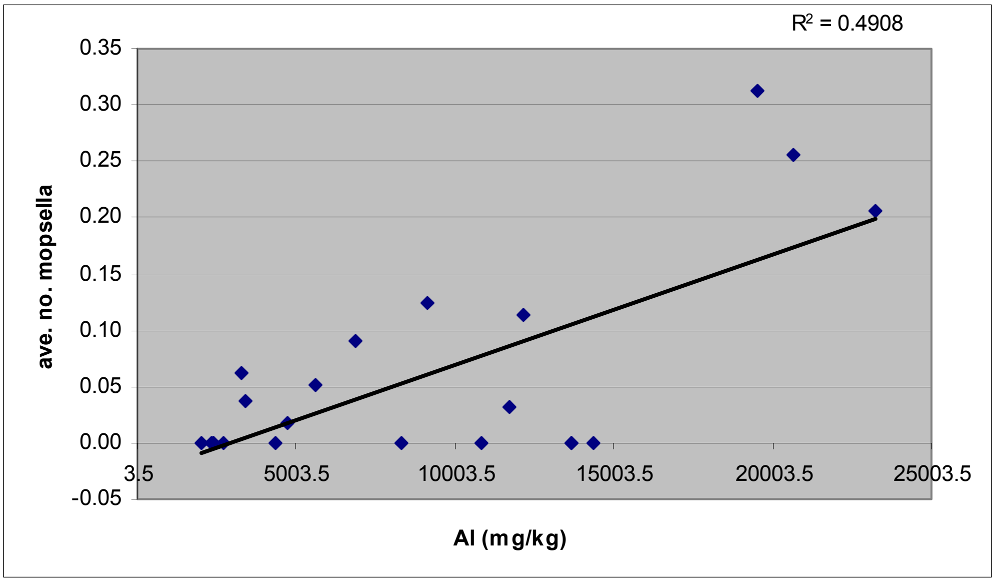

R² = 0.0418
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
ave. no. sponges
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
d15N ‰ AIR

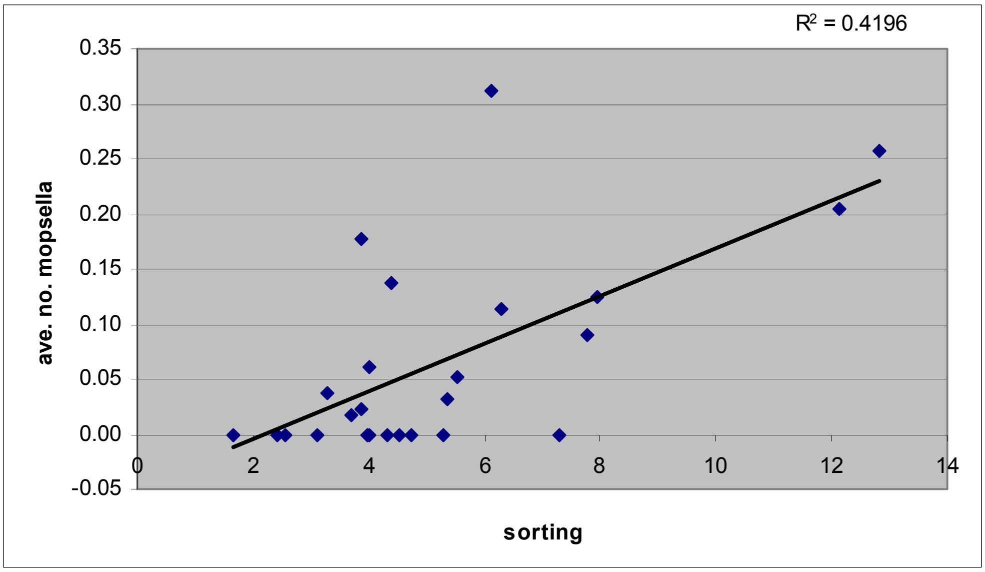

R² = 0.0399
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
ave. no. sponges
0.0
10.0
20.0
30.0
40.0
50.0
% Gravel

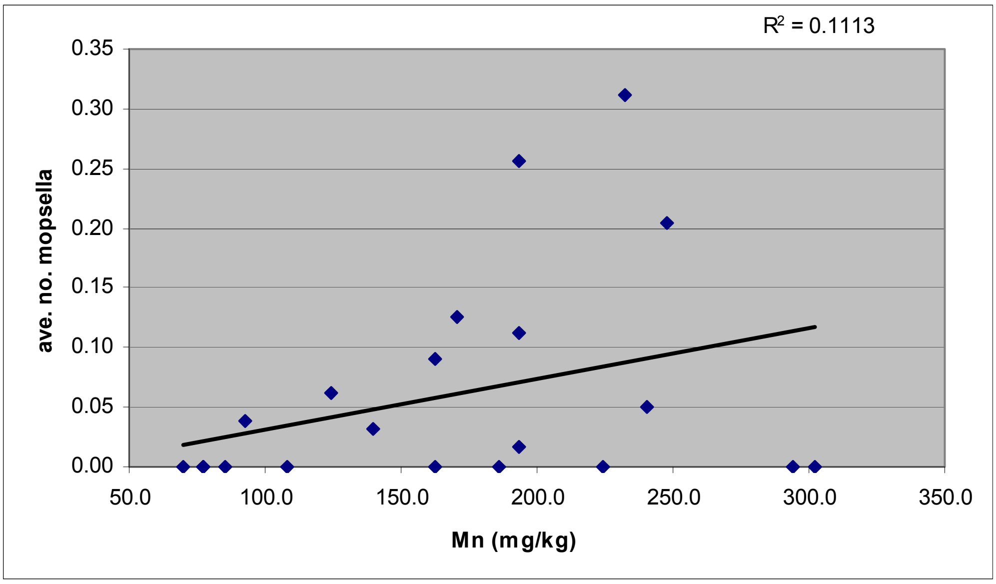

14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
ave. no. sponges
R² = 0.0012
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
% Mud

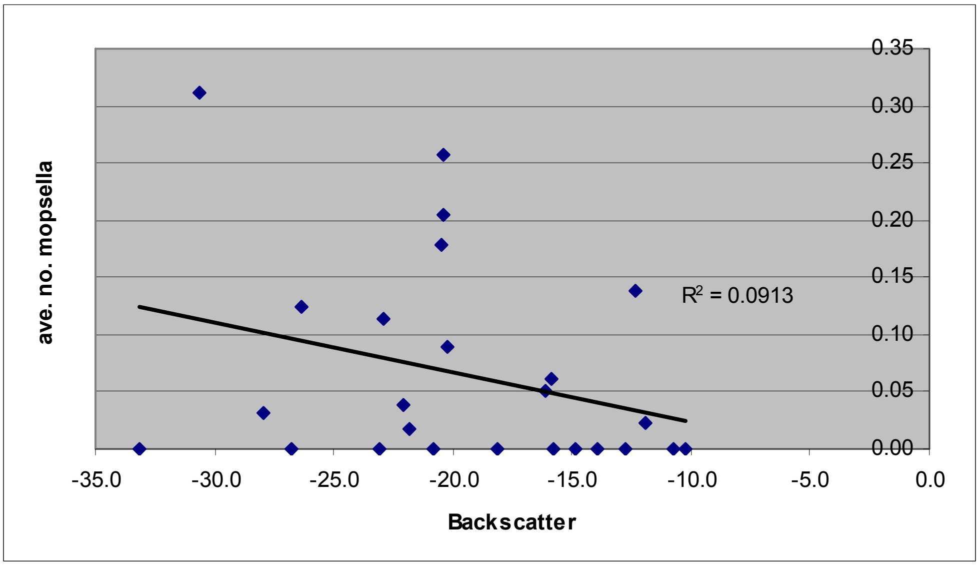
Mopsella

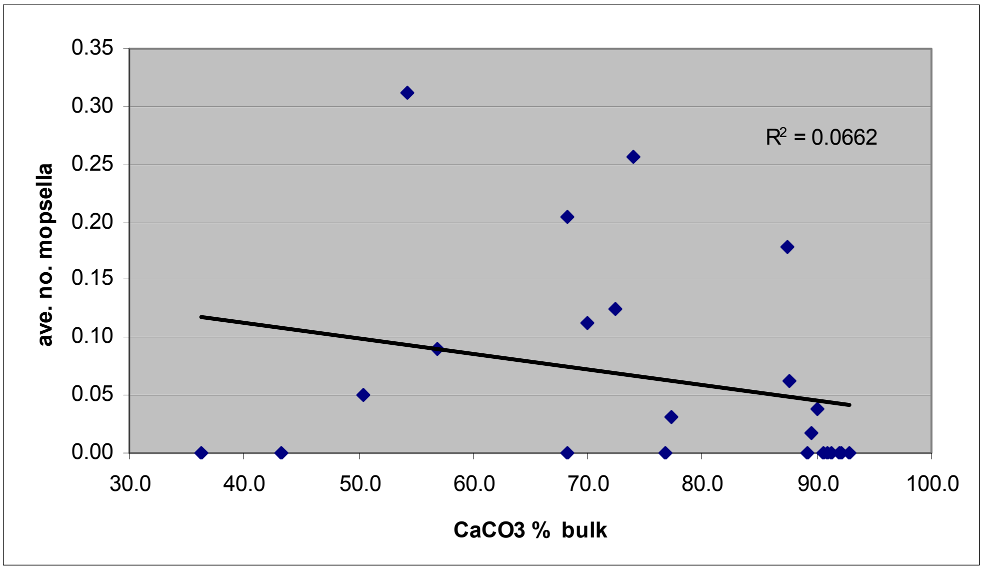

R² = 0.5613
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
ave. no. mopsella
Pheophytin (ug/g dwt)

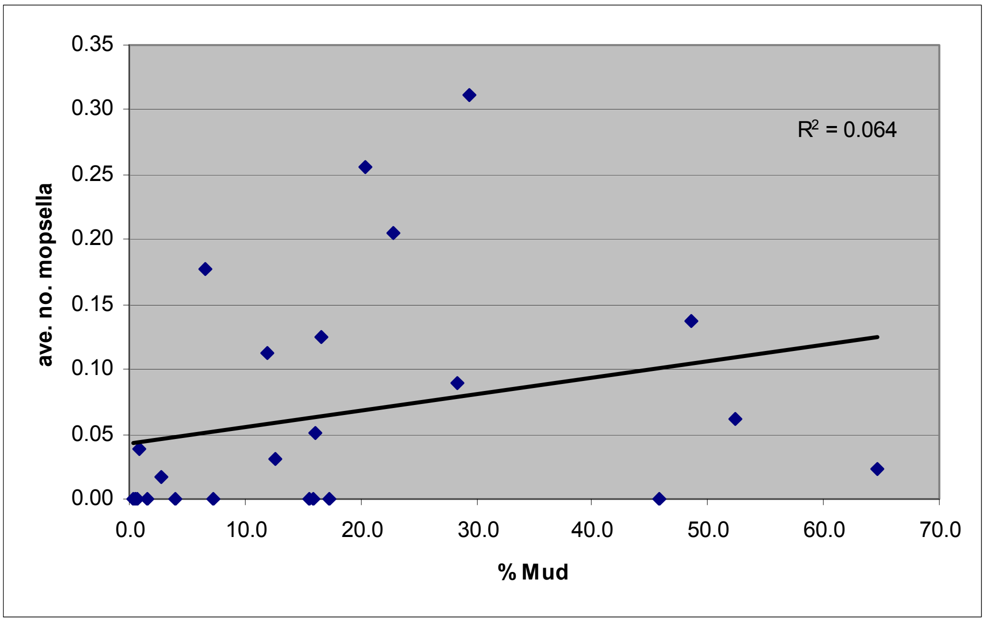

R² = 0.4908
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
3.5
5003.5
10003.5
15003.5
20003.5
25003.5
ave. no. mopsella
Al (mg/kg)


R² = 0.4196
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0
2
4
6
8
10
12
14
ave. no. mopsella
sorting

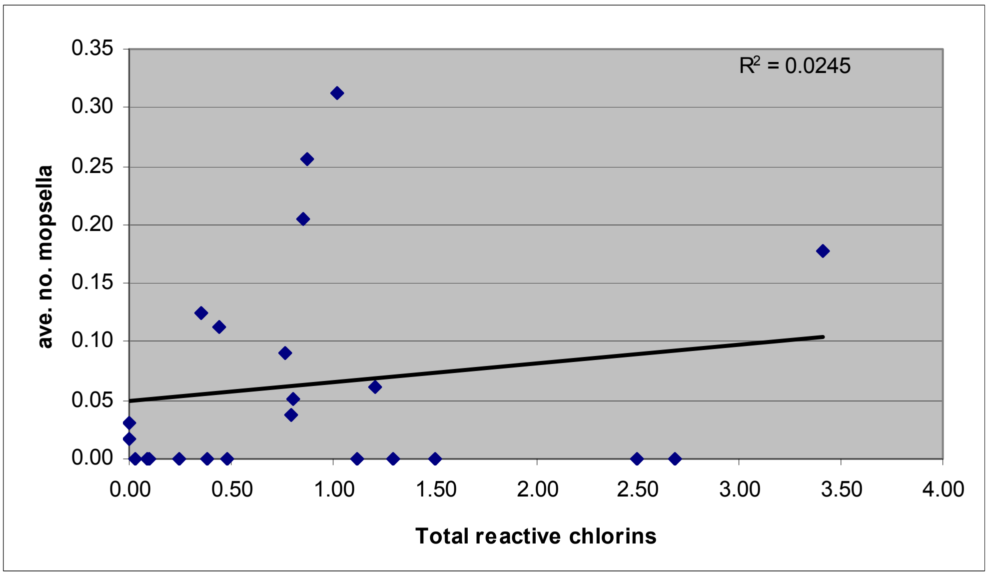

R² = 0.1113
ave. no. mopsella
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Mn (mg/kg)


ave. no. mopsella
R² = 0.0913
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0
Backscatter

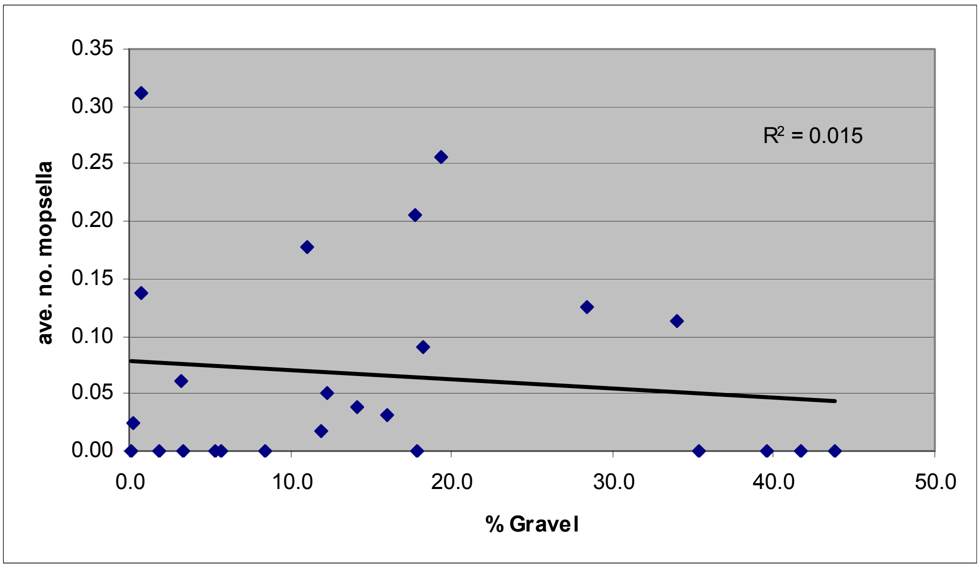

R² = 0.0662
ave. no. mopsella
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
CaCO3 % bulk



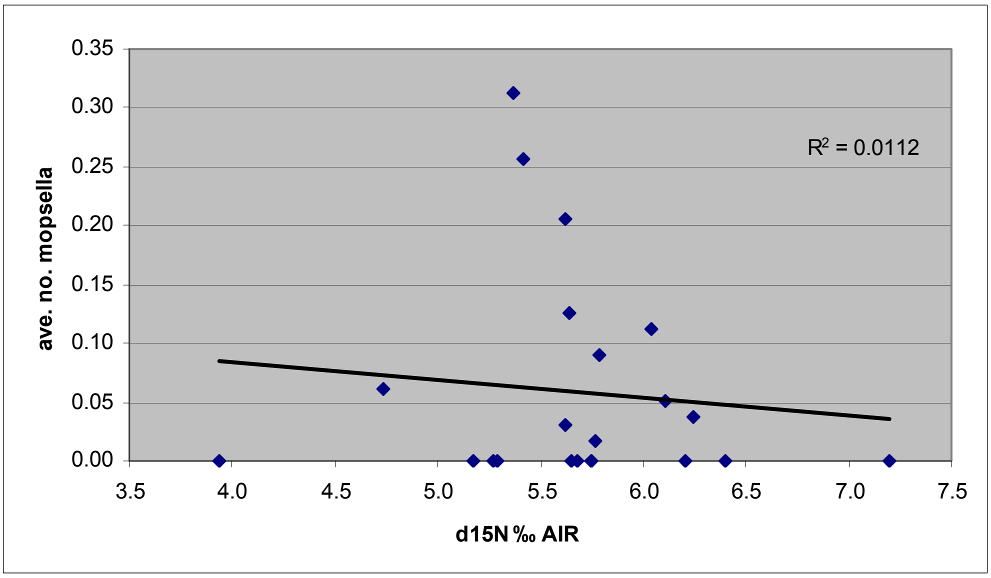
ave. no. mopsella
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
% Mud
R² = 0.064

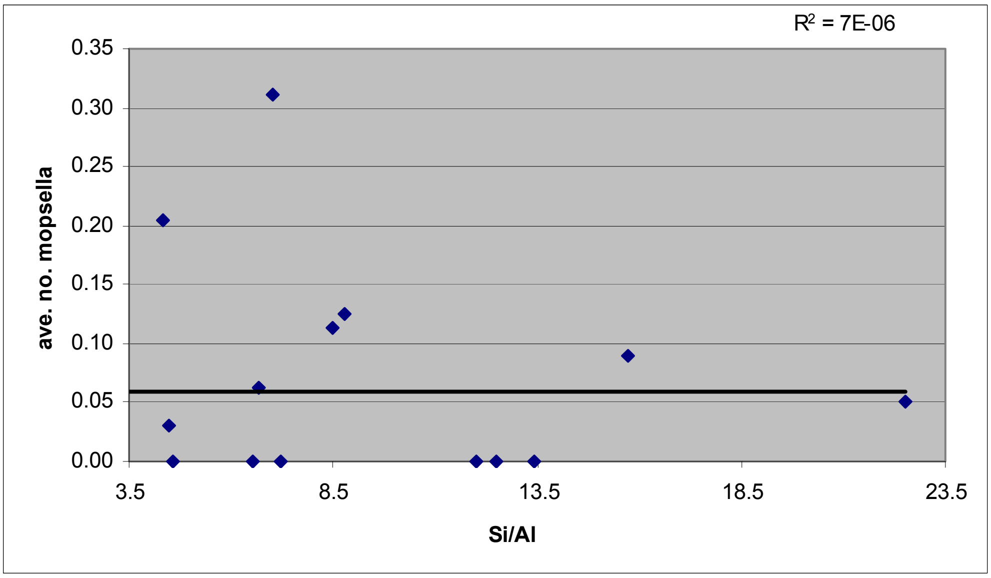


ave. no. mopsella
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Total reactive chlorins
R² = 0.0245

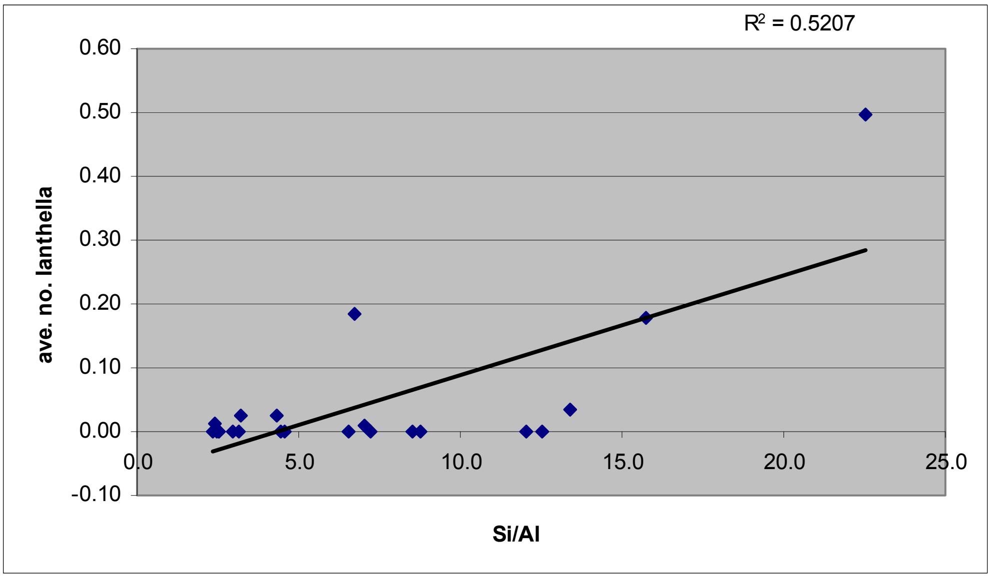


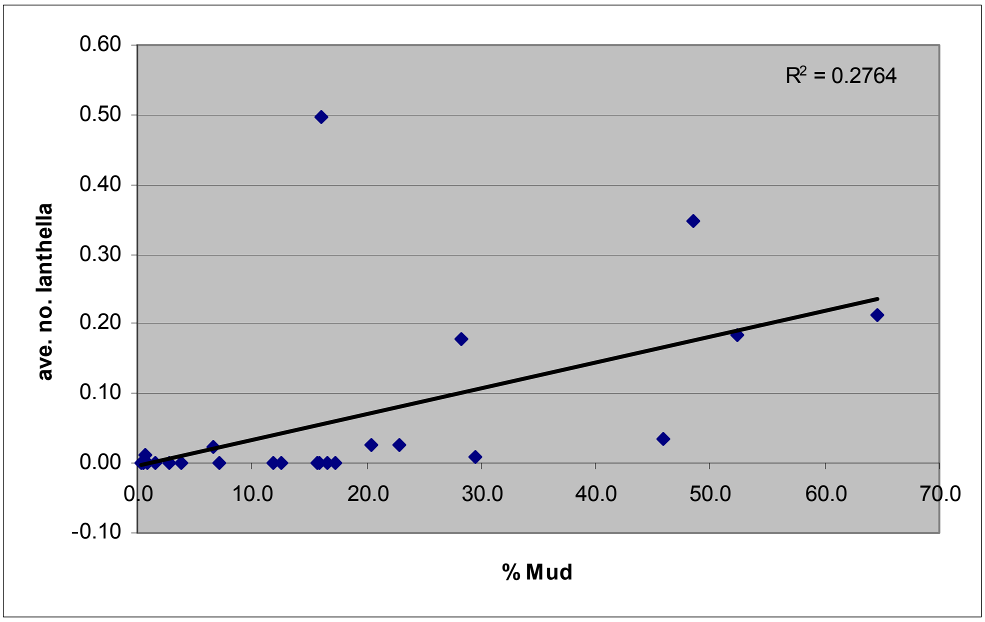
ave. no. mopsella
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
10.0
20.0
30.0
40.0
50.0
% Gravel
R² = 0.015

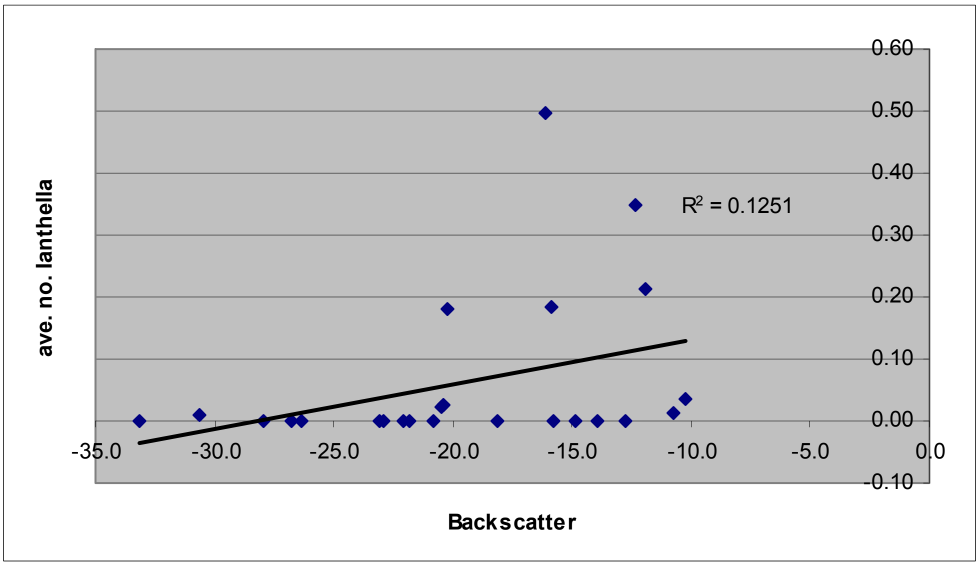

R² = 0.0112
ave. no. mopsella
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
d15N ‰ AIR

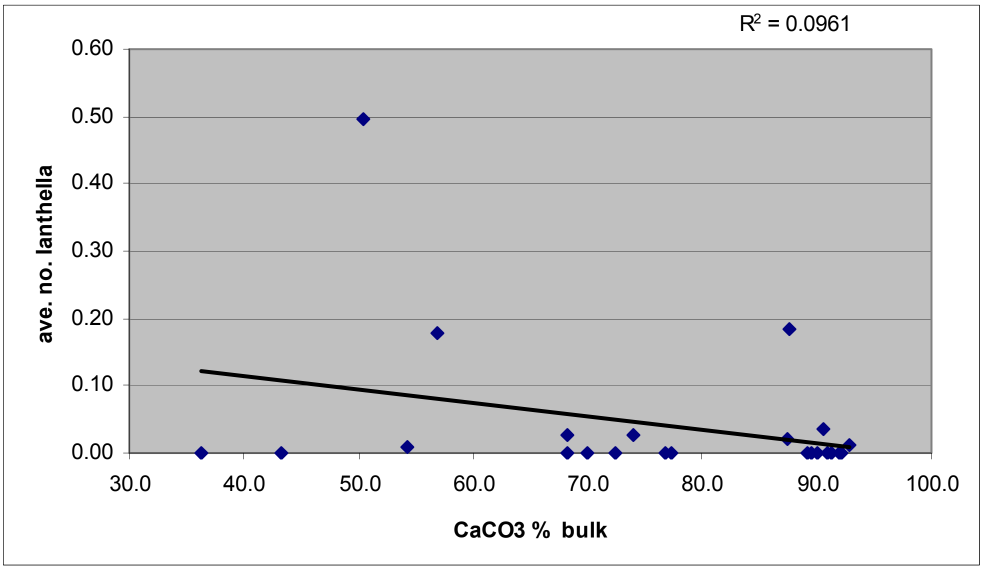

R² = 7E-06
ave. no. mopsella
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
3.5
8.5
13.5
18.5
23.5
Si/Al

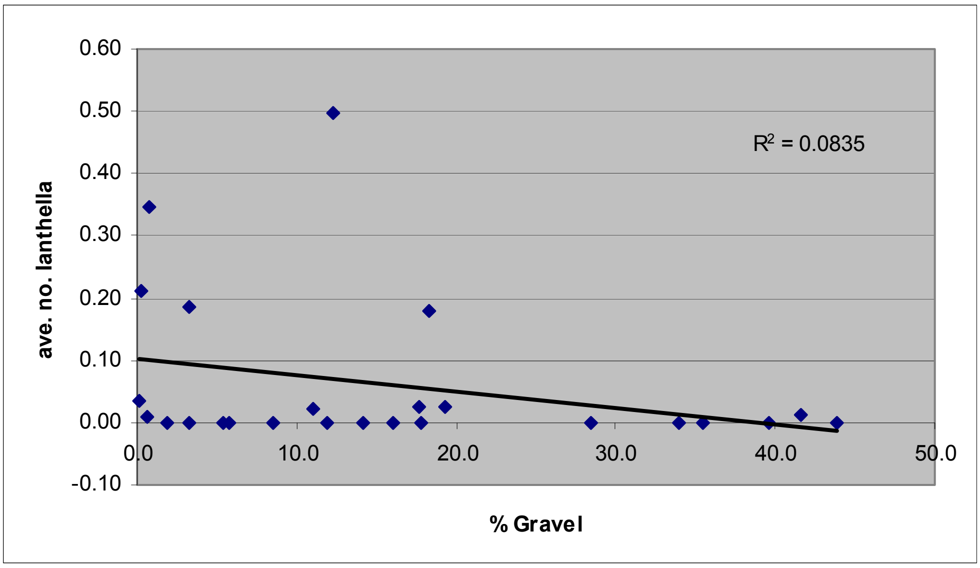
Ianthella

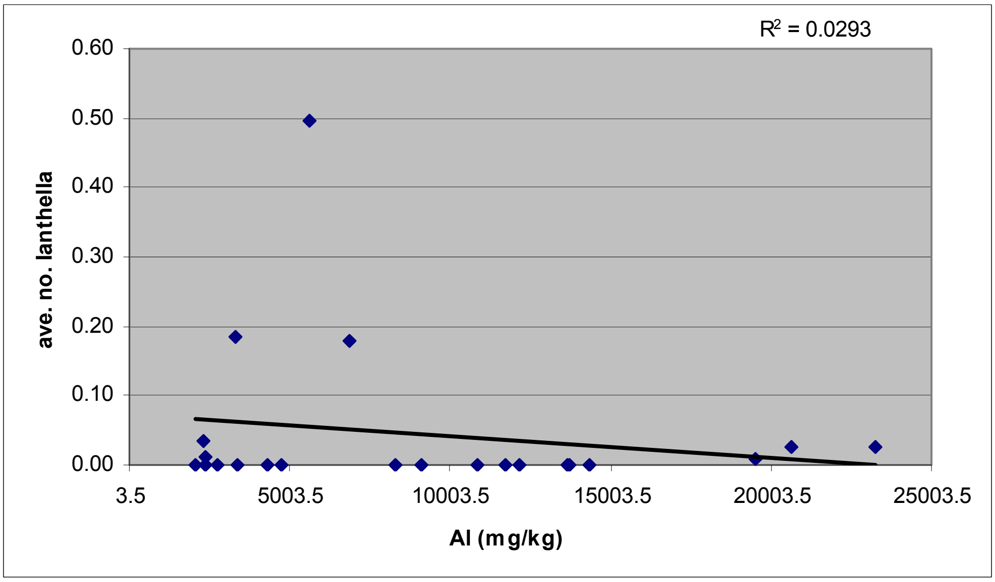

R² = 0.5207
ave. no. Ianthella
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0.0
5.0
10.0
15.0
20.0
25.0
Si/Al

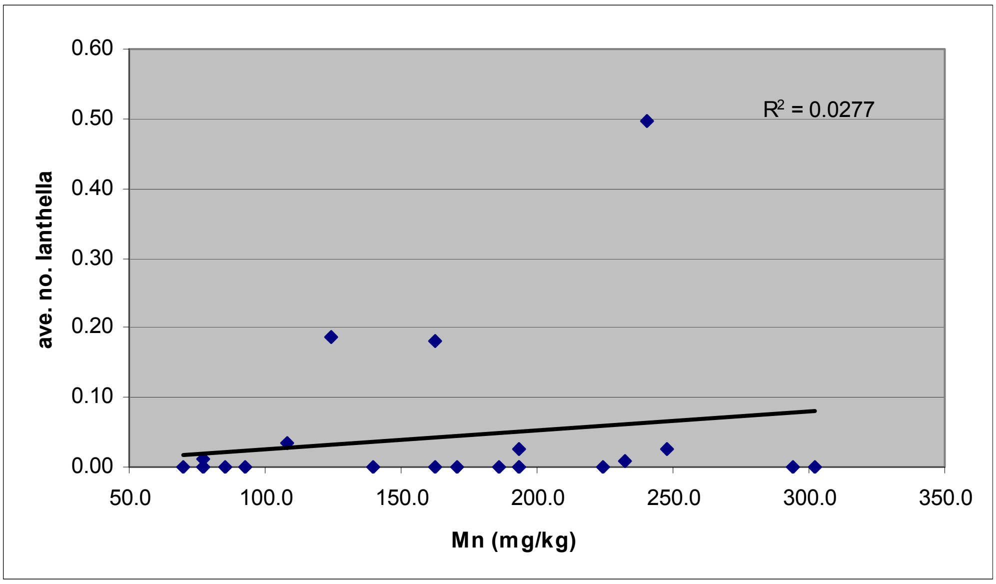

R² = 0.2764
ave. no. Ianthella
% Mud
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0

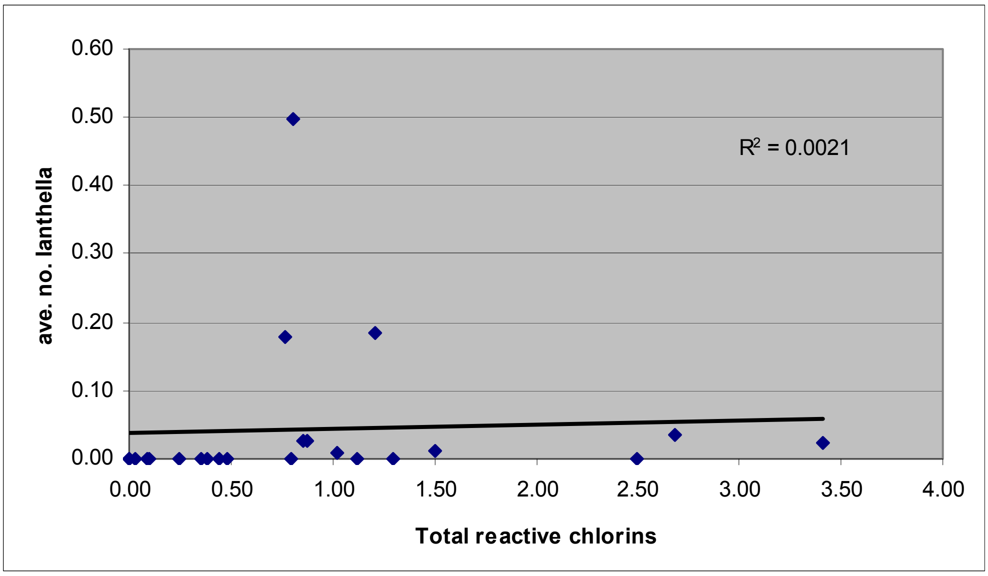

R² = 0.1251
ave. no. Ianthella
Backscatter
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0

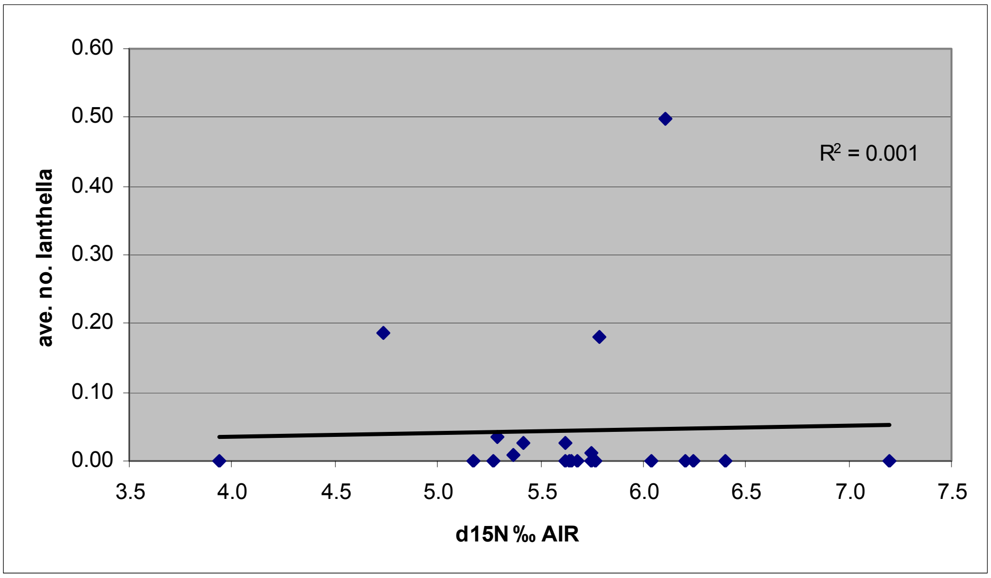

R² = 0.0961
ave. no. Ianthella
CaCO3 % bulk
0.60
0.50
0.40
0.30
0.20
0.10
0.00
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0

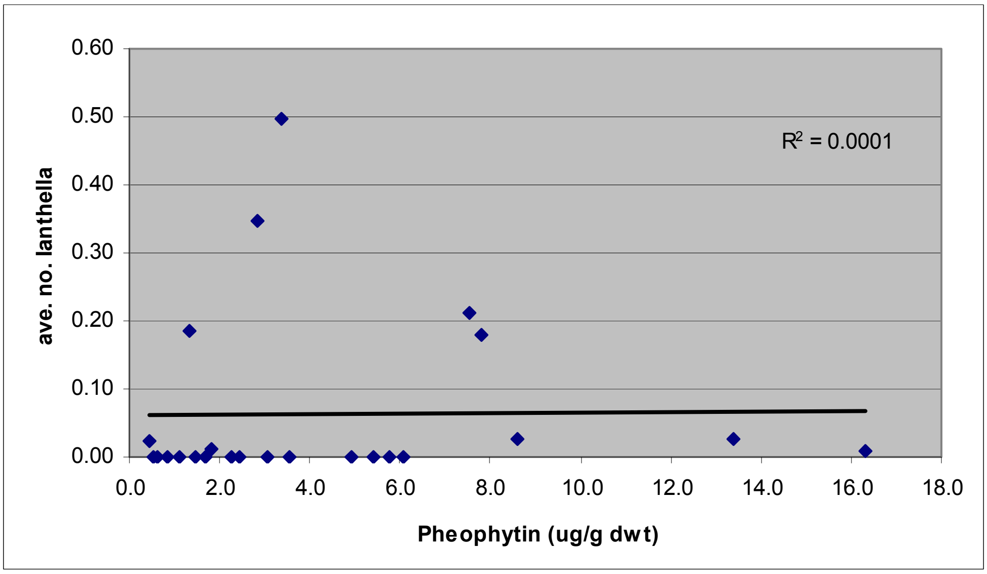

R² = 0.0835
ave. no. Ianthella
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0.0
10.0
20.0
30.0
40.0
50.0
% Gravel

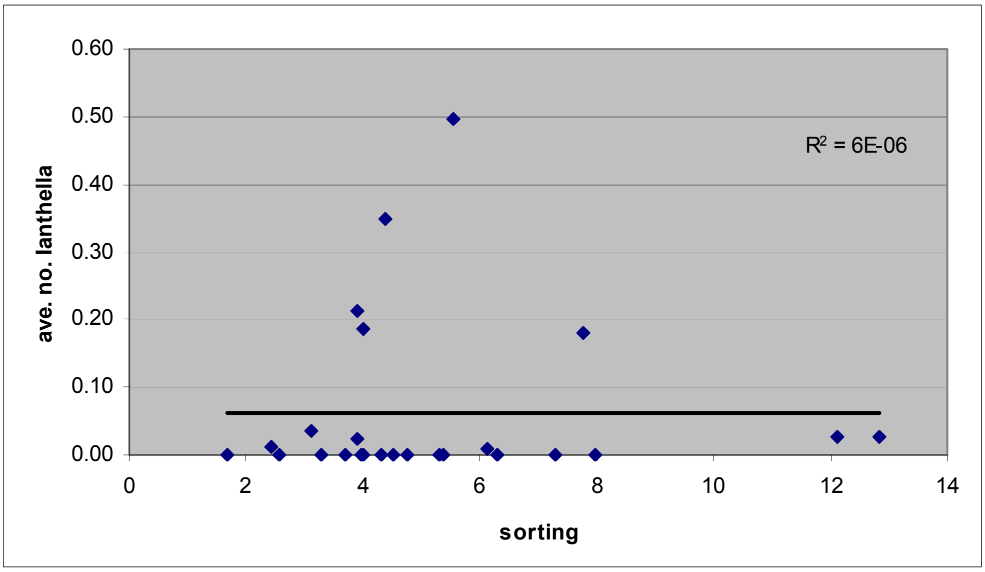

R² = 0.0293
ave. no. Ianthella
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3.5
5003.5
10003.5
15003.5
20003.5
25003.5
Al (mg/kg)


R² = 0.0277
ave. no. Ianthella
0.60
0.50
0.40
0.30
0.20
0.10
0.00
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Mn (mg/kg)

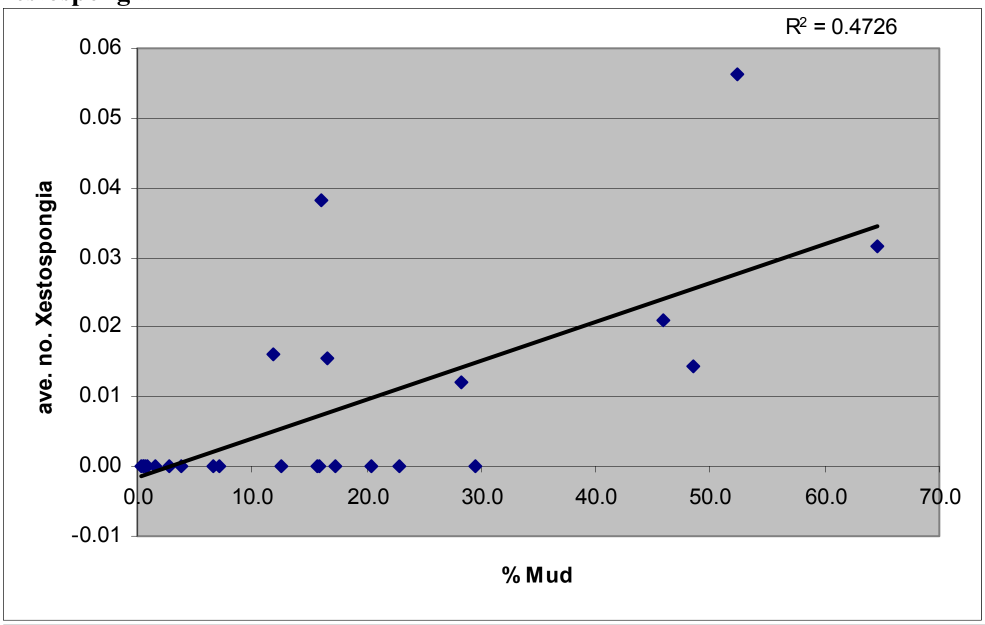

ave. no. Ianthella
0.60
0.50
0.40
0.30
0.20
0.10
0.00
R² = 0.0021
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Total reactive chlorins

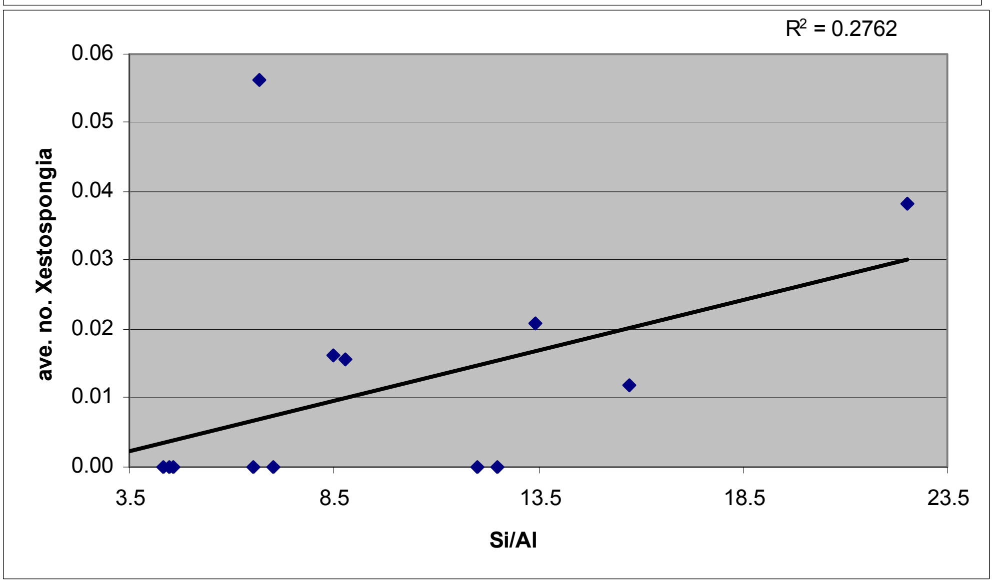

ave. no. Ianthella
0.60
0.50
0.40
0.30
0.20
0.10
0.00
R² = 0.001
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
d15N ‰ AIR

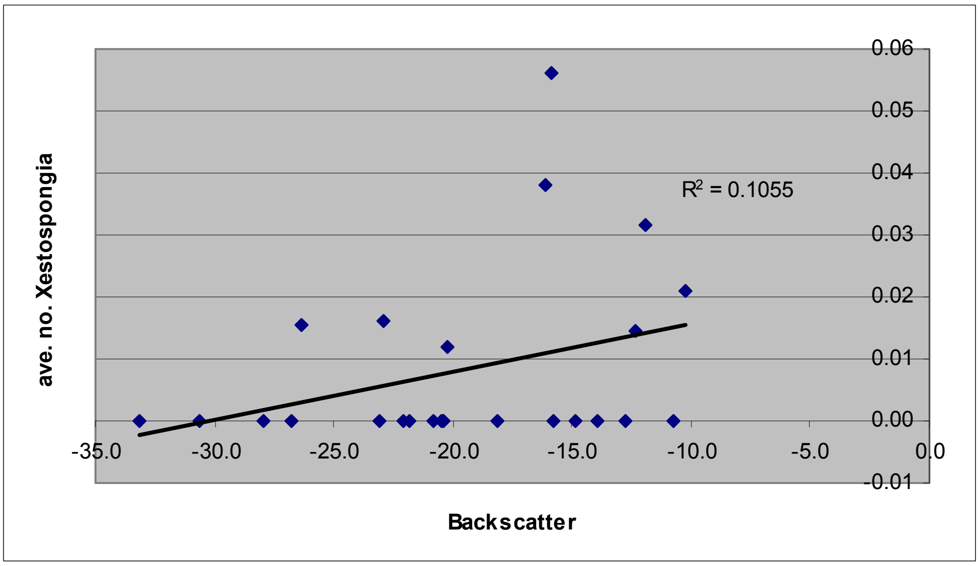

ave. no. Ianthella
0.60
0.50
0.40
0.30
0.20
0.10
0.00
R² = 0.0001
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Pheophytin (ug/g dwt)

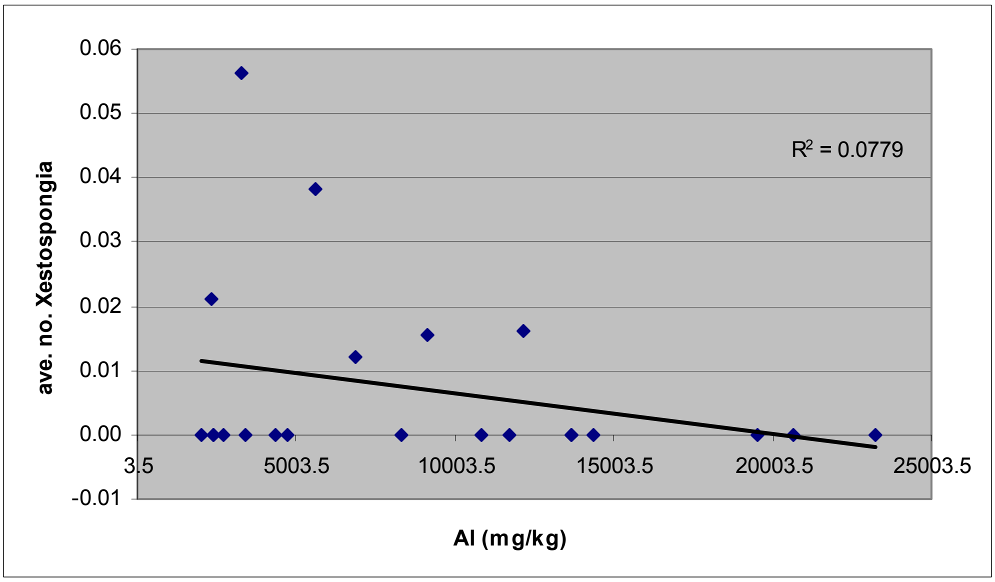


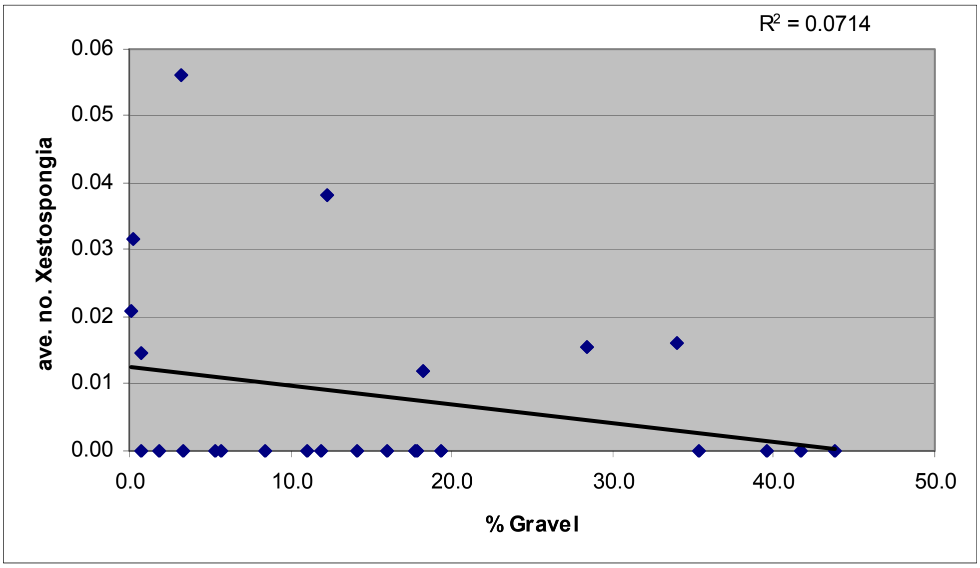
Xestospongia

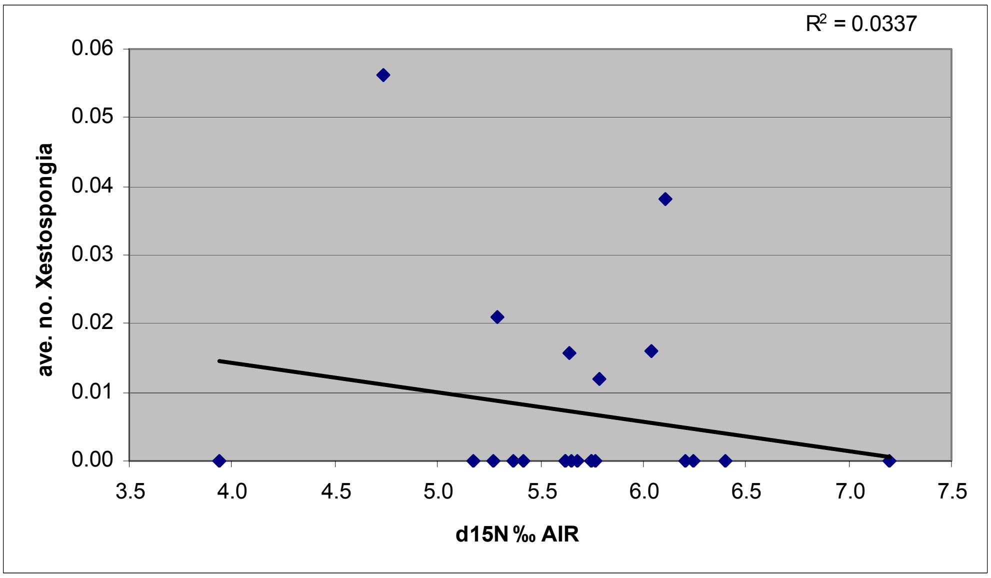


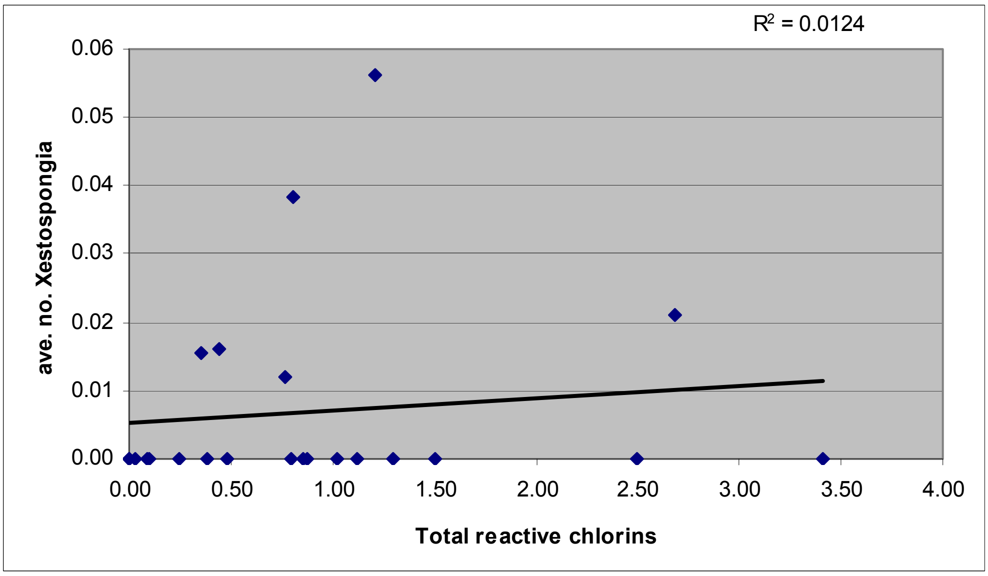


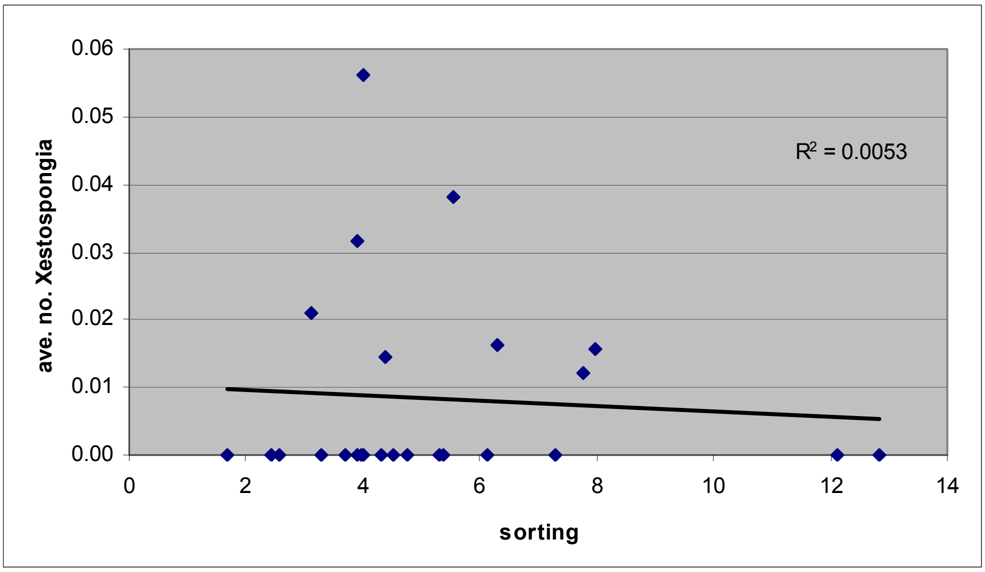

ave. no. Xestospongia
R² = 0.1055
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0
Backscatter

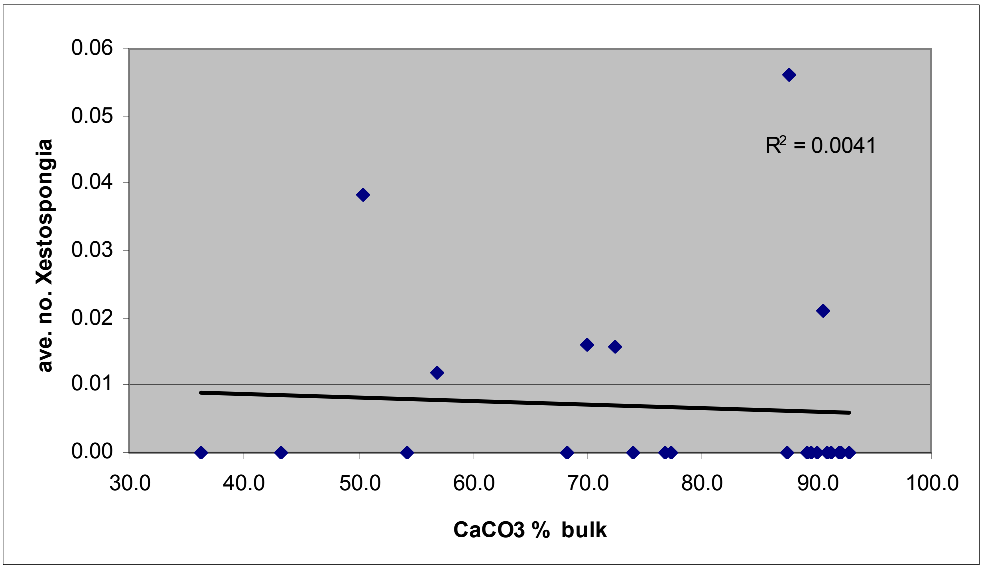

ave. no. Xestospongia
R² = 0.0779
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
3.5
5003.5
10003.5
15003.5
20003.5
25003.5
Al (mg/kg)


R² = 0.0714
ave. no. Xestospongia
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0.0
10.0
20.0
30.0
40.0
50.0
% Gravel

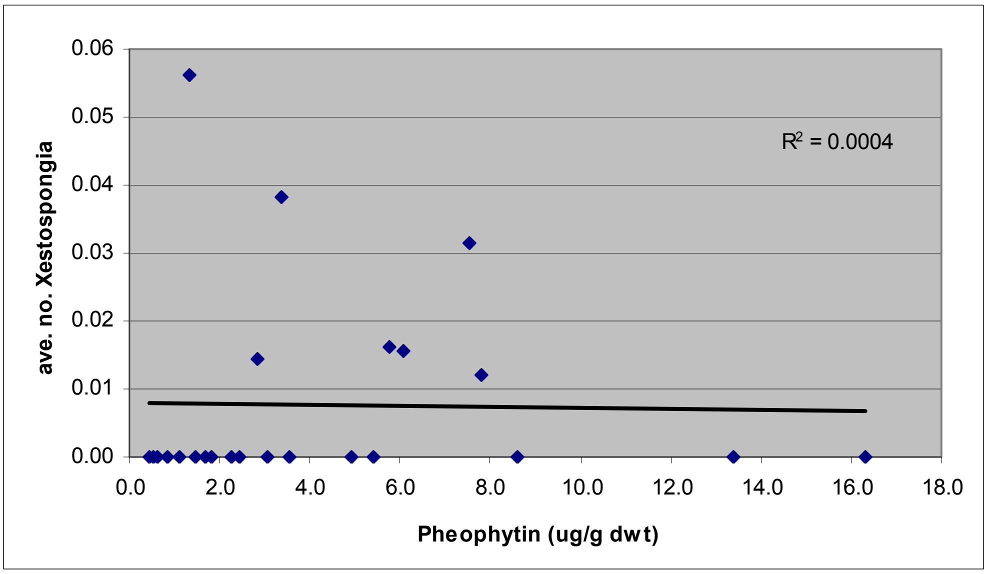

R² = 0.0337
ave. no. Xestospongia
0.06
0.05
0.04
0.03
0.02
0.01
0.00
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
d15N ‰ AIR


R² = 0.0124
ave. no. Xestospongia
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Total reactive chlorins

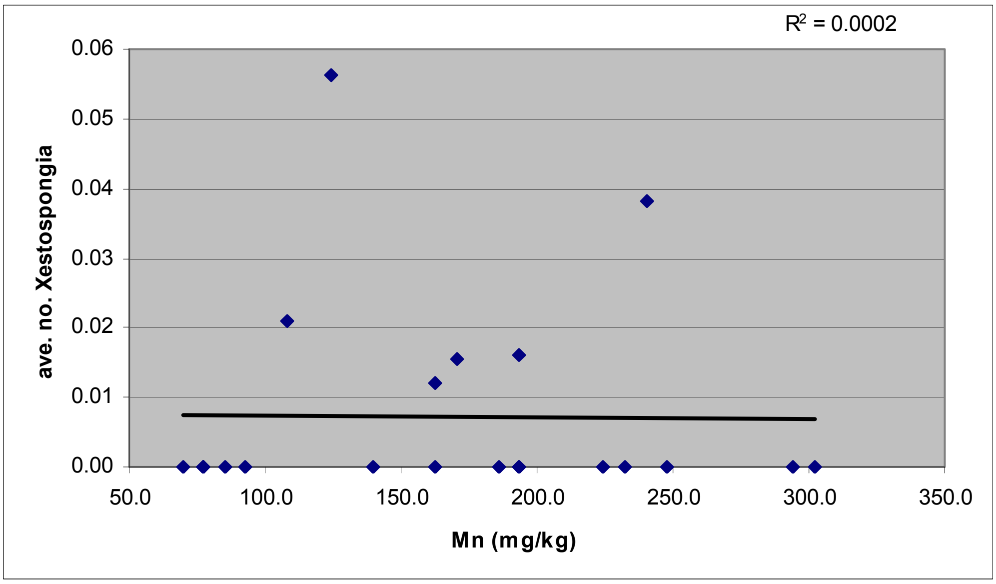

R² = 0.0053
ave. no. Xestospongia
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
2
4
6
8
10
12
14
sorting



ave. no. Xestospongia
0.06
0.05
0.04
0.03
0.02
0.01
0.00
R² = 0.0041
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
CaCO3 % bulk

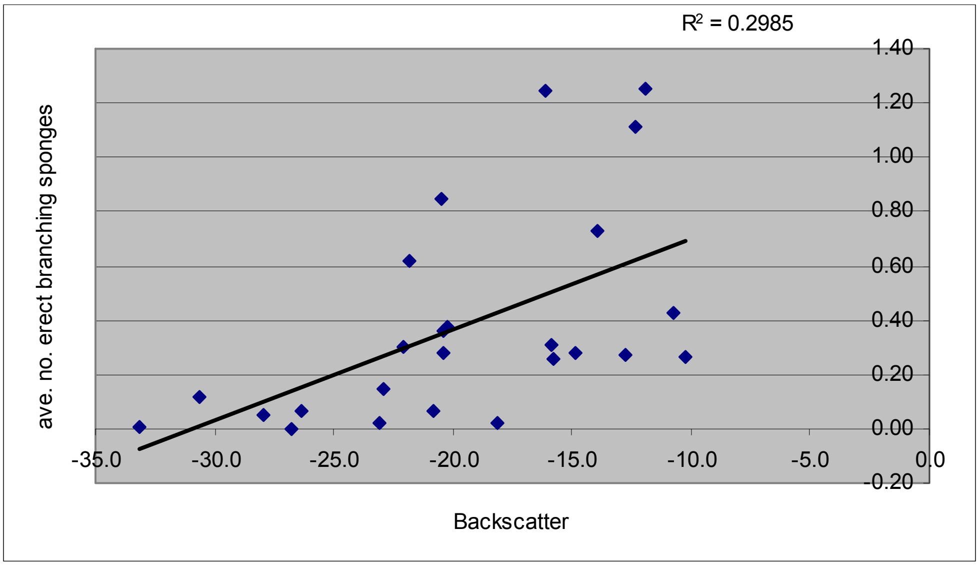


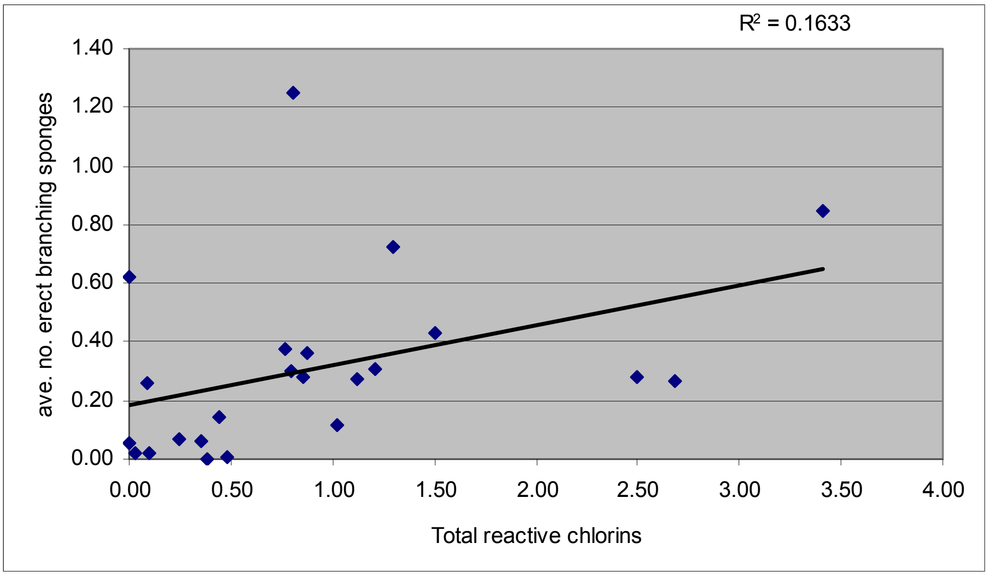
ave. no. Xestospongia
0.06
0.05
0.04
0.03
0.02
0.01
0.00
R² = 0.0004
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Pheophytin (ug/g dwt)

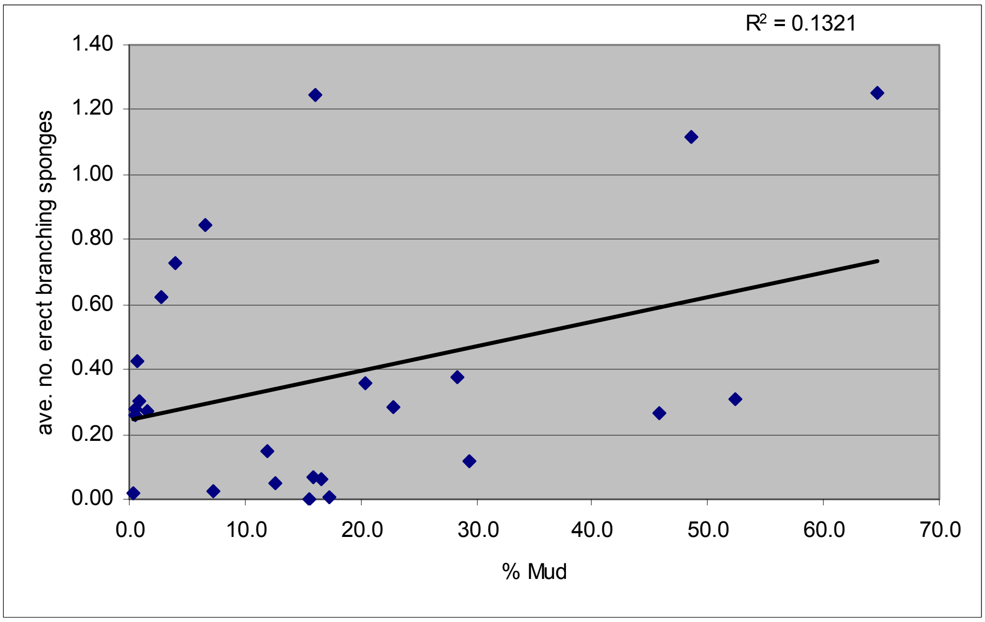


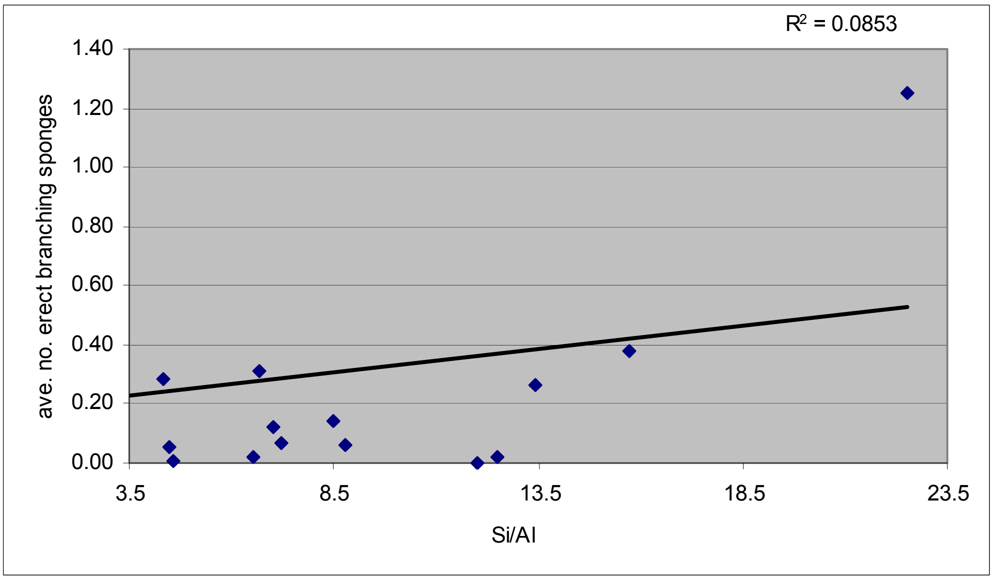
R² = 0.0002
ave. no. Xestospongia
0.06
0.05
0.04
0.03
0.02
0.01
0.00
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Mn (mg/kg)

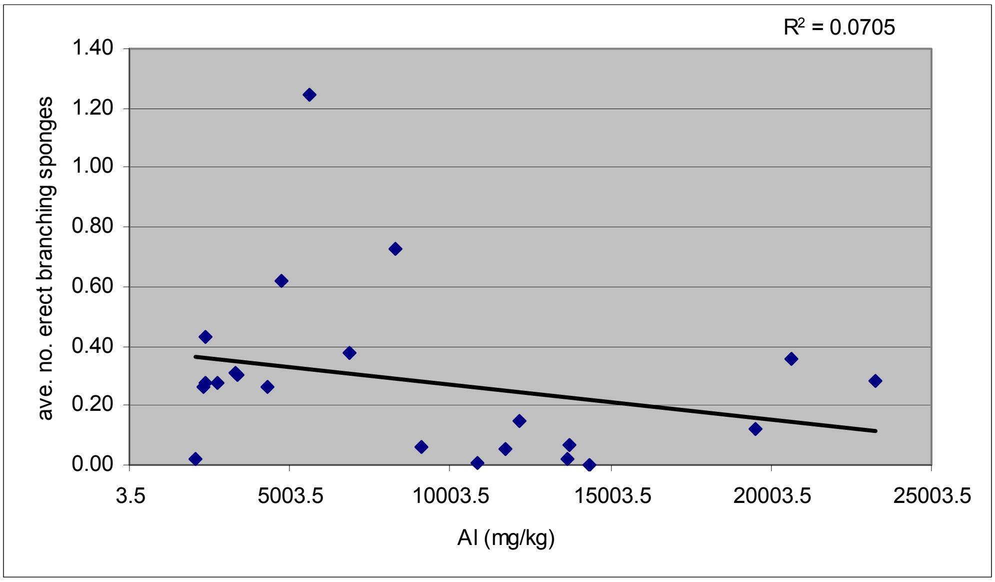
Erect Branching Sponges

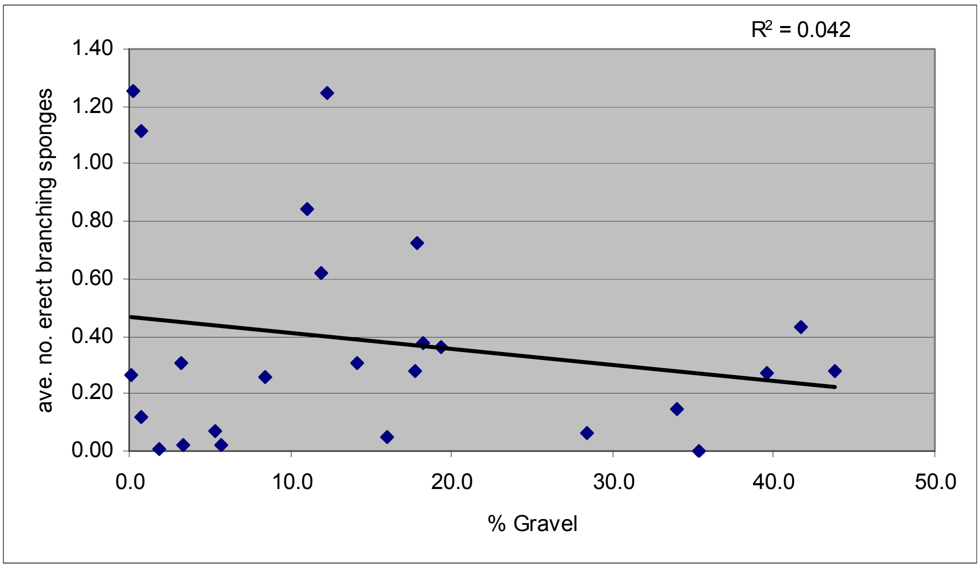


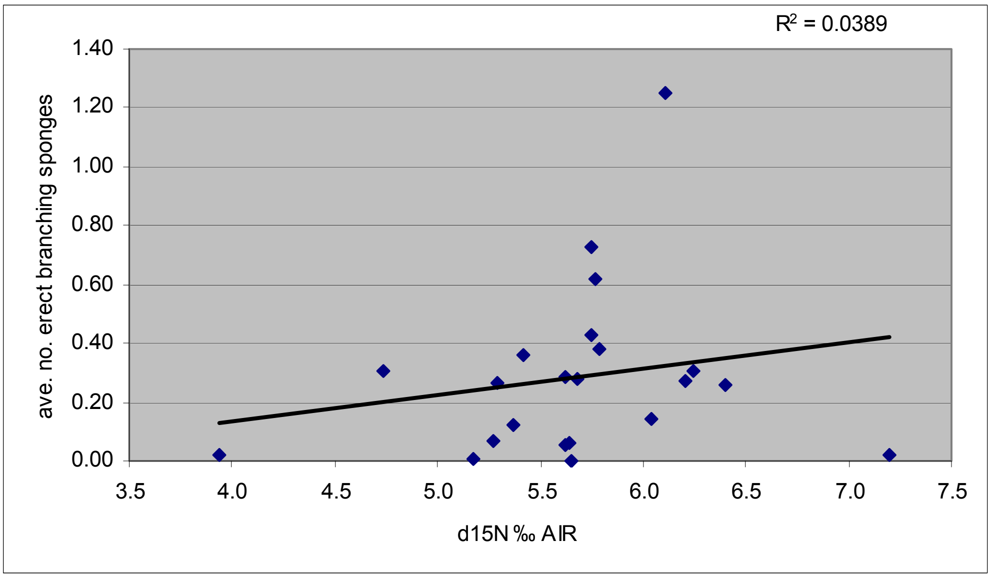


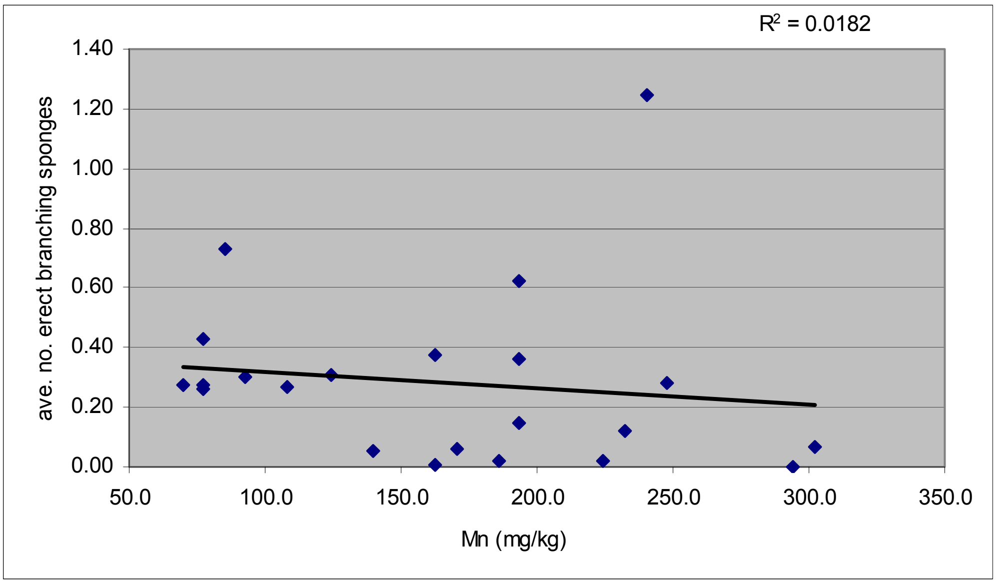


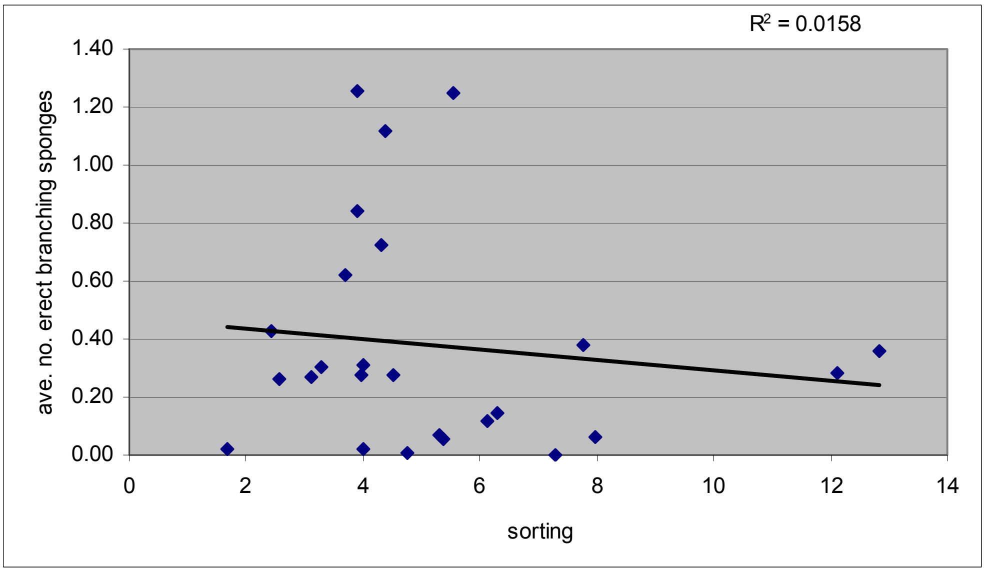

R² = 0.0853
ave. no. erect branching sponges
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
3.5
8.5
13.5
18.5
23.5
Si/Al

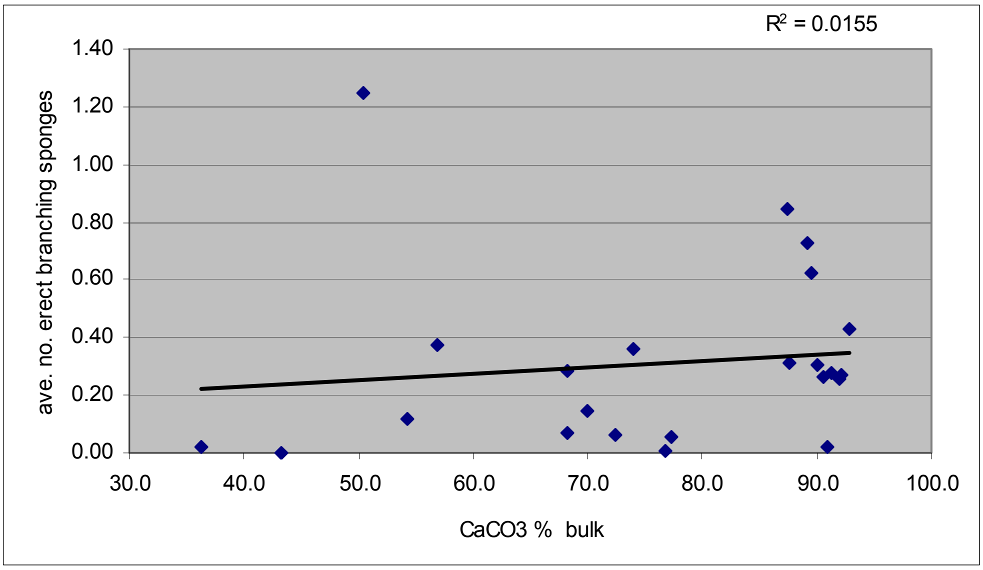

R² = 0.0705
ave. no. erect branching sponges
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
3.5
5003.5
10003.5
15003.5
20003.5
25003.5
Al (mg/kg)

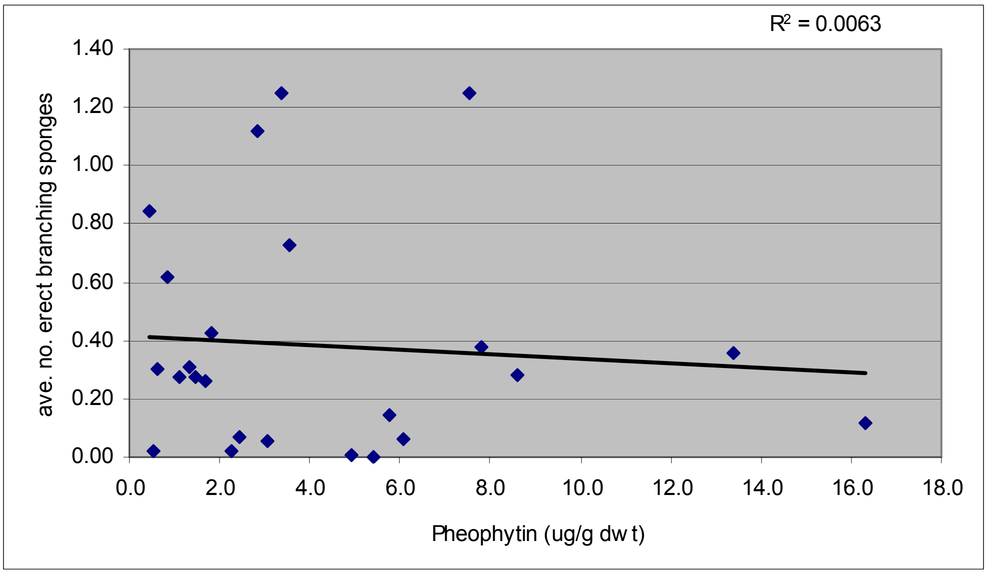

R² = 0.042
ave. no. erect branching sponges
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.0
10.0
20.0
30.0
40.0
50.0
% Gravel


R² = 0.0389
ave. no. erect branching sponges
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
d15N ‰ AIR

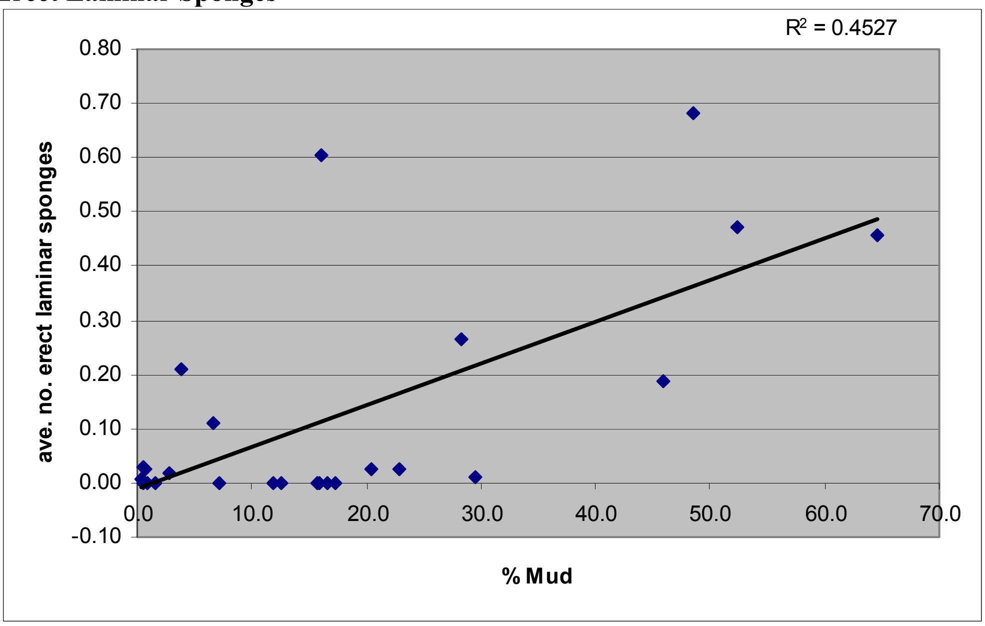

R² = 0.0182
ave. no. erect branching sponges
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Mn (mg/kg)

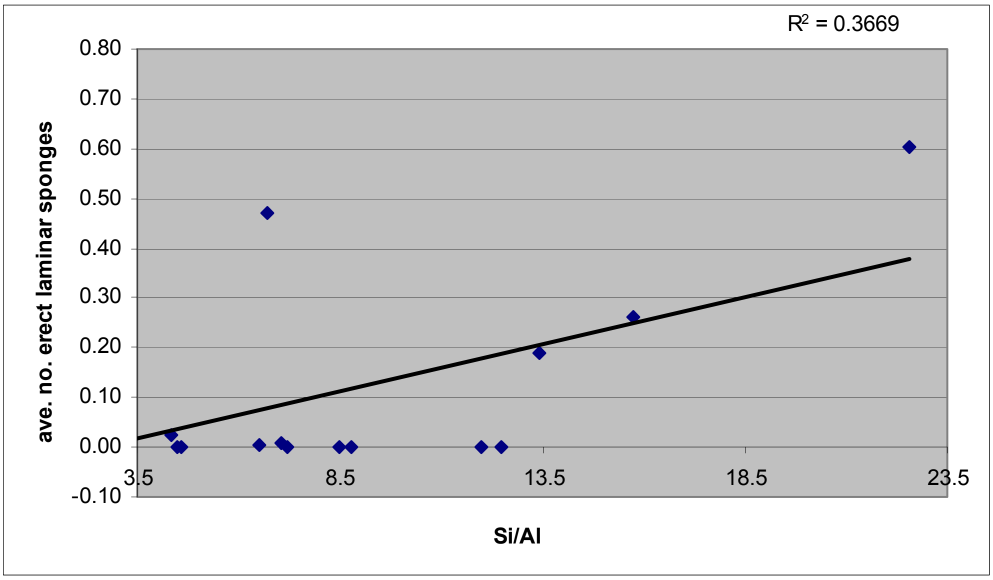

R² = 0.0158
ave. no. erect branching sponges
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
2
4
6
8
10
12
14
sorting

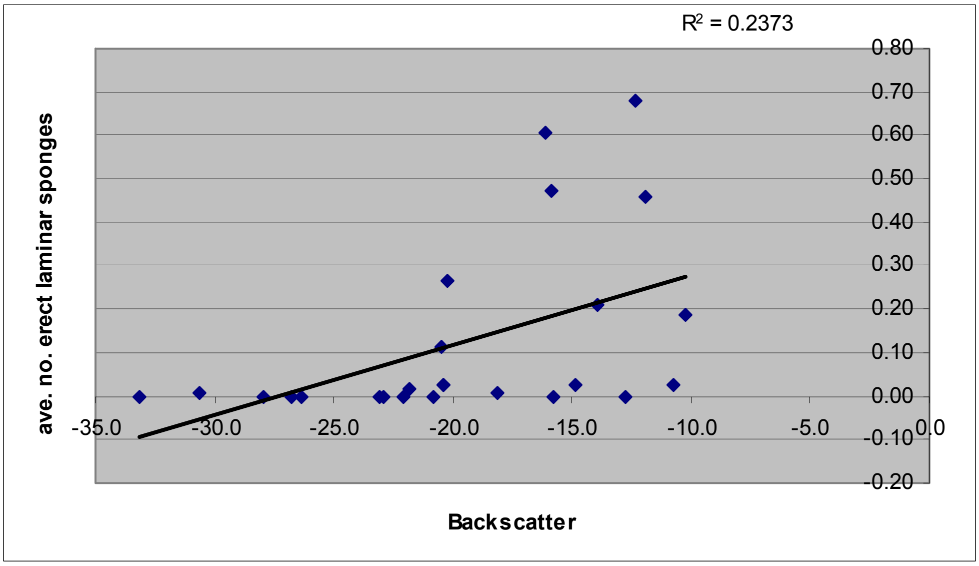


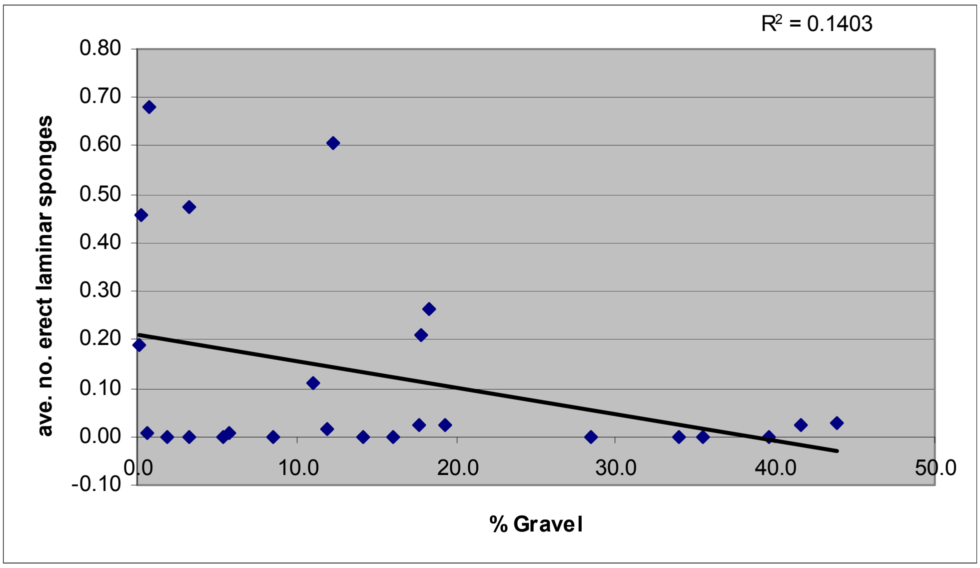


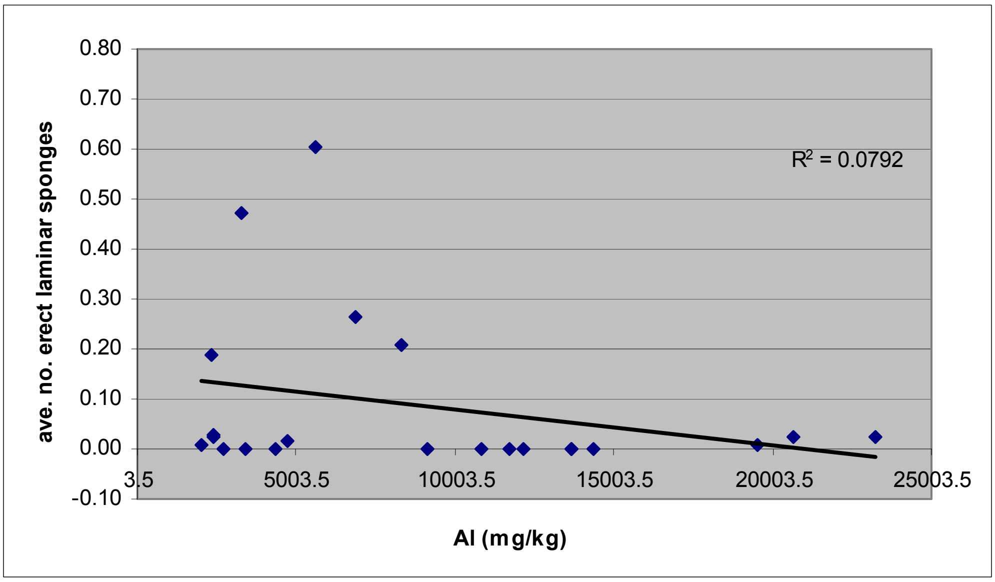
Erect Laminar Sponges

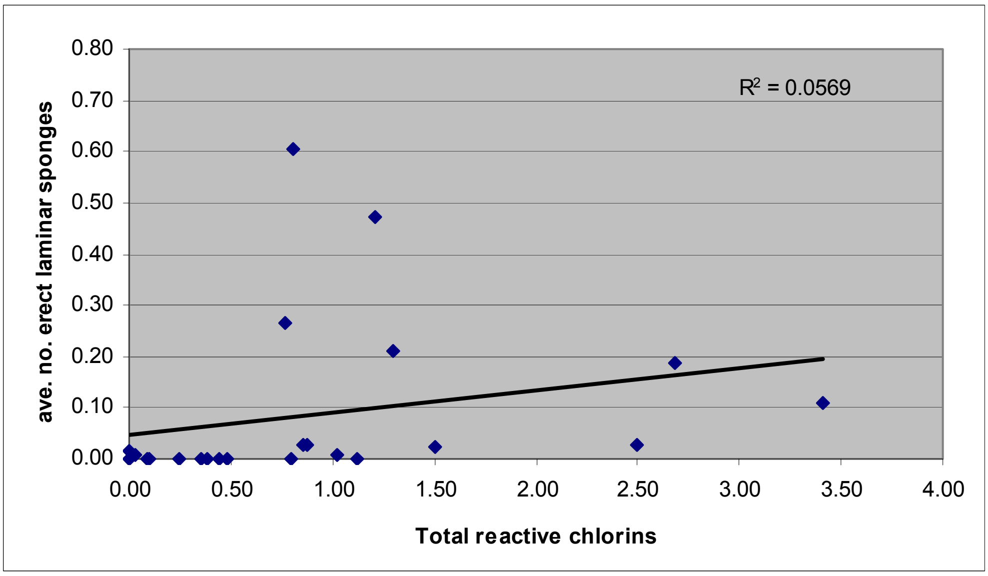


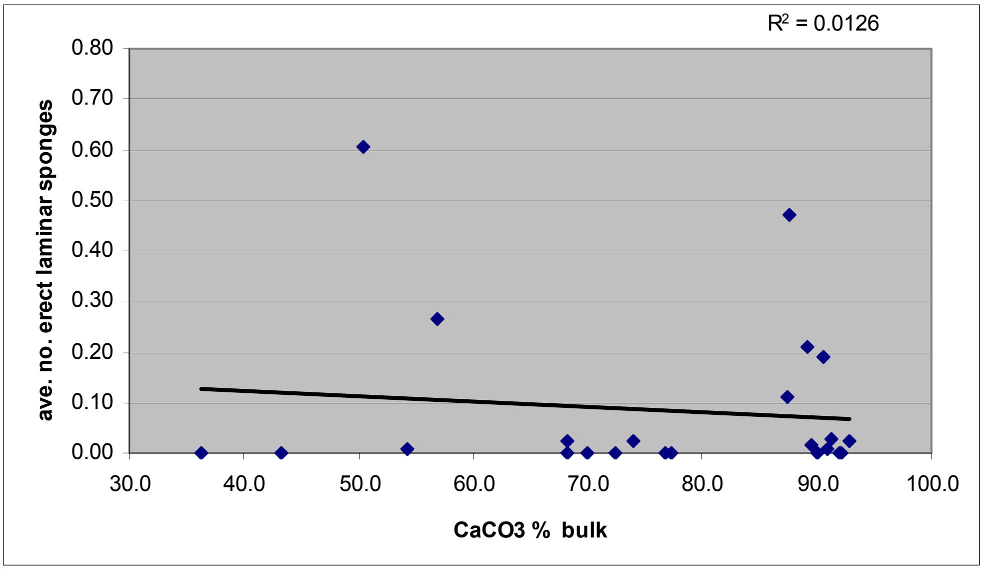

R² = 0.3669
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
3.5
8.5
13.5
18.5
23.5
ave. no. erect laminar sponges
Si/Al

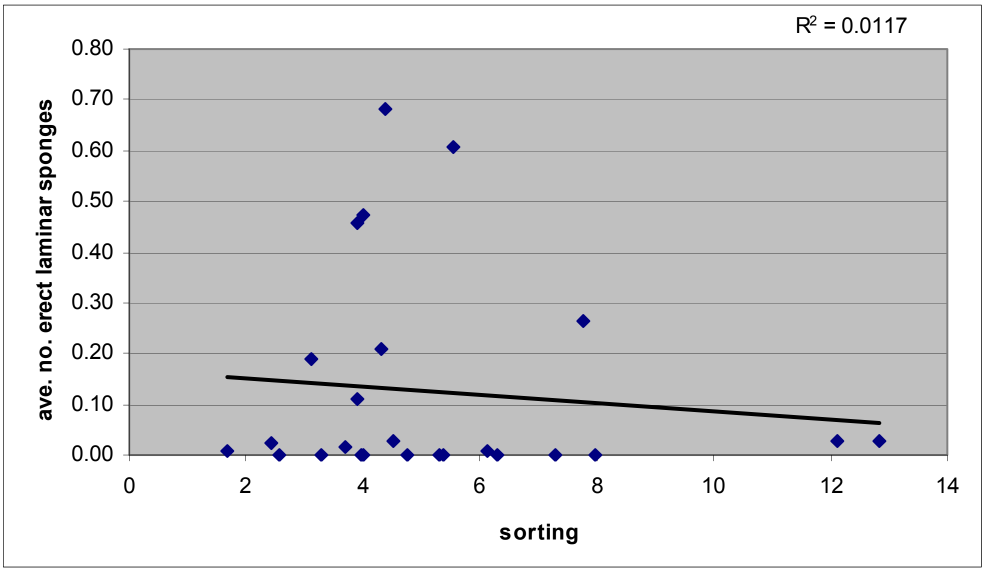

R² = 0.2373
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0
ave. no. erect laminar sponges
Backscatter

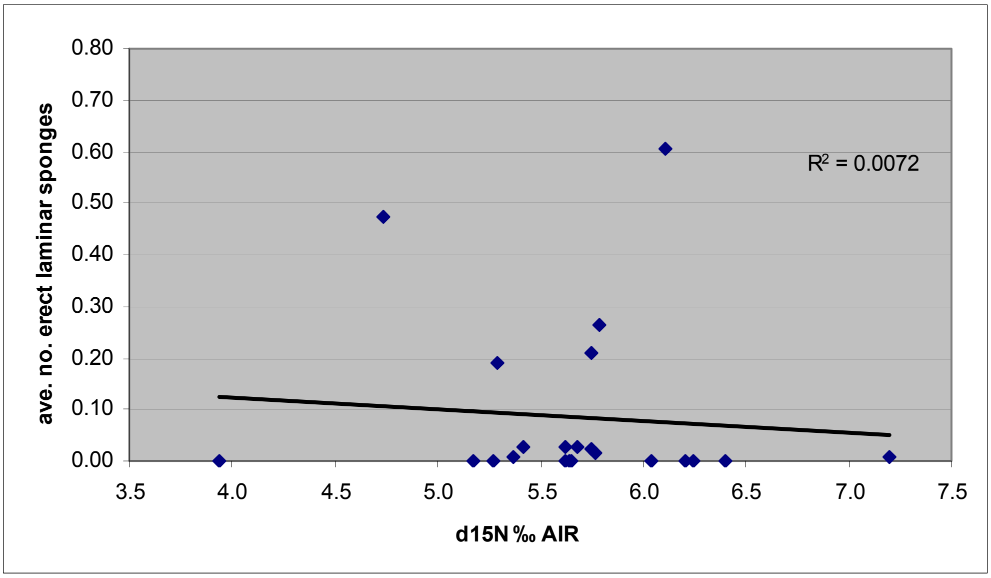

R² = 0.1403
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0.0
10.0
20.0
30.0
40.0
50.0
ave. no. erect laminar sponges
% Gravel

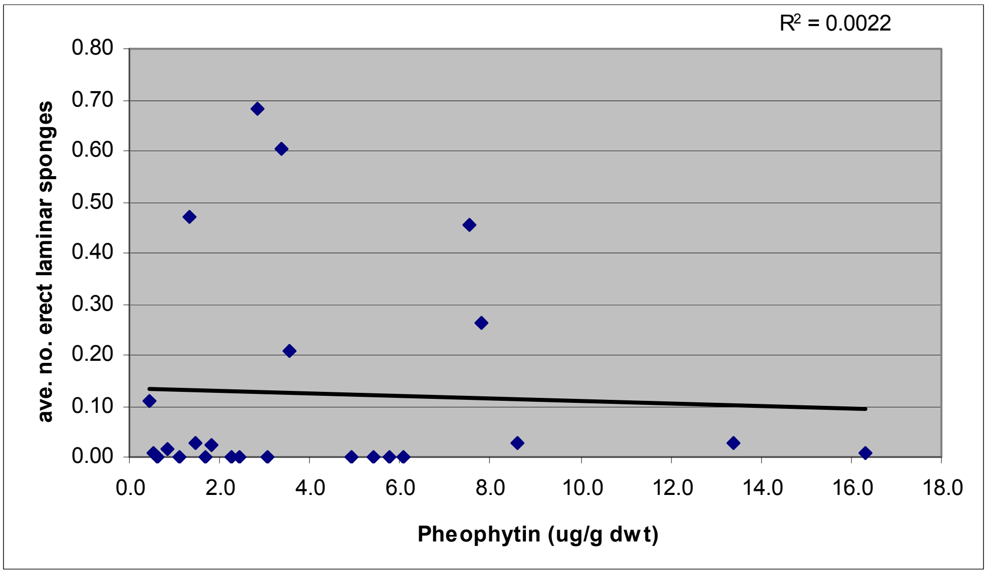

ave. no. erect laminar sponges
R² = 0.0792
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
3.5
5003.5
10003.5
15003.5
20003.5
25003.5
Al (mg/kg)

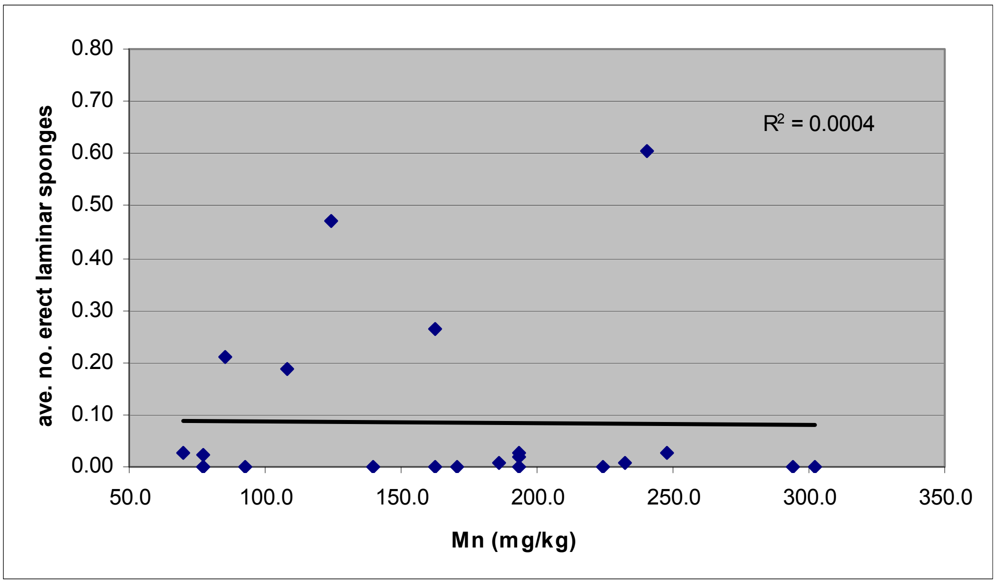

ave. no. erect laminar sponges
R² = 0.0569
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Total reactive chlorins


R² = 0.0126
ave. no. erect laminar sponges
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
CaCO3 % bulk

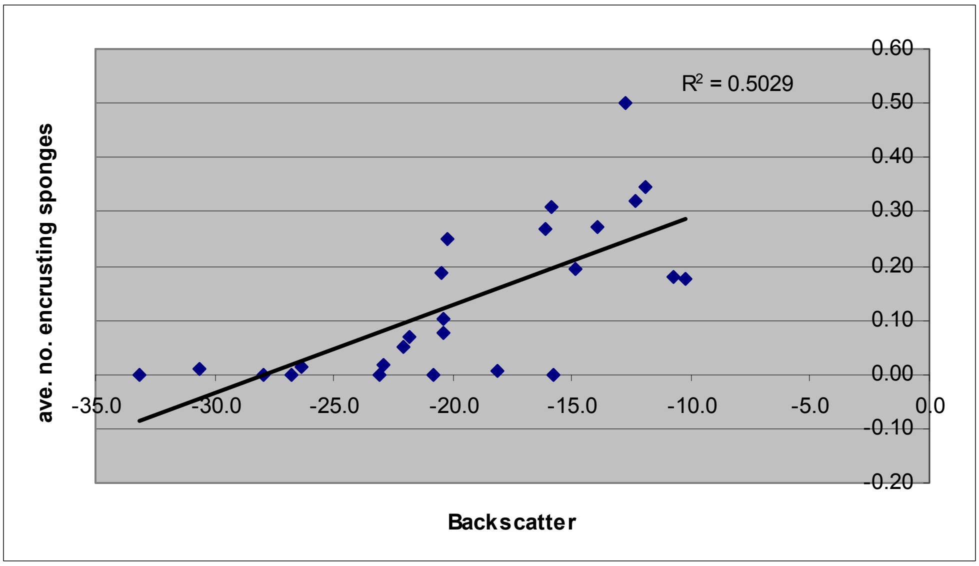

R² = 0.0117
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
ave. no. erect laminar sponges
0
2
4
6
8
10
12
14
sorting

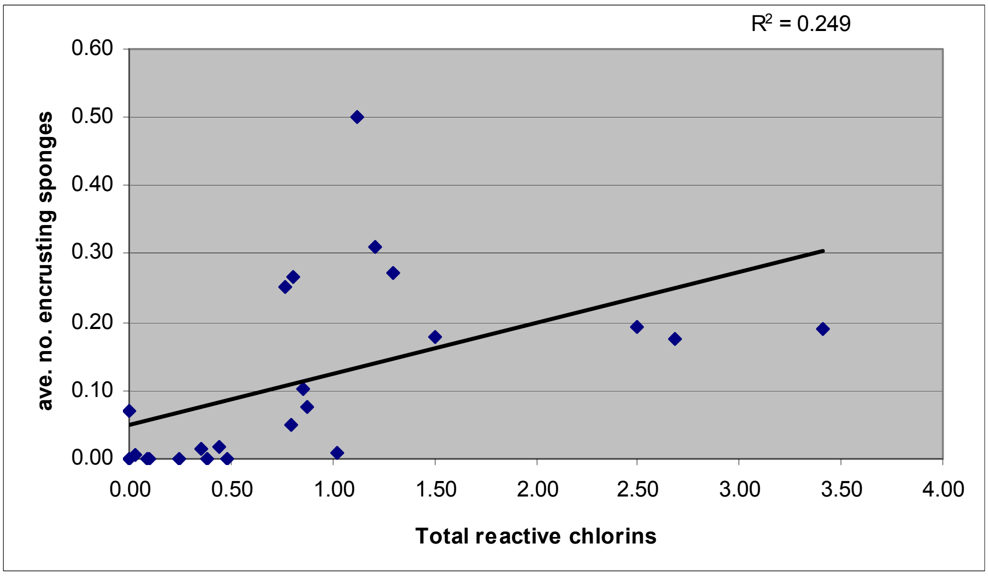

R² = 0.0072
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
ave. no. erect laminar sponges
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
d15N ‰ AIR

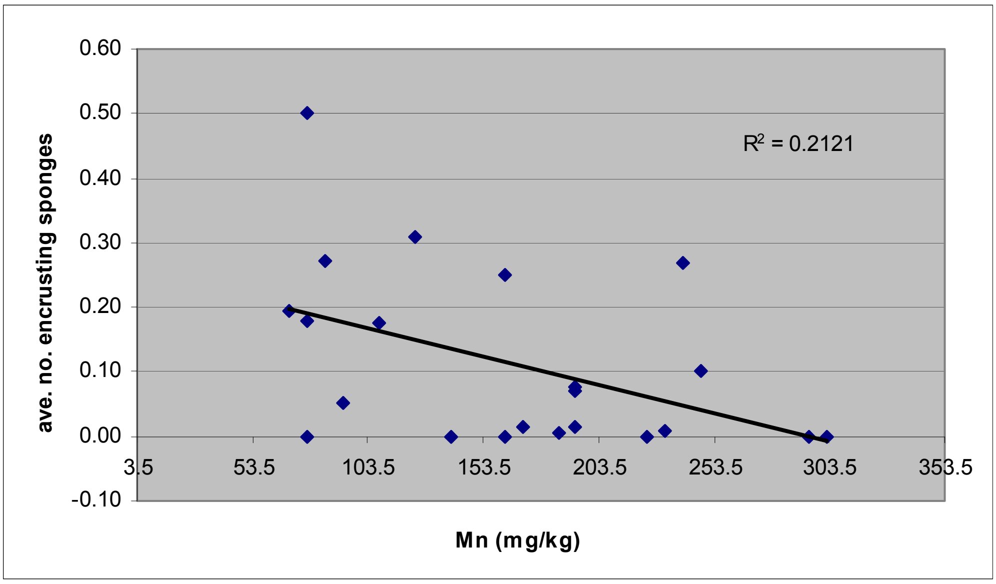

R² = 0.0022
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
ave. no. erect laminar sponges
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Pheophytin (ug/g dwt)

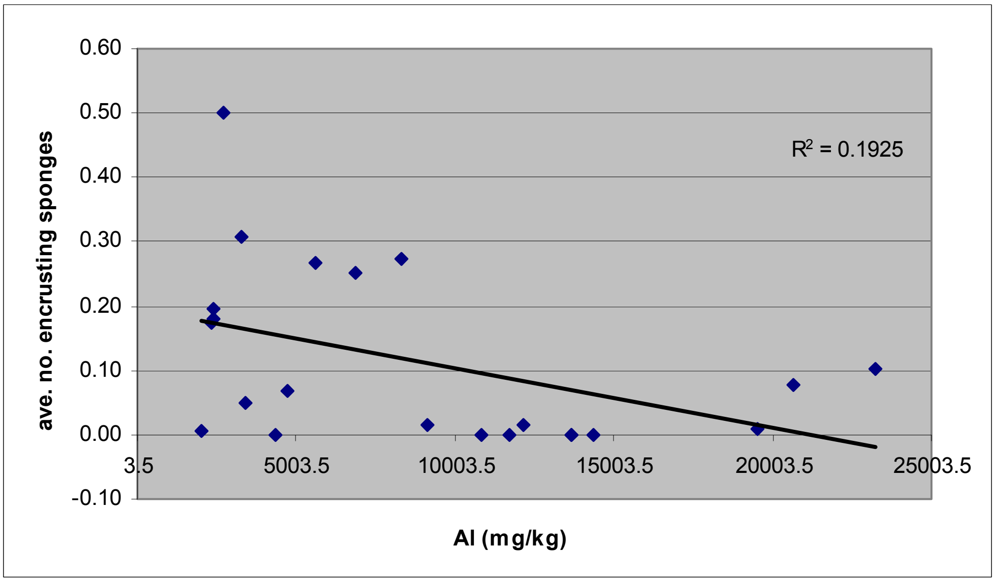


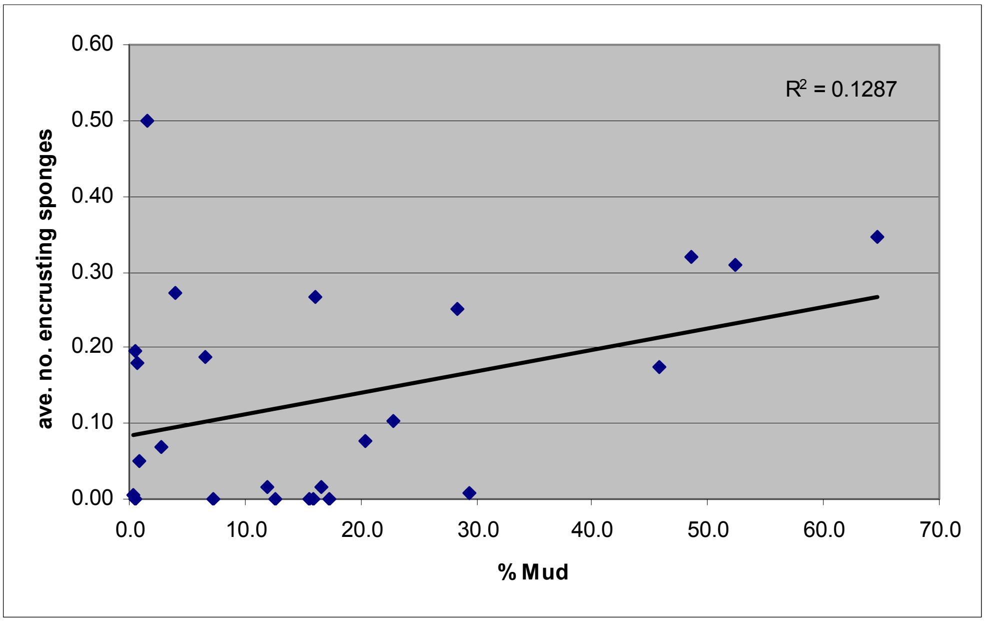
Hollow Massive Sponges

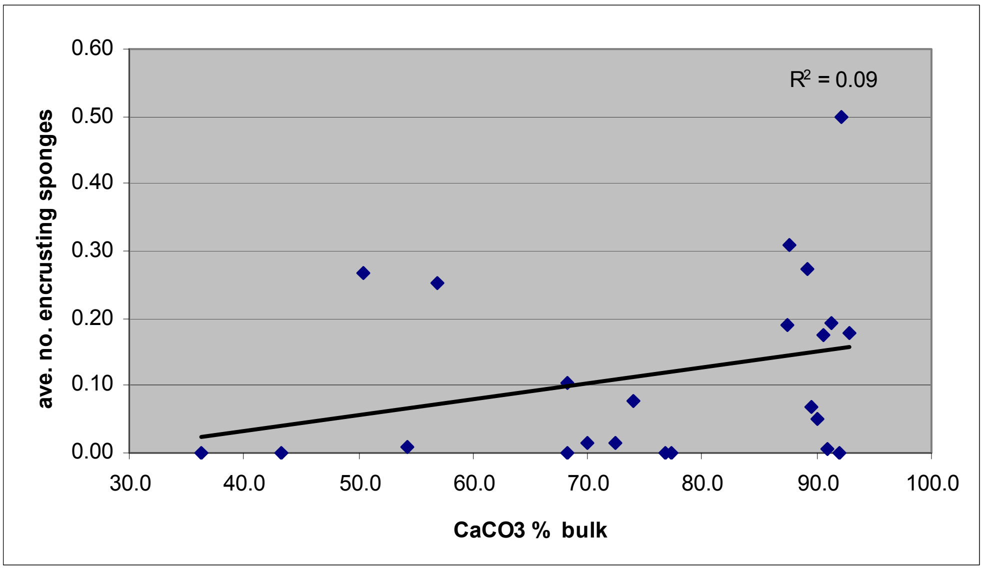




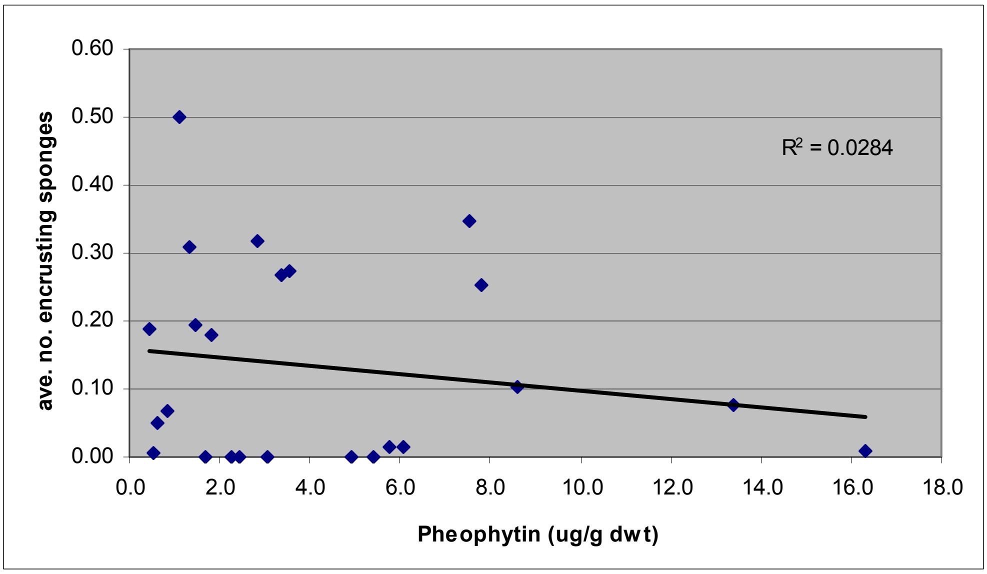

R² = 0.2121
ave. no. encrusting sponges
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
3.5
53.5
103.5
153.5
203.5
253.5
303.5
353.5
Mn (mg/kg)


R² = 0.1925
ave. no. encrusting sponges
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
3.5
5003.5
10003.5
15003.5
20003.5
25003.5
Al (mg/kg)

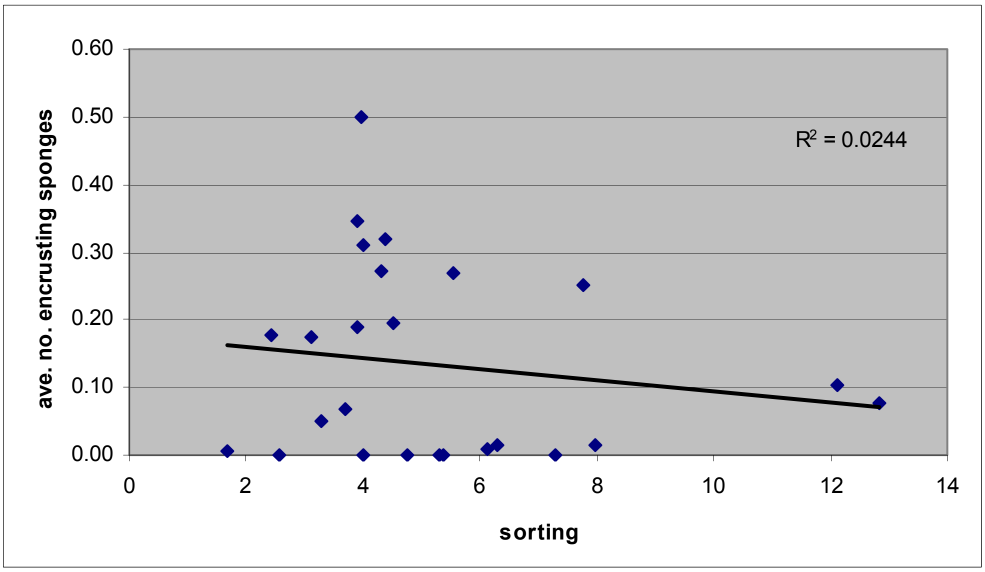

R² = 0.1287
ave. no. encrusting sponges
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
% Mud



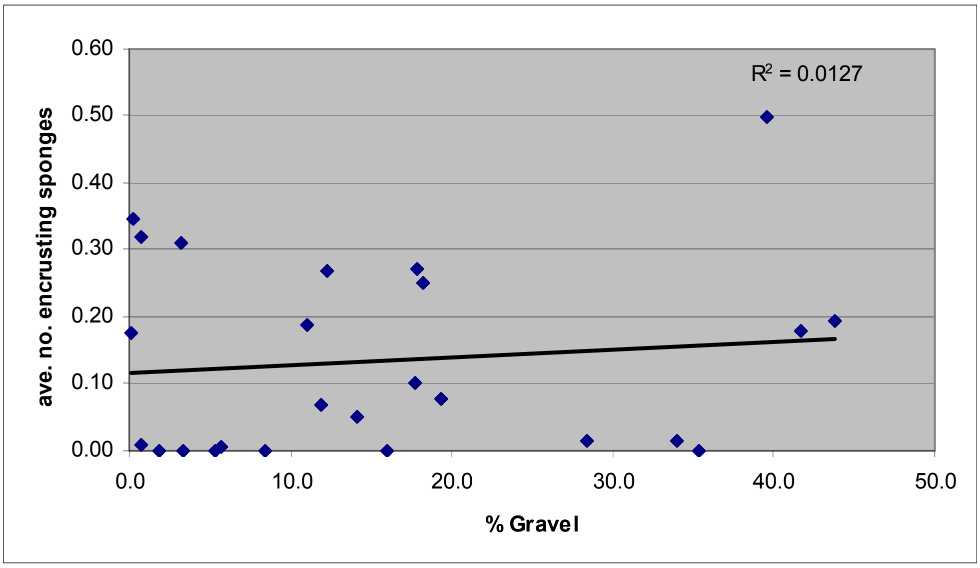
R² = 0.09
ave. no. encrusting sponges
0.00
0.10
0.20
0.30
0.40
0.50
0.60
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
CaCO3 % bulk

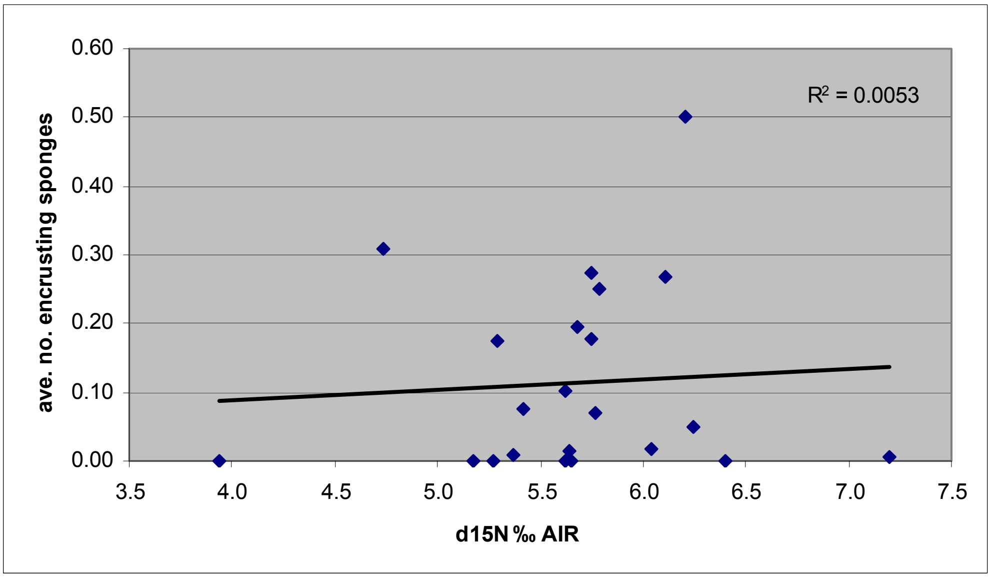


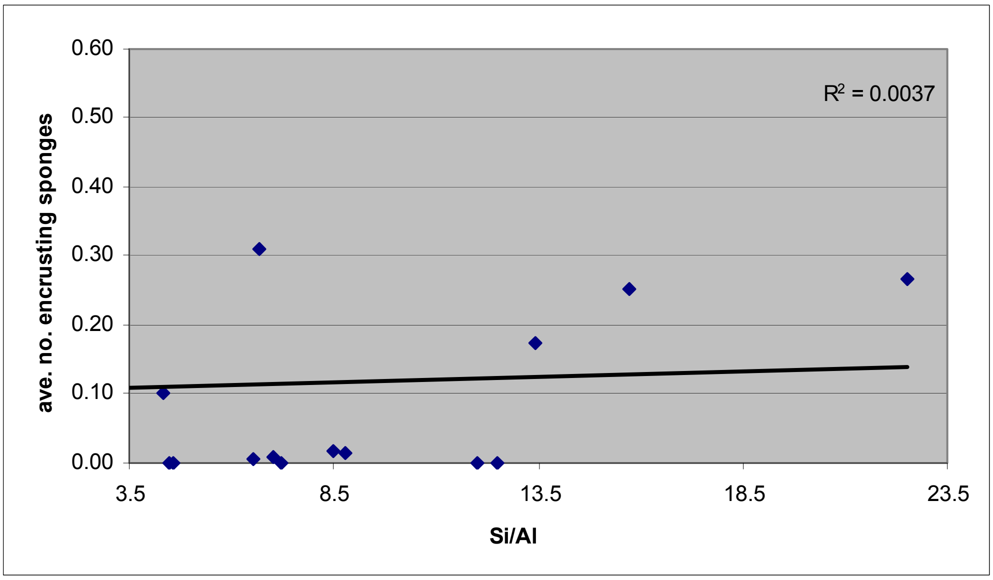
R² = 0.0284
ave. no. encrusting sponges
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Pheophytin (ug/g dwt)



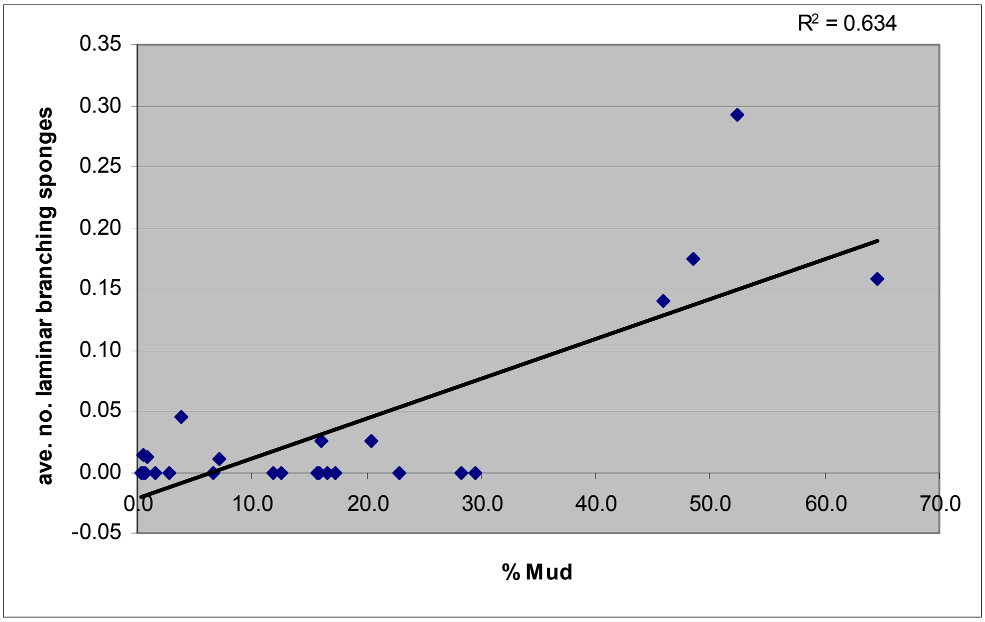
R² = 0.0244
ave. no. encrusting sponges
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0
2
4
6
8
10
12
14
sorting

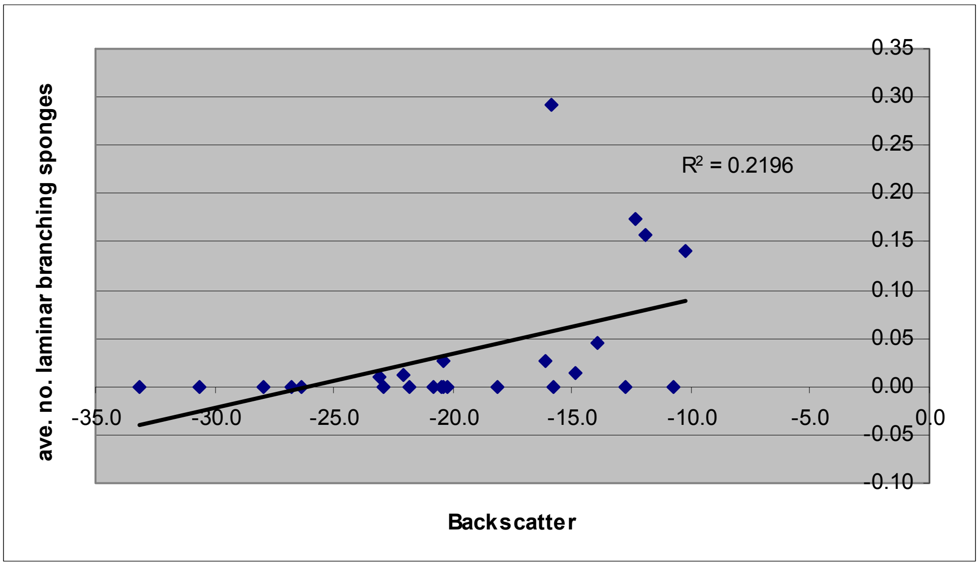

R² = 0.0127
ave. no. encrusting sponges
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
10.0
20.0
30.0
40.0
50.0
% Gravel

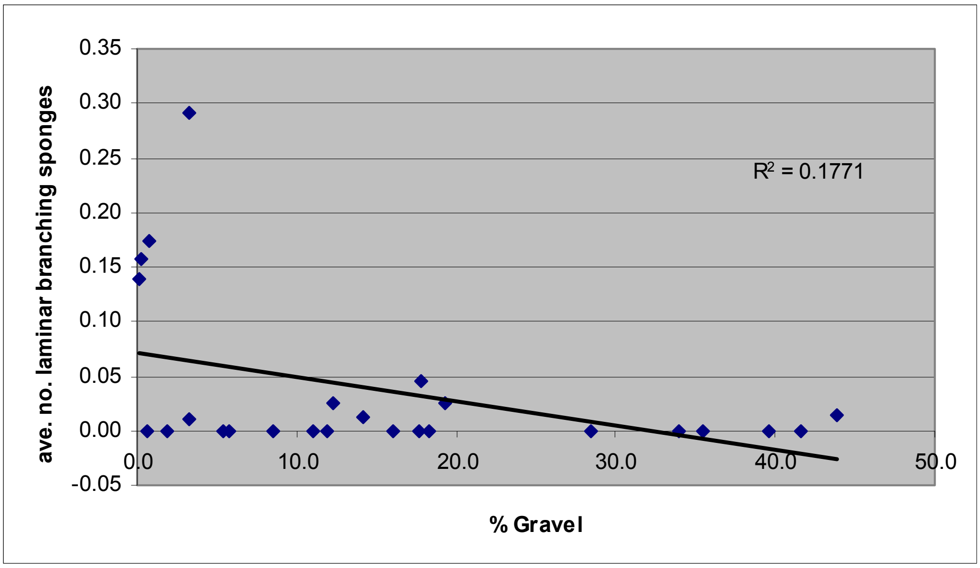

R² = 0.0053
ave. no. encrusting sponges
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
d15N ‰ AIR

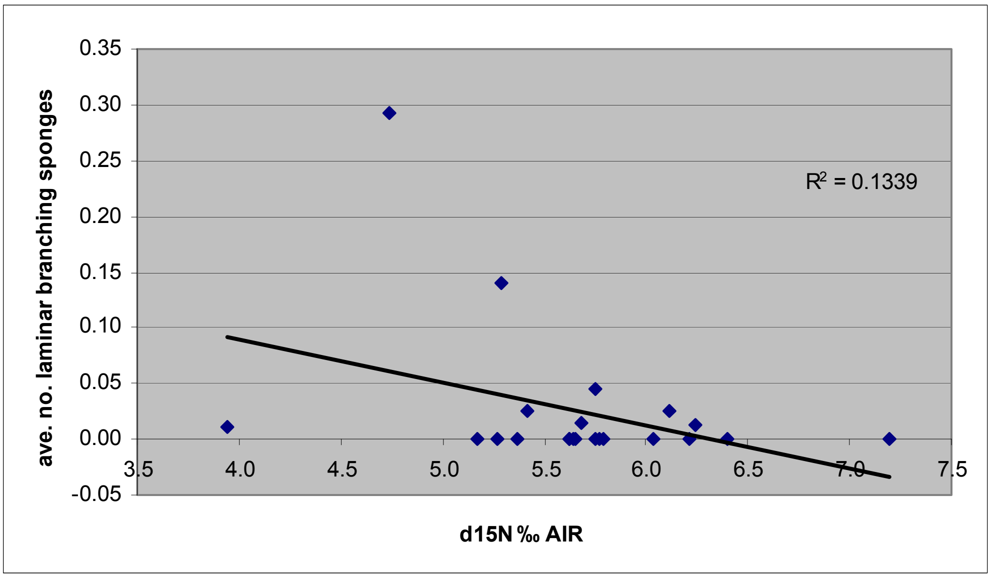

R² = 0.0037
ave. no. encrusting sponges
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3.5
8.5
13.5
18.5
23.5
Si/Al

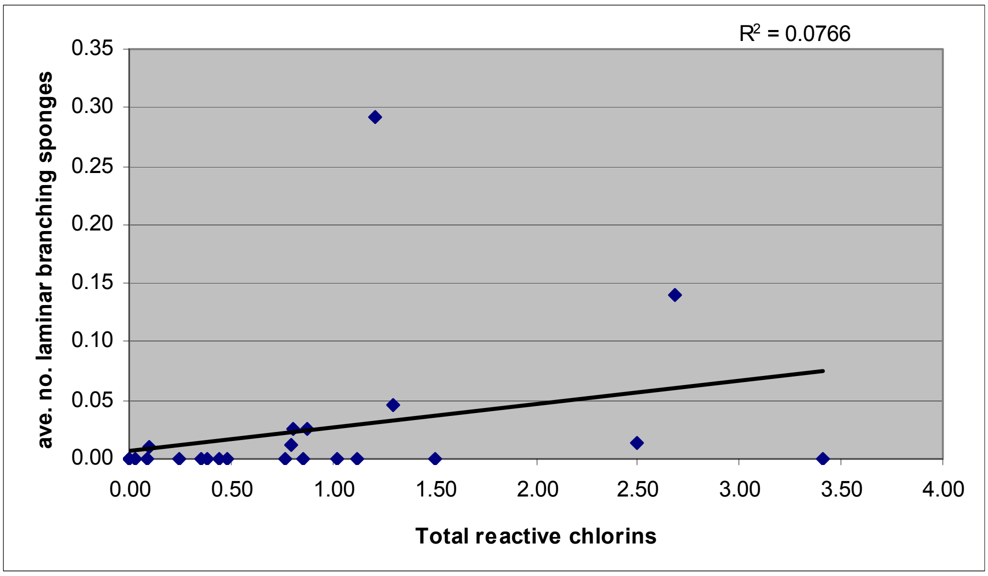
Laminar Branching Sponges

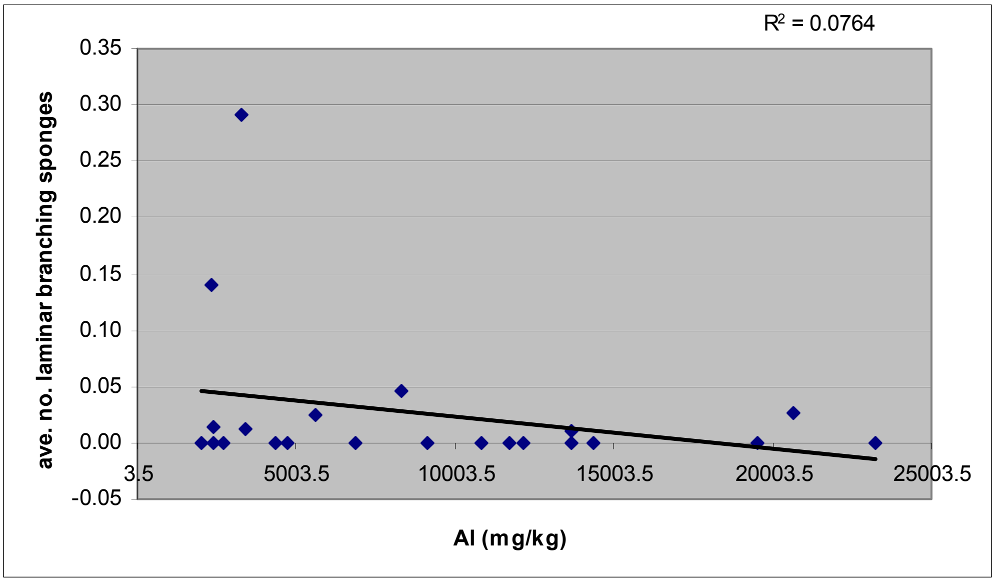


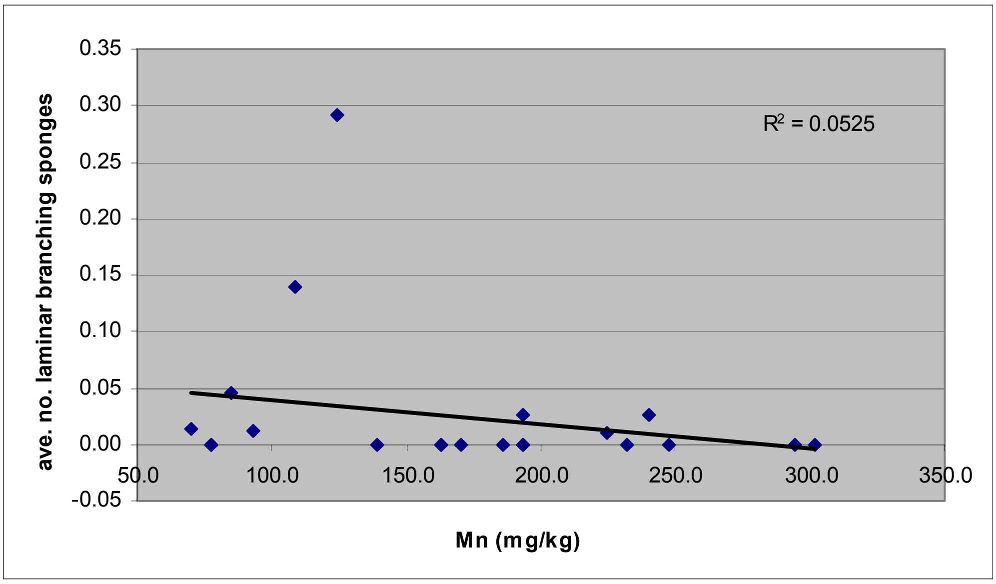


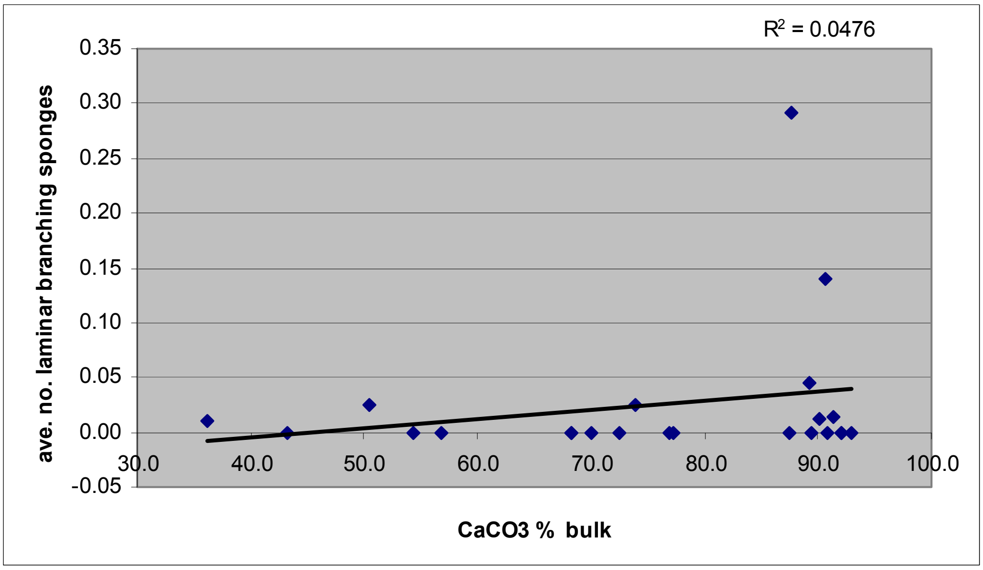


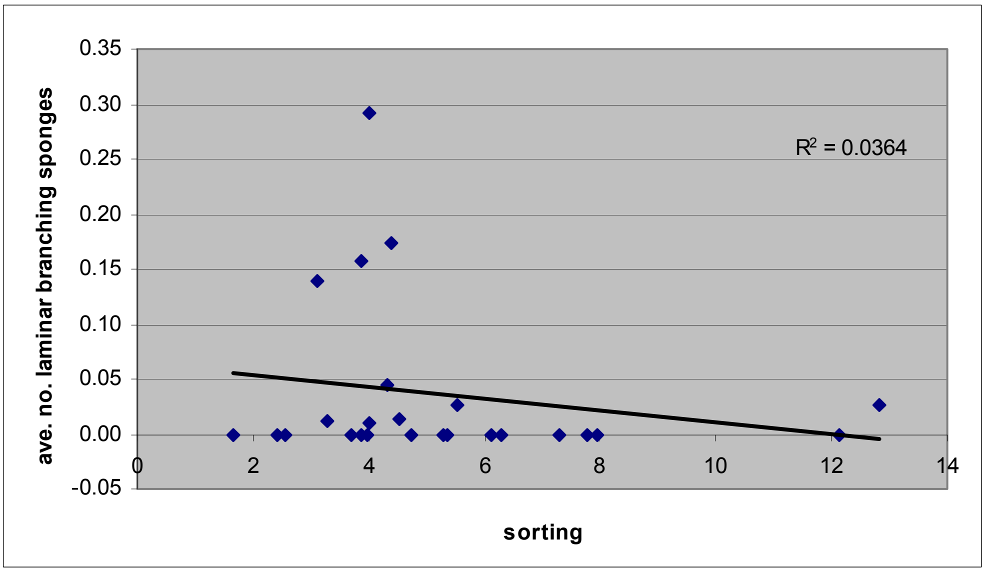

ave. no. laminar branching sponges
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
R² = 0.1339
d15N ‰ AIR

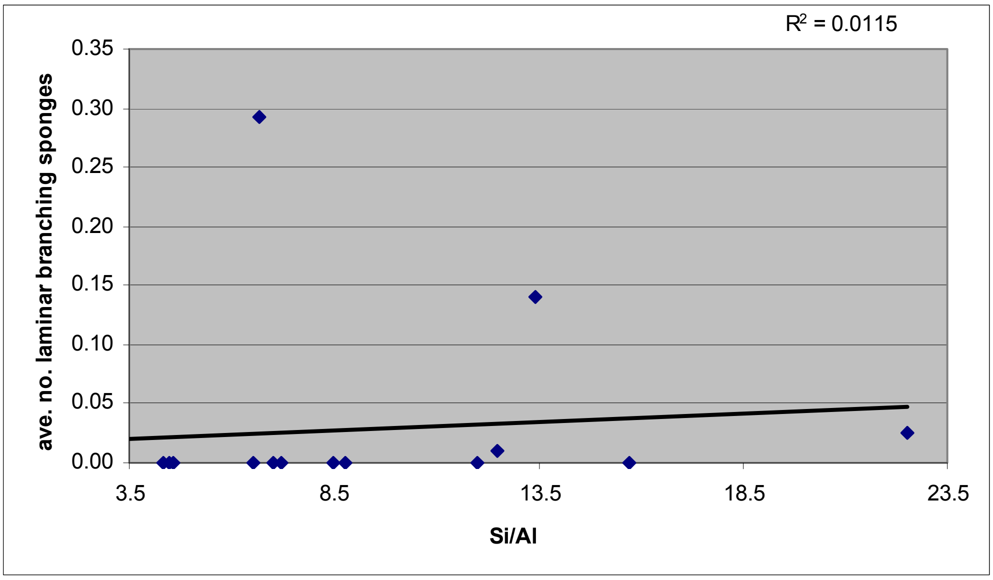

R² = 0.0766
ave. no. laminar branching sponges
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Total reactive chlorins

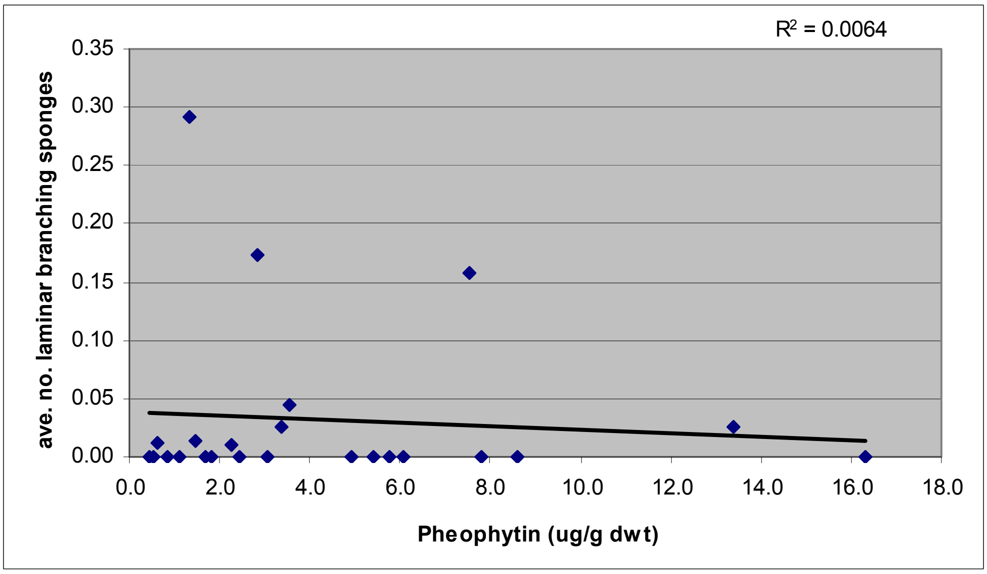

R² = 0.0764
ave. no. laminar branching sponges
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
3.5
5003.5
10003.5
15003.5
20003.5
25003.5
Al (mg/kg)


ave. no. laminar branching sponges
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
50.0
100.0
150.0
200.0
250.0
300.0
350.0
R² = 0.0525
Mn (mg/kg)

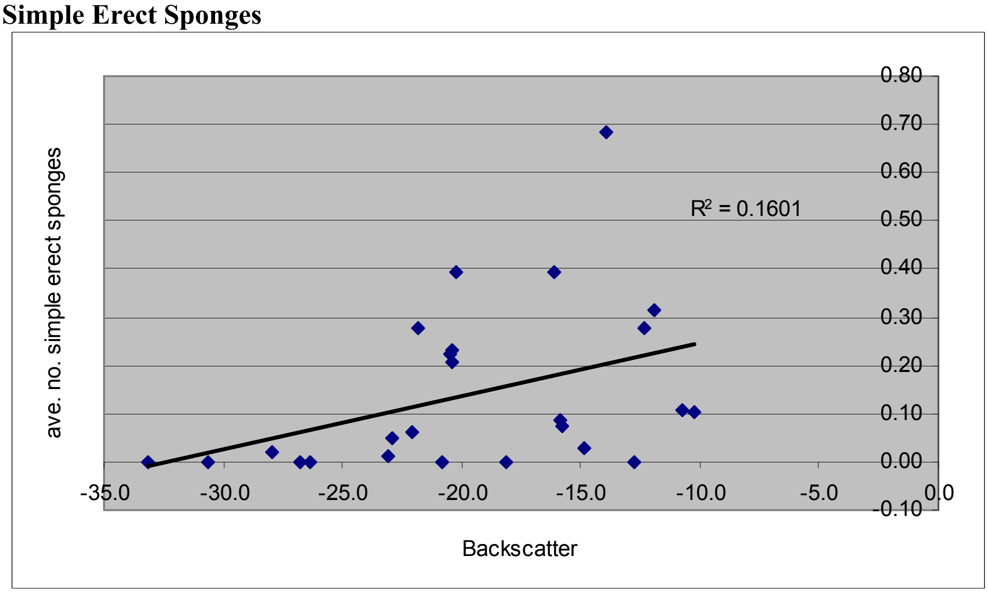

R² = 0.0476
ave. no. laminar branching sponges
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
CaCO3 % bulk

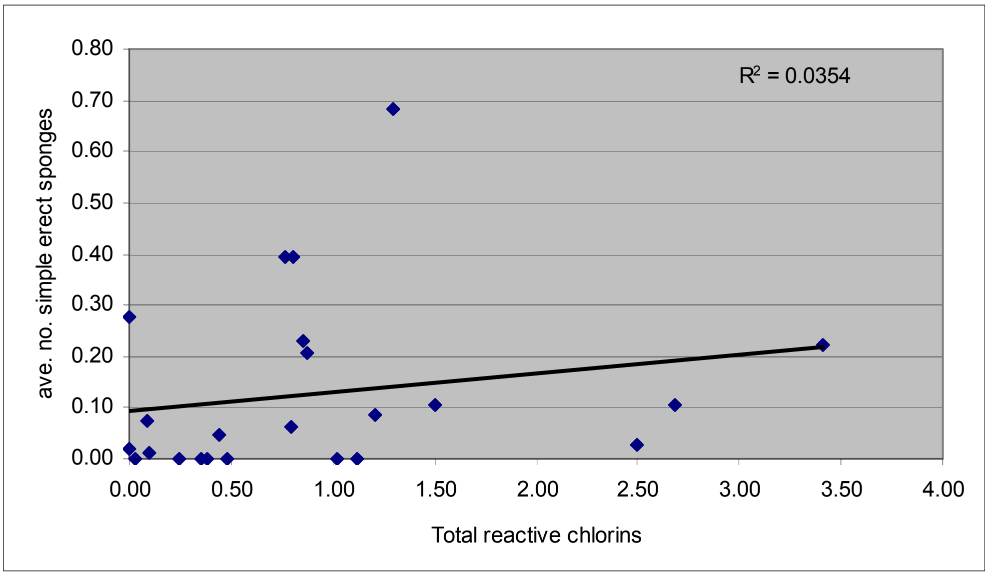

ave. no. laminar branching sponges
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0
2
4
6
8
10
12
14
R² = 0.0364
sorting

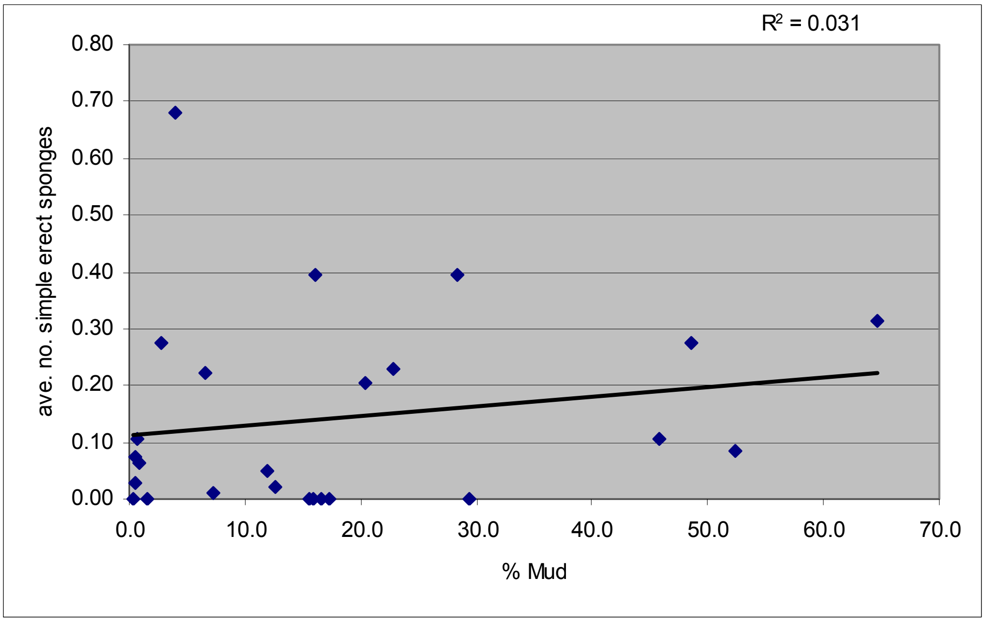


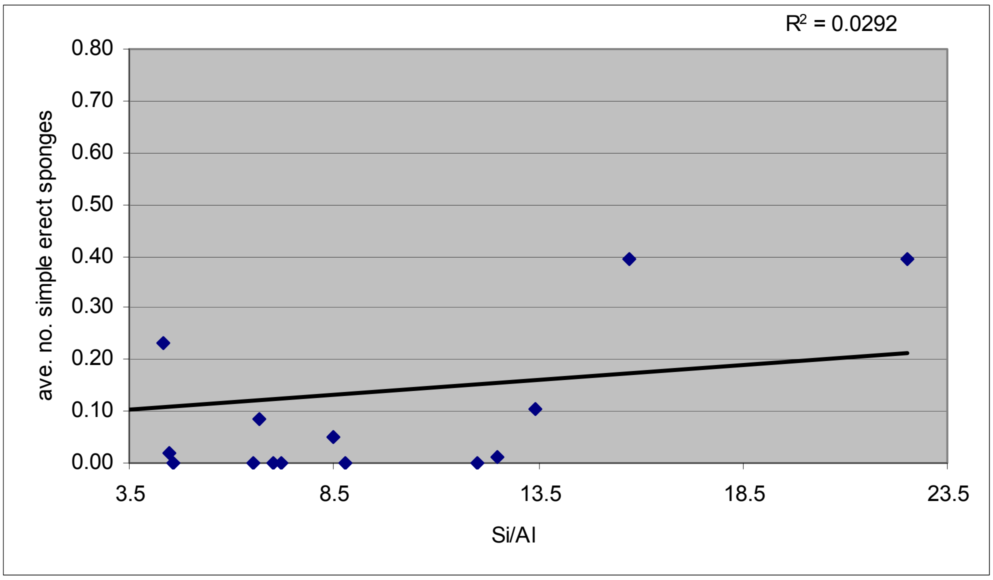


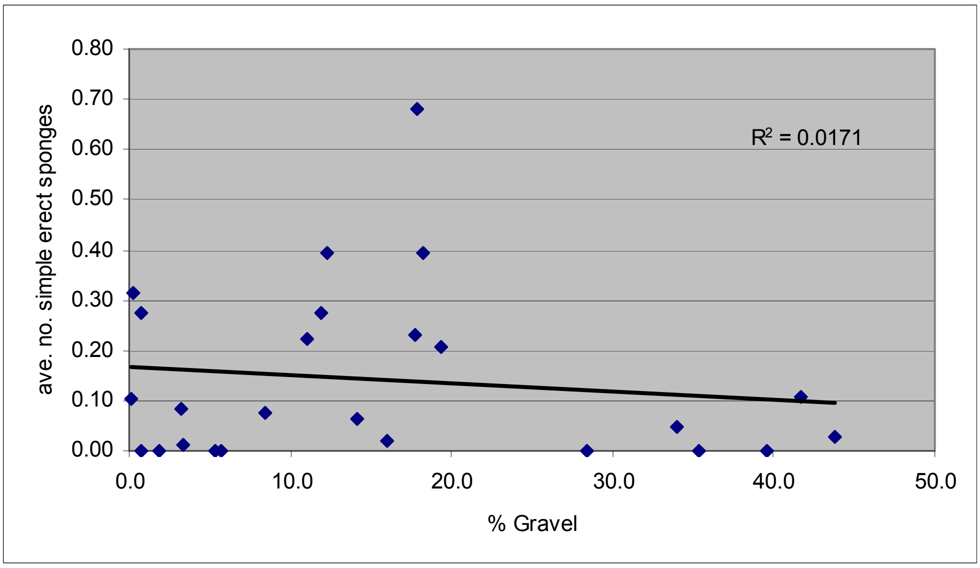
Simple Erect Sponges

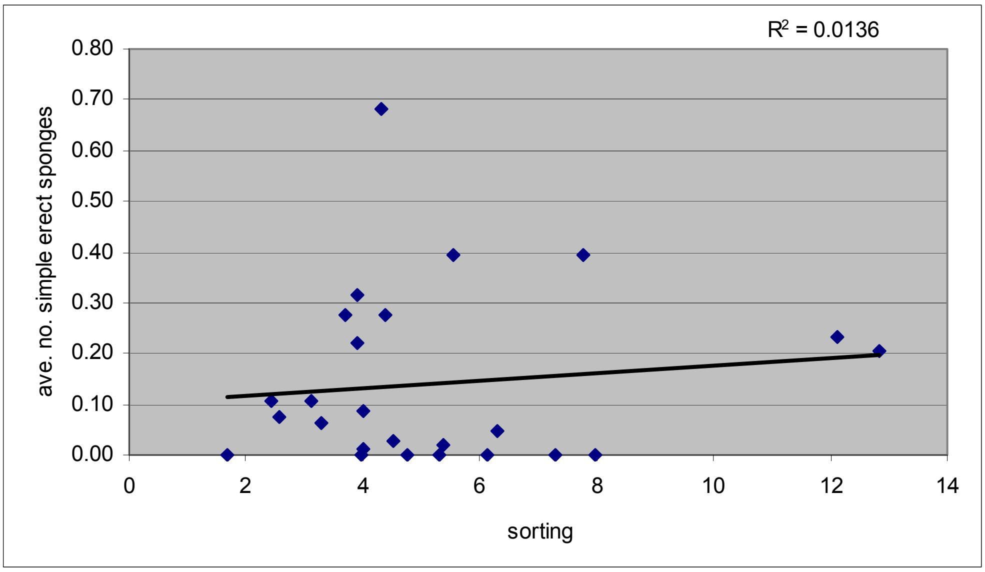


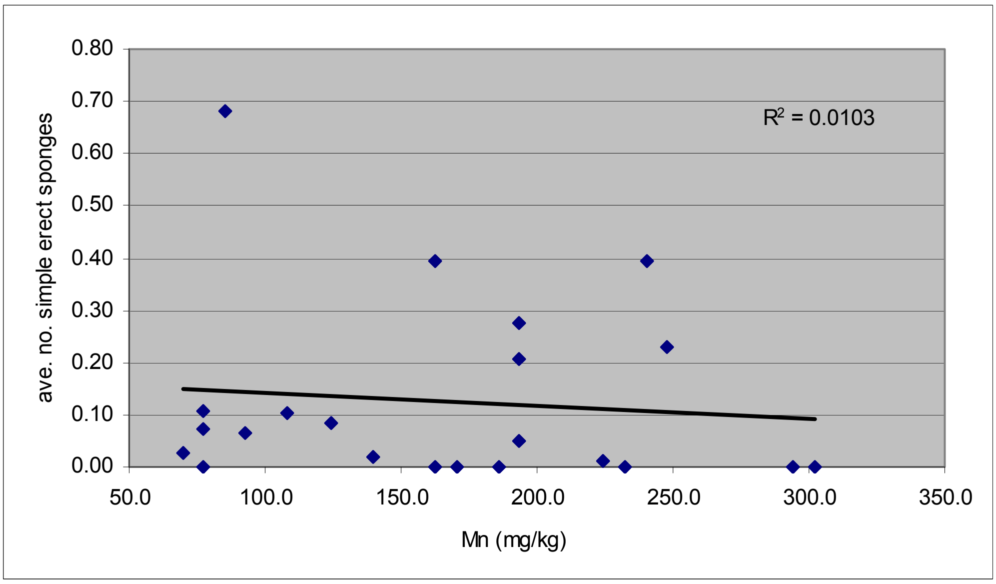

R² = 0.0354
ave. no. simple erect sponges
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Total reactive chlorins

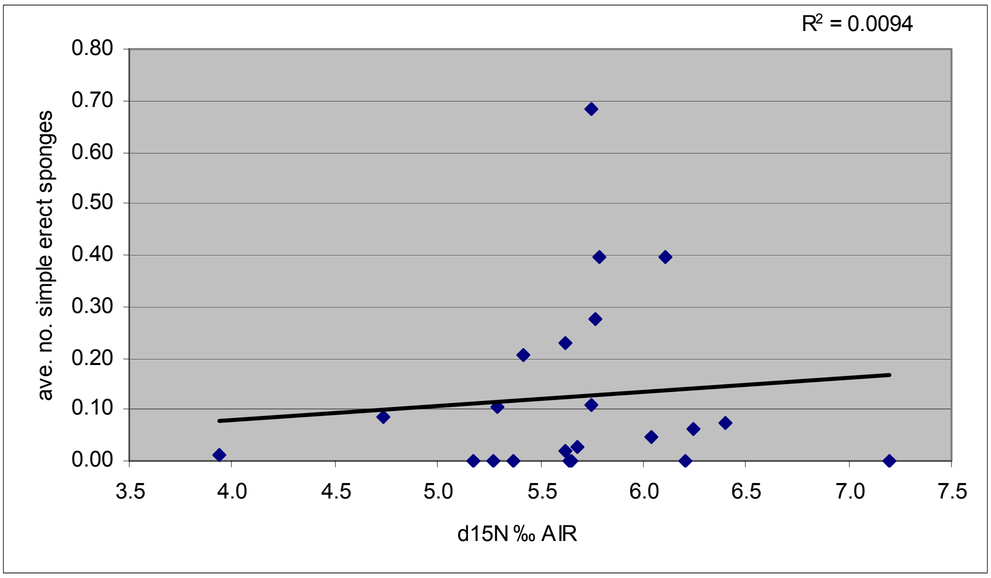

R² = 0.031
ave. no. simple erect sponges
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
% Mud

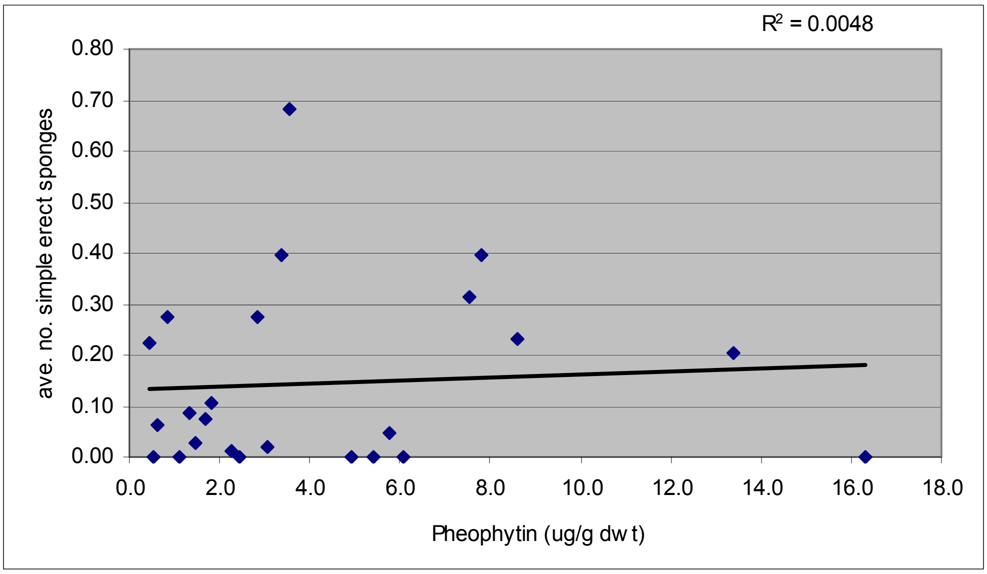

R² = 0.0292
ave. no. simple erect sponges
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
3.5
8.5
13.5
18.5
23.5
Si/Al

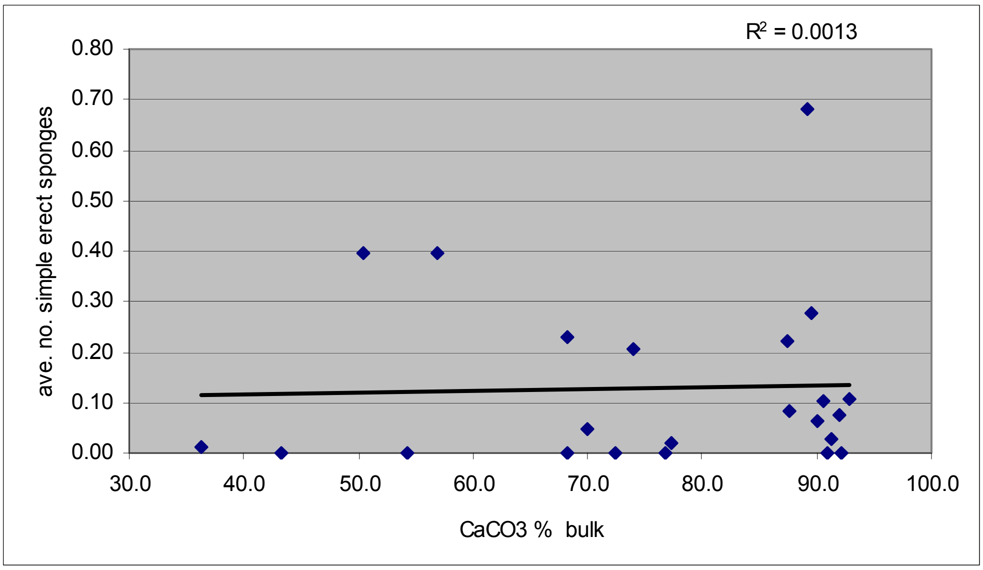

ave. no. simple erect sponges
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
10.0
20.0
30.0
40.0
50.0
% Gravel
R² = 0.0171

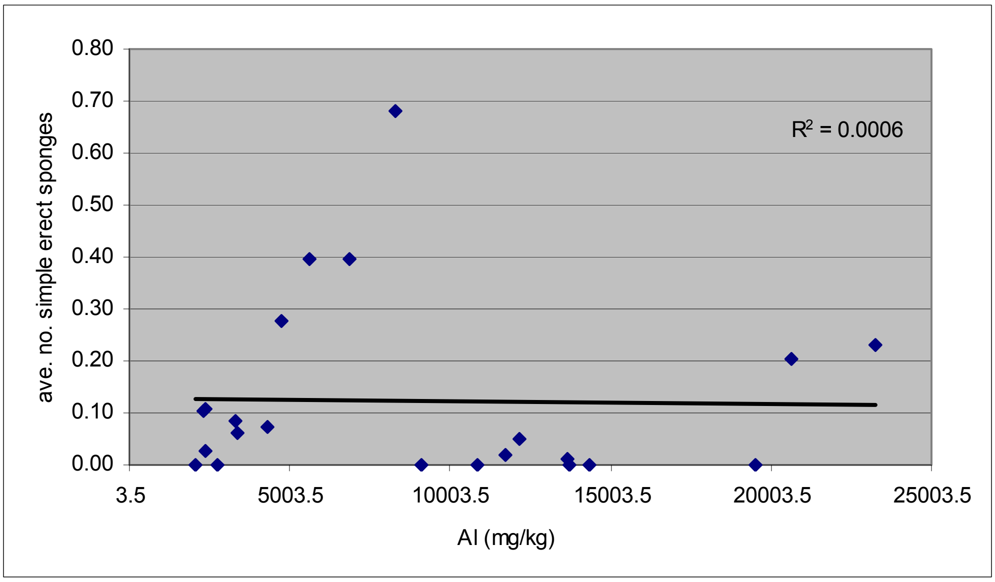

ave. no. simple erect sponges
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
2
4
6
8
10
12
14
sorting
R² = 0.0136


ave. no. simple erect sponges
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Mn (mg/kg)
R² = 0.0103

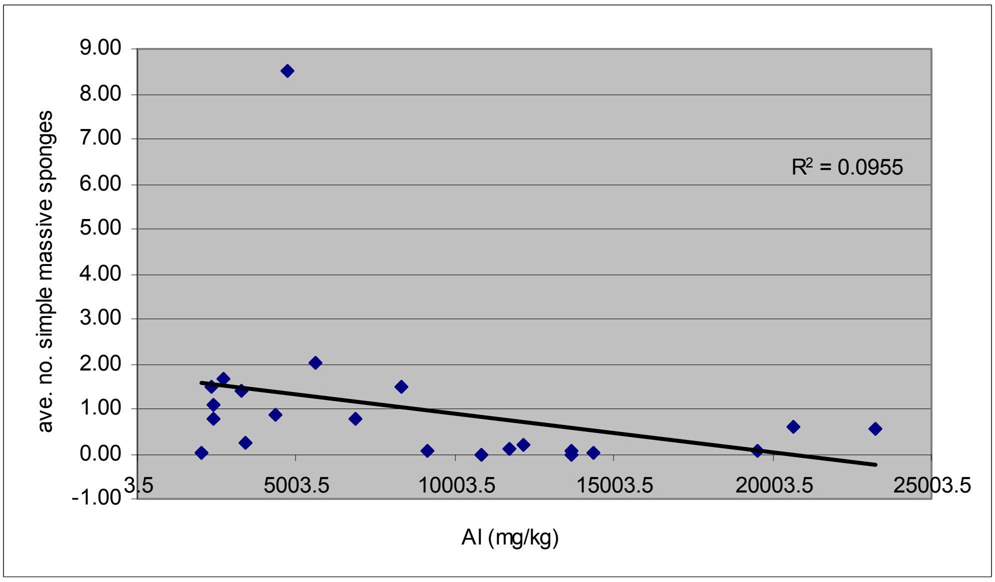

R² = 0.0094
ave. no. simple erect sponges
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
d15N ‰ AIR

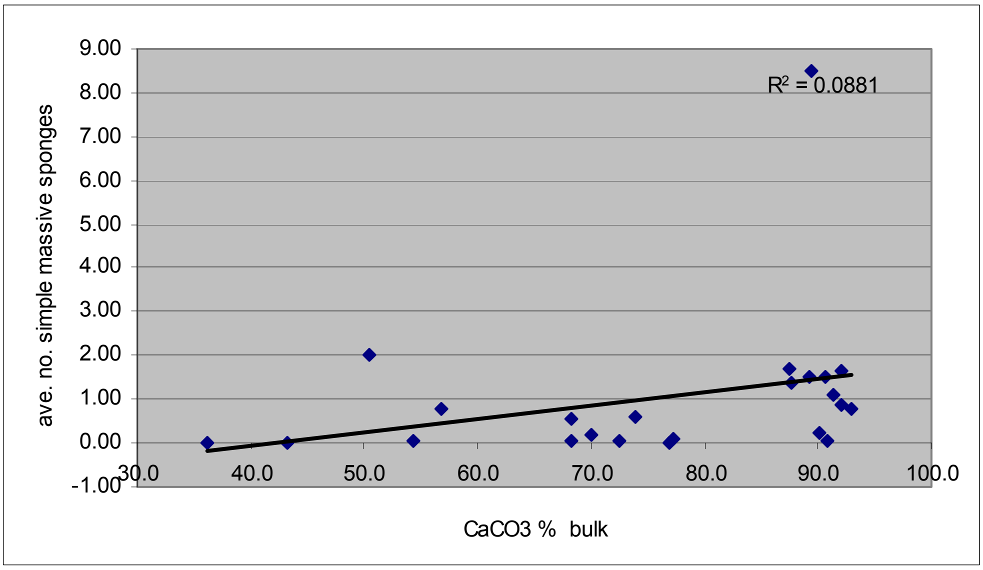

R² = 0.0048
ave. no. simple erect sponges
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Pheophytin (ug/g dw t)

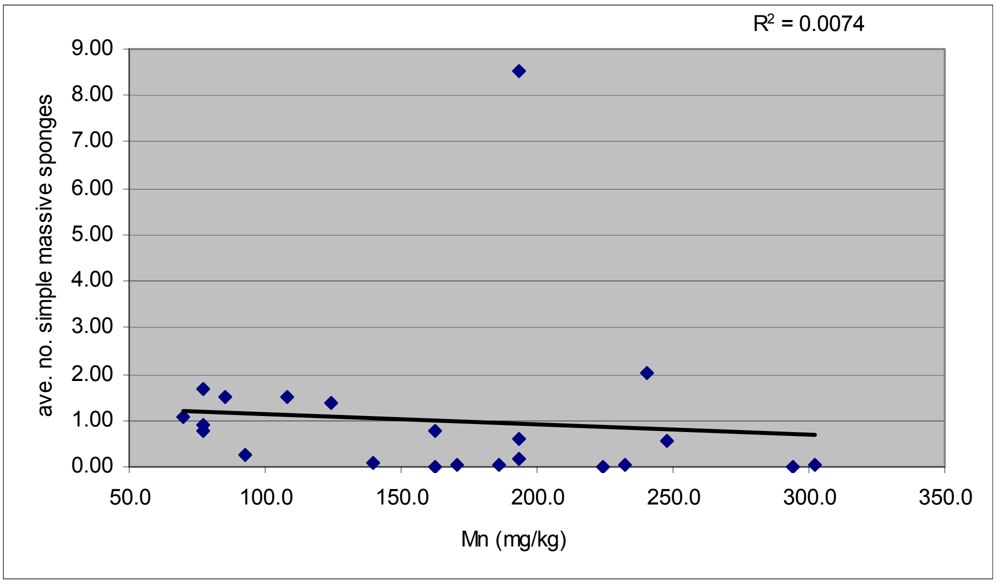

R² = 0.0013
ave. no. simple erect sponges
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
CaCO3 % bulk

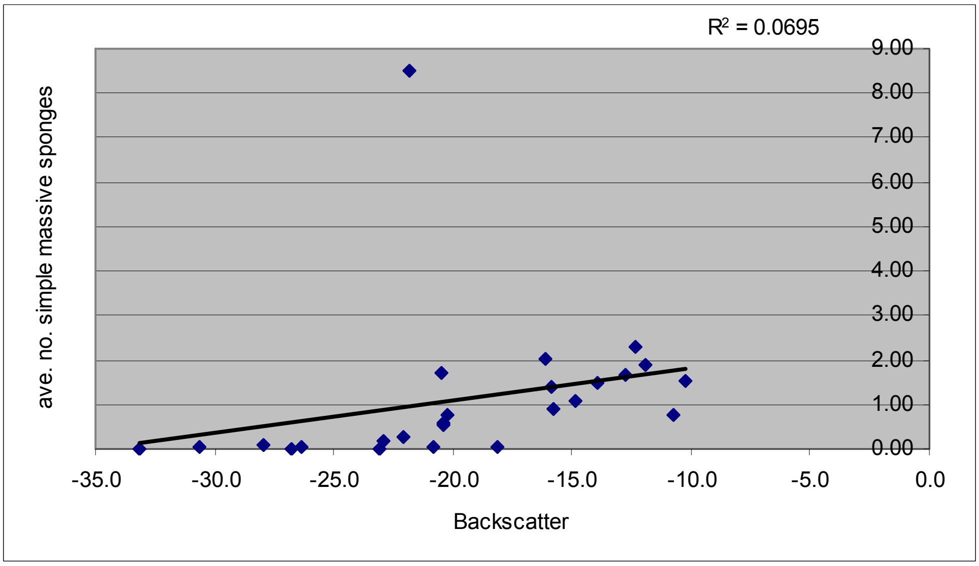


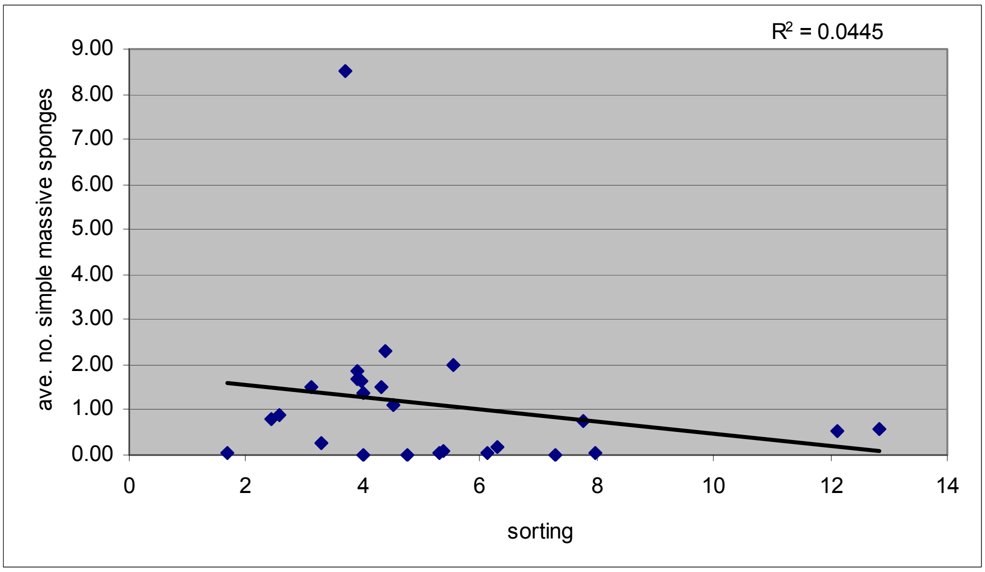
Simple Massive Sponges

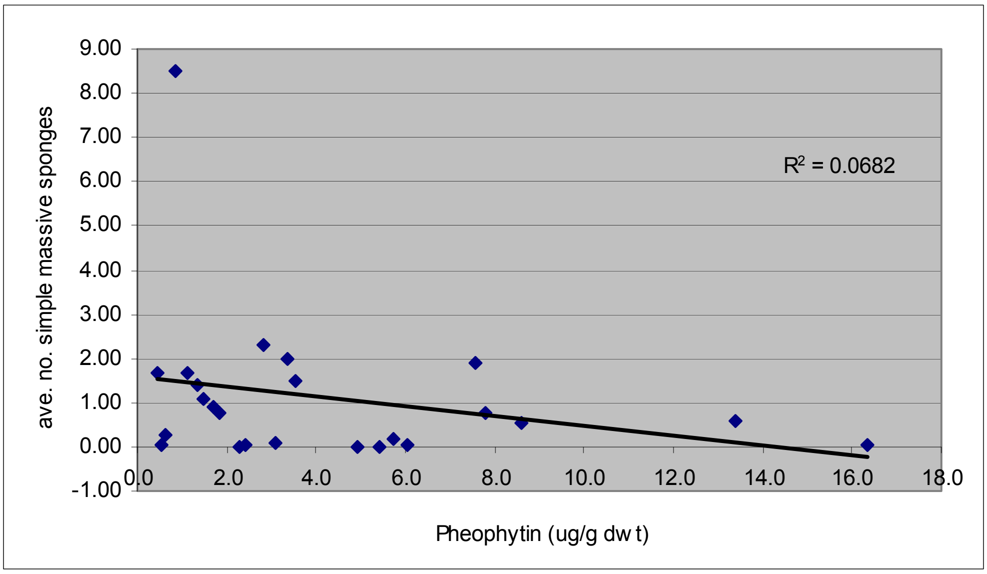


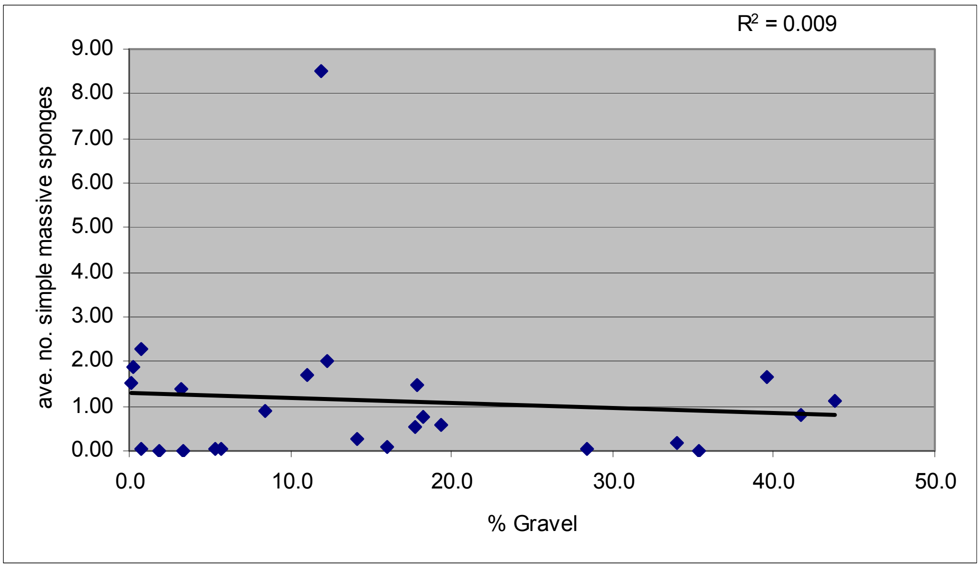


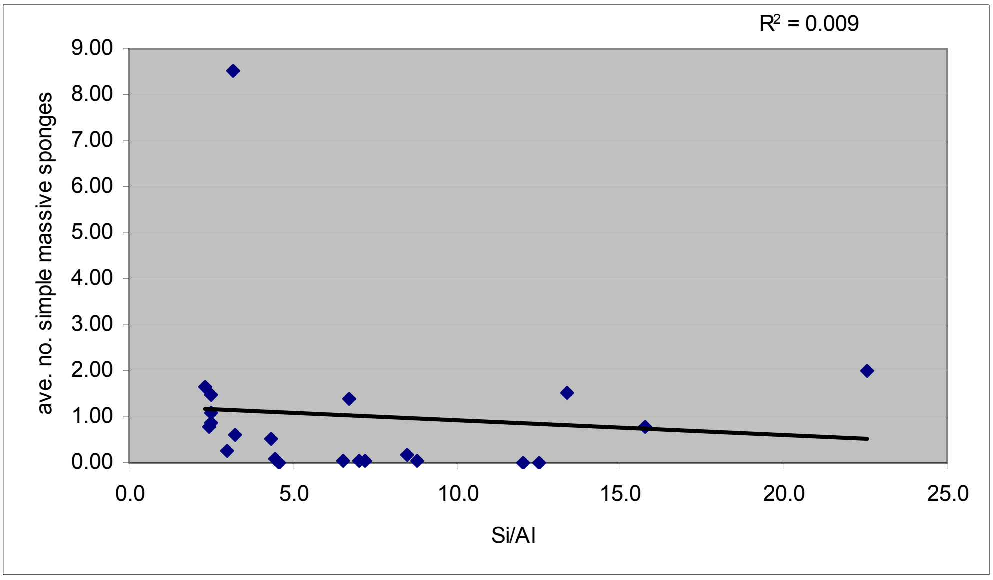

R² = 0.0074
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Mn (mg/kg)
ave. no. simple massive sponges

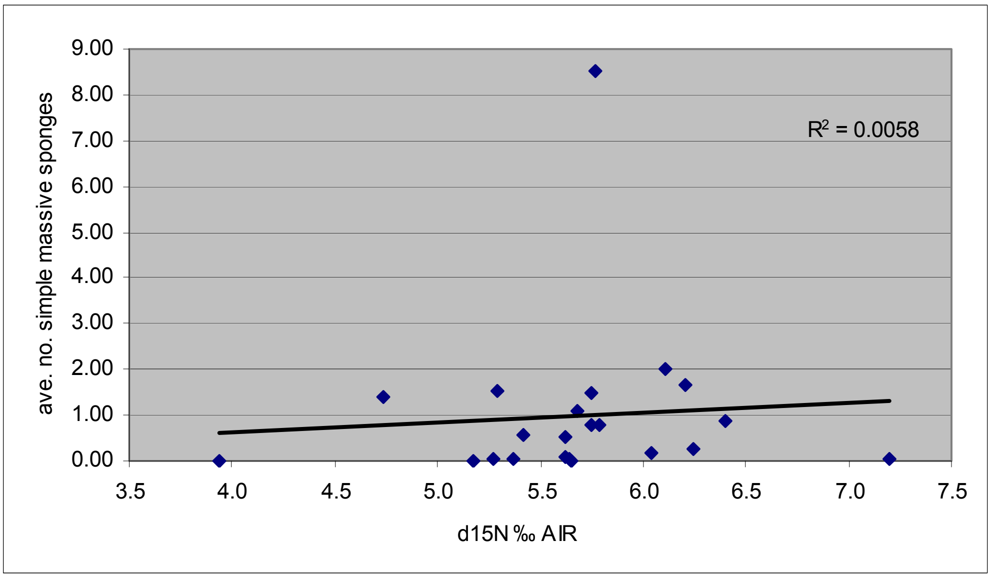

R² = 0.0695
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0
Backscatter
ave. no. simple massive sponges

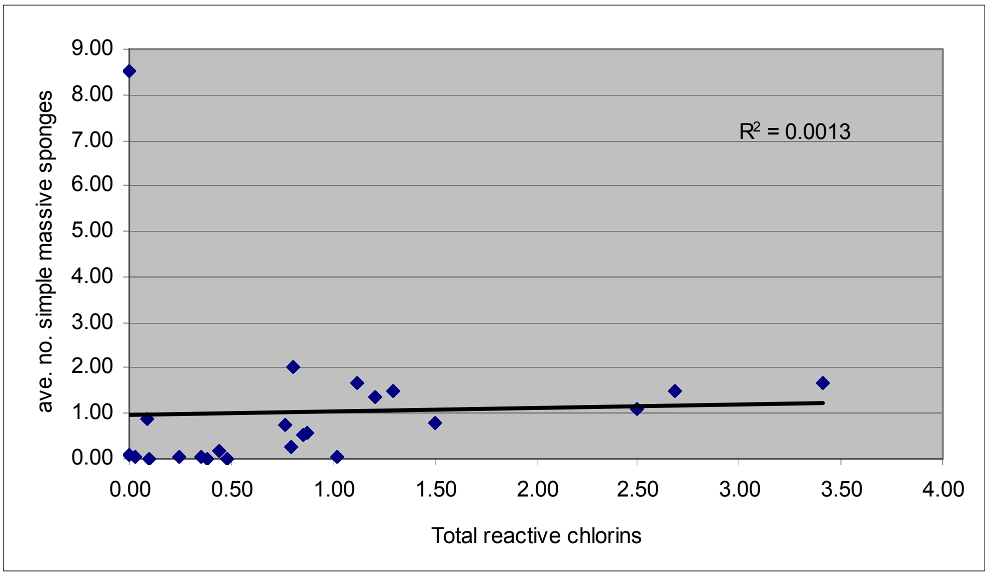

R² = 0.0445
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
2
4
6
8
10
12
14
sorting
ave. no. simple massive sponges

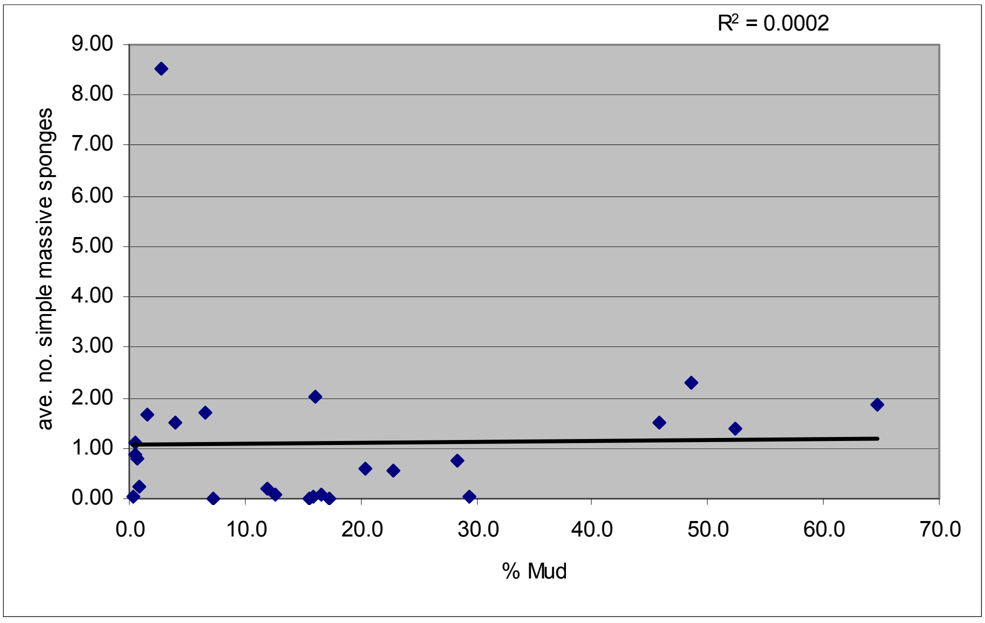

ave. no. simple massive sponges
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
R² = 0.0682
Pheophytin (ug/g dw t)


R² = 0.009
ave. no. simple massive sponges
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.0
10.0
20.0
30.0
40.0
50.0
% Gravel

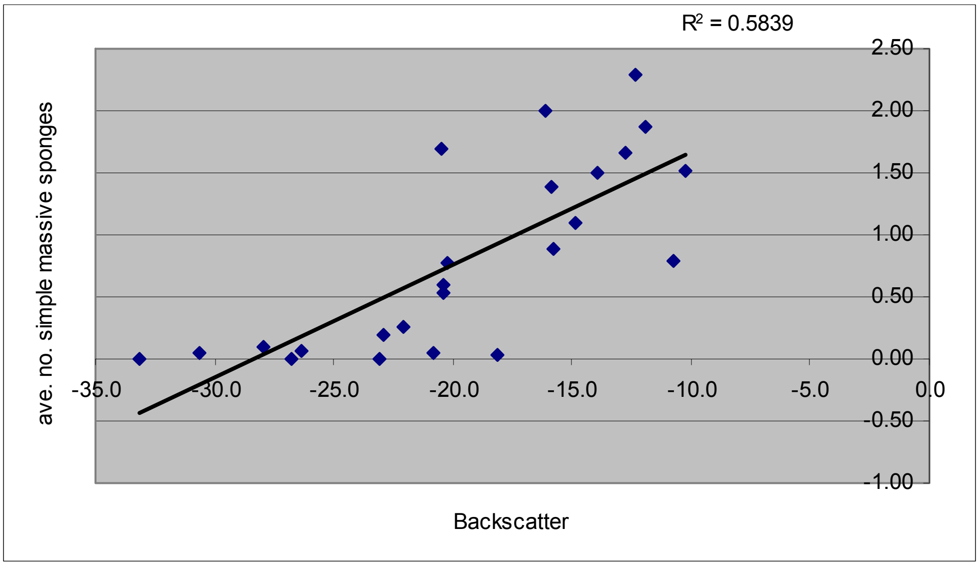

R² = 0.009
ave. no. simple massive sponges
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.0
5.0
10.0
15.0
20.0
25.0
Si/Al

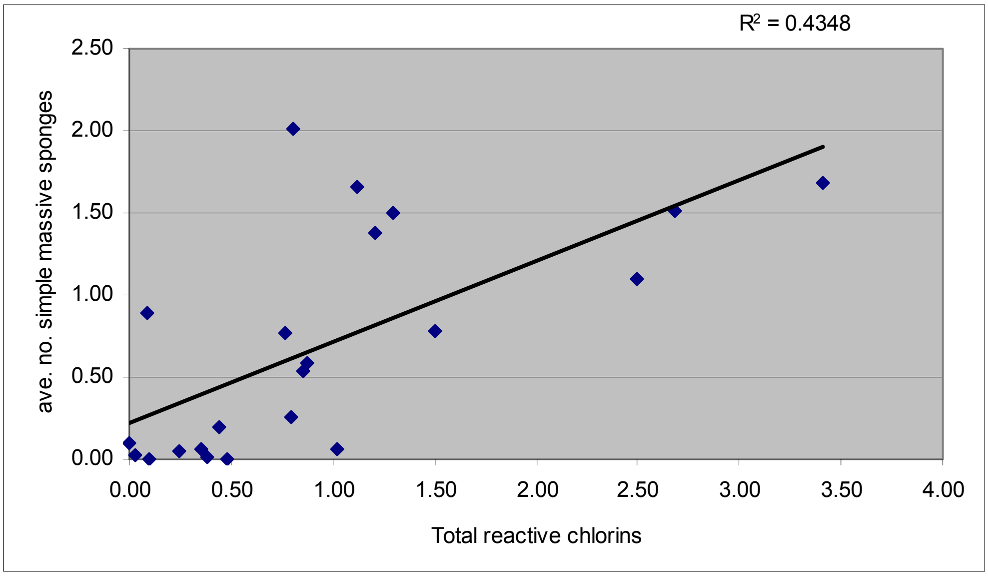

ave. no. simple massive sponges
d15N ‰ AIR
R² = 0.0058
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5

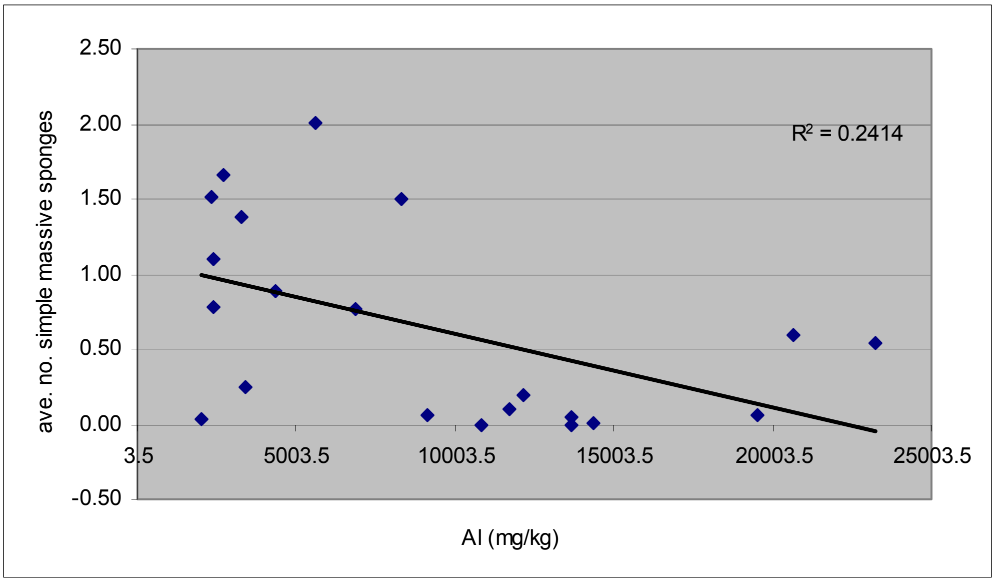

ave. no. simple massive sponges
Total reactive chlorins
R² = 0.0013
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00

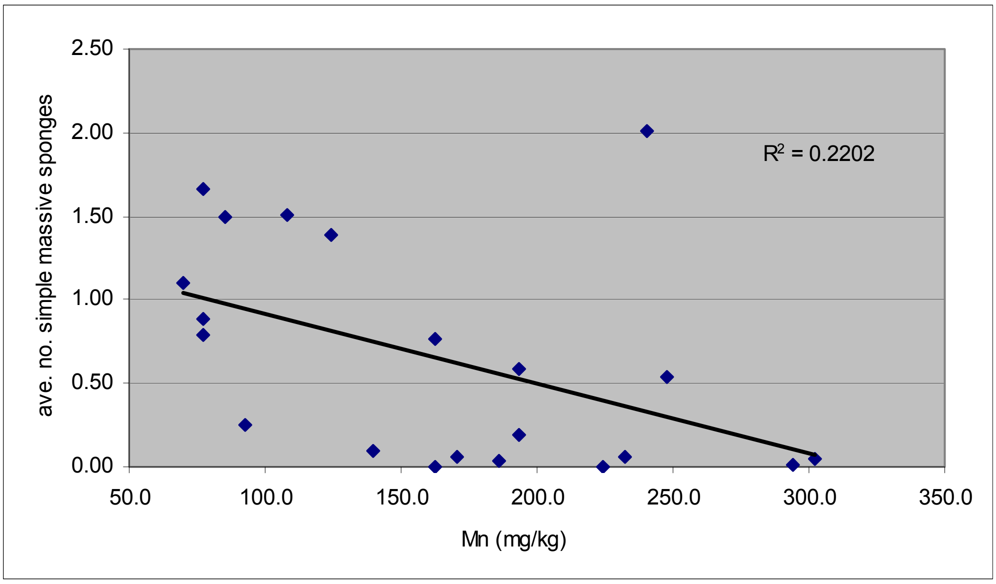

ave. no. simple massive sponges
% Mud
R² = 0.0002
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0

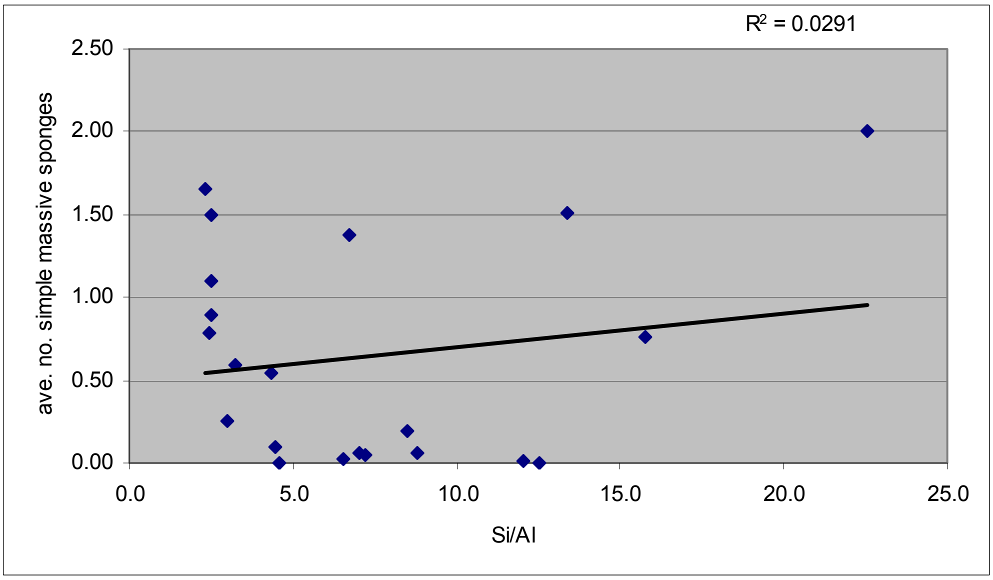
Simple Massive Sponges – No outlier

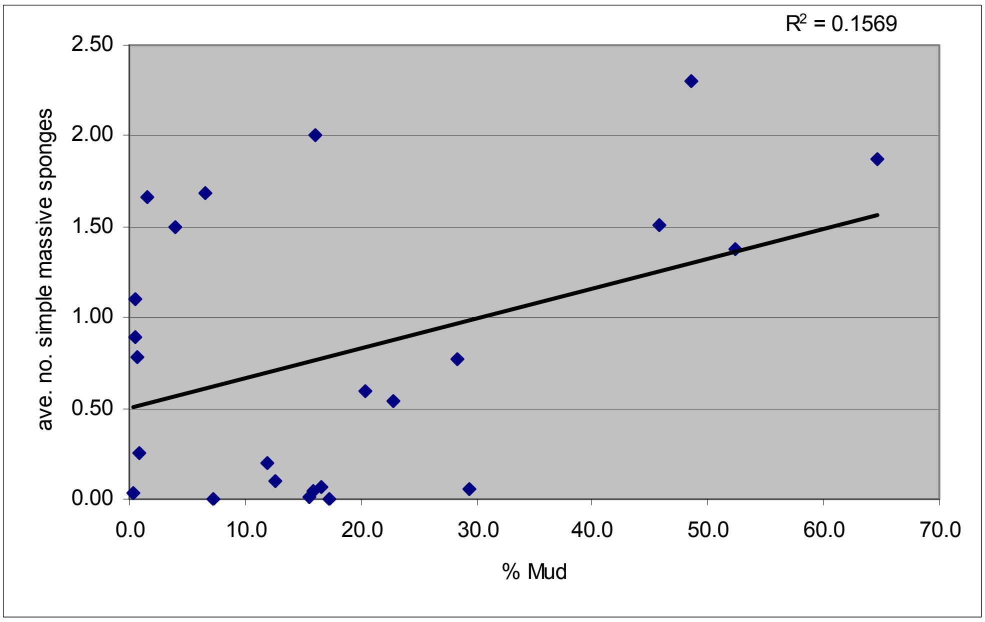


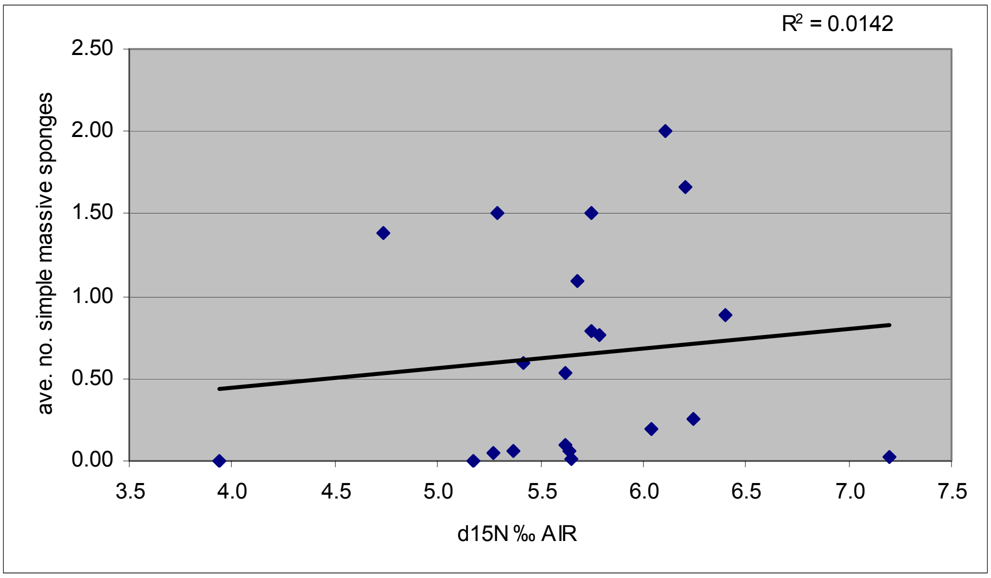


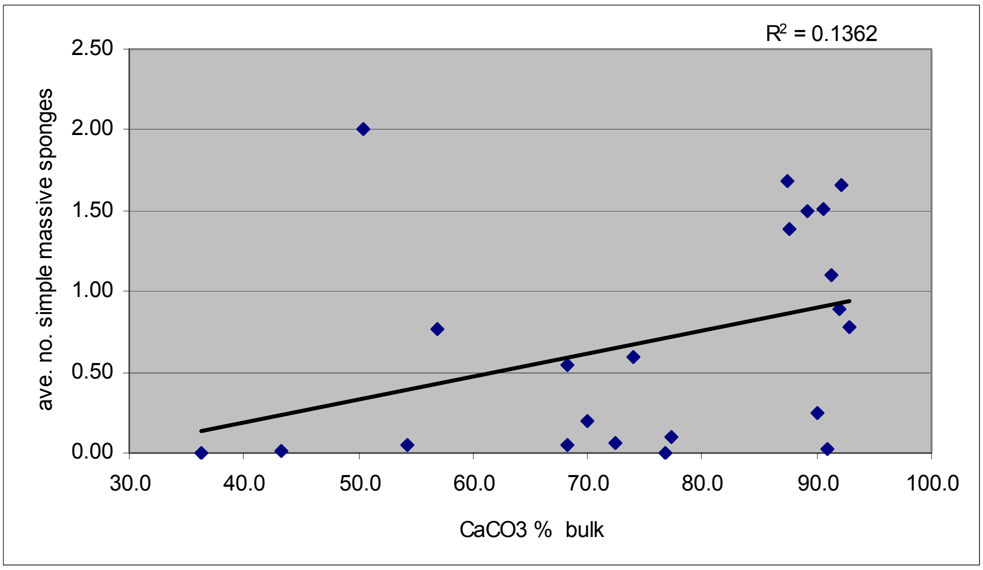


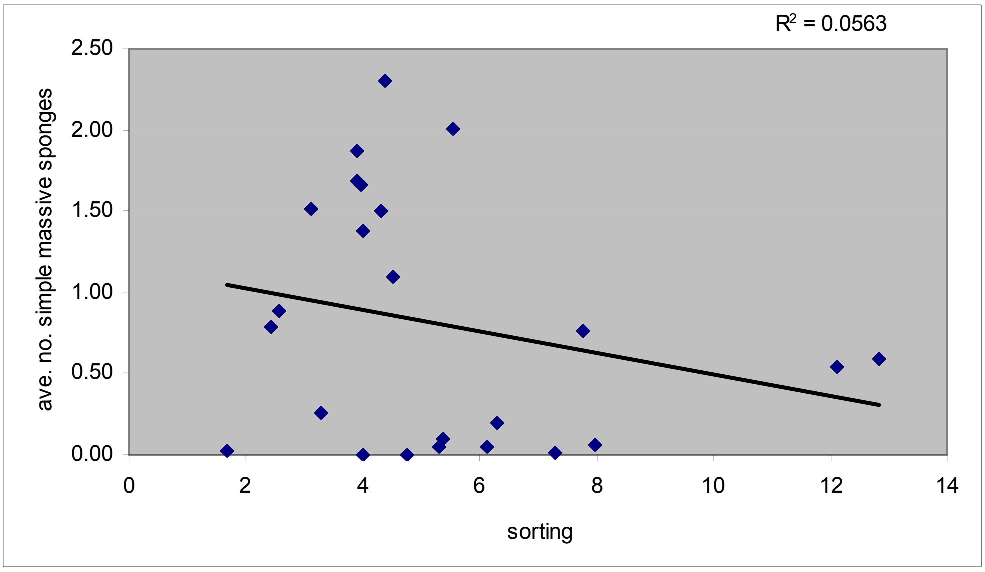

ave. no. simple massive sponges
Mn (mg/kg)
R^2 = 0.2202
2.50
2.00
1.50
1.00
0.50
0.00
50.0
100.0
150.0
200.0
250.0
300.0
350.0

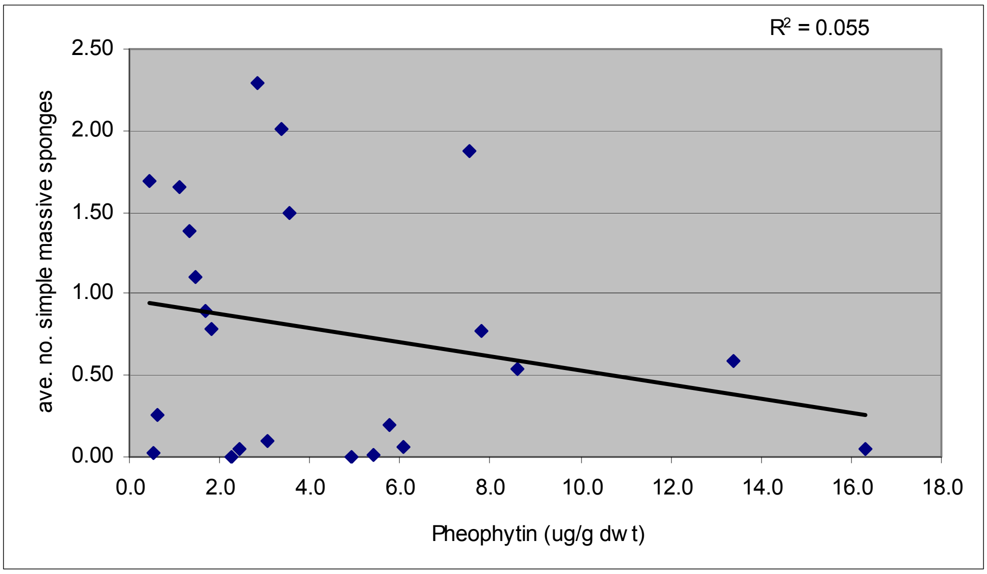

ave. no. simple massive sponges
Si/Al
R^2 = 0.0291
2.50
2.00
1.50
1.00
0.50
0.00
0.0
5.0
10.0
15.0
20.0
25.0

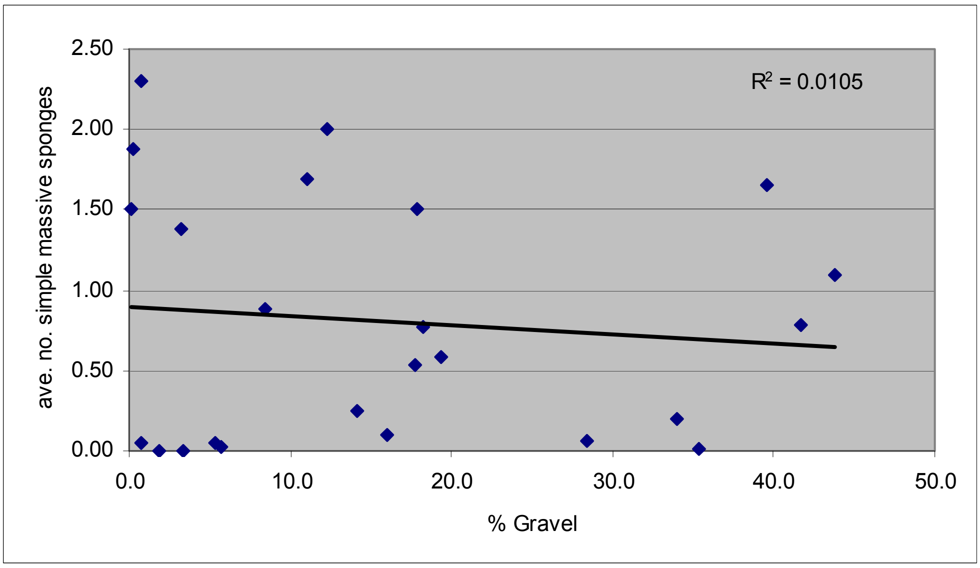

ave. no. simple massive sponges
% Mud
R^2 = 0.1569
2.50
2.00
1.50
1.00
0.50
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0


R² = 0.0142
ave. no. simple massive sponges
2.50
2.00
1.50
1.00
0.50
0.00
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
d15N ‰ AIR

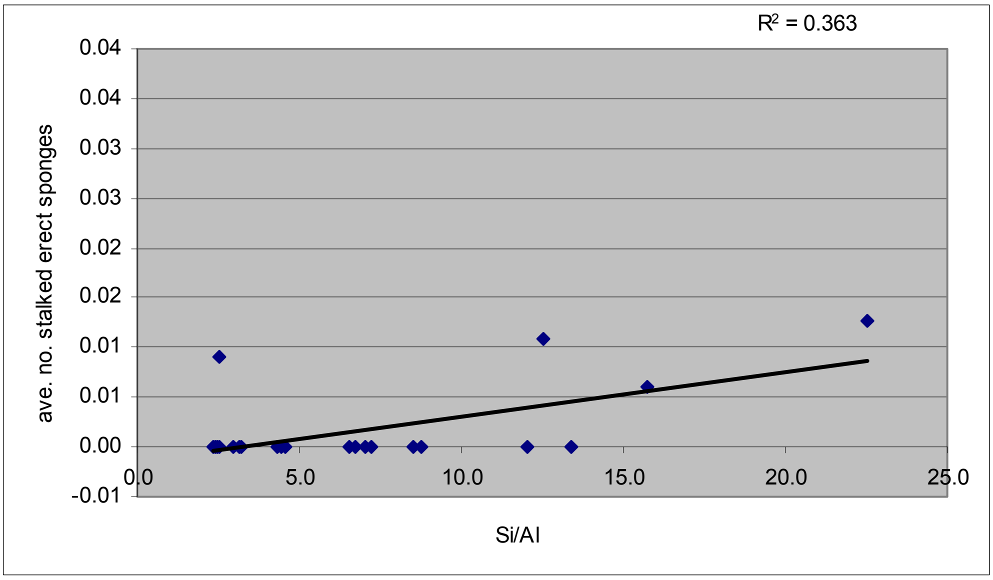

R² = 0.1362
ave. no. simple massive sponges
2.50
2.00
1.50
1.00
0.50
0.00
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
CaCO3 % bulk

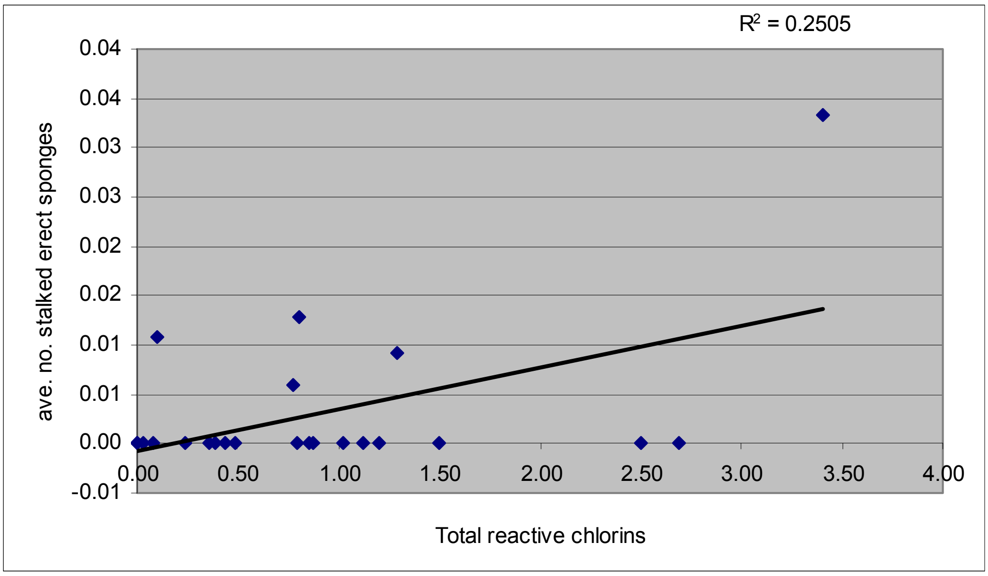

R² = 0.0563
ave. no. simple massive sponges
2.50
2.00
1.50
1.00
0.50
0.00
0
2
4
6
8
10
12
14
sorting

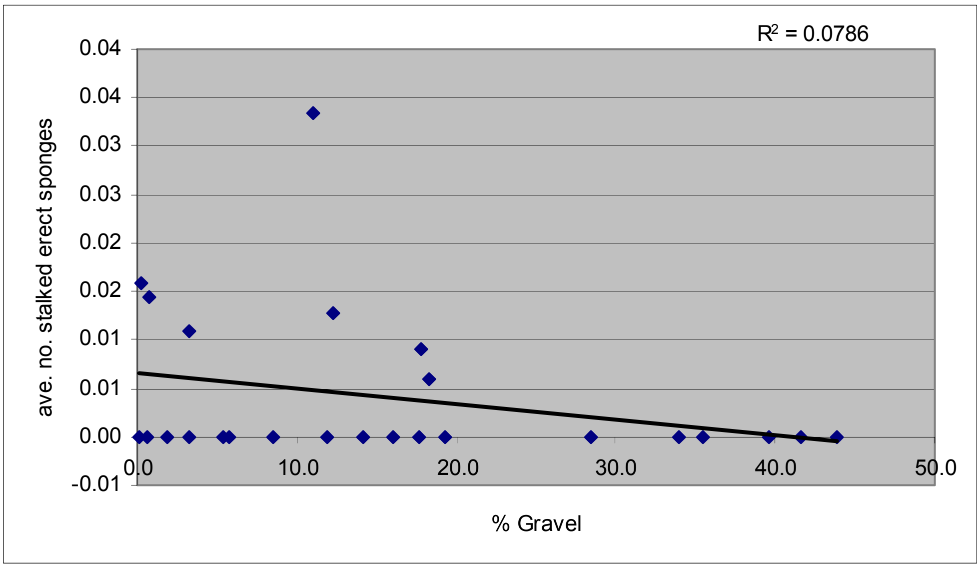


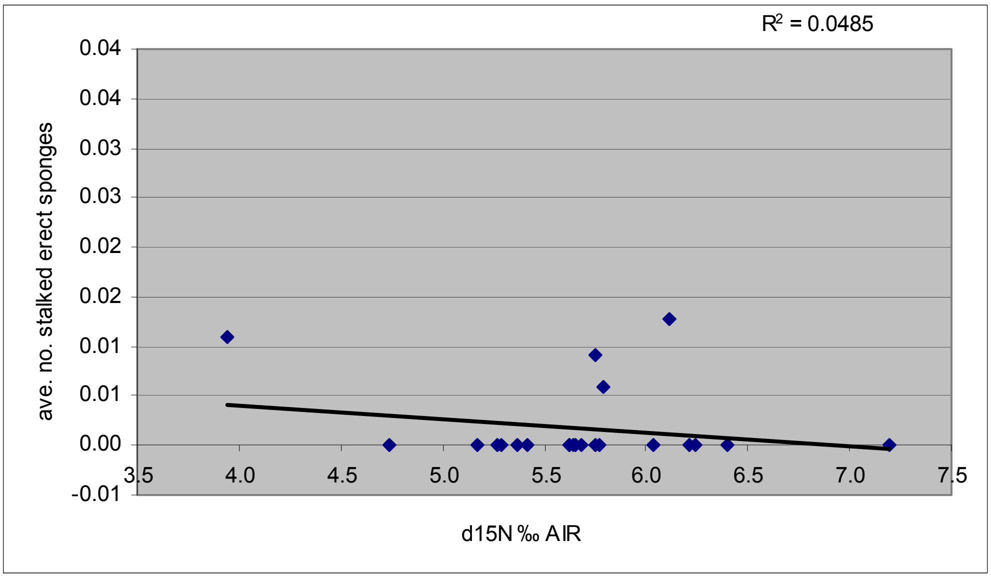


Stalked Erect Sponges

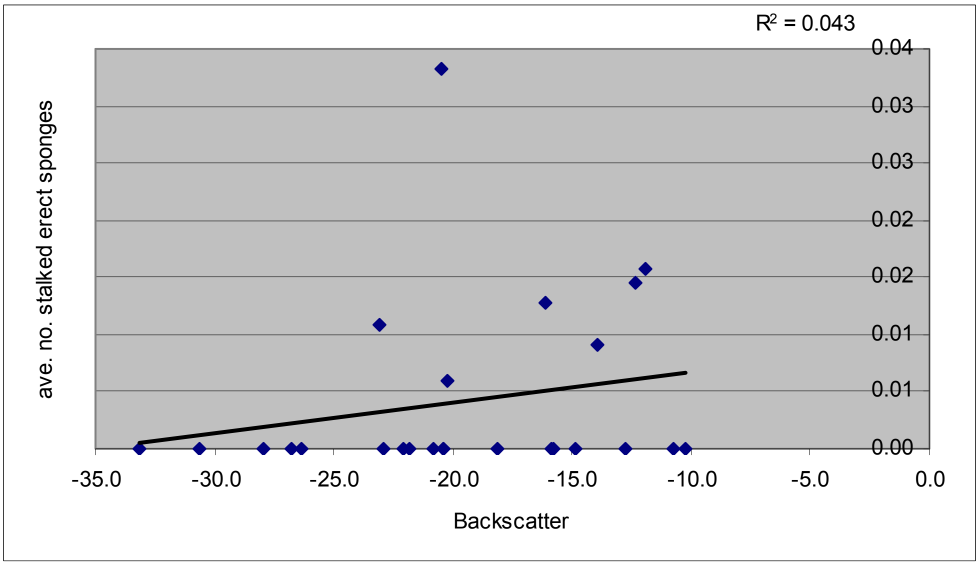



R² = 0.2505
0.04
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
-0.01
ave. no. stalked erect sponges
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Total reactive chlorins

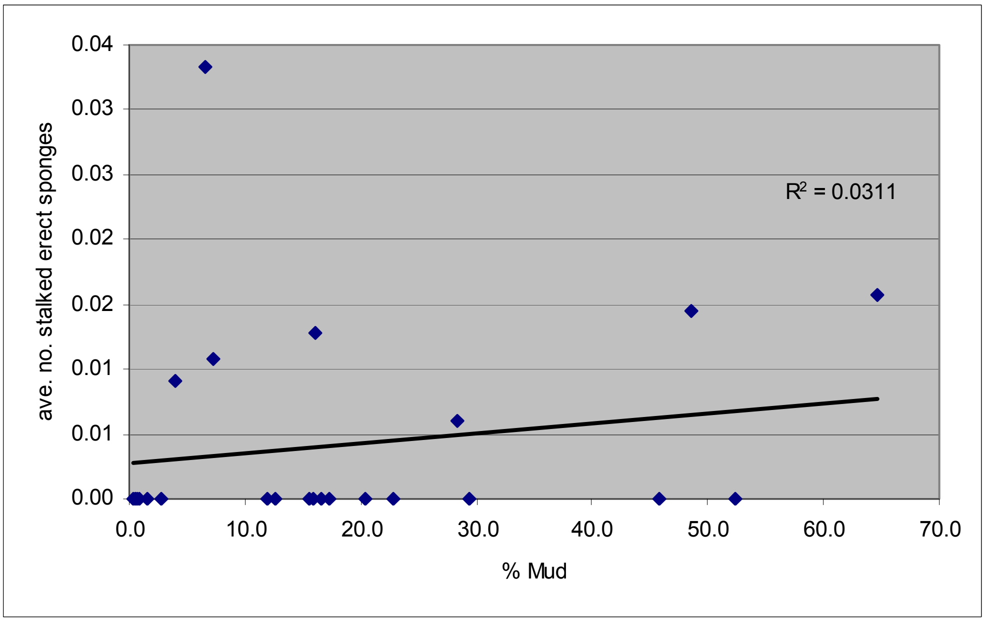

R² = 0.0786
0.04
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
-0.01
ave. no. stalked erect sponges
0.0
10.0
20.0
30.0
40.0
50.0
% Gravel



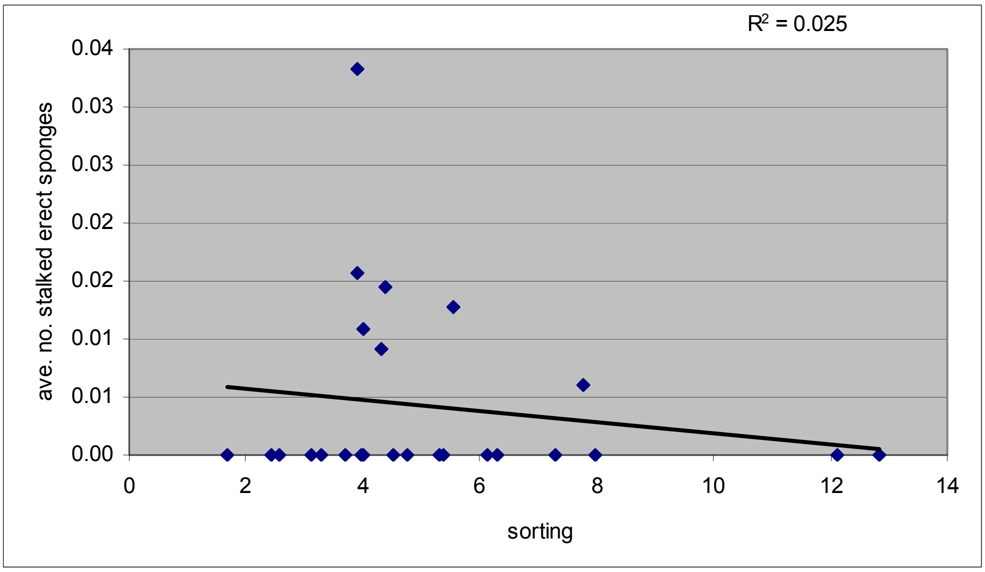
R^2 = 0.0485
0.04
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
-0.01
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
ave. no. stalked erect sponges
d15N ‰ AIR

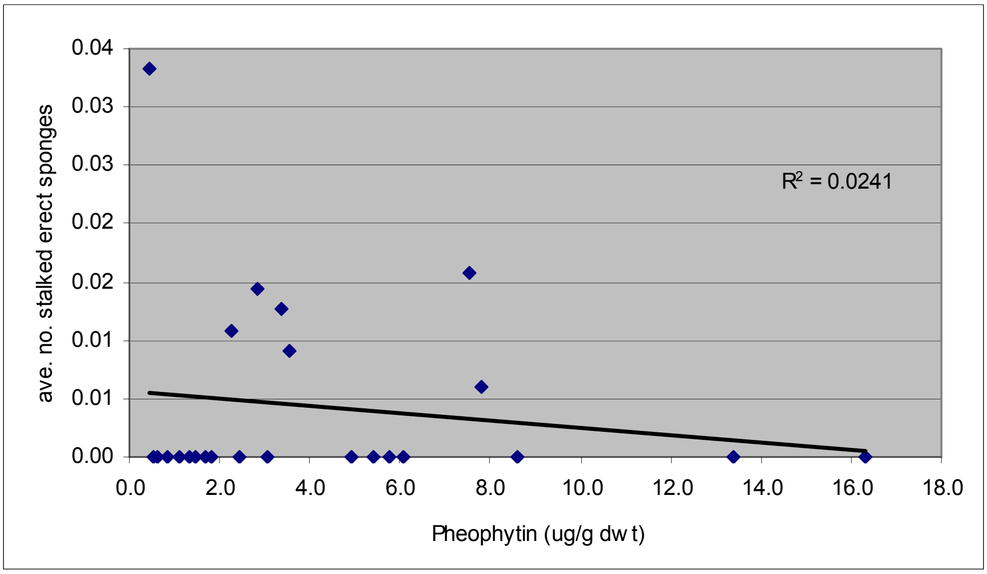


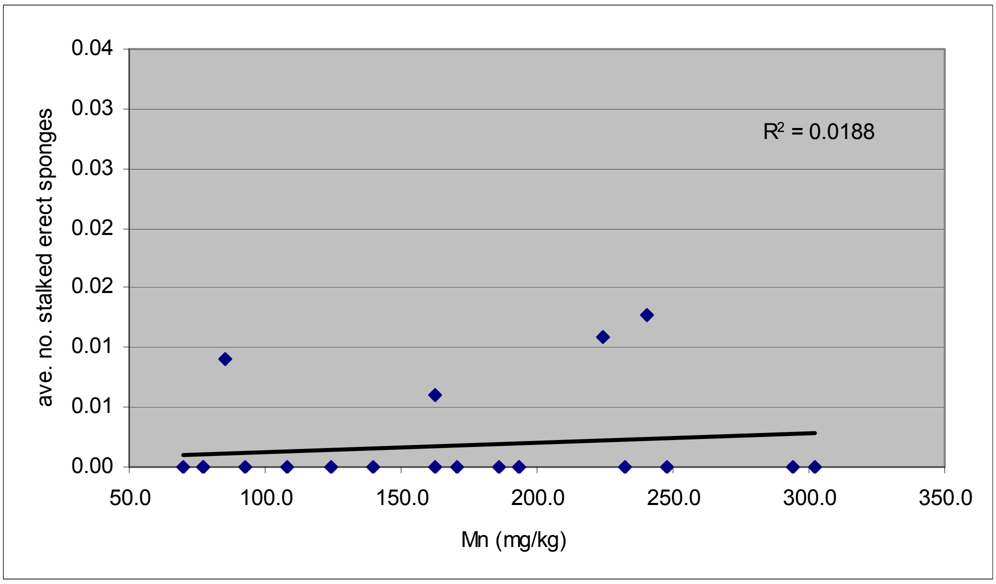
R^2 = 0.043
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0
ave. no. stalked erect sponges
Backscatter

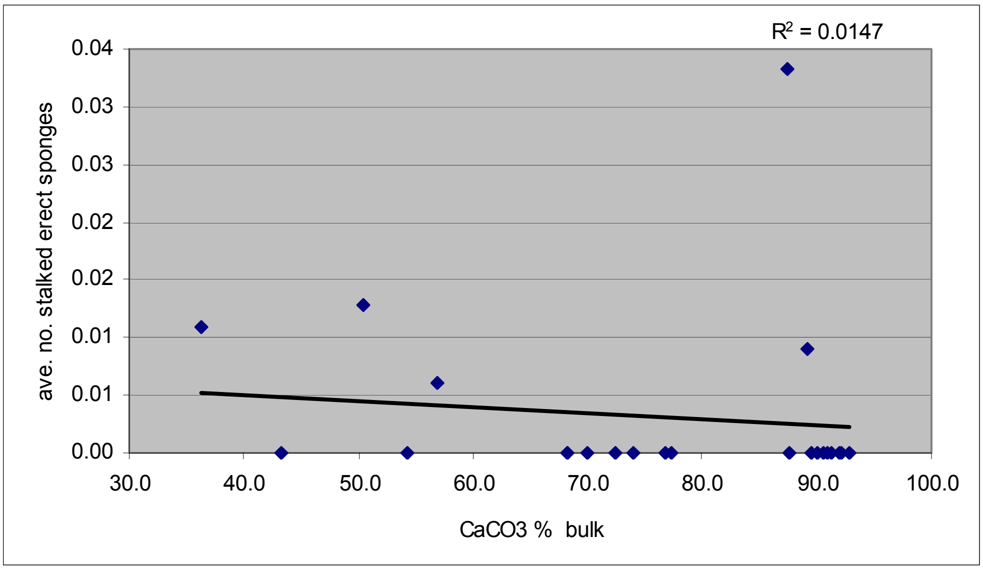


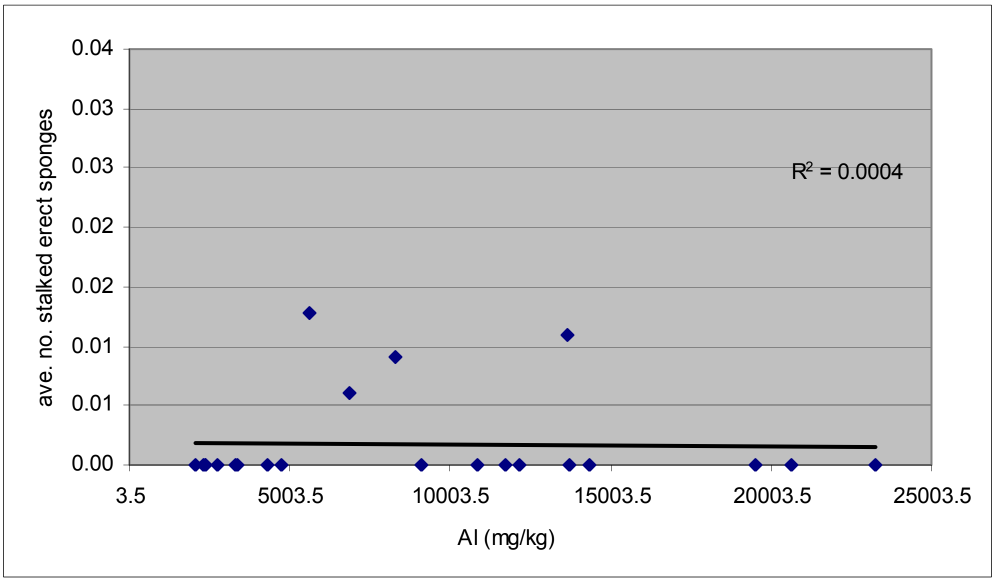
R^2 = 0.0311
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
ave. no. stalked erect sponges
% Mud


R² = 0.025
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
ave. no. stalked erect sponges
0
2
4
6
8
10
12
14
sorting


0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
ave. no. stalked erect sponges
R² = 0.0241
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Pheophytin (ug/g dw t)


0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
ave. no. stalked erect sponges
R² = 0.0188
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Mn (mg/kg)


R² = 0.0147
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
ave. no. stalked erect sponges
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
CaCO3 % bulk


0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
R² = 0.0004
ave. no. stalked erect sponges
3.5
5003.5
10003.5
15003.5
20003.5
25003.5
Al (mg/kg)

APPENDIX C: AVERAGE NO. INDIVIDUALS PER IMAGE, PER STATION, FOR EACH GEOMORPHOLOGICAL REGION

	%none	% sparse	% oct	%sponge	%mixed	%HC	%mixed (HC)	%other
geomorph	Average	Average	Average	Average	Average	Average	Average	Average
Deep (n=4)	0.44	0.43	0.11	0.00	0.01	0.00	0.00	0.00
Bank (n=12)	0.01	0.21	0.02	0.59	0.08	0.03	0.06	0.02
Ridge (n=3)	0.47	0.39	0.05	0.01	0.09	0.00	0.00	0.00
Terrace (n=6)	0.13	0.41	0.01	0.29	0.14	0.00	0.00	0.02
Plain (n=1)	0.41	0.59	0.00	0.00	0.00	0.00	0.00	0.00

	Gorgs	Whips	Sponges	Mopsella	Ianthella	Xestospongia
geomorph	Average	Average	Average	Average	Average	Average
Deep (n=4)	0.37	0.24	0.13	0.09	0.00	0.00
Bank (n=12)	0.47	0.16	8.86	0.06	0.10	0.01
Ridge (n=3)	0.33	0.19	0.43	0.08	0.00	0.01
Terrace (n=6)	0.62	0.10	4.31	0.06	0.06	0.01
Plain (n=1)	0.00	0.00	0.11	0.00	0.00	0.00

	Erect Laminar	Laminar Branching	Erect branching	Simple erect	Stalked erect	Simple massive	Hollow massive	Encrusting
geomorph	Average	Average	Average	Average	Average	Average	Average	Average
Deep (n=4)	0.00	0.00	0.04	0.01	0.00	0.04	0.00	0.04
Bank (n=12)	0.20	0.07	0.58	0.21	0.00	1.26	0.21	6.36
Ridge (n=3)	0.00	0.00	0.08	0.02	0.00	0.09	0.01	0.23
Terrace (n=6)	0.14	0.05	0.41	0.17	0.01	2.11	0.15	1.41
Plain (n=1)	0.00	0.00	0.07	0.00	0.00	0.05	0.00	0.00