The Application of Univariate and Distributional Analyses to Assess the Impacts of Diamond Mining on Marine Macrofauna off the Namibian Coast

by

Heidi Winckler

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MASTER OF SCIENCE

Supervisor: Professor John G. Field

Marine Biology Research Institute
Department of Zoology
University of Cape Town
Private Bag, Rondebosch, 7701

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DECLARATION

This thesis reports the results of original research which I carried out under the auspices of the Marine Biology Research Institute, University of Cape Town. All assistance that I received has been fully acknowledged. This work has not been presented for a degree at any other university.

Heidi Winckler

Date

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A special note of thanks to Prof. Field for initiating my interest in benthic macrofauna and his excellent scientific guidence during the completion of this dissertation. I especially thank Prof. Field for not allowing me to give up when I wanted to.

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Finally, I wish to thank all my friends and family who continued to enquire about my dissertation and so encouraged me to complete it.

My husband has been a pillar of strength and I thank him from the bottom of my heart for his love and support during the completion of this dissertation.

ABSTRACT. Winckler, H. 1999. *The application of univariate and distributional analyses to assess the impacts of diamond mining on marine macrofauna off the Namibian coast.*. M.Sc. thesis. University of Cape Town.

This study is one of three based on grab samples of macrobenthos obtained before and at different times after mining for diamonds off the coast of Namibia. The first study dealt with multivariate clustering analysis of the first samples before and after mining. The second study focused on recovery times after mining and this study is aimed at estimating the amount of stress encountered by benthic communities, for comparision with the descriptive multivariate approach.

Two research areas, classified as 'northern' and 'southern' were investigated. Data were aggregated and analysed at the genus level. Graphical and statistical analyses were conducted on the data which was classified in three ways. First, on all unmined sites from the two research areas together to test for natural site-to-site variability. Secondly and thirdly, each research area (north and south) was analysed separately to test for differences between unmined and mined sites at each area. Stress levels in the community were assessed by Caswell's neutral model (the V-statistic) and by interpretation of the value of the W-statistic (a summary statistic of the ABC curves). Correlation techniques were applied to assess if there was any relationship between the diversity indices (as indicators of the influence of disturbance on community structure) on the one hand, and the environmental indicators of disturbance (percentage gravel, sand, mud) on the other.

The results of the statistical analyses (ANOVA, Tukey tests and Chi-squared tests) of the diversity indices, the V-statistic and the W-statistic (as a representative of distributional techniques) confirmed that: there are some differences among the unmined sites (indicating the heterogeneity of the benthic communities) but no definite north-south distinction in the unmined sites; the northern unmined site shows indications of disturbance before mining and no differences between unmined and mined sites are apparent; and in the southern area, there are significant differences between the unmined and mined sites and there are indications of another disturbance (possibly hypoxic water) acting on the community 22 months after mining.

Graphical representations of mean diversity indices have indicated change in the benthic community after mining, the mined categories having reduced mean values compared with the unmined category.

The ABC curves have proved to be successful as absolute measures of disturbance in the benthic community. They have: provided the easiest identification of differences among the unmined sites (the two curves of each ABC plot acting as an 'internal control' against each other); shown that the northern unmined site was a "disturbed" site before mining, and thus explain why no significant differences were found (by statistical analyses) between unmined and mined samples in the northern area; and indicated that, in the southern area, there are significant differences between the unmined and mined sites and shown evidence of a disturbance, other than mining, acting on the benthic community 22 months post-mining after initial signs of recovery 15 months post-mining.

The V-statistic, W-statistic and ABC plots have been successful in explaining, in terms of biological "stress", the results of multivariate analyses (comparative methods) of the same data. The multivariate analyses provided a description of biotic differences among sites and between areas, but did not explain any possible causes for these differences or provide a theoretical underpinning which the ABC method and the V- and W-statistics have done.

CONTENTS

CHAPTER 1

GENERAL INTRODUCTION

GENERAL INTRODUCTION

In the community approach to environmental impact assessment, usually only one component of the biota is examined and it is assumed that the performance of this component is a general reflection of the health of the system. In this context, the macrobenthos is the most widely used component of the marine biota in environmental impact studies (Warwick 1993).

Warwick (1993) summarises the advantages of soft-bottom marine macrobenthos as follows: (1) they are relatively non-mobile and are therefore useful for studying the local effects of pollutants (Bilyard 1987), (2) their taxonomy is moderately easy, and their response to perturbation at taxonomic levels higher than species has been better tested than any other component of the biota, (3) quantitative sampling is relatively easy and (4) there is extensive research literature on the effects of pollution, particularly organic enrichment, on macrobenthic communities, against which particular case histories can be evaluated.

Despite this, they do have several disadvantages: (1) the potential response time of the macrobenthos to a pollution/disturbance event is slow. Their generation times are measured in years, so that although losses of species due to pollution/disturbance may take immediate effect, the colonization of new species which may take advantage of the changed conditions is slow. Thus, the full establishment of a community characterizing the new environmental conditions may take several years. (2) The macrobenthos are generally unsuitable for causality experiments in mesocosms, because such experiments can rarely be run long enough for fully representative community changes to occur, and recruitment of species to mesocosm systems is often a problem because of the planktonic larval stages of the majority of taxa. (3) Because of the vagaries of life in the plankton, settlement and recruitment of spat to the bottom are often very erratic, and as a result dramatic changes in the abundances of individual species may occur from year to year, resulting in natural temporal changes in community structure. Sometimes an ecologically important long-lived species may be represented in a community by a single year class, which may die out completely and further affect community structure indirectly. Thus, the baseline against which anthropogenic effects are to be measured is inherently unstable (Warwick 1993).

Numerical and Statistical Techniques:

A wide variety of numerical and statistical techniques has been developed for handling community data. The choice of a method of analysis ultimately depends on the aims of the study, but also on the nature of the data and the validity of the statistical assumptions (Heip *et al.* 1988). The available methods have been classified by Clarke and Warwick (1994) as:

1. **Univariate methods**, which reduce the full set of species abundances for a sample into a single coefficient, for example a *diversity index*. This might be some measure of the numbers of different species for a fixed number of individuals (species richness) or the extent to which the community counts are dominated by a small number of species (dominance/evenness index), or some combination of these. (The *a priori* selection of a single taxon as an indicator species, amenable to specific inferences about its response to a particular environmental gradient, also gives rise to a univariate analysis.)

2. **Distributional techniques**, also termed graphical or curvilinear plots (when they are not strictly distributional), form a class of methods which summarise the set of species abundances for a single sample by a curve or histogram. One example is *k*-dominance curves (Lambshead *et al.* 1983), which rank the species in decreasing order of abundance, convert the values to percentage abundance relative to the total number of individuals in the sample, and plot the cumulated percentages against the species rank. This, and the analogous plot based on species biomass, are superimposed to define the ABC (abundance-biomass comparison) curves which have proved a useful construct in investigating disturbance effects (Warwick 1986, Warwick *et al.* 1987).

Such distributional techniques relax the constraint in the previous category that the summary from each sample should be a single variable; here the emphasis is more on diversity curves than single diversity indices. Note, that for both these categories, the comparisons between samples are not based on particular taxon identities: two samples can have exactly the same diversity or distributional structure without possessing a single taxon in common.

3. Multivariate methods. Multivariate methods base their comparisons of two or more samples on the extent to which these samples share particular species as well as their relative importance in terms of abundance or biomass. The primary objective of multivariate analysis is to reduce the raw data set to a low-dimensional graphical form in order to discern the most salient patterns in the community data (Field *et al.* 1982, Warwick and Clarke 1991).

Multivariate ordination or clustering methods preserve taxon-specific information and will generally be rather sensitive in detecting changing community patterns (Warwick *et al.* 1990). Distributional and univariate summaries may, however, hope to extract universal features (e.g. biodiversity) which are not a function of the specific taxa present, and may therefore be related to levels of biological "stress". An example is Warwick's (1986) hypothesis that for an ABC plot in a disturbed benthic environment, the macrofaunal abundance curve will fall above the biomass curve, and *vice versa* for a stable climax community (Clarke 1990). The ABC method is not necessarily more sensitive than diversity indices at detecting disturbance, and is certainly less sensitive than multivariate methods in discriminating differences in community structure (Warwick *et al.* 1990, Warwick and Clarke 1991). It does, however, have the advantage of providing an absolute rather than a comparative measure of disturbance, and is based on the theory of *r*- and *k*-selection (Warwick 1993).

This study is the third of three which attempts to illuminate the changes which occur in macrobenthic communities following unnatural physical disturbance due to mining. The first study, a multivariate analysis in a M.Sc. thesis by Candida Savage (1996), showed the overall pattern of changes which occur in the stressed macrobenthic community. Using multivariate techniques, community changes have been shown but not all of these changes are explained by disturbance due to mining. Also, some changes appear to be as major as the changes attributed to mining disturbances (Savage *et al.* 1999).

The second study, by Karen van der Merwe (M.Sc. thesis 1996) focused on the recovery rate of the stressed community. An extended data set was used after a third cruise was initiated to complete the time sequence of the samples. All three major statistical techniques used for studying macrobethic communities (univariate, distributional and multivariate), were used in this study.

This third study utilizes the univariate and distributional techniques as absolute measures of the mining disturbance on the benthic community. The results obtained are viewed together with the results from a multivariate analysis (a taxon-specific, comparative technique) of the same data in an attempt to explain patterns in the biotic data in terms of biological “stress” (see Chapter 5).

Taxonomic level:

Taxonomic sufficiency is required only to the level that indicates the community response (Ellis 1985). In many situations changes in natural environmental variables from place to place or time to time may result in species replacement, since species are normally adapted to rather narrow ranges of environmental conditions. This may confound any change in pattern due to the perturbation under investigation, particularly when large and heterogeneous geographical areas are considered. However, the natural environmental variables (e.g. water depth or sediment granulometry) may not alter the proportions of major taxa present, and if there is a degree of coherence among species in these higher taxa with respect to their response to perturbation, the response will be more evident above the natural environmental noise (Warwick 1993).

Many recent environmental impact studies have explored the taxonomically sufficient level by aggregating the data into successsively higher groupings (species, genera, families, phyla). For many groups of benthic organsims (macrobenthos, meiobenthos, reef-corals) effects of perturbation were detectable at remarkably high taxonomic levels (Heip *et al.* 1988, Warwick 1988, Gray *et al.* 1990, Warwick *et al.* 1990).

This study analyses the data at genus level. Univariate and distributional techniques are considered less sensitive than multivariate techniques (Gray *et al.*

1990, Warwick *et al.* 1990, Warwick & Clarke 1991), and so the genus level may sufficiently eliminate environmental noise and yet prove more sensitive than family or phylum level analyses in depicting the perturbation on the community.

The community data were analysed using the computer package PRIMER (Plymouth Routines In Multivariate Ecological Research), which was primarily designed for studies of soft-bottom benthos.

Main aims of the study:

The six aims of this study are as follows:

1. To test the hypothesis that there are differences among unmined sites (i.e. natural site-to-site variability) (sections 3.2.1A and 4.2.1A).

2. To test the hypothesis that there are differences between unmined and mined groups in (i) the northern research area (sections 3.2.1B and 4.2.1B) and (ii) the southern research area (sections 3.2.1C and 4.2.1C).

3. To compare the observed diversity with predictions from Caswell's neutral model (Caswell 1976), a univariate technique for measuring stress levels (section 3.2.2).

4. To measure stress levels in the benthic community by interpretation of values of the W-statistic (a summary statistic of the ABC curves) (section 4.2.2).

5. To test whether there is a relationship between the sedimentology of the area and the indices (sections 3.2.3 and 4.2.3).

6. To compare the univariate and distributional results obtained in this study with each other and with the results of a multivariate analysis of the same data (chapter 5).

CHAPTER 2

METHODS

METHODS

2.1 STUDY AREA

De Beers Marine operates in concession areas off the west coast of southern Africa which extend from the Orange river mouth in the south to Luderitz in the north. Mining activity is limited to the Namibian continental shelf off the Orange River at depths of between 110-135 metres. Seven sampling sites were selected north of the Orange river 20-30km off the Namibian coast. These seven sites are divided into a northerly component (sites 1-4, mean depth 130m) and a southerly component (sites 5-7, mean depth 110m) (see Figure 2.1). The northern and southern research areas are approximately 30km apart. The five sampling areas at the seventh site (*Pentow Salvor* cruise 2) are at most 150m away from the southern sites 5 & 6 (see site 7 in Figure 2.1).

2.1.1 Description of the mining operation

Mining takes place on the continental shelf off the Namibian coast in waters between 85 and 200 metres below mean sea level. Two mining processes are used, the underwater crawler and the large rotating drill, which can be considered equivalent in their severity of disturbance (M. Mittelmeyer, *pers. comm.*). Both methods use high-powered air-lift suction to deliver the gravel to the anchored mining vessel. To achieve the "airlift", compressed air is pumped down to the drill apparatus on the sea-floor. The air is then allowed to bubble up a thick-walled pipe and the difference between external and internal fluid densities creates a suction. This partial vacuum sucks up gravel from the sea-floor which is screened and treated on board for diamonds. The processed gravel is then released overboard in the form of tailings. During the mining process all sediments, except the largest boulders, are removed to the level of bedrock. Sedimentological studies (Rogers 1995) showed that mining significantly changes the environment in which benthic organisms usually live. The unmined sediment was a stratified sequence of gravels overlain by very fine sand. The upper layer is characterised by relatively large amounts of organic matter (~7%) and total nitrogen (~0.6%). As a consequence of

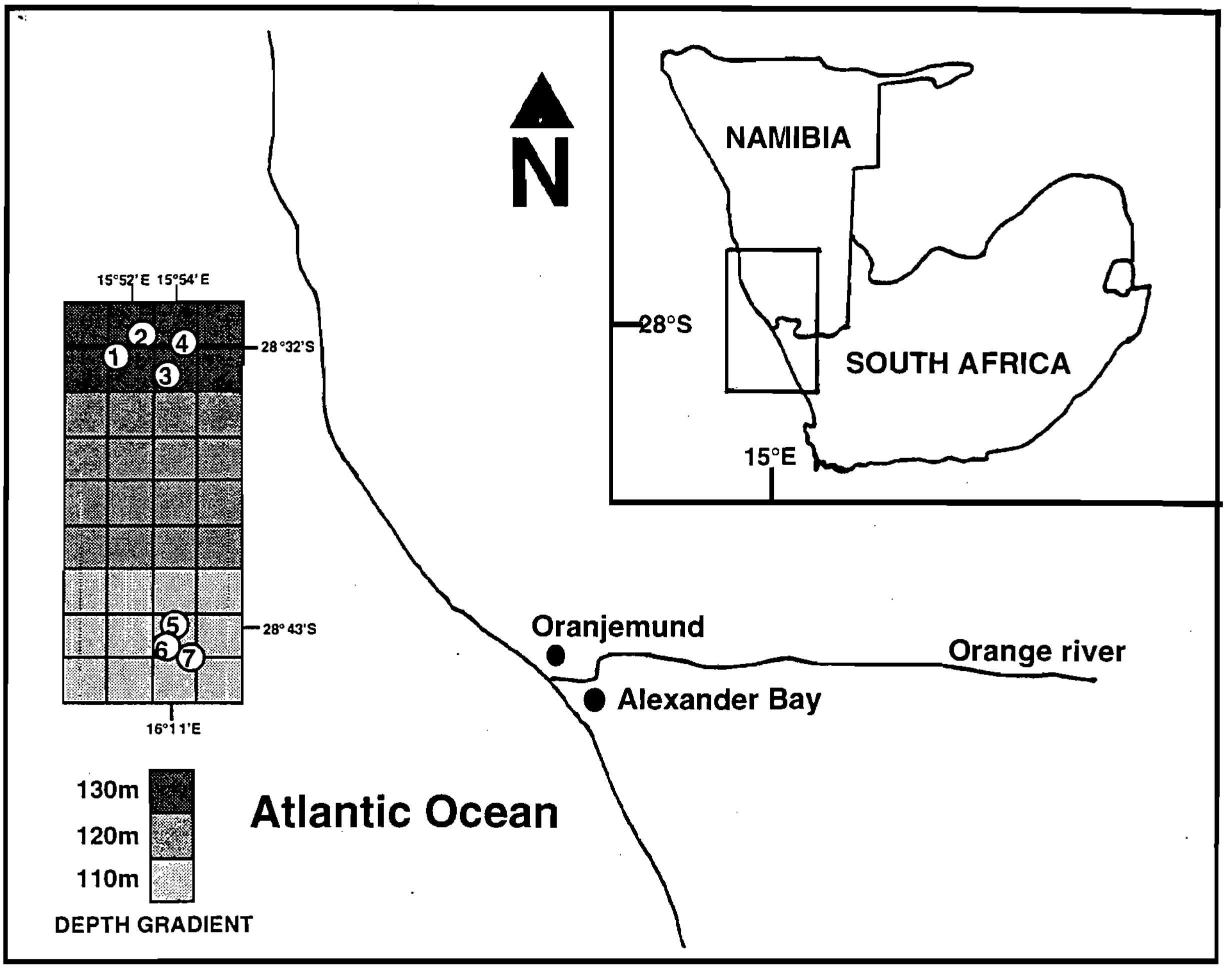


Figure 2.1: Map of study site off the west coast of southern Africa. The seven sampling sites are positioned in a grid drawn to scale where each block represents a 5km x 5km (25km^2) area.

mining, the sequence is disturbed and the sediment is returned to the sea floor as a mixture. The fine sand component remains suspended in the water column and is gradually dispersed over a wide area by the prevailing currents and sedimentation processes. The net result is an increase in the relative percentages of the coarser mud and gravel components, little organic matter and negligible total nitrogen content (Rogers 1995).

2.2 SAMPLE COLLECTION

The first six sites were sampled twice over a period of 8 months, June 1994 (*Rockfish* cruise) and February 1995 (*Pentow Salvor* cruise 1). Site seven was sampled on a third cruise in January 1996 (*Pentow Salvor* cruise 2). Site seven is divided into five areas at which the replicate samples were taken.

At each site enough replicates (10 for the first cruise and 6 for the second and third cruises) were taken to account for the natural variability inherent at each site. The replicates of the first two cruises are numbered by a double numbering system. The first number designates the site of sampling and the second number designates the replicate within that site. For example, 3.4 means that the sample was taken from site three and it is the fourth replicate taken at that site. The replicates of the third cruise are numbered by a triplicate number e.g. 7.3.1 means that the sample was taken at area three within site seven and it is the first replicate taken at that area. The numbers are preceded by a letter which designates on which of the three cruises the sample was taken. R = *Rockfish* cruise (June 1994), S= *Pentow Salvor* cruise 1 (February 1995) and DB = *Pentow Salvor* cruise 2 (January 1996).

Two unmined sites from the *Rockfish* cruise (R1 and R2) and one unmined site from each of the *Pentow Salvor* cruises (S2 and DB7.4) were kept as reference sites. R1 was mined between the *Rockfish* and *Pentow Salvor* 1 cruises. This site was to serve as a reference to ascertain the composition of the benthic community before and various months after mining. However, after an initial multivariate analysis (Field, Wickens, Savage and Winckler: EEU Report No. 11/95/143 (1995)) and geological analysis (Rogers 1995) it was found that a few "unmined" replicates had been taken from the mined areas and *vice versa.* The particle size analysis provides clues as to the level of disturbance for each replicate sample. Unmined areas are characterised by a uni- or bi-modal size frequency distribution whereas mined areas typically exhibit a polymodal distribution (Rogers 1995). See Figure 2.2.

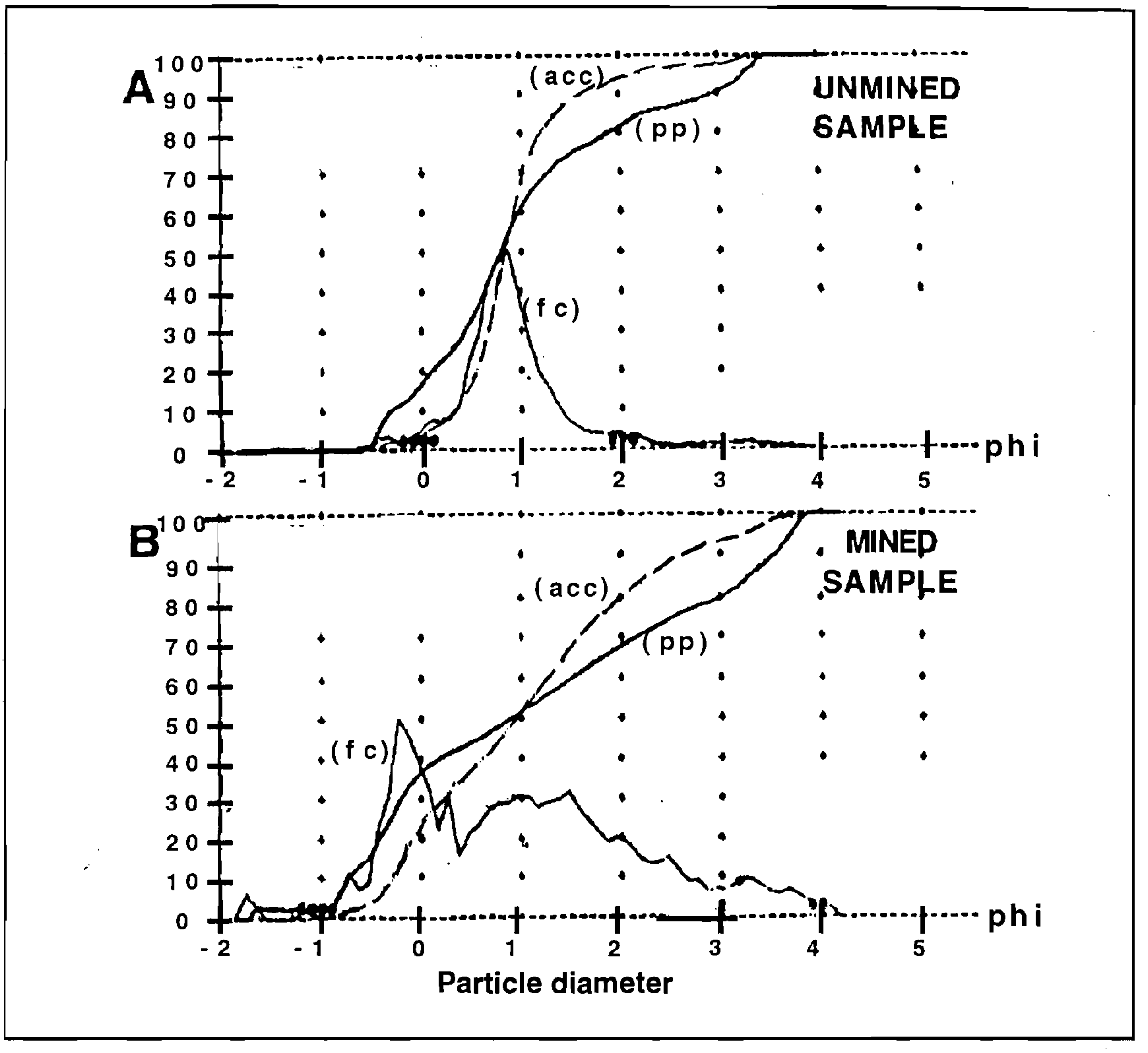


Figure 2.2: Characteristic size frequency distributions of sediments from (a) an unmined and (b) a mined sample. Y-axis is in cumulative percent for the arithmetic cumulative curve (acc = dashed line). The 0%, 50% and 100% points on the y-axis are accurate for the probability plot (pp). The major mode of the frequency curve (fc) has been artificially raised to the 50% mark to aid inter-graph comparisons. The x-axis is on a log scale to the base 2, the figures representing particle diameters in phi units (the negative logarithms, to the base 2 of the diameters in millimetres). The graphs refer to settling-tube data only from sand-fractions (from Rogers 1995).

With the use of detailed maps, the mining status of each 50m block of the research sites 1-7 was ascertained. Then, together with the sediment size frequency distribution, the condition (i.e. unmined or when mined) of each replicate sample was determined.

From initial Multi-dimensional Scaling (MDS) and ANOSIM analyses (Field *et. al.* 1996) it was ascertained that the southern sites 5 and 6 were significantly different from the northern sites 1-4 (Figure 2.1). This may be due to the influence of the Orange River in the southern area. It was therefore necessary to treat the northern and southern areas separately and have reference sites for each.

It was decided to use those samples falling outside the targeted mined sites as reference sites for the mined sites 1-7. There are northern and southern reference sites made up of unmined replicates from each of the four sites from the north and each of the three sites from the south. For the northern area samples from the first two cruises were combined to obtain enough replicates for each time group. For the southern area it was decided to use the third cruise data (*Pentow Salvor* cruise 2) only. The *Pentow Salvor* cruise 2 southern data gives a complete sequence of temporal categories (unmined to mined 22-24 months previously), while the *Rockfish* and *Pentow Salvor* cruise 1 southern data are limited to: a number of unmined replicates, one mined 15-19 months previously and six replicates mined 43-51 months previously. It was considered best not to combine the replicates from the three cuises as the five sites of the *Pentow Salvor* cruise 2 are in a different area to the sites of the first two cruises. A description of the temporal categories used and the replicates assigned to those categories is given in Table 2.1.

Several replicates were uncertain in terms of their exact position and hence mining status and were subsequently excluded from the study. The replicates are R5.2, R6.1-6.5 and DB 7.5.3.

A 0.2 m^2 Van Veen grab was used. Samples were brought on board, emptied into a bucket to measure the volume and then sieved using a mesh size of 1cm and 1mm. Sediment samples were kept for analysis by geologists and all organisms sieved were killed and temporarily preserved in 10% formalin.

Table 2.1: Temporal categories for all three cruises. R = *Rockfish* cruise (June 1994), S = *Pentow Salvor* cruise 1 (February 1995), DB = *Pentow Salvor* cruise 2 (January 1996). TOTAL: 121 grab samples.

CONDITION	AREA	SAMPLES	N
Never mined	north	**R:** 1.1 - 1.11/ 2.1 - 2.10/ 3.1/ 3.3/ 3.5 - 3.10/ 4.1/ 4.3 - 4.5 **S:** 1.15/ 2.2 - 2.7/ 3.5	**41**
	south	**R:** 5.1/ 5.4 - 5.10/ 6.6/ 6.7 **S:** 5.2/ 5.3/ 5.5/ 5.6/ 5.9/ 5.11/ 6.2/ 6.4/ 6.6 **DB:** 7.4.1 - 7.4.6	**25**
Mined 1 - 3 months previously	north	**R:** 3.2/ 3.4 **S:** 1.1/ 1.11/ 1.14/ 1.17/ 3.1/ 3.2	**8**
	south	**DB:** 7.5.1/ 7.5.2/ 7.5.4 - 7.5.6	**5**
Mined 7 - 9 months previously	north	**R:** 4.2/ 4.6 - 4.10 **S:** 1.5/ 3.3/ 3.4/ 3.7	**10**
	south	**DB:** 7.1.1 - 7.1.6	**6**
Mined 15 - 19 months previously	north	**S:** 4.2/ 4.6/ 4.8/ 4.9/ 4.13 - 4.15	**7**
	south	**R:** 5.3 **DB:** 7.2.1 - 7.2.6	**7**
Mined 22 - 24 months previously	south	**DB:** 7.3.1 - 7.3.6	**6**
Mined 43-51 months previously	south	**R:** 6.8 - 6.10 **S:** 6.1/ 6.3/ 6.5	**6**

2.3 LABORATORY METHODS

In the laboratory the samples were thoroughly rinsed in freshwater to remove all traces of formalin as this dissolves the calcium carbonate in the gastropod shells. Alcohol leaches the colour from the organisms, and therefore the samples were transferred to 1% phenoxatol. The samples were hand-sorted in large trays, separating the main groups: polychaetes, amphipods, gastropods etc. The individuals were then identified to the lowest taxon possible. Although family level would be sufficient for this analysis, the identification of species was needed for future reference. The polychaetes were difficult to identify to species level as many of the characteristic structures, such as tentacles, had broken off. They were therefore only identified as far as family or genus level. Each taxon is carefully labelled and counted and stored in polytop vials in 1% phenoxatol. The individuals were then blot-dried and weighed on an electronic balance to obtain the biomass. The gastropods were weighed with their shells after all excess preserving liquid was shaken out of the shell and the animal was blot-dried. Any organism weighing less than 0.01g was recorded as 0.01g to record its presence in the sample.

The biomass and numbers of each individual were entered into two separate worksheets, one for abundance and one for biomass, see Appendices I and II, respectively.

2.4 NUMERICAL METHODS

2.4.1 Normality and Homogeneity of Variances

The data matrices of benthic studies characteristically have a relatively high ratio of species to samples and a prevalence of zeros (greater than 50% of the matrix). Standard normal analyses (Mardia *et al.* 1979) of such data are ruled out; they require that the number of species be small compared to the number of samples, and that the abundance and biomass values are transformable to approximate normality (Clarke and Warwick 1994).

One alternative is the reduction of each sample (column of matrix) to a single univariate description (Clarke and Warwick 1994). However, for standard analyses (e.g. Analysis of Variance (ANOVA)) the data must be normally distributed and have equal variances among samples (homogeneity of variances). The reduction of samples to single univariate descriptions may normalise the data but does not necessarily result in homogeneity of variances (Field, *pers. comm.*). Many variance homogeneity tests have been proposed, but they are all adversely affected by non-normality, or are very low in power, or have other serious drawbacks (Zar 1984). The most common method employed to test for homogeneity of variances, Bartlett's test (Bartlett 1937) is powerful, but is also badly affected by non-normal populations (Box 1953, Box and Anderson 1955, Gartside 1972: as cited in Zar 1984). Because of the poor performance of tests for variance homogeneity, and the robustness of analysis of variance (ANOVA) for multisample testing among means, it is not recommended that the test for homegeneity of variances be performed as a test of the underlying assumptions of ANOVA (Zar 1984).

This study assumes normality of the data and utilizes parametric methods (ANOVA and the Tukey Multiple Comparison Test) to analyse the data.

2.4.2 Analysis of Variance (ANOVA)

The underlying tenet of analysis of variance (ANOVA), regardless of the complexity of the design of the model, is to estimate whether two or more sample means could have been obtained from populations with the same parametric means. That is, one is testing the null hypothesis (Ho): $\mu_1 = \mu_2 = ... = \mu_k$. To do this, the procedure identifies and partitions the sources of variation that potentially affect the means, and then examines each component of variation independently of all other components to determine the likelihood that the different levels of that component define different parametric population means (Johnson 1994).

One-way analysis of variance, or single classification ANOVA, is the simplest form of ANOVA model, and describes designs in which the different groups in an experiment are defined by different levels of a single factor. In this study the factor is 'effect of mining on the benthic community'. Further, the levels of the factor have been specifically chosen, i.e. the level of mining is graded from 'recently mined' to 'mined *x* months ago'. Thus, the design of this study is a *fixed effects model*, or a *Model I, ANOVA* (Johnson 1994).

The advantage of the ANOVA approach is that it is general, i.e. it can be applied to one-way models where there are two or more groups (*a* groups). The *n* means from the *a* groups are compared simultaneously in a single test, and only one of the groups has to differ from the others for the null hypothesis (H0) to be rejected (Johnson 1994).

F (the calculated value of the *F statistic*) is defined as:

$$F = MS_{\text{among groups}} / MS_{\text{within groups}}$$

MS = the mean square and is defined as (SS)/*df* = Sum of Squares / degrees of freedom.

The test compares the variance between the means of the *a* groups with the average variance within groups (= 'noise' due to random effects). Thus the comparison essentially asks the question, "can the differences between the means of the groups be accounted for by the variation in random sampling that is reflected in the variation among measurements made within each group"? If the null hypothesis is true, and all of the group means represent samples from the same parametric population mean, then the variation within groups (within each sample) would be expected to be the same as the variation among the groups (after correcting for degrees of freedom). Thus *F* is expected to equal one if the null hypothesis is correct and if the denominator and numerator degrees of freedom are indentical (Johnson 1994).

p gives the probability that the difference between the calculated value of *F* and the expected value of *F* if the null hypothesis is true, is due to the chance effects of random sampling. The values of *F* for any critical level of significance α (usually taken to be α=0.05) depend on both the denominator (error) and numerator (hypothesis) degrees of freedom (Johnson 1994).

The ANOVA procedure does not indicate which group differs from which other groups when the null hypothesis is rejected. For this one needs to do a multiple comparison test such as the Tukey test (Zar 1984).

2.4.3 The Tukey Multiple Comparison Test

The Tukey test (Tukey 1953) is among the most widely accepted and commony used multiple comparison tests (Zar 1984). The multiple comparison tests for means have the same underlying assumptions as does the analysis of variance: population normality and homogeneity of variance. Although the Tukey test appears to be robust with respect to departures from these assumptions (Keselman 1976: as cited in Zar 1984), adverse effects on both Type I and Type II errors are possible if the assumptions are greatly violated. The homogeneity of variance assumption apparently is the more serious, and parametric multiple comparison testing should not be performed if heteroscedasticity is pronounced (Zar 1984).

The multiple comparison procedure exemplified by the Tukey test (also known as the "honestly significant difference test" and the "wholly significant difference test") considers the null hypothesis H_0: $\mu_B = \mu_A$ versus the alternative hypothesis H_A: $\mu_B = \mu_A$, where the subscripts denote any possible pair of groups. For *k* groups, *k*(*k*-1)/2 different pairwise comparisons can be made.

A *q* value is calculated by dividing a difference between means by

$$SE = \sqrt{\frac{s^2}{n}}$$

Where s^2 is the error mean square from the analysis of variance and *n* is the number of data in each of groups *A* and *B*. If this calculated *q* value,

$$q = \frac{\overline{X}_B - \overline{X}_A}{SE}$$

is equal to or greater than the critical value, $q_{\alpha,v,k}$, from the table of critical values of the *q* distribution, then H_0: $\mu_B = \mu_A$ is rejected.

If the *k* group sizes are not equal (as in this study), a slight modification of the Tukey procedure is necessary. For each comparison involving unequal *n*, the standard error is calculated by the following approximation (Kramer 1956, Tukey 1953: as cited by Zar 1984):

$$SE = \sqrt{\frac{s^2}{2}\left(\frac{1}{n_A}+\frac{1}{n_B}\right)}$$

2.4.4 The Chi-squared test

In many situations, enumeration data are collected simultaneously for two variables, and it is desired to test the hypothesis that the frequencies of occurrence in the various categories of one variable are independent of the frequencies in the second variable.

The null hypothesis for contingency table testing is that the frequencies of observations found in the rows are independent of the frequencies of observations found in the columns (or, that the column frequencies are independent of the row frequencies). The most common procedure for analyzing contingency table data is by using the chi-square statistic.

For chi-square analysis of contingency tables, one uses the formula:

$$\chi^2 = \sum \sum \frac{(fij - \hat{f}ij)^2}{\hat{f}ij}$$

where, fij is the frequency observed in row i and column j and $\hat{f}ij$ refers to the frequency expected in row i and column j if the null hypothesis is true.

The formula for obtaining expected frequencies in a contingency table is:

$$\hat{f}ij = \frac{(Ri)(Cj)}{n}$$

Once χ^2 has been calculated its significance is ascertained from a table of critical values of the chi-square distribution, but to do so, one must determine the degrees of freedom of the contingency table. So DF(ν) = (r - 1)(c - 1), where r = the number of rows and c = the number of columns in the contingency table (Zar 1984).

In this study the chi-squared test will be utilized to test the relationship between the frequencies of the positive and negative V-statistics and the mining status (unmined *vs* mined) of sites in 2 x 2 contingency tables (i.e. consisting of 2 rows and 2 columns) (see section 3.2.2.2).

2.4.5 Correlation analysis

The relationship between two variables may be one of functional dependence of one on the other. That is, the magnitude of one of the variables (the *dependent variable*) is assumed to be determined by the magnitude of the second variable (the *independent variable*), whereas the reverse is not true. Such a dependent relationship is termed a regression.

In many kinds of biological data, however, the relationship between two variables is not one of dependence. In such cases, the magnitude of one of the variables changes as the magnitude of the second variable changes, but it is not reasonable to consider there to be an independent and a dependent variable. In such situations, correlation analyses are called for, and both variables are theoretically to be random-effects factors. The environmental analyses of this study (sections 3.2.3 and section 4.2.3) utilize such variables. The environmental variable (percentage gravel, sand or mud) is correlated with each of the indices studied (e.g. 'total number of genera', 'species richness', 'Shannon diversity' etc.).

In correlations, the Y's at each X are assumed to be normal and also the X values at each Y are assumed to have come at random from a normal population. This is referred to as sampling from *a "bivariate normal distribution".* The effect of deviations from the assumption of bivariate normality appears unimportant when there is only slight correlation in the population; but if there is substantial population correlation, then there may be a marked adverse effect of such nonnormality, this effect not being diminished by increasing sample size (Norris and Hjelm 1961: as cited by Zar 1984).

The **correlation coefficient** is calculated as:

$$r = \frac{\sum xy}{\sqrt{\sum x^2 \sum y^2}}$$

Although the denominator of this equation is always positive, the numerator may be positive, zero or negative, thus enabling *r* to be either positive, zero or negative, respectively. A positive correlation implies that for an increase in the value of one of the variables, the other variable also increases in value; a negative correlation indicates that an increase in value of one of the variables is accompanied by a decrease in value of the other variable. If $\sum xy = 0$, then $r = 0$, and one has a zero correlation, denoting that there is no linear association between the magnitudes of the two variables; that is, a change in magnitude of one does not imply a change in magnitude of the other. Further, *r* can never be greater than 1.0 nor less than -1.0 ($-1 < r < 1$) (Zar 1984).

CHAPTER 3

UNIVARIATE ANALYSES

UNIVARIATE ANALYSES

3.1 UNIVARIATE METHODS

A variety of different indices (single numbers) can be used as measures of some attributes of community structure in a sample. These include the total number of individuals (N), total number of species (S), the total biomass (B), and also ratios such as B/N (the average size of an organism in the sample) and N/S (the average number of individuals per species). These simple indices tend to be less informative than measures of the way in which the total number of individuals is divided up among the different species, i.e. *diversity indices* (Clarke and Warwick 1994).

A single index of species (or higher taxon) diversity is commonly employed in community studies, and is amenable to simple statistical analysis. Two different aspects of community structure contribute to the concept of community diversity:

i) **Species richness**. This is a measure related to the total number of species present. Obviously a sample containing more species than another is considered to be more diverse. Species richness is often given simply as the total number of species (S), which is obviously very dependent on sample size (the bigger the sample, the more species there are likely to be). More commonly **Margalef's index** (d) (Margalef 1958) is used, which also incorporates the total number of individuals (N) and is a measure of the number of species present for a given number of individuals:

$$d = (S-1) / \log N$$

ii) **Equitability**. This expresses how evenly the individuals are distributed among the different species, and is often termed **evenness**. For example, if two samples each comprising 100 individuals and four species had species abundances of (25, 25, 25, 25) in one and (97, 1, 1, 1) in the other, we would consider the former to be more diverse although the species richness is the same. The former has high evenness, but low **dominance** (essentially the reverse of evenness), while the latter has low evenness and high dominance (the sample being highly dominated by one species). Equitability is most commonly expressed as **Pielou's evenness index** (Pielou 1974):

$$J' = H'(observed) / H'_{max}$$

where H'_{max} is the maximum possible diversity which could be achieved if all species were equally abundant, and $H'_{max} = log\ S$.

Different diversity indices may emphasize the species richness or equitability components of diversity to varying degrees. The most commonly used diversity measure is the **Shannon-Weaver diversity index** (Shannon & Weaver 1949):

$$H' = -\Sigma_i\, p_i\, (log\ p_i)$$

where p_i is the proportion of the total count (or biomass etc.) arising from the ith species. This incorporates both the *species richness* and *equitability* components.

Any logarithmic base may be used to compute H'; bases 10, *e* and 2 (in that order of commonness are the most frequently encountered (Zar 1984). In this study Log_e has been used.

The univariate analysis may be viewed as comprising four stages. Table 3.1 outlines the four stages which will be applied in this study.

Table 3.1: Univariate analysis. Summary of the four stages of analysis (after Clarke and Warwick, 1994).

Stages	Univariate diversity indices
1) Representing communities	Means and 95% CI's for each site/condition
2) Discriminating sites / conditions	One-way analysis of variance (ANOVA) & multiple comparison tests (Tukey test)
3) Estimating stress levels	By reference to historical data (e.g. A decrease in diversity) or Caswell's Neutral Model
4) Linking to environment	Correlation techniques

Each temporal category (time since mining, as detailed in Table 2.1) will be **represented** by plots of its mean index with its 95% confidence interval (see section 3.2.1). The confidence intervals are equal for all the sites because they are based on similar variances among groups to be able to do the ANOVA (i.e. the pooled estimate of replication variability from the residual mean square in the ANOVA table is used).

The following indices have been calculated for each replicate grab sample:

- total individuals: N
- total taxa (species/genera): S
- species richness (Margalef's index): d = (S-1) / log N
- equitability (Pielou's evenness index): J'= H'(observed) / H'max
- Shannon-Weaver diversity index: $H' = -\Sigma_i \, p_i \, (\log p_i)$

Discrimination between sites is then demonstrated by one-way ANOVA with the null hypothesis that there are no differences in mean diversity among sites. The ANOVA will determine whether there are any significant differences but will not indicate between which groups these differences occur. Therefore, if a significant difference is found, the ANOVA is followed by the Tukey multiple comparison test for individual pairs of sites

Estimating stress levels. According to the general hypothesis of species diversity (Huston 1979), diversity is expected to rise at intermediate disturbance levels before its strong decline with gross disturbance. The response is however, not necessarily unidirectional. Determination of stress levels IS possible through relation to historical diversity patterns for particular environmental gradients. When levels of environmental stress are increased it is expected that;

- diversity (H') decreases
- species richness (d) decreases
- evenness (J') decreases
- dominance increases.

This interpretation may be an over-simplification. It is at intermediate levels of disturbance that diversity may be highest (*Intermediate disturbance hypothesis,* Connell 1978). It is difficult or impossible to say where the community represented by a particular sample is on the continuum. Thus, changes in diversity can only be assessed by comparisons among stations:

- with reference to a spatial disturbance gradient, or
- with reference to comparative historical data, or
- with reference to some theoretical expectation of diversity, given the number of individuals and species present.

The first two methods of assessing diversity changes have been addressed in two prior MSc theses. The first by Savage (1996) and the second by van der Merwe (1996). In this study Caswell's Neutral Model (Caswell 1976) will be utilized to compare the equitability component of diversity with a theoretical expectation of diversity calculated by Caswell's Model.

3.1.1 Caswell's Neutral Model - the V-statistic

Observed diversity can be compared with predictions from Caswell's neutral model (Caswell 1976). The neutral model program of Ewens (1972) was introduced into ecology by Caswell (1976). Lambshead and Platt (1988) noted that Ewens's program presented serious computational problems. Goldman & Lambshead (1989) developed a modified program making it suitable for personal computers. The PRIMER programme CASWELL is based on this program and has been used in this study to calculate the V-statistics.

This model constructs an ecologically 'neutral' community with the same number of species and individuals as the observed community, assuming certain community assembly rules (random births/ deaths and random immigrations/emigrations) and no interactions among species. The deviation statistic (V) is then calculated which compares the observed diversity (H') with that predicted from the neutral model (expected H' or E(H')):

$V = [H' - E(H')] / SD(H')$

V = the deviation statistic; H' = the Shannon diversity index; E(H') = the diversity predicted by the neutral model; SD (H') = the standard deviation of diversity.

When V=0 the sample is considered to be derived from a neutral assemblage. V>0 indicates a greater diversity in the observed community than that predicted by Caswell's model. V<0 implies excessive dominance in the observed community. Values of >+2 and <-2 indicate significant departure from neutrality.

It should be noted that deviation in the observed diversity (H') from the neutral model prediction of diversity (E(H')) depends only on differences in equitability (J'), since E(H') is based on a 'neutral' community with the same number of species and individuals as the observed community (i.e. species richness (d) is fixed between the two communities). Also, the equitability component of diversity may behave differently from the species richness component in response to stress (see Figure 3.1).

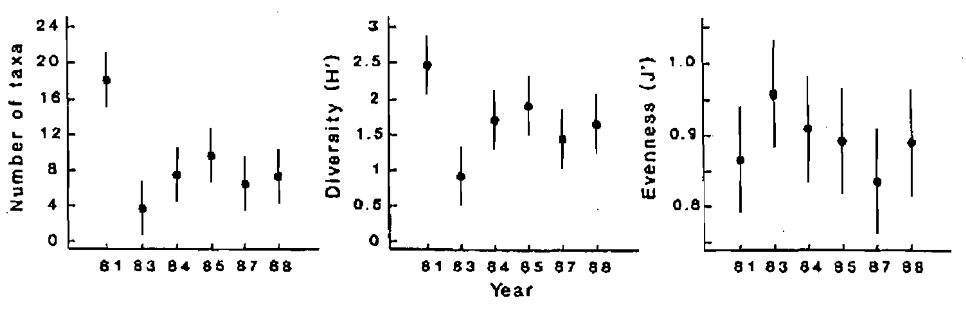


Figure 3.1: A depiction of the different responses of the S and J' components of H' to stress. Graphs are based on coral species cover data along transects from Indonesian reef corals, South Tikus Island, spanning the 1982-3 El Nino, from Clarke & Warwick 1994.

Also, it is quite possible that the 'intermediate disturbance hypothesis' will apply to the values of V in response to disturbance, and increased disturbance may either cause V to decrease or to increase.

Linking to the environment is then done by condensing the environmental variables into one (or a small number of) key summary statistics. Simple (or multiple) correlation of the diversity index as the "dependant" variable, against the environmental descriptors as "independent" variables, is then technically feasible. However, in practice this is rarely very informative given the over-condensed nature of the information utilised (Clarke and Warwick 1994).

3.2 UNIVARIATE RESULTS

3.2.1 GRAPHICAL REPRESENTATION AND DISCRIMINATION OF GROUPS BY ANOVA AND TUKEY TESTS

3.2.1(A) Analysis of unmined data from the northern and southern research areas.

(Combined cruise data: Rockfish and Pentow Salvor cruises 1 and 2)

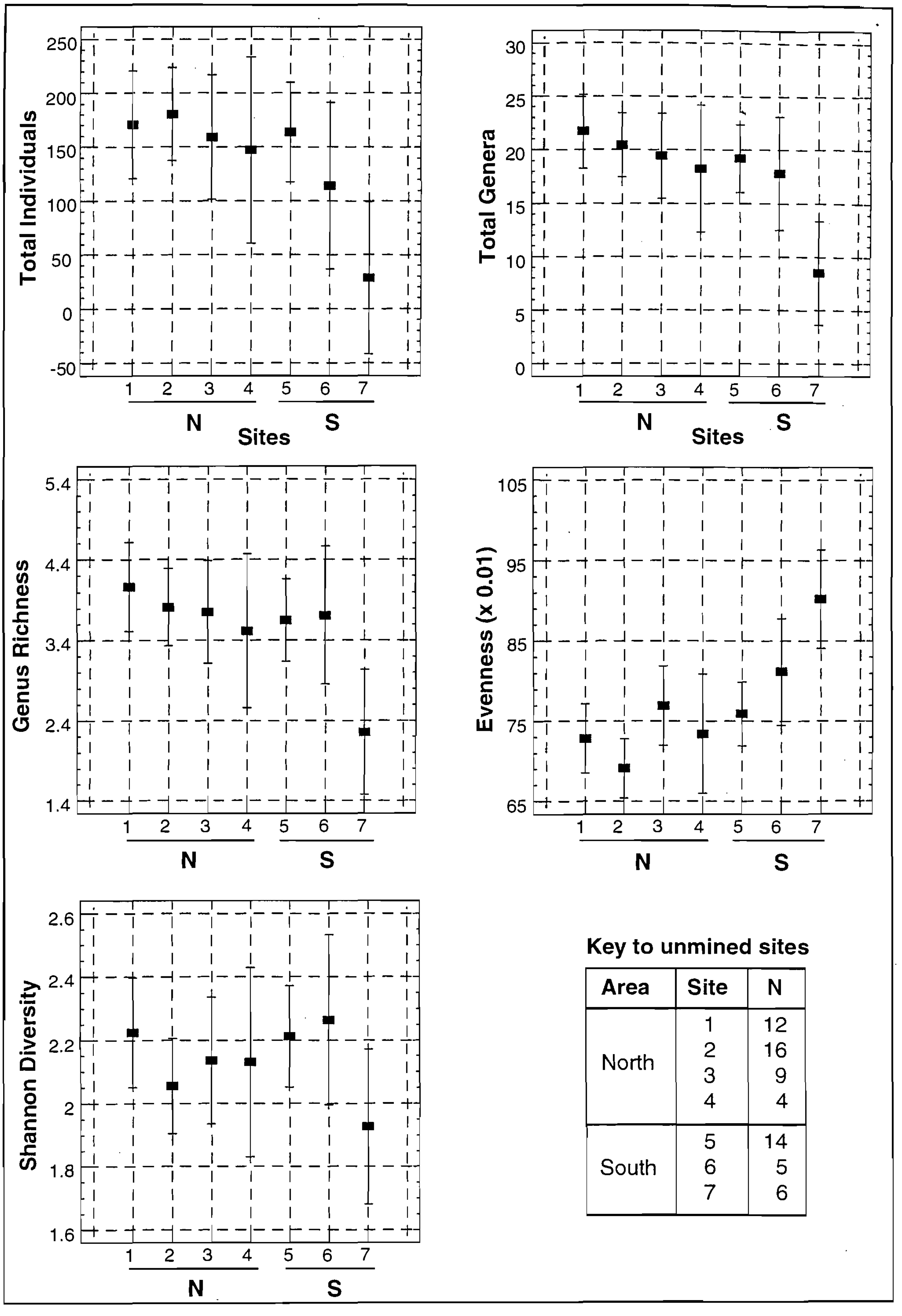
Seven sites of unmined samples are analysed. Sites one to four are situated in the northern research area, whereas sites five to seven are situated in the southern research area. The unmined replicates from two different cruises (*Rockfish*, *Pentow Salvor* 1) were combined within the first six sites (assuming no seasonality effects). Site seven consists only of the unmined samples from the third cruise, *Pentow Salvor* 2.

A(i) Graphical representation of northern and southern unmined data.

Figure 3.3 provides a graphical representation of the unmined data, grouped into the seven unmined sites, plotted as the means of the indices with their 95% confidence intervals.

For all the indices only site 7 appears to separate from the other sites. All the other sites show little variation in the values of the indices even though sites 1-4 are from the northern area and sites 5-7 are from the southern area.

The overlapping confidence intervals suggest that the 'Shannon diversity' index shows no significant differences among any of the sites.



Key to unmined sites

Area	Site	N
North	1	12
	2	16
	3	9
	4	4
South	5	14
	6	5
	7	6

Figure 3.3: UNMINED SITES: Mean diversity indices (and 95% CI's) plotted for the northern sites (1-4) and the southern sites (5-7).

A(ii) ANOVA employed to test for differences among unmined conditions from the seven sites (i.e. natural site-to-site variability).

Null hypothesis: There is no difference in diversity indices among the unmined groups from different sites.

Table 3.2: Key to groups used to test for differences among unmined sites. N is the number of replicate grab samples in each site.

Group (in ANOVA)	N	Research Area	Site (replicates)
1	12	North	1
2	16	North	2
3	9	North	3
4	4	North	4
5	14	South	5
6	5	South	6
7	6	South	7

Table 3.3: Results of ANOVA tests on the seven unmined sites.

Index	Test statistic (*F*)	df	Significance level (*p*)	Ho accepted or rejected
Total genera	3.742	6,59	0.003	rejected
Total individuals	2.635	6,59	0.025	rejected
Genus richness	2.625	6,59	0.025	rejected
Evenness	6.730	6,59	0.000	rejected
Shannon diversity	1.162	6,59	0.339	accepted

For 'total genera', 'total individuals', 'richness' and 'evennes' the null hypothesis is rejected ($p<0.05$) and there is a significant difference among the seven unmined sites. For the 'Shannon diversity' index, the null hypothesis is accepted ($p>0.05$) and there is no significant difference among the seven unmined sites.

A(iii) Tukey tests on significant results from the ANOVA tests.

Table 3.4: Significant Results of the Tukey tests.

(X= a significant difference)

Signif. different pairs	Total genera	Total individuals	Genus richness	Evenness
1-7	X	X	X	X
2-6				X
2-7	X	X	X	X
3-7	X			X
4-7				X
5-7	X	X		X

The null hypothesis was accepted for the 'Shannon diversity' index; thus no Tukey test was necessary for this index.

For all the other indices there is a significant difference between site 7 and *some* of the other sites 1 to 5.

Evenness shows a significant difference between *all* of the sites 1-5 and site 7. Evenness also shows a significant difference between sites 2 (north) and 6 (south). Here the Tukey test depicts the north-south differences.

All the indices show that site 6 is not significantly different from site 7. Site 7 is situated closest (at most 150m away) to site 6 and so it is expected that the geology of these two sites would be similar.

None of the other sites (1-6) differ significantly from each other for any of the indices (except 'evenness', sites 2 vs. 6), even though sites 1 to 4 are northern sites and 5 to 6 are southern sites.

The statistical test results confirm and complement the graphical representation of each index in Figure 3.3 above.

In conclusion, even though the null hypothesis was rejected for four indices, this was due mainly to the finding that site 7 was different to the other sites. Thus there were very few natural site-to-site variabilities found in this analysis and even the northern and southern areas were not found to be significantly different. Even so, this study will analyse the two areas separately, as they are situated at least 30km from each other.

These data will again be analysed by distributional techniques in Chapter 4. It is possible that distributional techniques will be more sensitive in depicting differences between the northern and southern unmined sites.

3.2.1(B) Analysis of unmined and mined data from the northern research area.

(Combined cruise data: *Rockfish* and *Pentow Salvor 1*).

B(i) Graphical representation of unmined and mined data from the northern research area.

Figure 3.4 provides a graphical representation of the northern data, grouped into the unmined group (1) and mined groups (2 to 4), plotted as the means of the index with their 95% confidence interval.

The graphs of the 'total genera', 'genus richness' and 'Shannon diversity' indices depict a difference between the unmined group 1 and group 4. Group 4 (mined 15-19 months previously) shows a sudden decrease in the mean value of the indices in comparison to group 3 (mined 7-9 months previously). This may indicate that the community is still affected by the mining disturbance or perhaps another disturbance factor has been added to the effects of the mining disturbance.

No significant differences (i.e. confidence intervals not overlapping) are apparent among groups 1,2 and 3 for the 'total genera', 'genus richness' and 'Shannon diversity' indices although the mean value of the indices for group 2 (just mined 1-3 ma) and group 3 (mined 7-9 ma) are reduced compared to the unmined group1.

The other indices ('total individuals' and 'evenness') show no significant differences in their mean values between unmined and mined sites and no significant differences among mined sites.

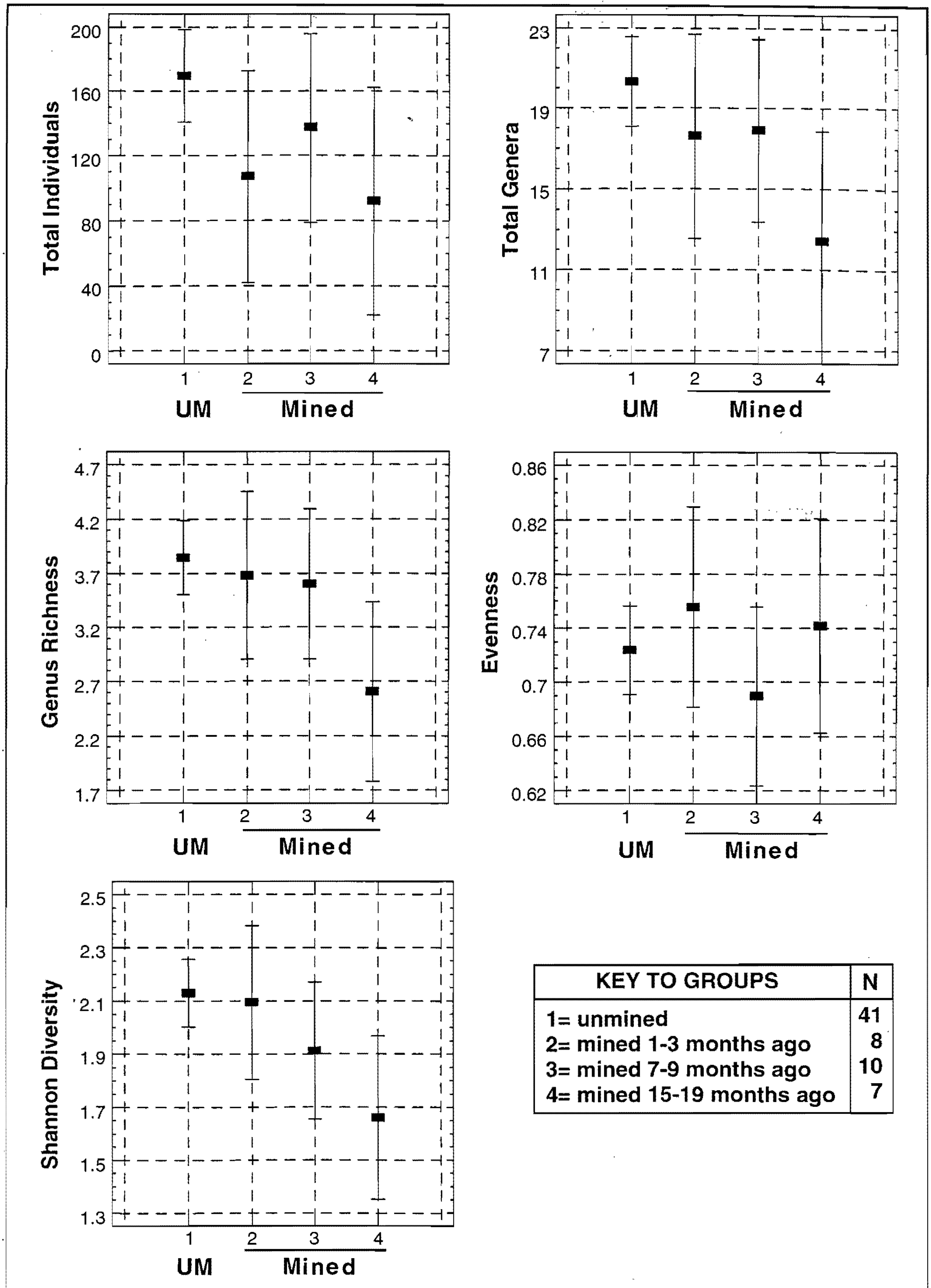


Figure 3.4: NORTHERN AREA:
Mean diversity indices (and 95% CI's) plotted for the unmined and mined sites.

B(ii) ANOVA employed to test for differences among unmined and mined conditions in the northern research area.

Null hypothesis: There is no difference in diversity indices among unmined and mined groups in the northern research area.

Table 3.5: Key to groups used to test treatments in the North. N is the number of replicate grab samples in each group.

GROUP	N	TREATMENT
1	41	Unmined
2	8	Mined 1-3 months ago
3	10	Mined 7-9 months ago
4	7	Mined 15-19 months ago

Table 3.6: Results of ANOVA tests on the unmined and mined sites of the northern area.

Index	Test statistic (F)	df	Significance level (p)	Ho accepted or rejected
Total genera	2.570	3,62	0.062	accepted
Total individuals	2.152	3,62	0.103	accepted
Genus richness	2.547	3,62	0.064	accepted
Evenness	0.666	3,62	0.576	accepted
Shannon diversity	3.050	3,62	0.035	rejected

The null hypothesis is rejected for the 'Shannon diversity' index which indicates that there is a difference among the groups tested. For all the other indices the null hypothesis has been accepted and there are no significant differences in the other diversity indices among the groups tested.

B (iii) Results of the Tukey test

The Tukey test on the 'Shannon diversity' index (null hypothesis rejected) indicates that groups 1 and 4 were significantly different. This result is an anomaly in the light of the fact that only the group which has had the most time to recover is found to be different from the unmined group. The 'Shannon diversity' index may be indicating the occurence of some natural disturbance (e.g. low oxygen water) which the other indices do not show.

For the analysis of the northern area data, the graphics (Figure 3.4) have shown more detailed information than the statistical tests. Only the graph of the 'Shannon diversity' index has been confirmed by the statistical analysis. The ANOVA has not been sensitive enough to show the significant differences in the other indices which are as apparent (from Figure 3.4) as the differences in the 'Shannon diversity' index.

3.2.1(C) Analysis of unmined and mined data from the southern research area (*Pentow Salvor 2* data only).

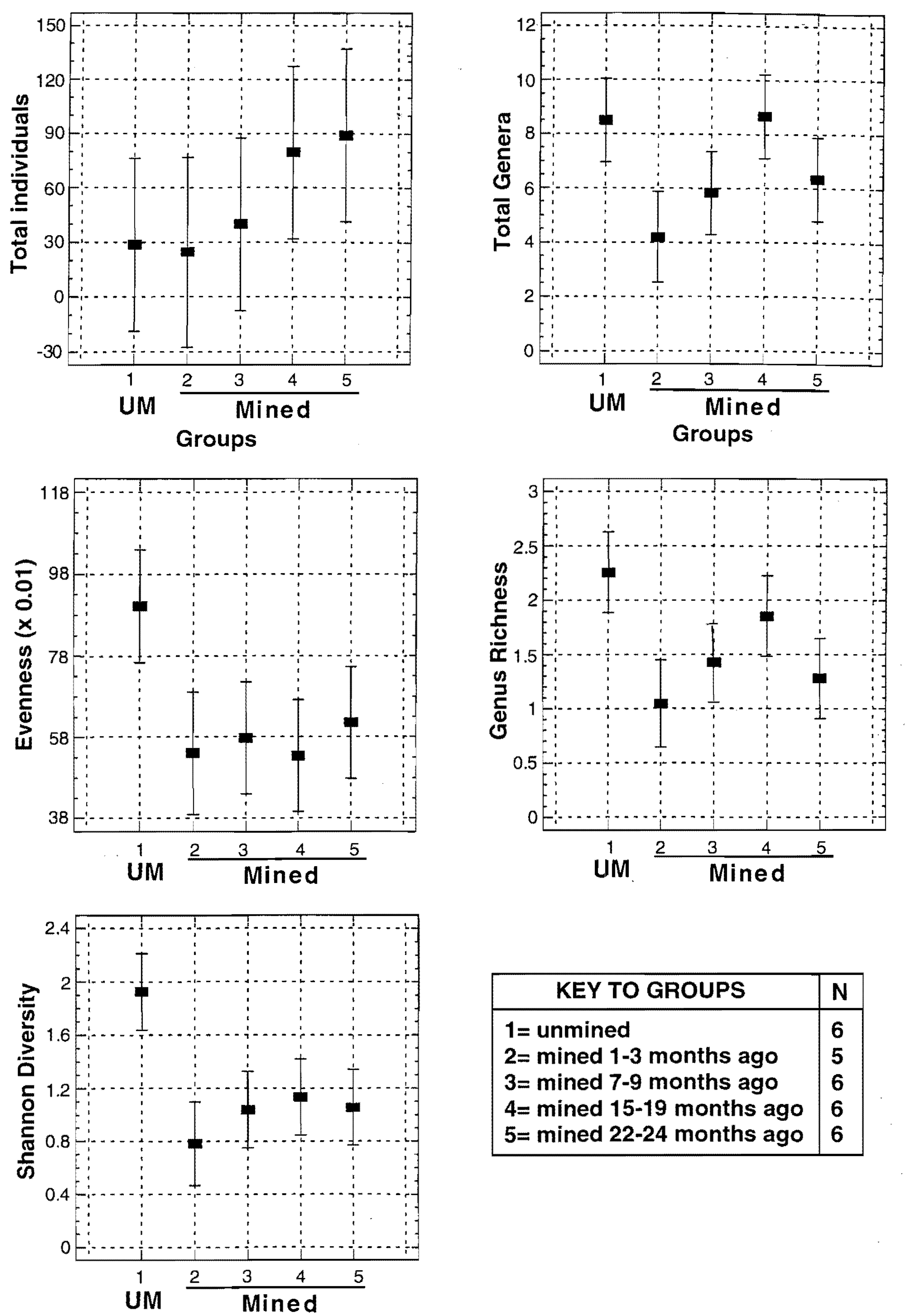
The *Pentow Salvor 2* data give a complete time series (just mined to mined two years previously) for the southern research area. It was decided to eliminate the *Rockfish* and *Pentow Salvor 1* data from this test as these two cruises were sampled in a different area to the *Pentow Salvor 2* cruise. There may be geological differences between the sites of the cruises which could interfere with differences due to mining.

C (i) Graphical representation of the unmined and mined data from the southern research area.

Figure 3.5 provides a graphical representation of the southern data, grouped into unmined and variously mined groups, plotted as the means of the index with their 95% confidence intervals.

For most of the indices (except 'total individuals' and 'total genera') there is a clear separation of the mined groups from the unmined group. The 'total individuals' index shows change only 7-9 months after mining when it starts increasing. Not that the 'total individuals' index continues to increase with time after mining (even 22-24 months after mining) which possibly indicates the influx of *r*-selected species in response to disturbance of the benthic community.

The 'total genera' and 'genus richness' indices show a recovery in their mean values after 15-19 months (groups 1 and 4 have overlapping confidence intervals) but are then again reduced 22-24 months after mining although not significantly (group 4 and 5 still have overlapping confidence intervals).



KEY TO GROUPS	N
1= unmined	6
2= mined 1-3 months ago	5
3= mined 7-9 months ago	6
4= mined 15-19 months ago	6
5= mined 22-24 months ago	6

Figure 3.5: SOUTHERN AREA (Pentow Salvor cruise 2 data only): Plots of the mean diversity indices (and the 95% CI's) for unmined and mined sites.

C(ii) ANOVA employed to test for differences between undisturbed and disturbed conditions in the southern research area

Null hypothesis: There is no difference in diversity indices among unmined and mined groups in the southern research area

Table 3.7: Key to groups used to test treatments in the southern research area. N is the number of replicate grab samples in each group.

GROUP	N	TREATMENT
1	6	Unmined
2	5	Mined 1-3 months ago
3	6	Mined 7-9 months ago
4	6	Mined 15-19 months ago
5	6	Mined 22-24 months ago

Table 3.8: Results of ANOVA tests on the unmined and mined sites of the southern area.

Index	Test statistic (*F*)	df	Significance level (*p*)	Ho accepted or rejected
Total genera	5.937	4,24	0.002	rejected
Total individuals	1.608	4,24	0.205	accepted
Genus richness	6.845	4,24	0.001	rejected
Evenness	5.225	4,24	0.004	rejected
Shannon diversity	9.342	4,24	0.0001	rejected

For most of the indices (except 'total individuals') the null hypothesis is rejected ($p<0.05$) and there are signficant differences among the diversity indices for the groups tested.

C(iii) Tukey tests on significant results from the ANOVA tests.

Table 3.9: Significant results of the Tukey test.
(X= significant difference)

Signif. different pairs	Total genera	Genus richness	Evenness	Shannon diversity
1-2	X	X	X	X
1-3		X	X	X
1-4			X	X
1-5		X	X	X
2-4	X	X		

The unmined group is significantly different from the recently mined group for all the indices. For the 'shannon diversity' and 'evenness' indices, the unmined group is also significantly different from all the other mined groups (even mined 22-24 months ago).

The 'genus richness' index shows differences between the unmined group (1) and groups 2 and 3 (i.e. mined up to 7-9 months ago). There then appears to be a recovery in the index after 15-19 months (groups 1-4 not significantly different). The index is again reduced 22-24 months after mining. The recently mined group (2) is different from group 4 and the unmined group 1.

The 'total genera' index shows a similar pattern of disturbance (groups 1-2 differ significantly) and recovery (groups 1-3 do not differ significantly)

These results confirm the graphical representation in Figure 3.5. This is interpreted as suggesting that 'genus richness' is sharply decreased by mining but recovers steadily to pre-mining levels by 15-19 months. The significantly lower value after 22-24 months is not easily explained, but may be due to a natural disturbance such as the periodic influx of oligo-oxic water (see chapter 5, section 5.4).

3.2.2 ASSESSING STRESS LEVELS - CASWELL'S NEUTRAL MODEL

Caswell's Neutral Model is decribed in section 3.1. The deviation statistic, V, compares the observed diversity (H') with that predicted from the neutral model (expected H' or E(H')).

The V-statistic has been calculated using the PRIMER programme CASWELL (based on the paper by Caswell 1976) for each replicate in each of the unmined and mined groups studied. The frequencies of the positive and negative V-statistics produced are presented in Figure 3.6 and interpreted in section 3.2.2.1. The frequencies of the V-statistics are then analysed, using a two-way classification chi-squared test, in section 3.2.2.2. The chi-squared analysis tests whether the two variables (mining status and value of the V-statistic) are independent or not.

When the V-statistic is negative it indicates that there is a lower diversity in the sample than predicted by Caswell's neutral model. When the V-statistic is positive it indicates that there is a greater diversity in the sample than predicted by Caswell's neutral model. V = >+2 or <-2 indicate significant departures from the neutral community predicted by Caswell's model.

3.2.2.1 Interpretation of Figure 3.6 - Histograms of the positive and negative V-statistics for the northern and southern unmined and mined samples.

Fig. 3.6 (A): UNMINED SITES ONLY (northern and southern areas)

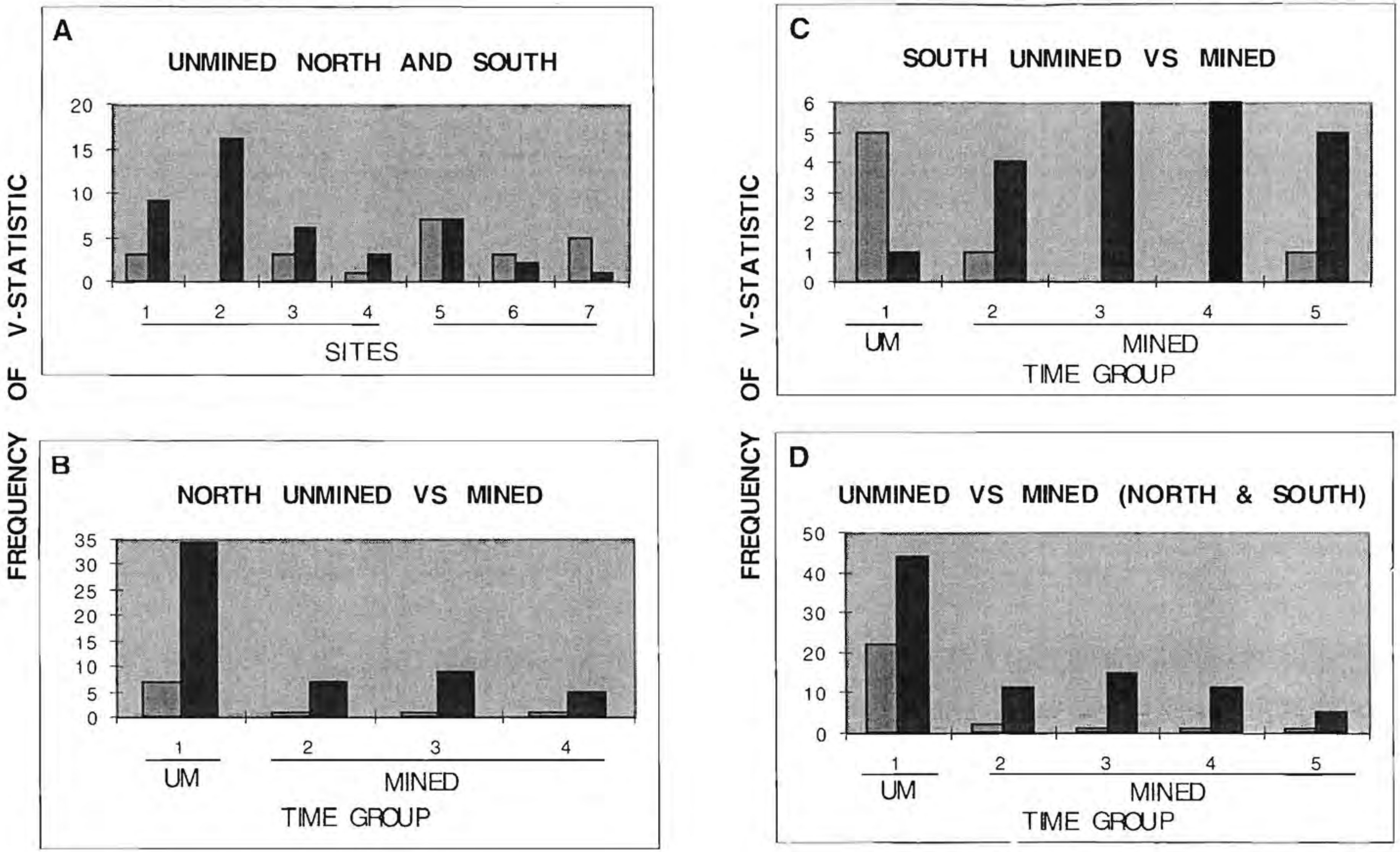
The southern unmined sites have a 15:10 ratio of positive (+) to negative (-) V-statistics. The frequencies are slightly inclined to positive V-statistics, indicating that the southern unmined sites have a greater diversity than predicted by Caswell's neutral model.

The northern unmined sites have a 7:34 ratio of positive to negative V-statistics. The frequencies are very inclined to the negative V-statistics, indicating that the northern unmined sites have a considerably lower diversity than predicted by Caswell's neutral model.

Therefore, the northern unmined area has a lower diversity in comparison to the southern unmined area. There may be some factor other than mining affecting the benthic community in the northern area.

Fig. 3.6 (B): NORTHERN AREA (unmined *vs* mined sites)

The unmined sites have a 7:34 ratio of positive to negative V-statistics. The mined sites have a 3:21 ratio of positive to negative V-statistics. Therefore, the frequencies of both the unmined and mined sites are inclined towards negative V-statistics, indicating that both have a lower diversity than predicted by Caswell's neutral model. This confirms the interpretation in (A) above that the northern sites as a whole have a considerably lower diversity than predicted by Caswell's neutral model.



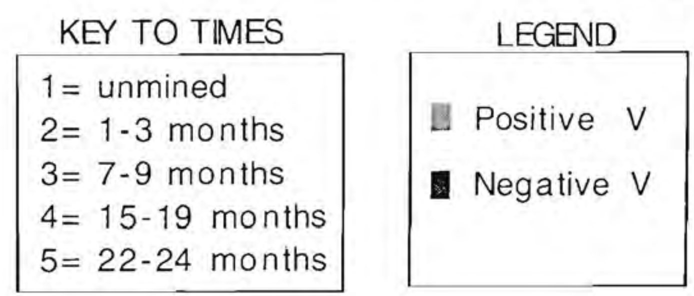


Figure 3.6: Histograms of the positive and negative V-statistics for :

A. The northern and southern unmined sites,

B. The northern unmined vs mined sites,

C. The southern unmined vs mined sites,

D. The northern and southern unmined vs mined sites.

Fig. 3.6 (C): SOUTHERN AREA (unmined *vs* mined sites)

The unmined sites have a 5:1 ratio of positive to negative V-statistics, indicating greater diversity than predicted by Caswell's neutral model. The mined sites have a 2:21 ratio of positive to negative V-statistics, indicating a lower diversity than predicted by Caswell's neutral model. There is therefore a significant (see pg. 44) difference in the community diversities between the unmined and mined sites of the southern area; the unmined sites having a higher community diversity than the mined sites.

Fig. 3.6 (D): ALL SITES (NORTH & SOUTH) (unmined *vs* mined sites)

The unmined sites have a 22:44 ratio of positive to negative V-statistics, indicating a lower diversity than predicted by Caswell's neutral model. The mined sites have a 5:42 ratio of positive to negative V-statistics which is very inclined to a lower diversity than predicted by Caswell's neutral model.

The ratio of the unmined sites is slightly more inclined to the positive V-statistics than the mined sites which indicates a slightly more diverse benthic community in the unmined sites. This result confirms the finding for the unmined *vs* mined sites of the southern area alone.

3.2.2.2 Chi-squared analyses of the frequencies of the positive and negative V-statistics

A) UNMINED SITES ONLY (northern and southern areas)

The null hypothesis that the frequencies of positive or negative V-statistics are related to mining area (north or south) was tested in a two-way contingency table.

Table 3.12: Frequencies of the positive and negative values of the V-statistic of all the unmined sites.

	NORTH UNMINED		SOUTH UNMINED		TOTAL
	$\hat{f}$	f	$\hat{f}$	f	
POSITIVE V	13.67	7	8.33	15	22
NEGATIVE V	27.33	34	16.67	10	44
TOTAL	41		25		66

A two-way chi-squared test showed a significant difference in the frequencies of positive and negative V-statistics between northern and southern unmined areas (X^2 = 12.89, $p<0.01$, d.f.=1). This confirms the interpretation of Figure 3.6 A above.

3.2.3 ENVIRONMENTAL VARIABLES

3.2.3.1 Correlation of diversity indices with environmental variables

It is expected that the pattern of disturbance and recovery in the values of the indices would relate to the characteristics of the sediments (i.e. percentage mud, sand and gravel) in undisturbed and disturbed areas. Van der Merwe (1996) did an analysis of the particle-size data in her MSc thesis and found that the unmined sites showed a predominance of muddy sediments and the mined sites showed a predominance of sandy and/or gravelly sediments. In van der Merwe's thesis the environmental variables were related to the biological data by a multivariate technique, MDS (Multi-dimensional Scaling plots), proposed by Field *et al.* (1982).

This study is concerned with univariate techniques and therefore correlation techniques were utilised to attempt to relate the diversity indices to the environmental variables. Assuming normality of the data and that the variables (indices and environmental factors) are independent of each other, the indices were each correlated against three environmental variables: percentage gravel, percentage sand and percentage mud present in the geological sample for each replicate. These correlations were done for the unmined sites, the northern sites and also the southern sites.

The correlations did not show any promising results. Most of the graphs showed a lot of scatter and there is no reason to expect linear relationships (see Figures 3.8 to 3.16). The statistical results of the correlations are given in Tables 3.14 to 3.22.

A summary of the correlation results is given in section 3.2.3.2 (see Table 3.23).

3.2.3.1(A) CORRELATIONS WITH PERCENTAGE MUD

Table 3.14: Indices correlated with percentage mud: UNMINED SITES

INDEX	Correlation coefficient r	No correlation $p>0.05$	Is a correlation $p<0.05$	Strong correlation $p<0.01$
Total individuals	-0.136	p=0.318	–	–
Total genera	-0.317	–	p=0.017	–
Evenness	0.244	p=0.069	–	–
Genus richness	-0.343	–	–	p=0.0096
Shannon diversity	-0.142	p=0.297	–	–

The indices for the unmined sites have two correlations with percentage mud. 'Total genera' has a weak negative correlation and 'genus richness' has a strong negative correlation with percentage mud. See Figure 3.8.

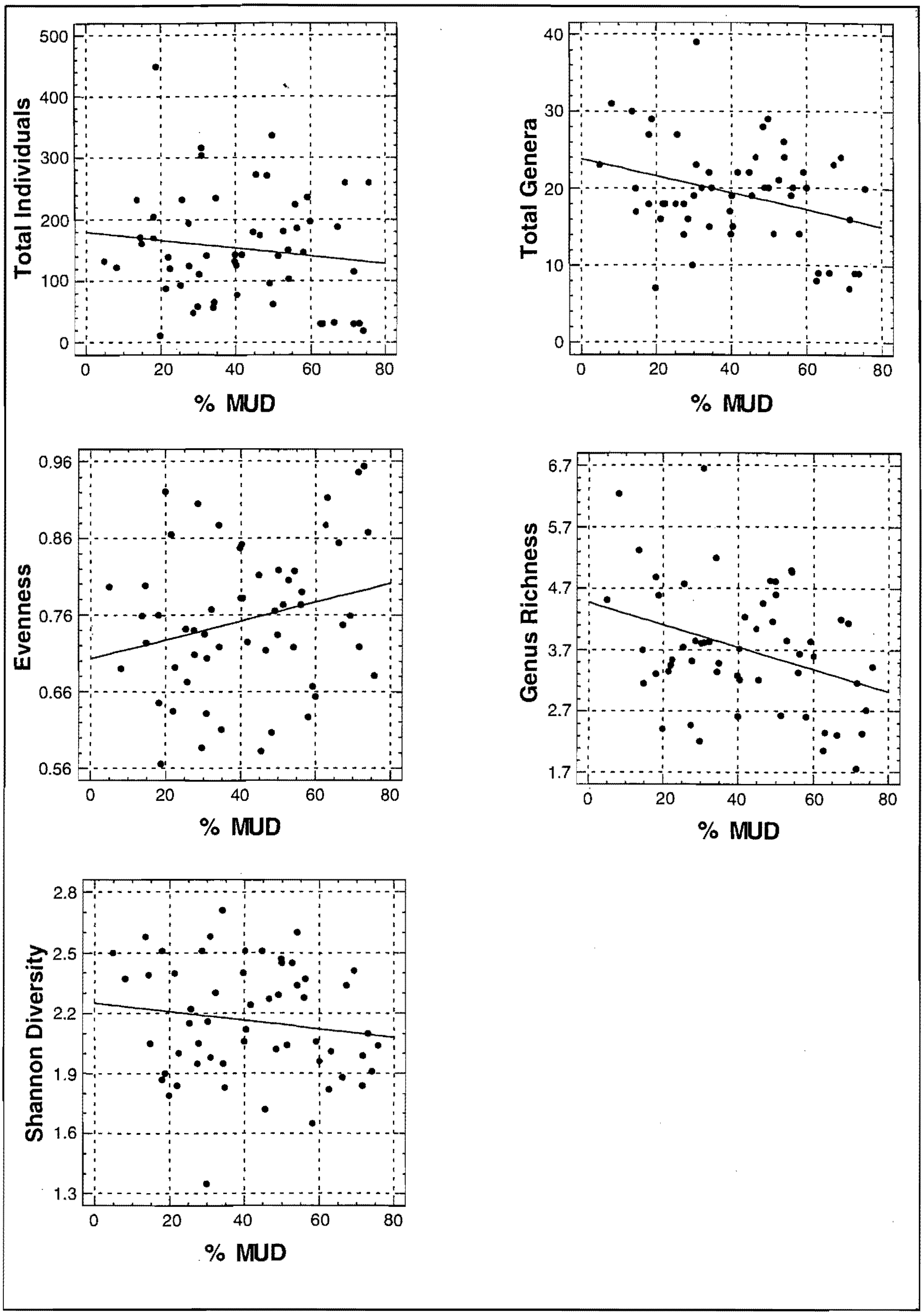


Figure 3.8: UNMINED SITES: Diversity indices correlated against percentage mud.

Table 3.15: Indices correlated with percentage mud: NORTHERN AREA

INDEX	Correlation coefficient r	No correlation $p>0.05$	Is a correlation $p<0.05$	Strong correlation $p<0.01$
Total individuals	0.045	p=0.755	–	–
Total genera	-0.085	p=0.556	–	–
Evenness	0.145	p=0.314	–	–
Genus richness	-0.068	p=0.638	–	–
Shannon diversity	3.109×10^{-3}	p=0.983	–	–

None of the indices for the northern sites have a significant correlation with percentage mud. See Figure 3.9.

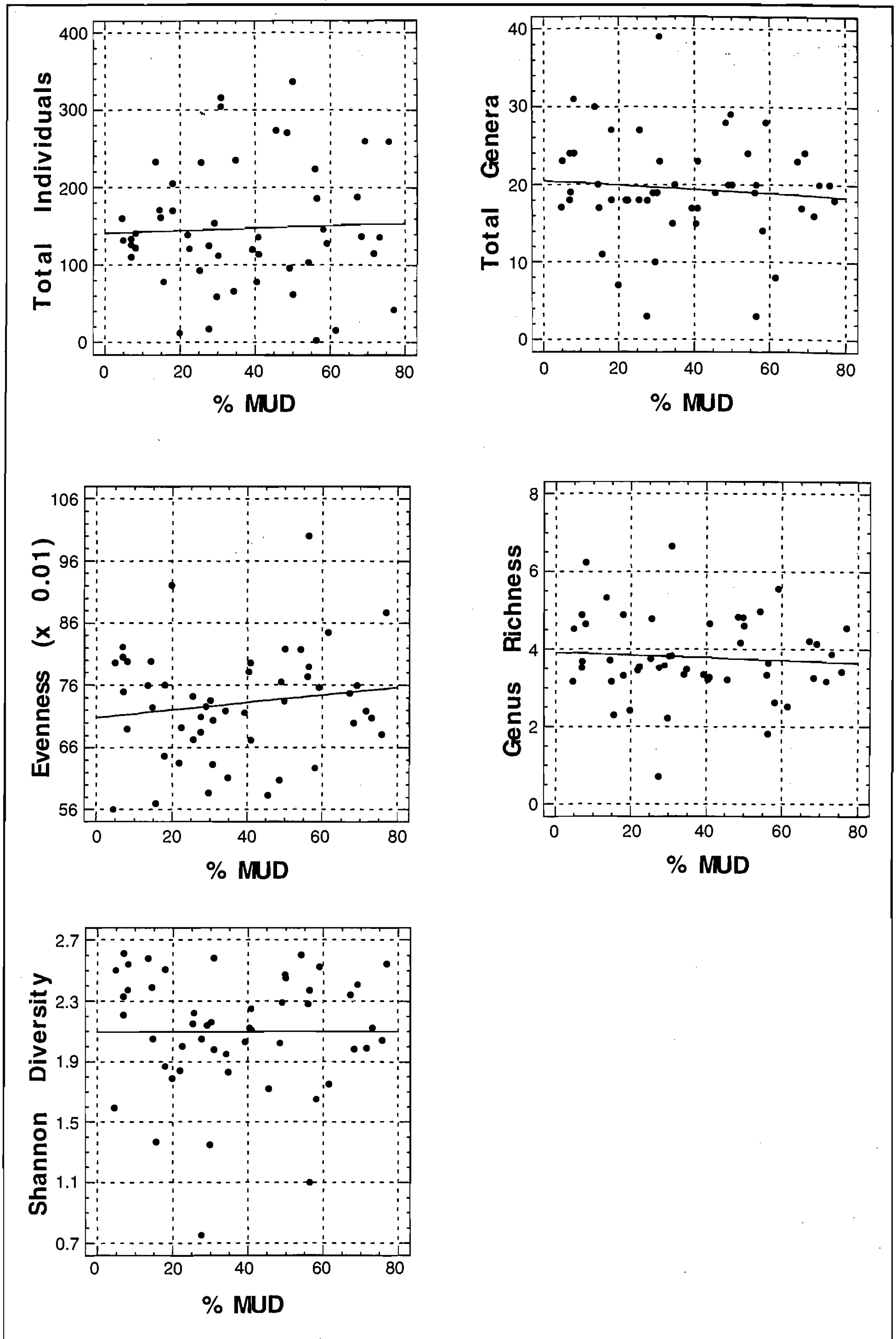


Figure 3.9: NORTHERN AREA: Diversity indices correlated against percentage mud.

Table 3.16: Indices correlated with percentage mud: SOUTHERN AREA.

INDEX	Correlation coefficient r	No correlation p>0.05	Is a correlation p<0.05	Strong correlation p<0.01
Total individuals	-0.213	p=0.267	_	_
Total genera	-0.194	p=0.312	_	_
Evenness	0.239	p=0.213	_	_
Genus richness	-0.049	p=0.798	_	_
Shannon diversity	0.125	p=0.518	_	_

None of the indices for the south have a significant correlation with percentage mud. See Figure 3.10.

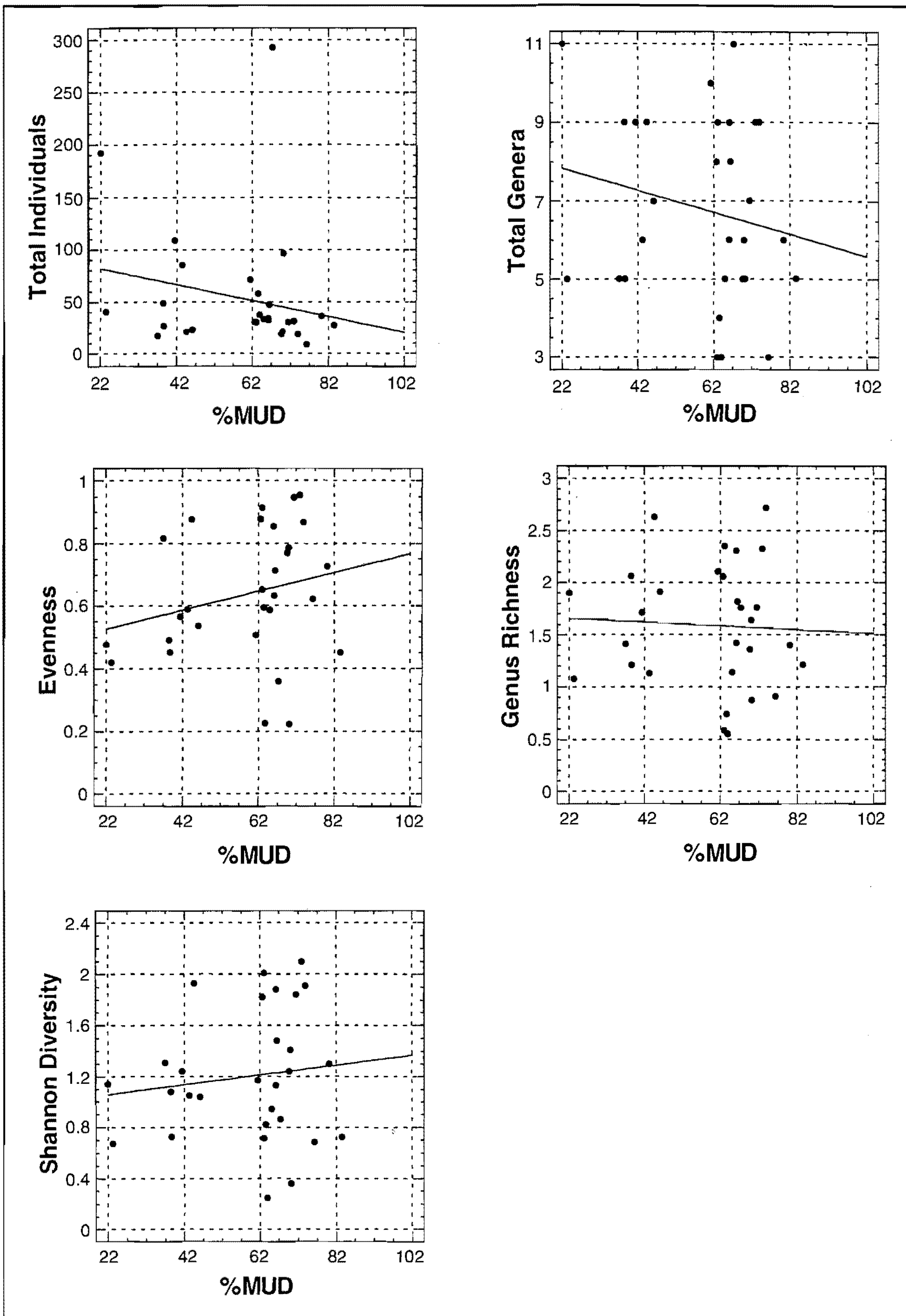


Figure 3.10: SOUTHERN AREA: Diversity indices correlated against percentage mud.

3.2.3.1(B) CORRELATIONS WITH PERCENTAGE SAND

Table 3.17: Indices correlated with percentage sand: UNMINED SITES

INDEX	Correlation coefficient r	No correlation $p>0.05$	Is a correlation $p<0.05$	Strong correlation $p<0.01$
Total individuals	0.294	_	p=0.028	_
Total genera	0.301	_	p=0.024	_
Evenness	-0.378	_	_	p=0.004
Genus richness	0.200	p=0.139	_	_
Shannon diversity	0.027	p=0.843	_	_

The indices of the unmined sites have three significant correlations with percentage sand. 'Total individuals' and 'total genera' both have a weak positive correlation with percentage sand, whilst 'evenness' has a strong negative correlation with percentage sand. See Figure 3.11.

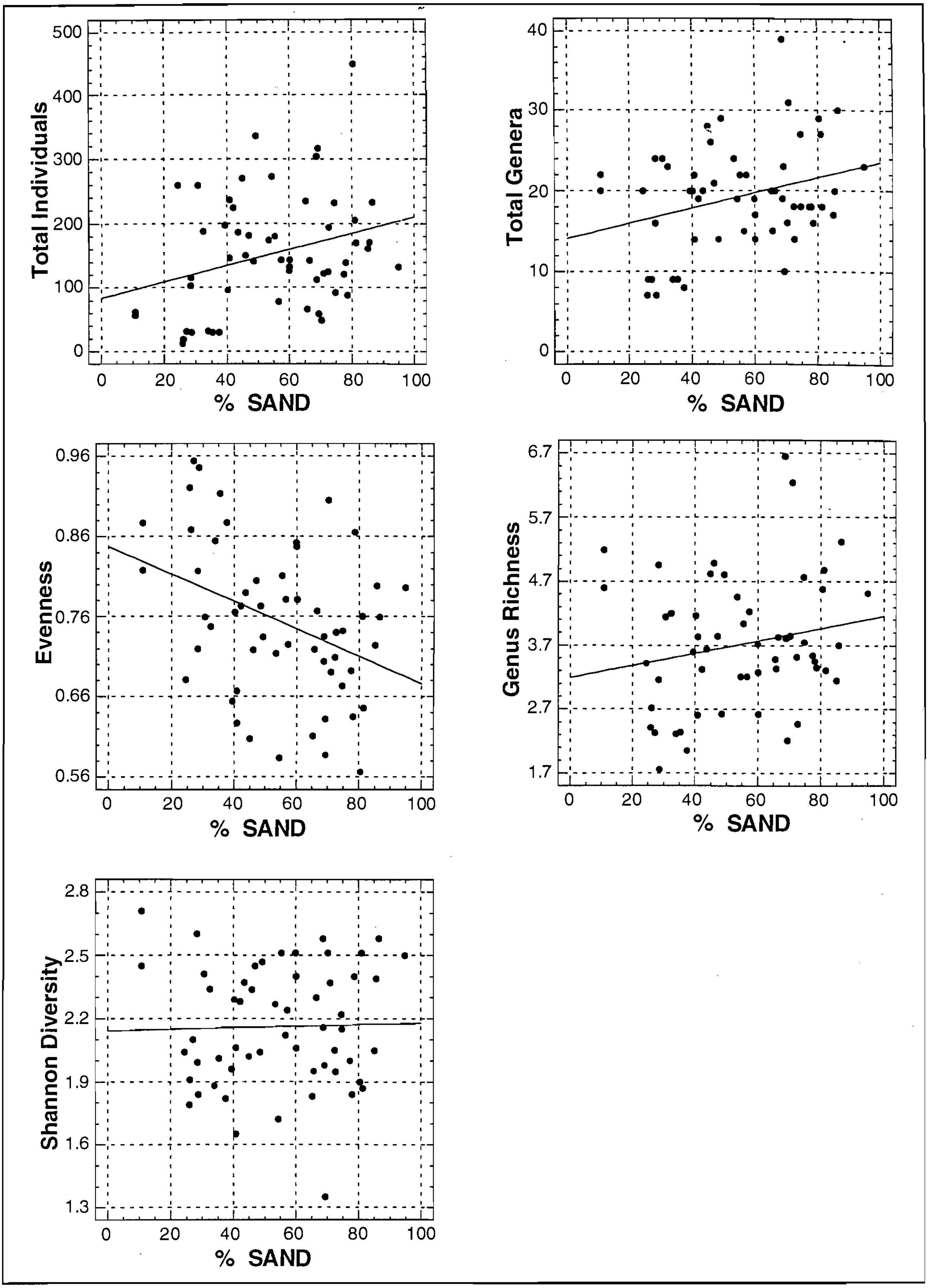


Figure 3.11: UNMINED SITES: Diversity indices correlated against percentage sand

Table3.18: Indices correlated with percentage sand: NORTHERN AREA

INDEX	Correlation coefficient r	No correlation p>0.05	Is a correlation p<0.05	Strong correlation p<0.01
Total individuals	0.222	p=0.121	_	_
Total genera	0.235	p=0.100	_	_
Evenness	-0.197	p=0.170	_	_
Genus richness	0.148	p=0.304	_	_
Shannon diversity	0.136	p=0.347	_	_

None of the indices in the north have a significant correlation with percentage sand. See Figure 3.12.

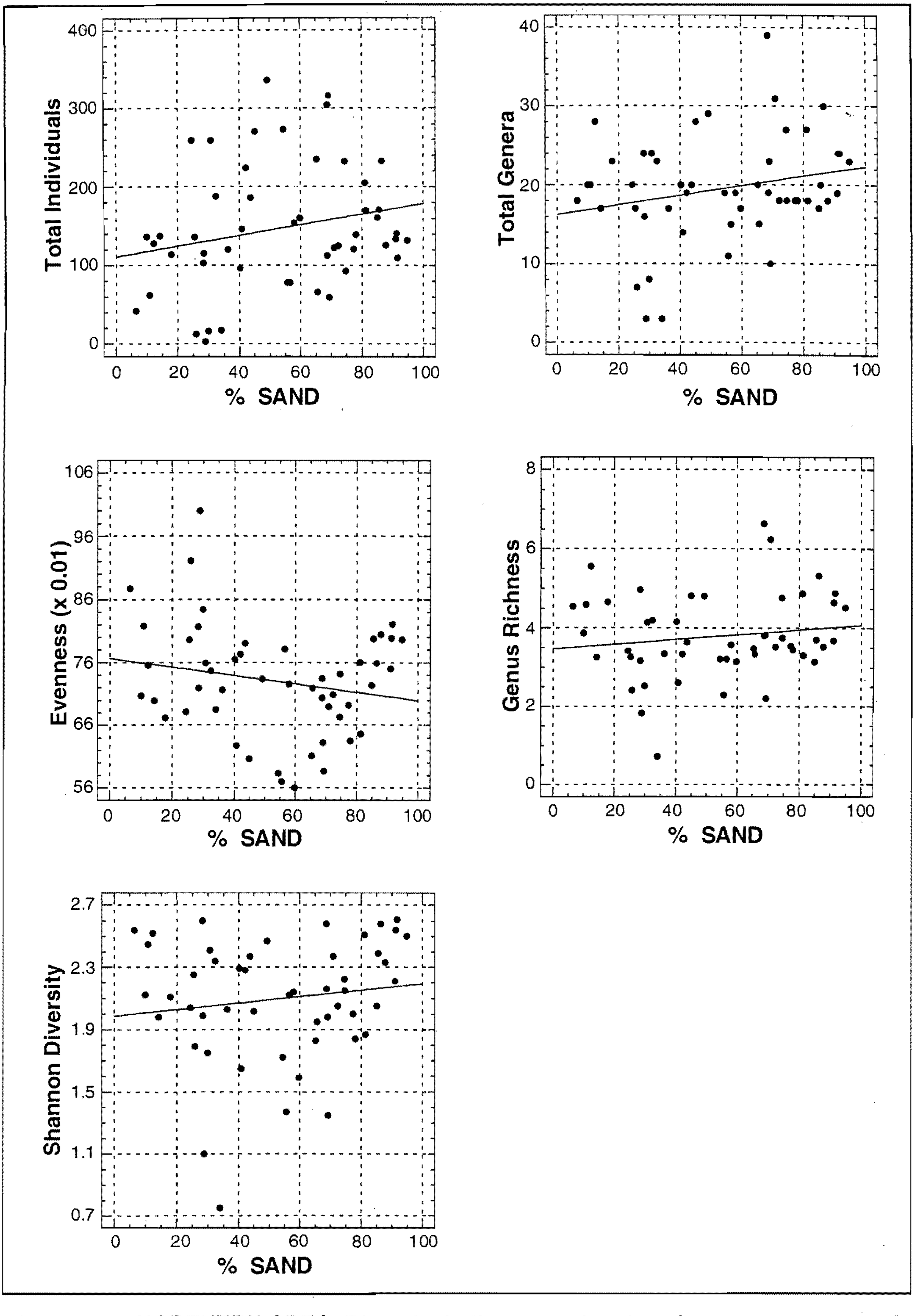


Figure 3.12: NORTHERN AREA: Diversity indices correlated against percentage sand.

Table 3.19: Indices correlated with percentage sand: SOUTHERN AREA

INDEX	Correlation coefficient r	No correlation $p>0.05$	Is a correlation $p<0.05$	Strong correlation $p<0.01$
Total individuals	0.125	p=0.520	_	_
Total genera	0.197	p=0.307	_	_
Evenness	0.059	p=0.762	_	_
Genus richness	0.152	p=0.431	_	_
Shannon diversity	0.119	p=0.540	_	_

None of the indices for the southern sites have a significant correlation with percentage sand. See Figure 3.13.

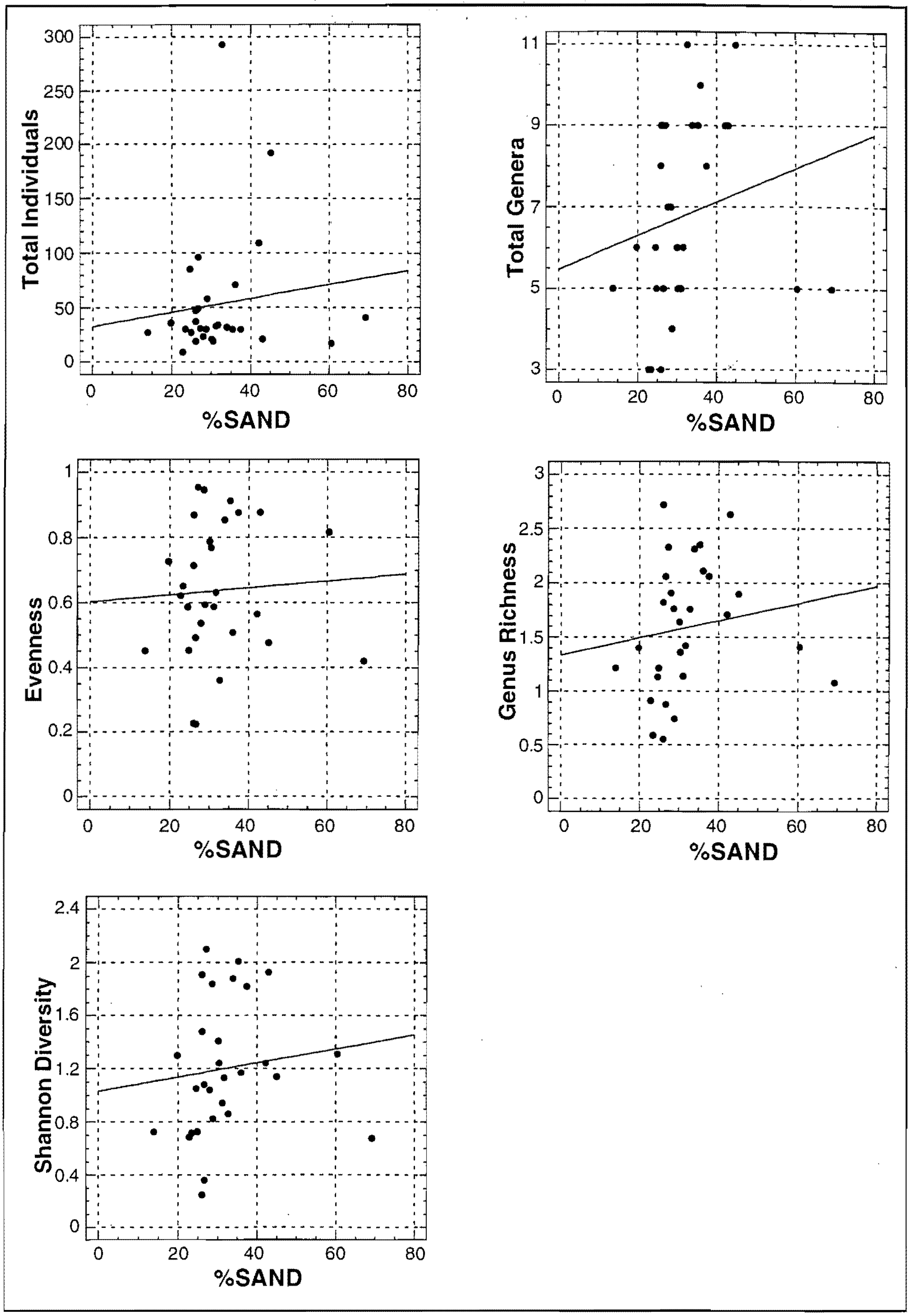


Figure 3.13: SOUTHERN AREA: Diversity indices correlated against percentage sand.

3.2.3.1(C) CORRELATIONS WITH PERCENTAGE GRAVEL

Table 3.20: Indices correlated with percentage gravel: UNMINED SITES

INDEX	Correlation coefficient r	No correlation p>0.05	Is a correlation p<0.05	Strong correlation p<0.01
Total individuals	-0.306	_	p= 0.023	_
Total genera	-0.023	p= 0.864	_	_
Evenness	0.280	_	p=0.036	_
Genus richness	0.198	p=0.143	_	_
Shannon diversity	0.182	p=0.179	_	_

The indices for the unmined sites have two weak correlations with percentage gravel. 'Total individuals' is negatively correlated and 'evenness' is positively correlated. See Figure 3.14.

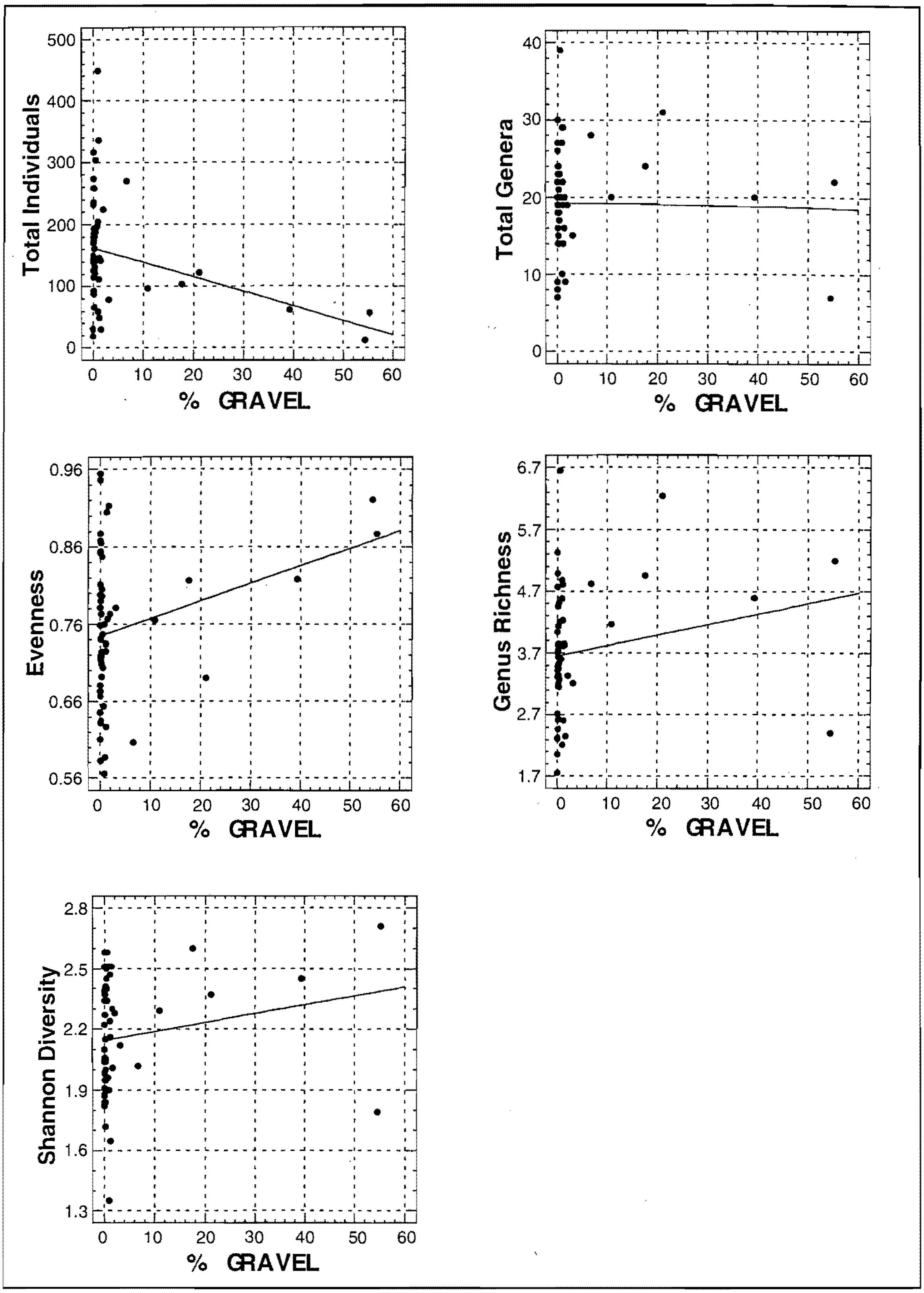


Figure 3.14: UNMINED SITES: Diversity indices correlated against percentage gravel.

Table 3.21: Indices correlated with percentage gravel: NORTHERN SITES

INDEX	Correlation coefficient r	No correlation $p>0.05$	Is a correlation $p<0.05$	Strong correlation $p<0.01$
Total individuals	-0.479	_	_	p=0.0004
Total genera	-0.303	_	p=0.032	_
Evenness	0.143	p=0.321	_	_
Genus richness	-0.169	p=0.239	_	_
Shannon diversity	-0.254	p=0.074	_	_

The indices for the northern sites have two significant correlations with percentage gravel. 'Total individuals' is strongly negatively correlated to percentage gravel and 'total genera' has a weak negative correlation to percentage gravel. See Figure 3.15.

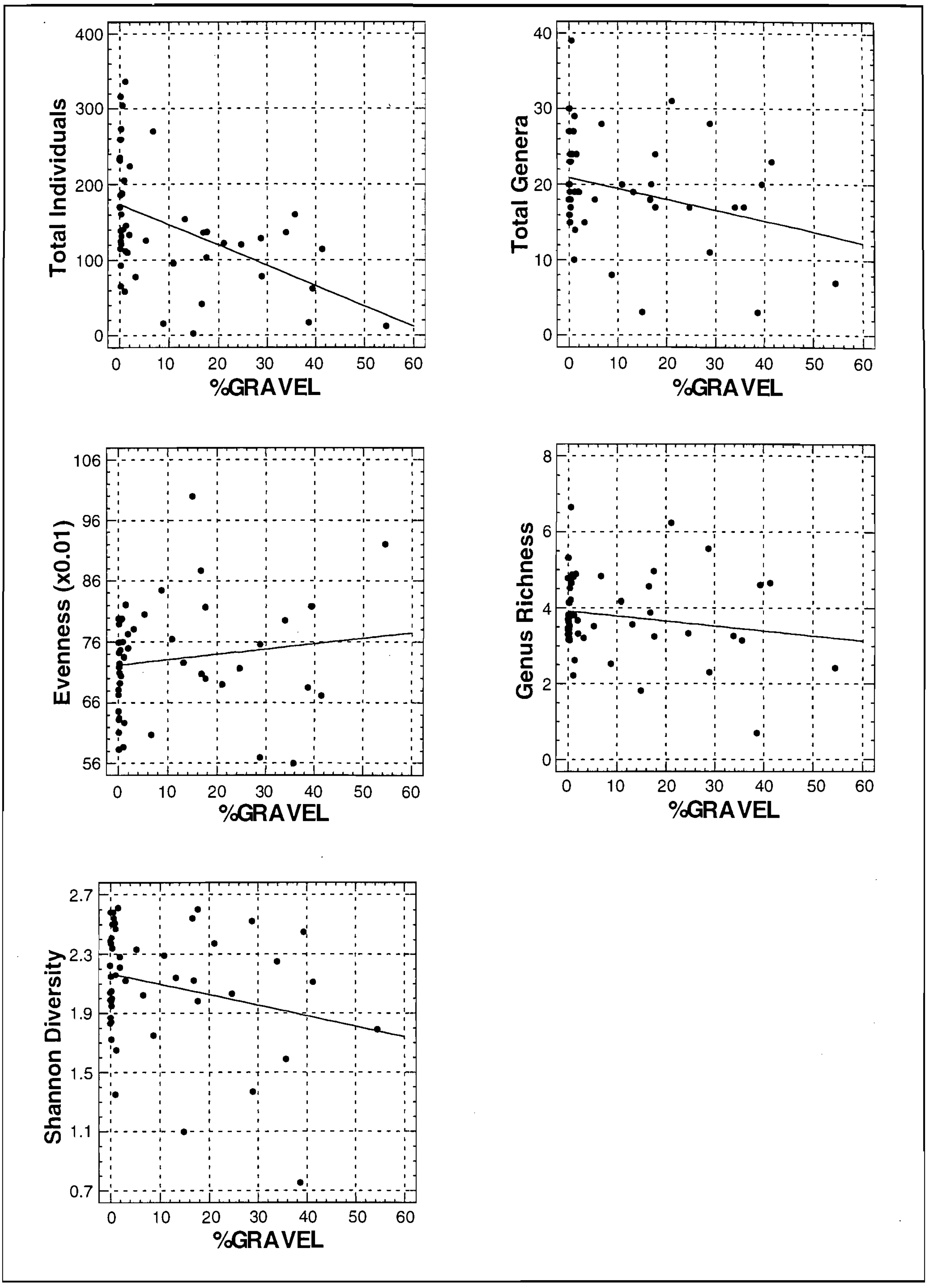


Figure 3.15: NORTHERN AREA: Diversity indices correlated against percentage gravel.

Table 3.22: Indices correlated with percentage gravel: SOUTHERN SITES

INDEX	Correlation coefficient r	No correlation p>0.05	Is a correlation p<0.05	Strong correlation p<0.01
Total individuals	0.173	p=0.368	_	_
Total genera	0.079	p=0.682	_	_
Evenness	-0.383	_	p=0.040	_
Genus richness	-0.076	p=0.693	_	_
Shannon diversity	-0.284	p=0.135	_	_

The indices for the southern sites have only one correlation with percentage gravel. There is a weak negative correlation of 'evenness' with percentage gravel. See Figure 3.16.

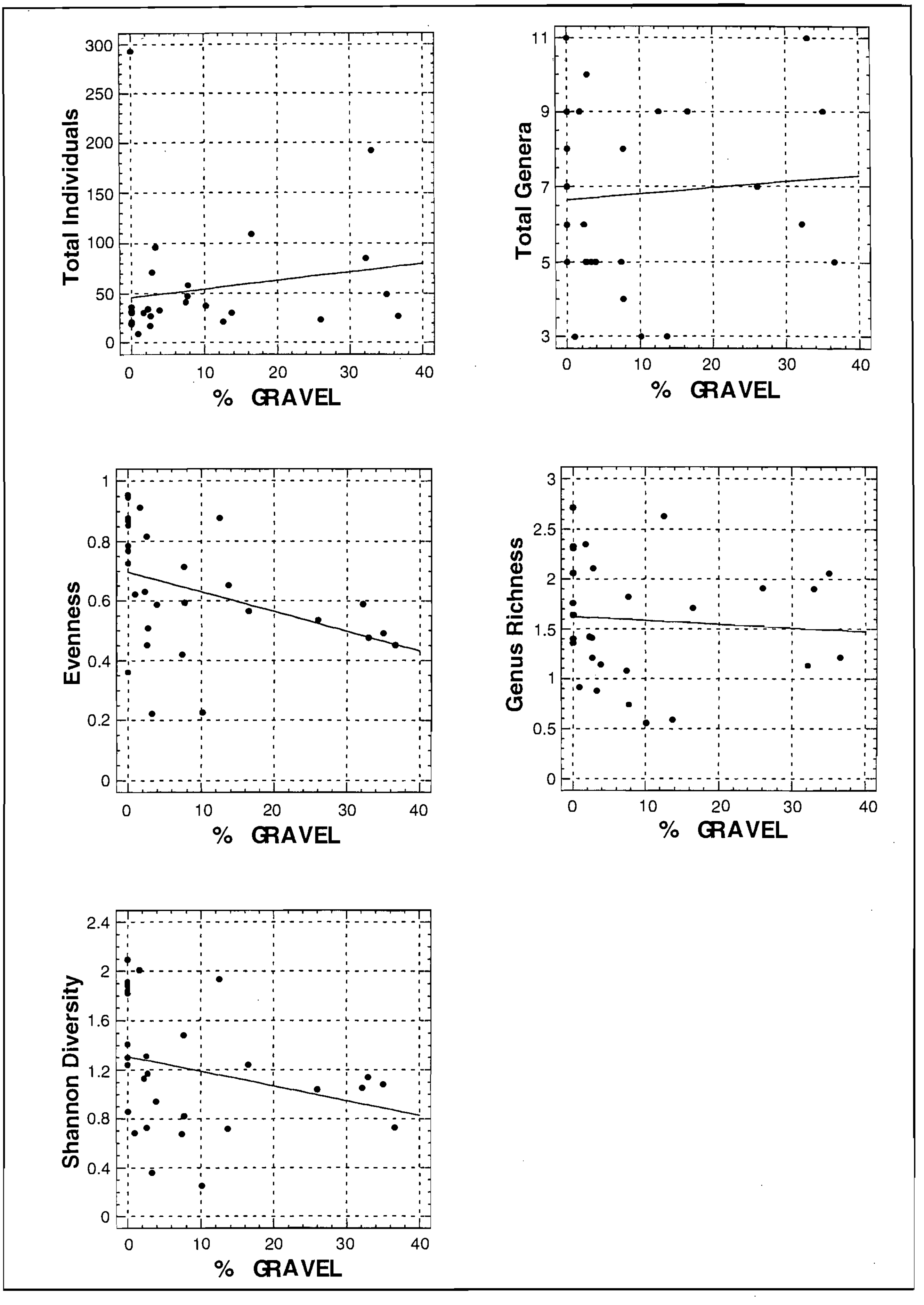


Figure 3.16: SOUTHERN AREA: Diversity indices correlated against percentage gravel.

3.2.3.2 Summary of correlation results

Table 3.23 below summarises the results of the correlations given in Tables 3.14 to 3.22 above.

Table 3.23: Summary of correlation results. POS= a positive correlation and NEG= a negative correlation (p<0.05). "strong" = p<0.01.

		INDEX			
AREA	**ENV. VAR.**	**TOT. INDIV.**	**TOT.GEN.**	**EVENNESS**	**GENUS RICH.**
Unmined sites	mud		NEG		strong NEG
	sand	POS	POS	strong NEG	
	gravel	NEG		POS	
Northern sites	mud				
	sand				
	gravel	strong NEG	NEG		
Southern sites	mud				
	sand				
	gravel			NEG	

Very few significant results (10 out of 45 correlations) were found by correlating the indices with the environmental variables. The significant correlations were mostly from the unmined sites and mostly weak correlations ($p<0.05$). The 'total individuals', 'total genera' and 'evenness' indices had the most significant correlations with sediment parameters. However, no general inferences (about the relationship between the indices and environmental variables from unmined and mined sites) could be made from these few correlations.

As mentioned in the methods section of this chapter this kind of uninformative result can be expected due to the over-condensed nature of the information utilised (i.e. for each diversity index calculated for a sample, the full set of species abundances for that sample has been reduced into a single index).

3.2.4 SUMMARY OF RESULTS

3.2.4.1 Graphical representation, ANOVA and Tukey tests

For the unmined sites (northern *vs.* southern areas) the graphical representation (means of the indices) and statistical tests both indicated no north-south differences (i.e. sites 1-4 *vs.* sites 5-6). Only site 7 was found to be significantly different from sites 1-5 but not from site 6. Site 7 is situated very close to site 6 in the southern area and it is expected that the sediment particle size distribution does not vary much between these two sites.

For the northern sites the graphical representation indicated no significant differences between unmined and mined samples. Although three of the indices ('total genera', 'genus richness' and 'shannon diversity') indicated a significant reduction in their mean value (compared to the unmined group 1) at 15-19 months after mining, there were no significant differences between the more recently mined groups and the unmined group. The statistical analyses also did not indicate any significant differences between unmined and mined sites.

The graphical representation and statistical test of the southern data indicated significant differences between unmined and mined samples. Two of the indices ('total genera' and 'genus richness') suggest a significant recovery in the community 15-19 months after mining with a reduction in their mean values 22-24 months after mining. This may be interpreted as an indication that another factor, other than mining, may have disturbed the community 19-22 months after mining (see chapter 5).

3.2.4.2 Caswell's Neutral Model (the V-statistic)

Chi-squared tests have shown that the frequencies of the positive or negative values of the V-statistic are related to:

(i) the area (north or south) from which the samples come (the northern area having a greater frequency of negative V-statistics (i.e. a lower diversity) than the south) and

(ii) whether the sample is unmined or mined (the mined samples having a greater frequency of negative V-statistics (i.e. a lower diversity) than the unmined samples).

3.2.4.3 Environmental variables

A few significant results were found by correlating the indices with the environmental variables. These significant correlations were mostly from the unmined sites and mostly weak correlations ($p<0.05$). The 'total individuals', 'total genera' and 'evenness' indices had the most significant correlations with sediment parameters:

- 'total genera' and 'genus richness' are negatively correlated to percentage mud,
- 'total genera' and 'total individuals' are positively correlated to percentage sand,
- 'evenness' is negatively correlated to percentage sand, and
- 'total genera' and 'total individuals' are negatively correlated to percentage gravel.

These results were found to be uninformative due to the over-condensed nature of the diversity index variables (the use of indices involves the reduction of the full set of species abundances for a sample into a single coefficient).

CHAPTER 4

DISTRIBUTIONAL ANALYSES

DISTRIBUTIONAL ANALYSES

4.1 DISTRIBUTIONAL METHODS

A method which assesses the disturbance status of a marine macrobenthic community without reference to a series of temporal or spatial control samples (Warwick 1986) is tested for its validity as a tool to assess changes in a macrobenthic community subjected to unnatural physical disturbance (i.e. mining). Warwick (1986) suggests that the distributions of numbers of individuals among species and of biomass among species in marine macrobenthic communities show a differential response to pollution-induced disturbance. A shift from biomass dominance to numerical dominance with increasing levels of disturbance can be shown by the abundance/biomass comparison (ABC) method. It involves plotting separate *k*-dominance curves (Lambshead *et al.* 1983) for abundance and biomass on a cumulative scale (y-axis) against the species ranked in order of importance according to these two attributes on a logarithmic scale (x-axis). According to this hypothesis, the presence of large *k*-selected organisms in undisturbed communities results in the biomass curve lying entirely above the abundance curve; in grossly disturbed communities, dominated by large numbers of small *r*-selected individuals, the abundance curve lies entirely above the biomass curve; in moderately disturbed communities, these curves are closely coincident and may cross over one or more times (Clarke and Warwick 1994) [see "Measuring stress levels" in this section].

Initial tests of the ABC technique by its developer (Warwick 1986) and co-workers suggested it could be used to identify areas disturbed by organic enrichment as well as in a wide range of disturbance and successional scenarios (Warwick 1986, Warwick & Ruswahyuni 1987, Warwick *et al.* 1987, Gray *et al.* 1988, Austen *et al.* 1989). Warwick, Pearson and Ruswahyuni (1987) found the ABC method to be a sensitive indicator of natural physical and biological disturbance as well as pollution-induced disturbance over both spatial and temporal scales. In other tests a false impression of disturbance has been given by the occurrence of large numbers of small individuals (usually of only one or a very few species) in apparently unperturbed situations (e.g. Beukema 1988, Ibanez and Dauvin 1988, Weston 1990). This problem is due to the overdependence of the elevation of the curves on the dominance of the first-ranked species, and can be mitigated by the use of "partial dominance" curves (Clarke 1990). The aforementioned situation did not arise in this study and the partial dominance curves were therefore not needed.

The ABC technique offers a less condensed form of summary of each sample than the use of the univariate indices. The advantage of distribution plots is that the distribution of species abundance among individuals and the distribution of species biomass among individuals can be compared on the same terms. Since the two have different units of measurement, this is not possible with diversity indices.

The distributional technique may be viewed as comprising four stages of analyses which are summarised in Table 4.1 herebelow.

Table 4.1: Distributional techniques. Summary of analyses for the four stages (adapted from Clarke and Warwick, 1994).

Stages	Distributional ABC (k-dominance) curves
1) Representing communities	Curves for each site/condition (or preferably replicate)
2) Discriminating sites/conditions	ANOVA on univariate summaries (eg. W), **or** ANOSIM test on "distances" between every pair of curves (not done in this study)
3) Measuring stress levels	Biomass curve drops below numbers curve under disturbance (i.e. negative W-statistic)
4) Linking to environment	Difficult, except for univariate summaries of the curves (W-statistic) and then applying correlation techniques

Representation is by histograms or curves either plotted for each replicate sample separately or for pooled data within sites or conditions. Plotting each replicate separately permits visual judgement of the sampling variation in the curves. Replication is required to **discriminate sites** (i.e. test the null hypothesis that two or more sites/conditions have the same curvilinear structure). To test the null hypothesis, each replicate curve is summarised by a single W-statistic (which is a measure of the extent to which the biomass curve "dominates" the abundance curve or vice versa) and then ANOVA is applied.

Assessing stress levels. Distributional techniques are graphical methods proposed specifically for this purpose. The distributional methods include various forms of graphical representation, namely; rarefaction curves, plots of geometric abundance groups, ranked species abundance (dominance) curves, *k*-dominance (cumulative ranked abundances) and Lorenz curves. This study concentrates on the ABC technique as originally described by Warwick (1986).

The ABC curves involve plotting separate *k*-dominance curves (Lambshead *et al.* 1983) for species abundance and species biomass on the same graph and making a comparison of the forms of these curves. The species are ranked in order of importance in terms of abundance or biomass on the x-axis (log scale) with percentage dominance on the y-axis (cumulative scale). This has a smoothing effect on the curves.

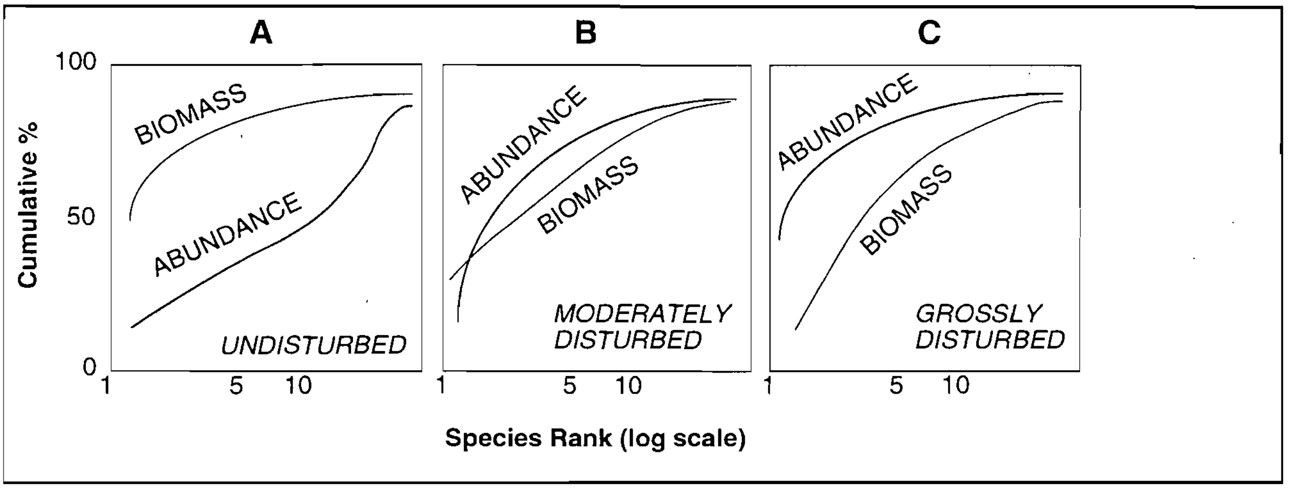


Figure 4.1: Hypothesized *k*-dominance curves for undisturbed, moderately disturbed and severely disturbed scenarios.

According to theory, in **undisturbed communities:**

The biomass is dominated by one or a few large *k*-selected species, each represented by rather few individuals, whilst the numerical dominants are small species with a strong stochastic element in their abundance. The distribution of numbers of individuals among species is more even than the distribution of biomass, the latter showing strong dominance. Thus, the *k*-dominance curve for biomass lies above the curve for abundance for its entire length (Fig. 4.1A).

Under **moderate disturbance:**

The large, long-lived, competitive dominants are eliminated and the inequality in size between the numerical and biomass dominants is reduced so that the biomass and abundance curves are closely coincident and may cross each other one or more times (Fig. 4.1B).

Under **severe disturbance:**

There is a loss of the large bodied "climax" species and the benthic communities become increasingly dominated by one or a few very small opportunist (*r*-selected) species which become numerically dominant. The abundance curve lies above the biomass curve throughout its length (Fig. 4.1C).

These three conditions should be recognisable in a community without reference to control samples in time or space, the two curves acting as an "internal control" against each other. Reference to control samples is, however, still desirable. Replication is important because large biomass dominants are represented by few individuals which are liable to larger sampling error than numerical dominants (Clarke and Warwick 1994).

Linking to environmental variables is often difficult. The curve(s) for each sample may be reduced to a summary statistic (e.g. W-statistic) which can be plotted against particular environmental variables.

4.1.1 Phyletic role in the ABC method

Warwick and Clarke (1994) have shown that the ABC response results from: (i) a shift in the proportions of different phyla present in communities, some phyla having larger-bodied species than others, and (ii) a shift in the relative distributions of abundace and biomass among species within the Annelida (specifically Polychaeta) but not within any of the other major phyla (Mollusca, Crustacea, Echinodermata). The shift within polychaetes reflects the substitution of larger-bodied (longer-lived) by smaller-bodied (shorter-lived) species, and not a change in the average size of individuals within a species. In most instances the phyletic changes reinforce the trend in species substitutions within the polychaetes, to produce the overall ABC response, but in some cases they may work against each other. Indications of pollution or disturbance detected by this method should be viewed with caution if the species responsible for the polluted configurations are not polychaetes. These observations provide an aid to interpretation of the ABC plots, especially in some situations where they have been deemed to give a false impression of the disturbance status of a community.

4.1.2 The W-statistic

When the number of sites, times or replicates is large, presenting ABC plots for every sample can be cumbersome, and it would be convenient to reduce each plot to a single summary statistic. Clearly, some information will be lost in such a condensation: one plots cumulative dominance curves rather than quoting a diversity index precisely because of a reluctance to reduce the diversity information to a single statistic. Nonetheless, Warwick's (1986) contention that the biomass and abundance curves increasingly overlap with moderate disturbance, and transpose altogether for the grossly disturbed condition, is a unidirectional hypothesis and very amenable to quantification by a single summary statistic.

A single statistic describing the degree and direction of separation of the abundance and biomass curves has been derived by several authors (Beukema 1988, Meire and

Dereu 1990, Clarke 1990, McManus and Pauly 1990), Clarke's W-statistic being appropriately scaled for the number of species, so that complete biomass dominance and an even "abundace" distribution gives a value of +1, and the reverse case a value of -1 (Clarke and Warwick 1994).

One produces difference curves (Biomass - Abundance) for each replicate sample. These are simply the result of subtracting the abundance (A*i*) from the biomass (B*i*) value for each species rank (*i*) in an ABC curve (refer to Figure 4.3 as an example).

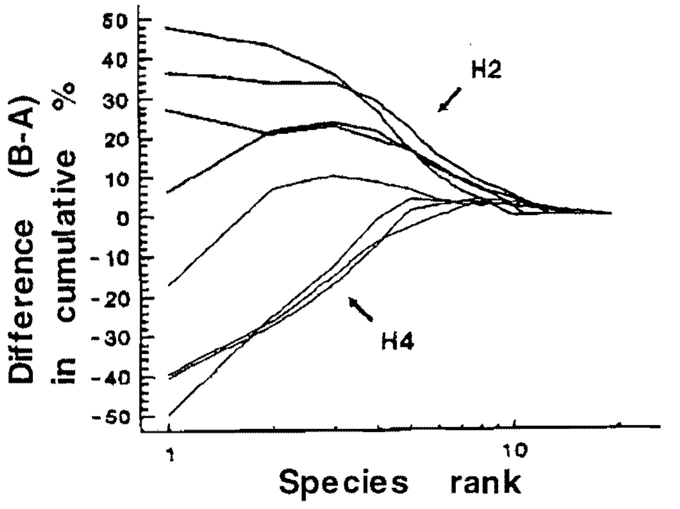


Figure 4.3: Difference (B-A) between cumulative dominance curves for biomass and abundance for four replicate samples at stations H2 (thick lines) and H4 (thin lines). (From Clarke and Warwick 1994).

Note that, with an ABC curve, B*i* and A*i* do not necessarily refer to values for the same species; the ranking is performed separately for abundance and biomass.

For the replicates for which the biomass curve is above the abundance curve throughout its length, the sum of the B*i* - A*i* values across the ranks will be strongly positive. In contrast, this sum will be strongly negative for the replicates for which abundance and biomass curves are largely transposed. Intermediate cases in which A and B curves are intertwined will tend to give $\sum(Bi - Ai)$ values near zero.

The summation requires some form of standardisation to a common scale, so that comparisons can be made between samples with differing numbers of species, and Clarke (1990) proposes the W (for Warwick) statistic:

$$W = \sum_{i=1}^{S} (Bi - Ai)/[50(S-1)]$$

It can be shown algebraically that W takes values in the range (-1,1), with W$\rightarrow$ +1 for even abundance across species but biomass dominated by a single species (undisturbed condition), and W $\rightarrow$ -1 in the converse case (though neither limit is likely to be attained in practice).

4.2 DISTRIBUTIONAL RESULTS

4.2.1 GRAPHICAL REPRESENTATION AND DISCRIMINATION OF GROUPS BY ANOVA AND TUKEY TESTS

4.2.1A UNMINED SAMPLES:

Identifying possible inherent differences between the northern and southern areas.

A(i) Figure 4.4 is a graphical representation of the abundance and biomass data of the unmined samples from both the northern and southern areas plotted as ABC curves. It is interpreted below.

NORTHERN AREA:
Site 1 is undisturbed or neutral (W = 0.039) with the biomass (B) curve close to and touching the abundance (A) curve. The B curve is, however, above the A curve for its full length giving the appearance of an undisturbed site.

Site 2 is slightly disturbed (W = -0.008) with the A curve above the B curve for most of its length.

Site 3 is undisturbed or neutral (W = 0.047) and similar to site 1 with the B curve close to and touching but above the A curve.

Site 4 is undisturbed with the B curve above the A curve throughout its length and W = 0.089.

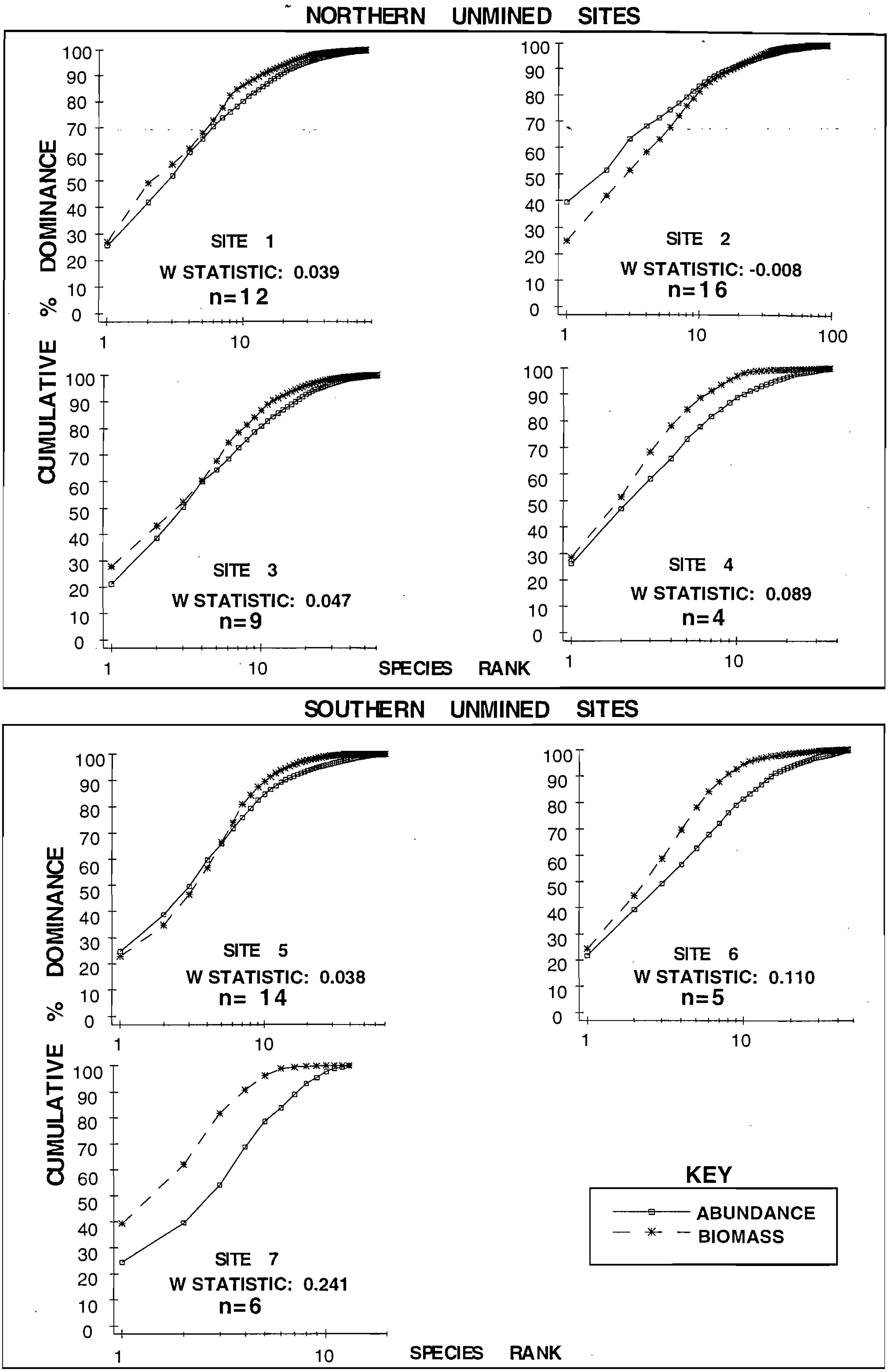


Figure 4.4: Distributional curves of the unmined sites from the northern and southern areas.

SOUTHERN AREA:

Site 5 shows signs of disturbance with a definite crossover making the A curve above the B curve for half the length of the curves. The W-statistic is however still positive (W = 0.038).

Site 6 is undisturbed and similar to the northern site 4 with the B curve above the A curve throughout the length of the curves (W = 0.110).

Site 7 is undisturbed and similar to sites 4 and 6 with the B curve above the A curve throughout their lengths (W = 0.241).

Therefore, from these interpretations of the ABC curves:
Site 1 (W= 0.039), site 3 (W= 0.047) and site 4 (W= 0.089) have a similar undisturbed/neutral ABC character. Site 2 differs from sites 1,3 and 4 as it depicts the disturbed ABC characteristic and a negative W= -0.008.

Site 5 (crossover with A curve above B curve for half the length) is different from sites 6 and 7 which are both undisturbed. Sites 6 and 7 do not differ from each other significantly. Site 7 appears to be in a better state than site 6 and this is reflected in the value of the W-statistics (site 7 = 0.241 and site 6 = 0.110).

Most importantly, the ABC curves show that:

- northern sites (1, 2 & 3) are different to the southern sites (6 & 7),
- the northern site 4 is similar to the southern sites 6 and 7 (undisturbed and no cross-overs of the A and B curves), and
- the southern site 5 is very similar to the northern site 1 with a difference of only 0.001 in the value of the W-statistic.

Therefore the ABC curves have been able to distinguish a few of the unmined northern sites from the unmined southern sites in terms of community response to stress.

A(ii) ANOVA employed to test for differences in the W-statistic of the unmined sites from the northern and southern areas.

In order to determine if there is a community difference among the unmined sites, the W-statistic for each of the samples has been calculated and then analysed by the ANOVA procedure to test the null hypothesis that there are no differences in the W-statistics among the unmined groups.

Table 4.2: Key to Groups used. N = the number of replicates at each site.

Group (in ANOVA)	N	Research Area	Site (replicates)
1	12	North	1
2	16	North	2
3	9	North	3
4	4	North	4
5	14	South	5
6	5	South	6
7	6	South	7

Results of the ANOVA test:

The test statistic (F) is 6.798, df= 6;59, with a significance level, $p < 0.001$. Thus the null hypothesis is rejected ($p < 0.05$) and there are significant differences in the W-statistics among the unmined groups.

A(iii) **Results of the Tukey Test on the W-statistics from the unmined samples.**

Table 4.3: List of significantly different pairs of groups (p< 0.05)

Significantly different group pairs	Description
1-6	Area 1 N - Area 6 S
1-7	Area 1 N - Area 7 S
2-6	Area 2 N - Area 6 S
2-7	Area 2 N - Area 7 S
3-7	Area 3 N - Area 7 S
5-7	Area 5 S - Area 7 S

None of the unmined areas in the North (areas 1-4) is significantly different from any other (and the southern area 5 also groups with these northerly areas). The southern area 5 is not different from area 6 but is different from area 7. Areas 6 and 7 in the south are not different from each other.

Representation of similarities among the sites: 1 2 3 4 5 6 7

The northern areas 1 & 2 are significantly different from the southern areas 6 and 7 (but not different from the southern area 5). The northern area 3 is significantly different from area 7 but not area 6. The northern area 4 is not different from any of the southern areas 5 to 7.

Representation of similarites among the sites: 1 2 3 4 5 6 7

4.2.1B THE NORTHERN AREA: Distinguishing between unmined and mined samples.

B(i) Figure 4.5 is a graphical representation of the northern abundance and biomass data (unmined and mined) plotted as ABC curves.

If one looks at the interaction of the abundance and biomass curves in Figure 4.5, the following can be seen:

ABC Graph 1 depicts the unmined group which might be expected to show undisturbed characteristics, but the ABC curve shows the A curve above the B curve for most of their length. This is interpreted as depicting a disturbed state.

Graphs (2, 3 & 4) depict the three mined groups of the northern area. Graph 2 (just mined 1-3 months ago (ma)) is undisturbed with the B curve above the A curve for the full length, graph 3 (mined 7-9 ma) is disturbed with two crossovers of the A and B curves and graph 4 (mined 15 - 19 ma) is undisturbed with the B curve above the A curve. There therefore appears to be a disturbance and recovery sequence among the mined groups. However, with the unmined group showing disturbance, it is not certain whether the disturbance depicted by the ABC curve in graph 3 (mined 7-9 months ago) is due to mining or some other factor.

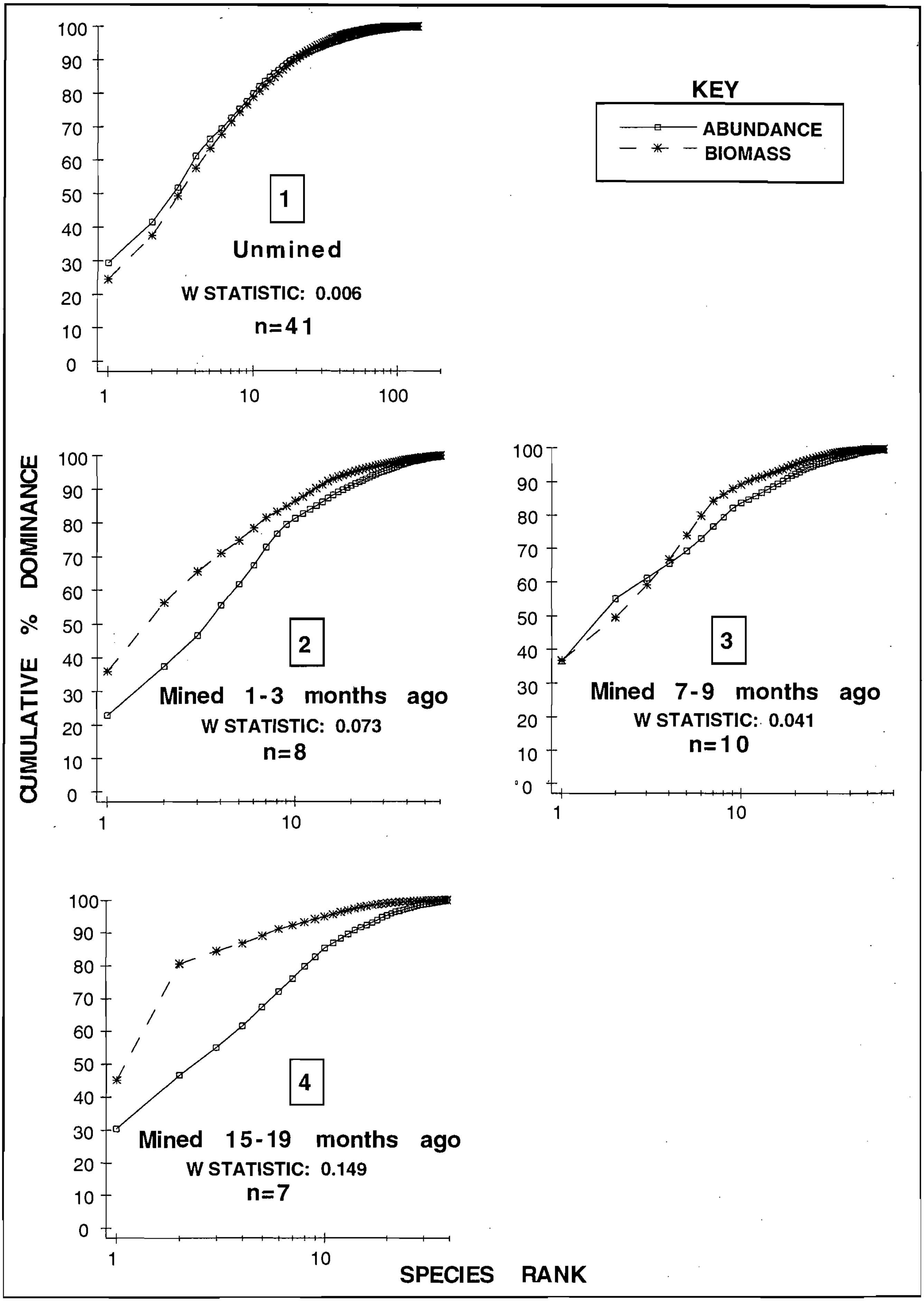


Figure 4.5: NORTHERN AREA: Distributional curves for the unmined and mined sites. n= the number of replicates at each site.

B(ii) ANOVA employed to test for differences in the W-statistic.

The W-statistic for each of the samples in the unmined and mined groups was calculated and analysed in an ANOVA to test the null hypothesis of no differences in the W-statistics among unmined and mined groups in the northern area.

Table 4.4: Key to groups used to test treatments in the North.
N = the number of replicates at each site.

GROUP	N	TREATMENT
1	41	Unmined
2	8	Mined 1-3 months ago
3	10	Mined 7-9 months ago
4	7	Mined 15-19 months ago

Results of the ANOVA test:

The test statistic (F) is 0.562, df= 3;62, with a significance level, $p = 0.642$. Thus the null hypothesis is accepted ($p > 0.05$) and there are no differences among unmined and mined groups in the northern research area.

4.2.1C THE SOUTHERN AREA: (Pentow Salvor cruise 2 data only)

Distinguishing between unmined and mined samples.

C(i) Figure 4.6 is a graphical representation of the southern abundance and biomass data plotted as ABC curves.

Graph 1 is an ideal example of an undisturbed ABC curve for the unmined group. Graphs 2 to 5 (mined groups) all have the disturbed ABC curve configuration (abundance and biomass curves intercept). Graph 3 is the most disturbed with the A curve high above the B curve (the W-statistic is also negative, -0.152). Graph 4 shows a slight recovery to a positive W = 0.020, but graph 5 shows the disturbed state with W = -0.061. This result is difficult to interpret and suggests a possible additional disturbance other than mining.

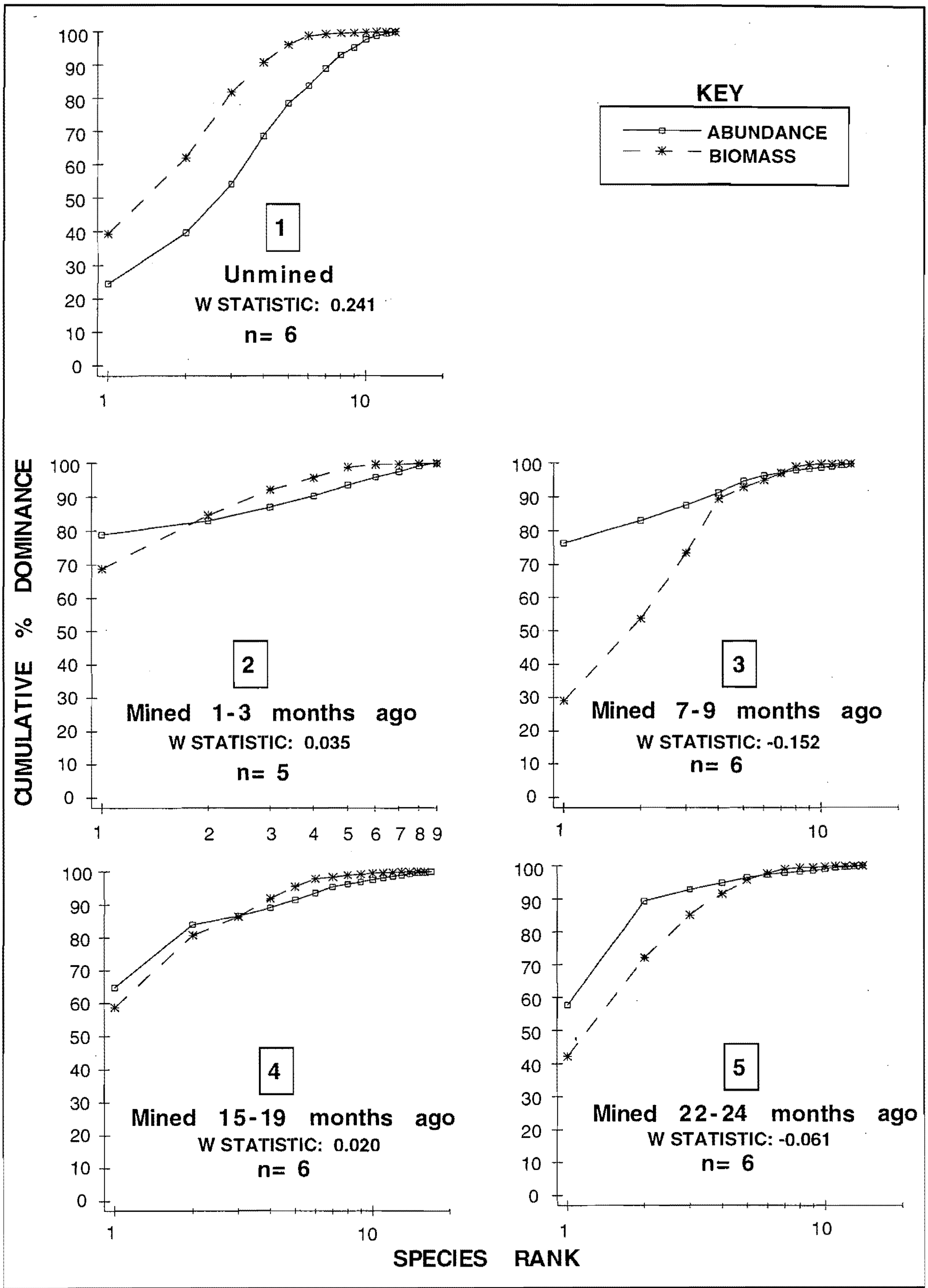


Figure 4.6: SOUTHERN AREA: (Pentow Salvor cruise 2 data only)
Distributional curves for the unmined and mined sites.
n= the number of replicates at each site.

C(ii) ANOVA employed to test for differences in the W-statistic among umined and mined sites in the southern research area.

The W-statistic for each of the samples was calculated and analysed in an ANOVA to test the null hypothesis that there is no difference in W-statistics among unmined and mined groups in the southern research area.

Table 4.5: Key to groups used to test treatments in the southern research area (*Pentow Salvor* 2 data only). N = the number of replicates at each site.

GROUP	N	TREATMENT
1	6	Unmined
2	5	Mined 1-3 months ago
3	6	Mined 7-9 months ago
4	6	Mined 15-19 months ago
5	6	Mined 22-24 months ago

Results of the ANOVA test:

The test statistic (*F*) is 6.146, df= 4;24, with a significance level, $p = 0.002$. Thus the null hypothesis is rejected ($p < 0.05$) and there are significant differences among the unmined and mined groups in the southern area.

C(iii) Results of the Tukey Test on the W-statistics from the southern area.

Table 4.6: List of significantly different pairs of groups ($p < 0.05$)

Signif. dif. group pairs	Description
1-2	unmined vs mined 1-3 months ago
1-3	unmined vs mined 7-9 months ago
1-4	unmined vs mined 15-19 months ago
1-5	unmined vs mined 22-24 months ago

The unmined group is significantly different from all the mined groups (even after 2 years). This unmined group was taken from the southern side of the mined area. It was expected that the prevailing water currents (flowing north to south) would carry significant amounts of sediments to this site thus giving it a slightly disturbed condition. However, according to the results of this Tukey test, this unmined site is significantly different from the mined sites.

None of the mined groups are significantly different from each other. It appears that the fauna becomes replaced in the mined sites by a fauna which is not the same as the fauna in the unmined group.

Representation of similarites among sites: 1 <u>2 3 4 5</u>

4.2.2 ASSESSING STRESS LEVELS - THE W-STATISTIC

The average W-statistics for each site/time group are represented in histograms in Figure 4.7. Note that the values of the W-statistic in these histograms are averages of W-statistics calculated for each replicate sample. In contrast, the values of the W-statistics in Figures 4.4, 4.5 and 4.6 were averages of the raw data calculated by the statistical programme PRIMER.

Fig. 4.7A: The unmined sites:

The average W-statistic is positive (W>0, i.e. undisturbed state) for all the unmined sites from the northern and southern areas. The average W-statistics for some of the sites (1, 2, 3, 5) are closer to zero (neutrality) than for others (sites 4, 6, 7). This pattern of average W-statistics confirms the interpretation of the ABC curves in section 4.2.1Ai, i.e.:

- the northern sites (1, 2 & 3) are different to the southern sites (6 & 7), and
- the northern site 4 is similar to the southern sites 6 and 7.

Fig. 4.7B: The northern area:

The average W-statistics of the unmined and mined groups are all positive (W>0) indicating "undisturbed" characteristics for all the groups. The benthic community does not appear to have been affected by the mining disturbance. This confirms the result in section 4.2.1Bii of an accepted null hypothesis of no differences among unmined and mined groups. The ABC curves (Figure 4.5, section 4.2.1Bi) do, however, show that group 1 (unmined) and group 3 (mined 7-9 months previously) indicate evidence of disturbance.

Fig. 4.7C: The southern area:

There is a marked difference in the average W-statistic between the unmined site and the mined sites. The unmined site has a very positive W-statistic (W= 0.34), while the mined sites have W-statistics very close to zero (neutrality) or a negative W-statistic (group 3: W= -0.051).

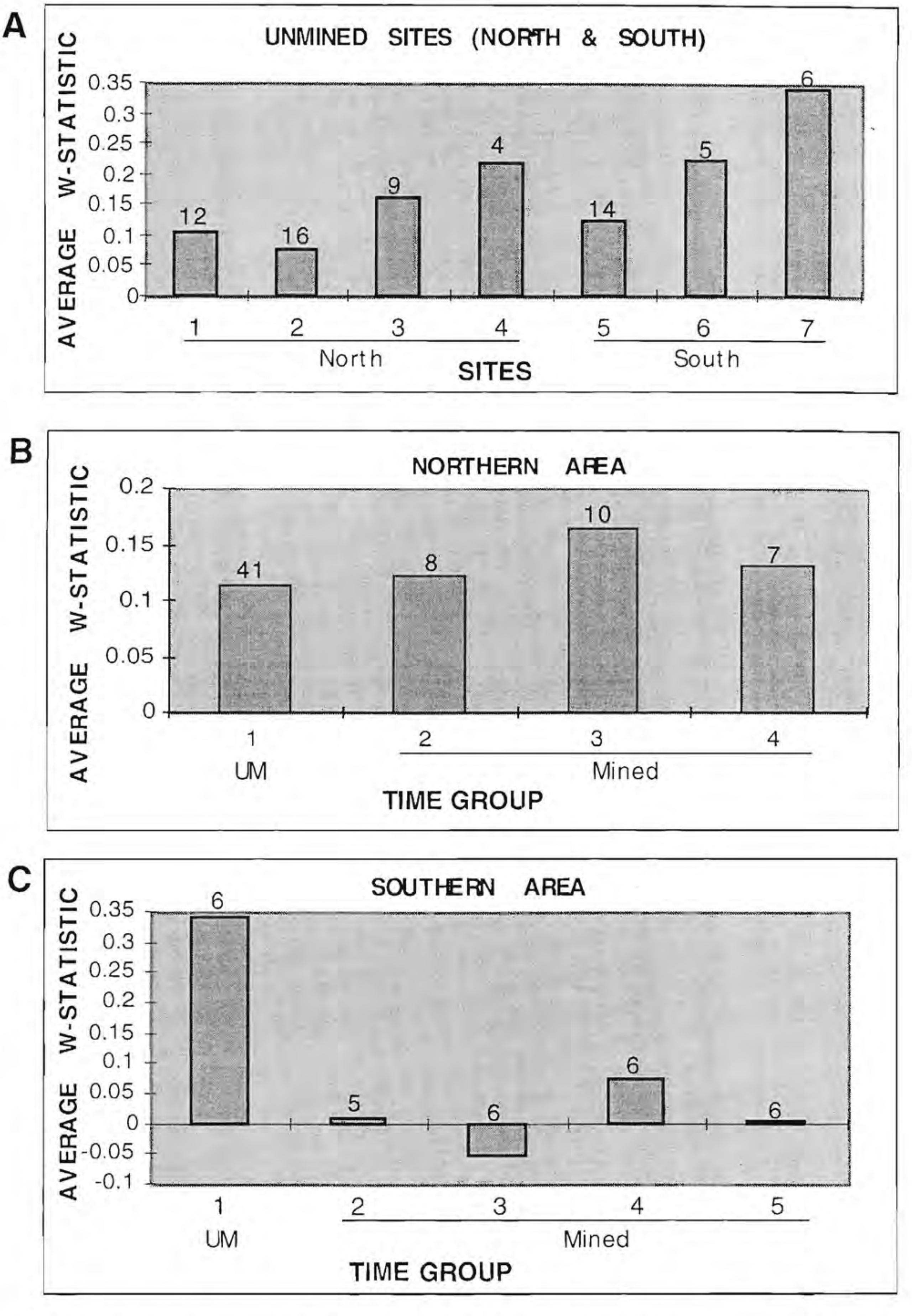


Figure 4.7: Histograms of the average W-statistic for: A) the unmined sites (north and south), B) the northern area (unmined & mined), C) the southern area (unmined & mined). Time group 1= unmined, 2= mined 1-3 monts ago, 3= mined 7-9 months ago, 4= mined 15-19 months ago, and 5= mined 22-24 months ago. n = the number of replicates and is written above the columns.

The average W-statistic for the site mined 15-19 months previously (group 4) shows a marked increase to a positive value (W= 0.075) after the negative W-statistic (W= -0.051) of group 3 (mined 7-9 months previously). The average W-statistic is again reduced almost to zero for group 5 (mined 22-24 months previously). This pattern of negative and positive average W-statistics among the mined groups may indicate that some other disturbance factor besides mining has influenced the benthic community 22-24 months after mining. This result is in concordance with the findings interpreted from the ABC curves in section 4.2.1Ci. The ANOVA and Tukey test (section 4.2.1Cii,iii), however, were only able to distinguish the unmined site from the mined sites.

4.2.3 LINKING THE W-STATISTIC TO ENVIRONMENTAL VARIABLES

4.2.3.1 Correlation tests

The W-statistic has been correlated with three environmental variables, namely; percentage gravel, sand and mud (silt + clay) present in the geological sample for each replicate. These correlations were done for the unmined sites (northern and southern areas), the northern sites (unmined & mined sites) and the southern sites (unmined & mined sites). Table 4.7 summarises the results of the correlation of the W-statistic with each environmental variable. Figures 4.8 to 4.10 give a graphical representation of the correlation between the W-statistic and the percentage gravel, sand and mud environmental variables respectively.

Table 4.7: Results of the correlation of the W-statistic with three environmental variables; percentage gravel, sand and mud.

	Correl. coef. r	No corel. $p>0.05$	Is a corel. $p<0.05$	A strong corel. $p<0.01$
GRAVEL				
UNMINED SITES	0.276	_	p=0.039	_
NORTHERN SITES	0.302	_	p=0.033	_
SOUTHERN SITES	-0.241	p=0.208	_	_
SAND				
UNMINED SITES	-0.505	_	_	p=0.00007
NORTHERN SITES	-0.439	_	_	p=0.001
SOUTHERN SITES	0.162	p=0.401	_	_
MUD				
UNMINED SITES	0.386	_	_	p=0.003
NORTHERN SITES	0.333	_	p=0.018	_
SOUTH	0.060	p=0.744	_	_

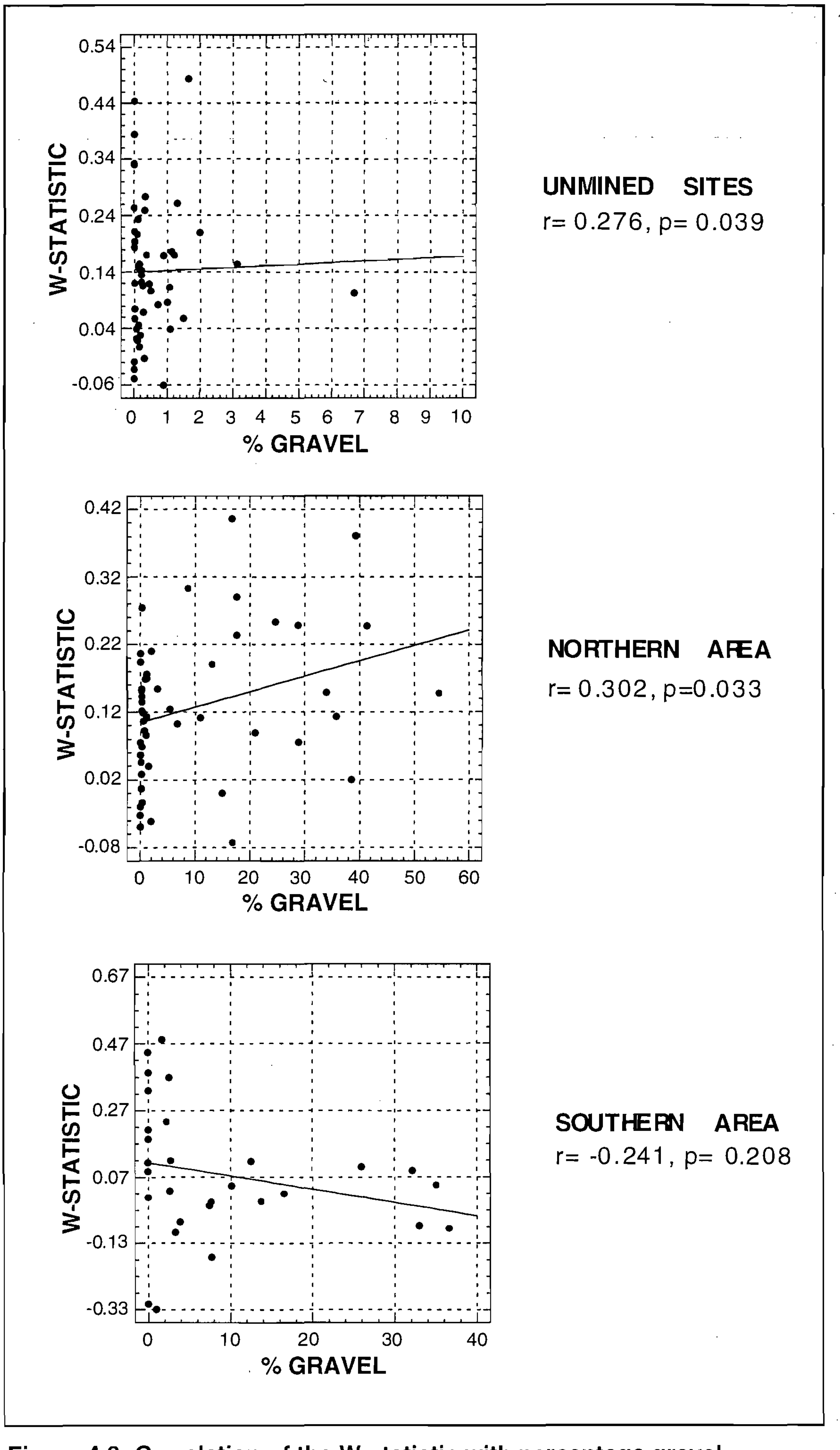


Figure 4.8: Correlation of the W-statistic with percentage gravel.

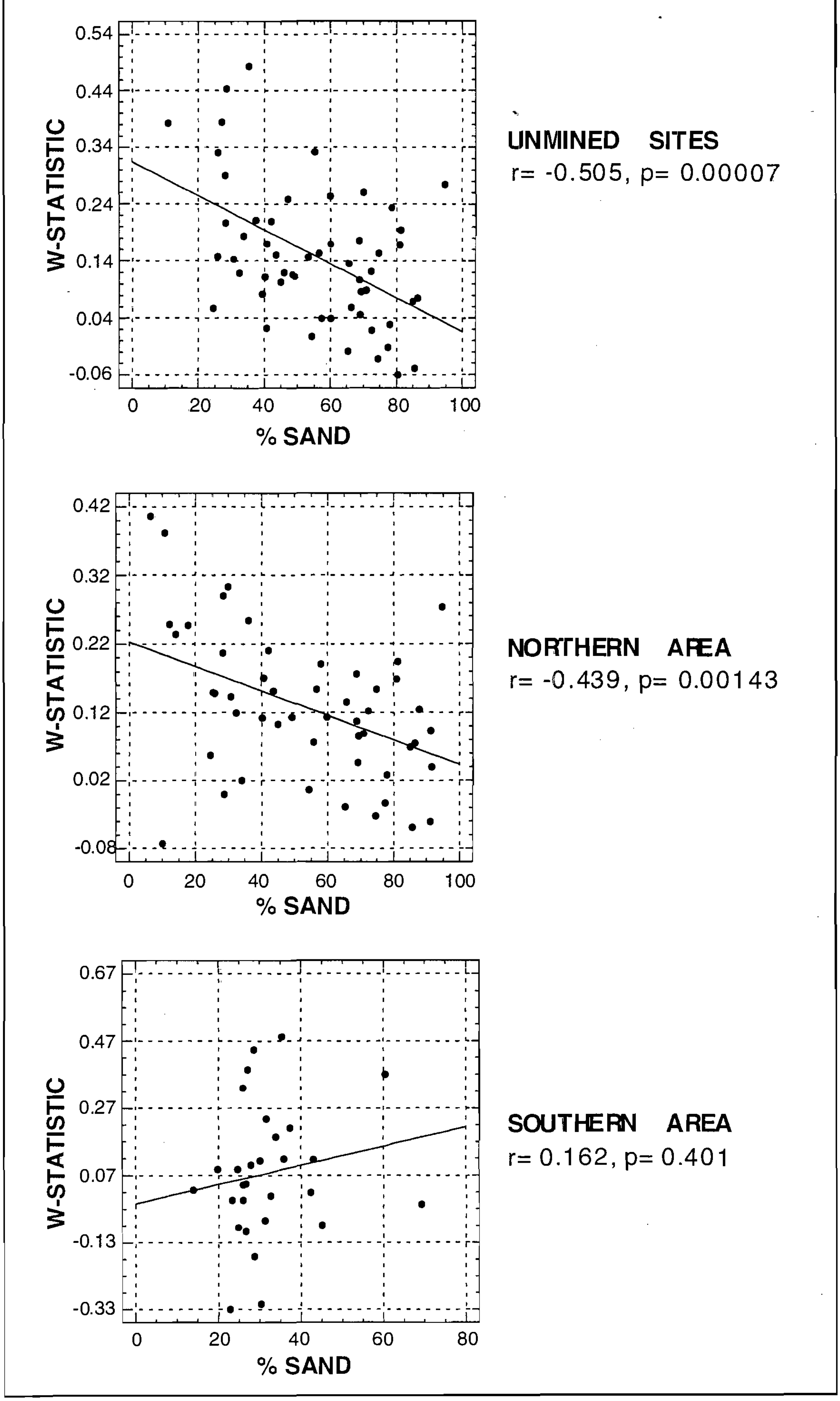


Figure 4.9: Correlation of the W-statistic with percentage sand.

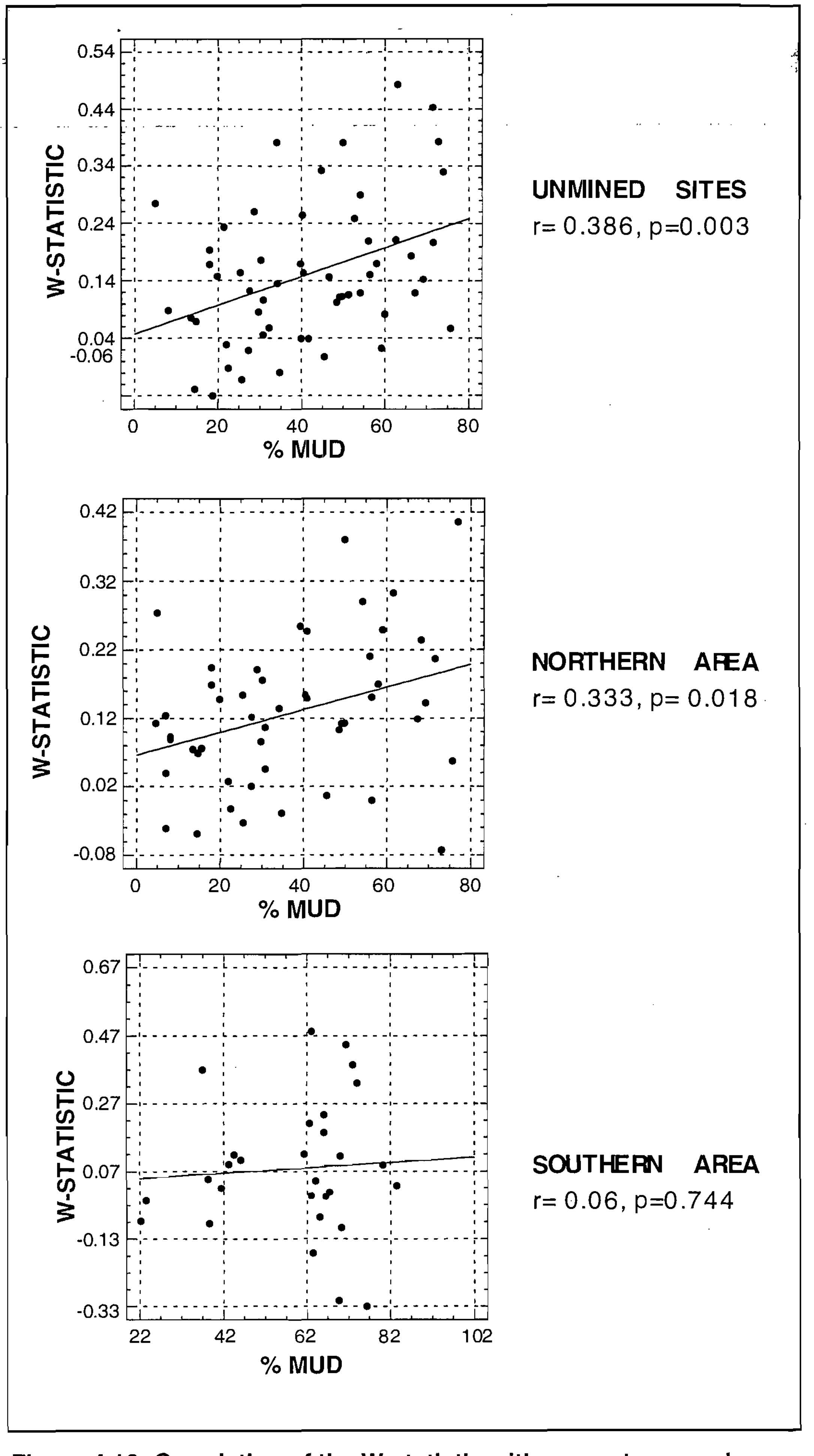


Figure 4.10: Correlation of the W-statistic with percentage mud.

The W-statistics of the **unmined sites** are correlated to all three environmental variables. The W-statistic is strongly negatively correlated with percentage sand (r= -0.505), i.e. as the sand content increases in the sediment, so the W-statistic becomes more negative (disturbed). The W-statistic is positively correlated to percentage gravel and strongly positively correlated with percentage mud, i.e. as the gravel and mud content increase in the sediment, so the W-statistic becomes more positive (undisturbed).

The W-statistics of the **northern area** are correlated to all three variables and is especially strongly negatively correlated with percentage sand (r= -0.439), i.e. as the sand content increases in the sample, so the W-statistic becomes more negative (disturbed). The W-statistic is positively correlated to percentage gravel and percentage mud, i.e. as the gravel and mud content increase in the sediment, so the W-statistic becomes more positive (undisturbed).

There is no correlation of the W-statistics of the **southern area** with any of the environmental variables.

4.2.4 SUMMARY OF RESULTS

4.2.4.1 Distributional (ABC) curves

The ABC curves of the unmined sites distinguished the northern and southern sites from each other (sites 1-3 have different ABC characteristics to sites 6 & 7). The northern site 4 was found to be similar to the southern sites 6 and 7. The southern site 5 was found to be similar to the northern site 1 with a difference of only 0.001 in the value of the W-statistic.

The curves of the northern (Figure 4.5) and southern (Figure 4.6) unmined versus mined sites show sequences of disturbance and recovery among the mined sites. For the northern sites it is uncertain as to whether the disturbance is due to mining or some other factor, as the unmined northern site showed disturbed characteristics. In the southern area the greater disturbance at 22-24 months after mining (after the recovery at 15-19 months after mining) may suggest that some factor, other than mining, is acting on the benthic community. It is speculated that seasonal low O_2 levels in the bottom water (see Chapter 5) may cause such community disturbances.

4.2.4.2 ANOVA and Tukey tests

The statistical analyses (ANOVA and Tukey tests) did not separate the northern and southern unmined sites in the same way as the ABC curves. Only sites 1 & 2 were significantly different from site 6 and sites 1, 2, 3 & 5 were significantly different from site 7.

No significant differences were found among the unmined and mined northern sites. The null hypothesis of the ANOVA was accepted (no differences among sites),
$F= 0.562$, $df= 3; 62$, $p= 0.642$.

From the southern sites only the unmined site was differentiated from the mined sites.

4.2.4.3 Assessing stress levels - the W-statistic

The interpretations of the histograms of the average W-statistic among sites (Figure 4.7) confirmed the interpretations of the ABC curves (Figures 4.4, 4.5 & 4.6) and the statistical analyses (ANOVA and Tukey tests) of the W-statistics.

4.2.4.4 Environmental variables

From the correlation analyses it was found that the W-statistic is negatively correlated to percentage sand and positively correlated to percentage gravel and mud for both the unmined sites (northern and southern areas) and the northern sites (unmined vs mined). That is, the W-statistic is negative (disturbed) when the percentage sand in the sediment of the sample increases and positive (undisturbed) when the percentage gravel or mud increases in the sediment of the sample. This agrees with the description of the undisturbed sediments as being bimodal in character with mud and gravel layers (Rogers (1995), section 2.1 and Figure 2.2).

CHAPTER 5

COMPARISON OF TECHNIQUES

COMPARISON OF UNIVARIATE, DISTRIBUTIONAL AND MULTIVARIATE TECHNIQUES

As mentioned in the introduction to this study (chapter 1) the multivariate ordination and clustering methods preserve taxon-specific information and are generally sensitive in detecting changing community patterns (Warwick *et al.* 1990). The univariate and distributional summaries are species-independent and may extract universal features (e.g. biodiversity) which are not a function of the specific taxa present (Clarke 1990), and may therefore be related to levels of biological "stress". Therefore, the univariate and distributional results may be used to explain patterns in the biotic data found by multivariate analysis, in terms of biological "stress".

In the following sections the data from the southern area seven (*Pentow Salvor* cruise 2) will be used to demonstrate the use of univariate (V-statistic) and distributional (ABC plots and W-statistic) methods to help support and interpret multivariate results.

5.1 IDENTIFYING COMMUNITY DIFFERENCES - MULTIVARIATE ANALYSES

Multivariate cluster analysis (using the Bray-Curtis measure of similarity) and multidimentional scaling (MDS) techniques, group samples together based purely on the biotic data, regardless of any other factors, and without making any assumptions about the nature of the data (Field *et al.* 1982). However, a good set of spatial or temporal control samples is needed for this comparative method. Analyses of the unmined data from the northern and southern areas has indicated that the areas studied are characterised by a heterogeneous environment. For this study six replicates were taken from an apparently unmined, and thus hopefully undisturbed, site to act as the control site.

ANOSIM (Analysis of Similarities)

The abundance data of the southern area seven was grouped into five temporal categories according to time since mining and analysed using the PRIMER programme ANOSIM.

A global R statistic of 0.534 was calculated for the southern research area, rejecting the null hypothesis of "no differences among temporal categories" at a significance level of P< 0.1% (i.e. there is a significant difference in community structure among temporal categories). Results of pairwise tests performed between every pair of temporal categories to assess where the differences lie are presented in Table 5.1. Significant differences were detected between all temporal categories except between those mined 15-19 and 22-24 months ago.

Table 5.1: Results of the one-way ANOSIM pairwise tests for variability between temporal categories, showing the R-statistic. Significant differences (p<0.05) are indicated by *. (m.a refers to "months ago"). Probabilities are not corrected for multiple testing.

SITE COMPARISON	R-VALUE	SIGNIF. LEVEL (P) (%)
Unmined vs Mined (1-3 m.a)	0.901	0.2*
Unmined vs Mined (7-9 m.a)	0.596	0.2*
Unmined vs Mined (15-19 m.a)	0.533	0.2*
Unmined vs Mined (22-24 m.a)	0.828	0.2*
Mined (1-3 m.a) vs Mined (7-9 m.a)	0.291	3.2*
Mined (1-3 m.a) vs Mined (15-19 m.a)	0.563	0.4*
Mined (1-3 m.a) vs Mined (22-24 m.a)	0.755	0.2*
Mined (7-9 m.a) vs Mined (15-19 m.a)	0.191	2.6*
Mined (7-9 m.a) vs Mined (22-24 m.a)	0.550	0.2*
Mined (15-19 m.a) vs Mined (22-24 m.a)	0.207	6.1 (not sign.)

Cluster Analysis of southern area samples

Figure 5.1: A Bray Curtis analysis of root-root transformed data shows two main groups (A & B) and two small groups of outliers at the 50% level of similarity. Group A consists of the unmined samples which cluster close to each other, plus the samples mined 15-19 and 22-24 months ago. Group B consists of the more recently mined samples (i.e. those mined 7-9 months ago) with some samples which were mined 1-3 or 22-24 months ago. Thus there is a clear distinction between the unmined and mined 15-24 months previously, on the one hand, and the more recently mined (1-9 months previously) on the other, with a few outliers.

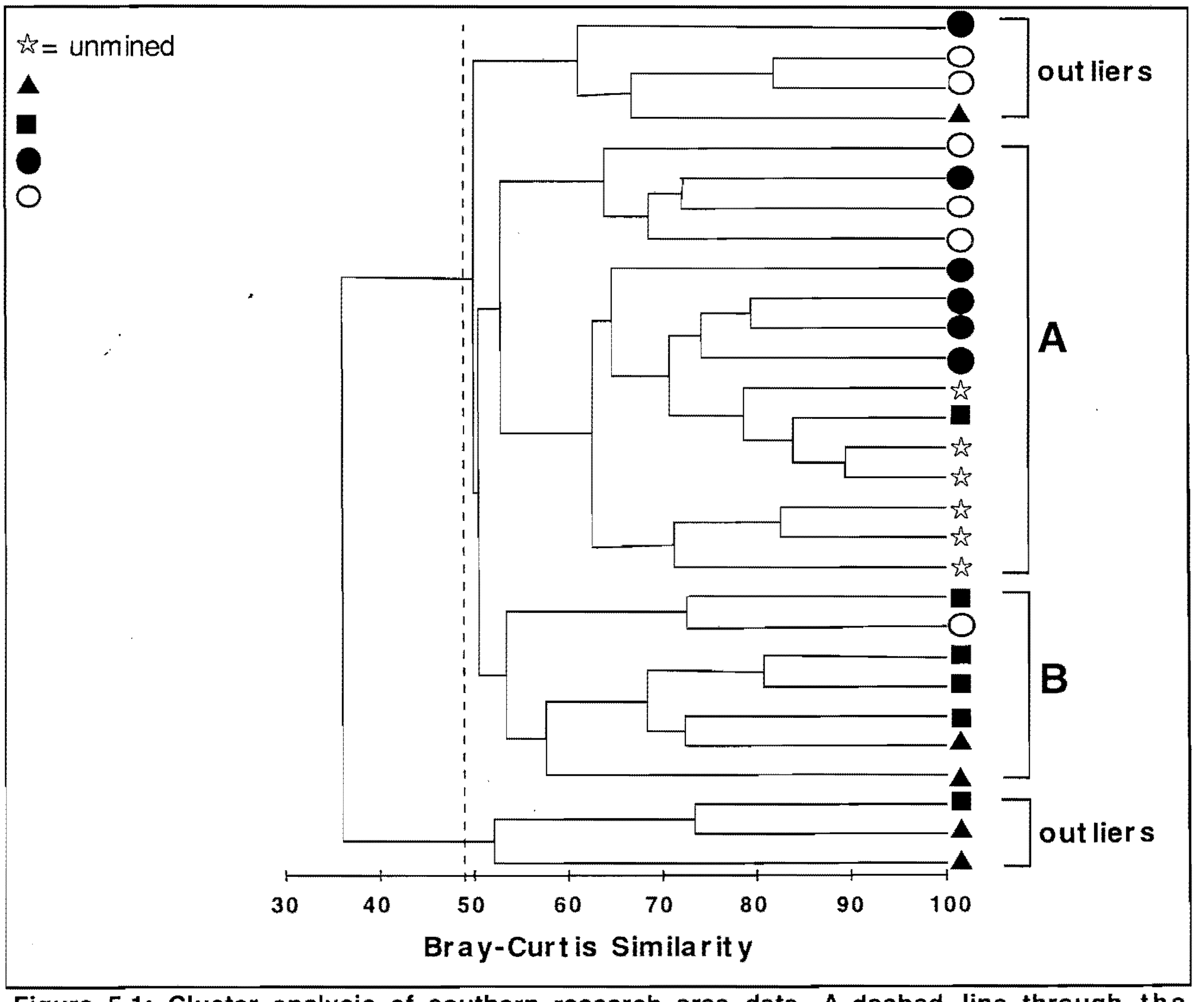


Figure 5.1: Cluster analysis of southern research area data. A dashed line through the 50% similarity level distinguishes 2 main groups (A and B) and 2 groups of outliers.

Multidimentional Scaling (MDS) Ordination of southern area data

In the MDS ordination of the same data there appears to be a clockwise pattern of disturbance and recovery. The unmined samples are located to the left of the plot. The recently mined samples (7-9 months ago) are positioned at the top right of the plot. The most recently mined samples (1-3 months ago) are placed the furthest from the unmined samples on the right of the plot. The samples mined 15-19 and 22-24 months ago are situated towards the bottom centre of the plot. It is interesting to note that the samples mined 15-19 months ago are situated closest to the unmined samples in the clockwise pattern with the samples mined 22-24 months ago below them. The MDS therefore suggests that some factor other than mining influenced the community 22-24 months after mining.

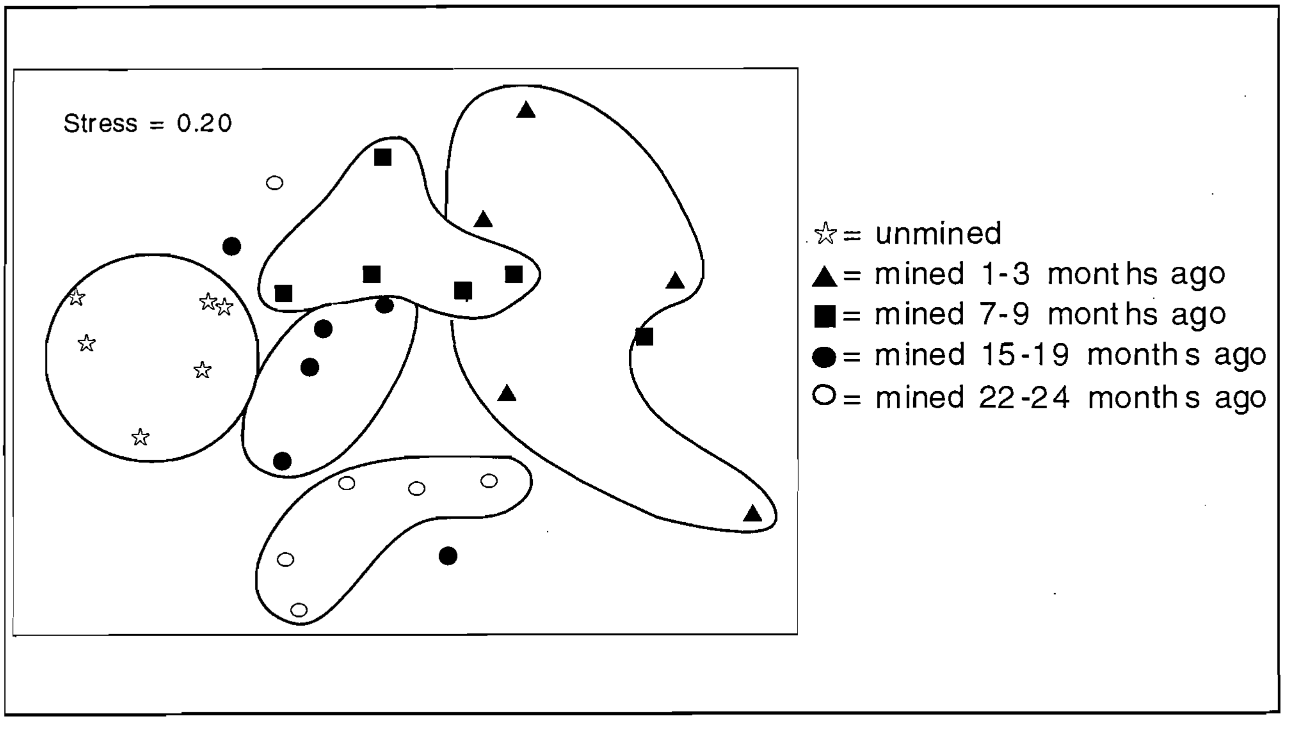


Figure 5.2: MDS plot of southern area data.

There are unexplained biotic patterns in the above multivariate results.

The ANOSIM shows that the categories "mined 15-19 months previously" and "mined 22-24 months previously" are not significantly different from each other and yet in the MDS plot in Figure 5.2 one can see a distinction between the two categories. Also, in the MDS plot, the samples mined 15-19 months previously are closer to the unmined samples than the samples mined 22-24 months previously. Why aren't the samples with the longest recovery time closest to the unmined samples?

The cluster analysis gives a confusing picture of outliers and clusters made up of samples from two or three different temporal categories. Why are samples from different categories clustered together?

There are community changes in the sampling areas over the period sampled, and not all of these can be explained by mining - indeed some appear to be as major as mining disturbances. The multivariate techniques have shown taxon specific community changes (Warwick *et al.* 1990) and give no indication of the cause(s) of the changes shown.

5.2 EVIDENCE FOR DISTURBANCE

Good spatial control samples may be difficult to obtain in a heterogeneous environment. Absolute rather than comparative measures of community degradation, which do not require an extensive temporal or spatial series of control samples, would be valuable in this context. It should be possible to take samples from a site of concern and draw some inferences from them as to whether the community there, is or is not showing signs of stress (Warwick 1993).

Caswell's neutral model (the V-statistic) provides a method by which the community structure at a particular location may be compared with some theoretical expectation of the undisturbed community without the need for a set of extensive spatial or temporal control samples (Warwick 1993) (see section 3.1, "Estimating stress levels").

The ABC plots (including the W-statistic) provide a method in which certain attributes of the structure of the community (species abundance and biomass) respond differently to the effects of disturbance, and can be compared, one acting as an internal control against the other (Warwick 1993). The ABC plots are also based upon an underlying theory of *r*- and *k*-selection (see section 4.1, "Measuring stress levels").

5.2.1 The V-statistic

Figure 5.4 depicts the average V-statistic for the unmined and mined samples from the southern area.

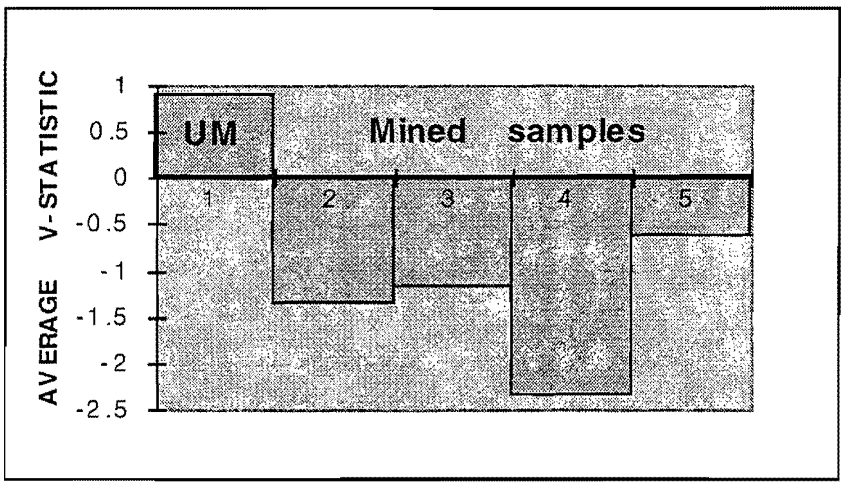


Figure 5.3: Average V-statistics for the unmined and mined samples from the southern area. Key: 1= unmined, 2= mined 1-3 months ago, 3= mined 7-9 months ago, 4= mined 15-19 months ago, 5= mined 22-24 months ago. n= 6 for all sites except site2 where n= 5.

In section 3.2.2.2 a chi-squared test for the southern area showed that the frequencies of the positive or negative V-statistics are related to whether the sample is unmined or mined (the mined samples having more negative V-statistics than the unmined samples). Thus the V-statistic makes a definite distinction between undisturbed and disturbed categories.

In Figure 5.4, the average V-statistic for the unmined category is +0.9 which shows a greater diversity than predicted by Caswell's neutral model but not a significant departure from neutrality (V>+2 is a significant departure). All the mined categories have a negative average V-statistic indicating excessive dominance in the observed disturbed community. That is, disturbance to the community causes a decrease in diversity and a related increase in dominance compared to the predicted neutral values (Caswell 1976).

Category four (mined 15-19 months ago) deviates significantly from neutrality (V= -2.4). This suggests the occurrence of a disturbance, other than mining acting on the benthic community which has reduced the diversity to levels significantly below those predicted by the neutral moedel.

5.2.2 The W-statistic

In section 4.2.1 C the ANOVA and Tukey tests on the W-statistic showed that the unmined category is significantly different from all the mined categories (even after 2 years) (F= 6.146, df= 4;24, p=0.002). The mined categories were found to be not significantly different from one another.

In Figure 5.4 the average W-statistics among unmined and mined categories are as follows:

- an "undisturbed" positive value (0.34) for the unmined category,
- changing to a "disturbed" negative value (-0.051) for the 7-9 months recovery category,
- reverting back to a relatively undisturbed value (0.075) for the 15-19 months recovery category,

- and then again showing a reduced value (0.005) for the category mined 22-24 months ago.

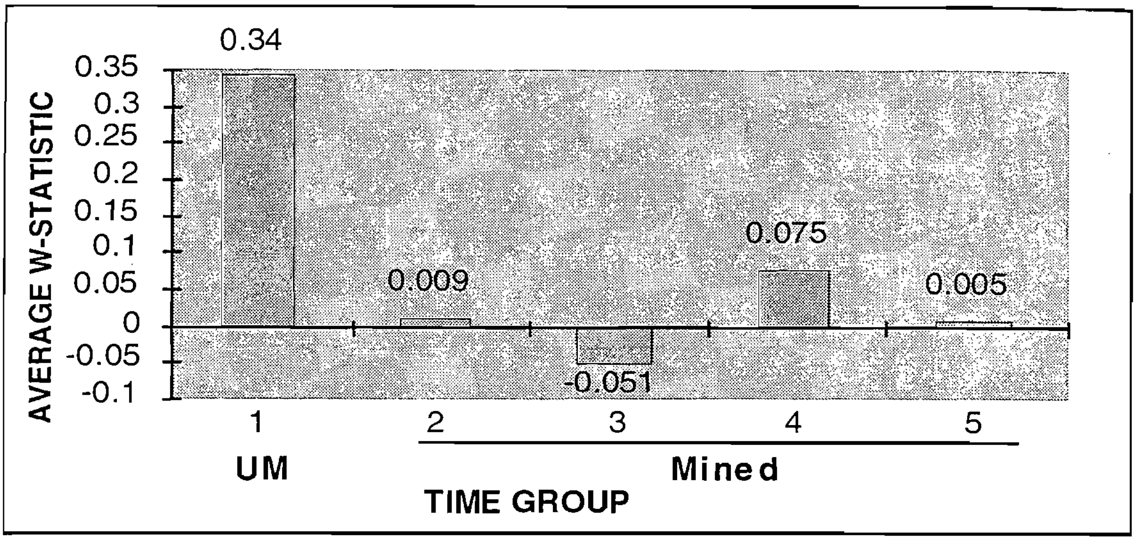


Figure 5.4: Average W-statistic for the unmined and mined categories of the southern data. Key: 1= unmined, 2= mined 1-3 months ago, 3= mined 7-9 months ago, 4= mined 15-19 months ago, 5= mined 22-24 months ago. n= 6 for all sites except site2 where n= 5.

The reduced average W-statistic after 22-24 months again suggests the occurrence of another disturbance besides mining acting on the benthic community.

5.2.3 ABC curves

The ABC plots in Figure 4.6 (section 4.2.1C) depict graphically and complement the disturbance-recovery-disturbance pattern given by the average W-statistics in Figure 5.4. The unmined site has an ideal “undisturbed” ABC curve (B curve above A curve with no cross-overs) and all the mined sites have “disturbed” ABC plots (B and A curves cross). The ABC plots suggest the effects of a disturbance other than mining acting on the benthic community 22-24 months after mining (W= -0.061) after evidence of a recovery at 15-19 months after mining (W= 0.020). The ABC curves therefore also suggest the presence of some disturbance other than mining.

5.3 DISTURBANCE DUE TO MINING ?

The multivariate analyses have shown patterns of community change and partial recovery after mining but do not suggest causality, nor are they based on theory. Also, they are comparative methods which depend on a “good” control sample against which to compare the other samples. Representative control samples may be difficult to obtain in an environment which is characteristically heterogeneous.

Caswell’s neutral model (V-statistic) and the W-statistic and ABC plots have indicated community changes due to the mining disturbance and an additional stress without the need for controls. The V-statistic (Figure 5.3) indicates a significant departure from neutrality 15-19 months after mining. The W-statistic (Figure 5.4) shows a reduced value at 22-24 months after mining and the ABC plot (Figure 4.6, graph 5) shows the abundance curve above the biomass curve 22-24 months after mining.

5.4 OTHER POSSIBLE DISTURBANCES

In the MDS plot of the multivariate analysis (Figure 5.2), the category “mined 15-19 months previously” was situated closer to the unmined category than the category mined 22-24 months ago. The V-statistic, the W-statistic and the ABC curves all show evidence of some disturbance, other than mining, acting on the community after 22-24 months. The V-statistic indicated that the diversity of the samples mined 15-19 months ago deviates significantly from neutrality (V= -2.4), confirming a significant effect.

The samples for this study were all taken at depths of no less than 110 metres. It is unlikely that natural mechanical disturbances (eg. sea storms) would disturb the benthic community at these depths.
Dissolved oxygen monitoring was undertaken in the northern research area (May 1995 to April 1996) (EEU Report No 11/96/158 (1996)). This monitoring indicated periods of very low oxygen levels in the bottom waters. At times the reading reached 0ml O_2/L (Figure 5.5).

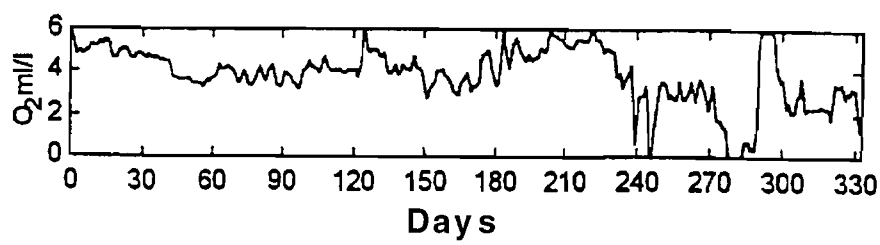


Figure 5.5: Daily dissolved oxygen variability (30 May 95 to 27 April 96) in bottom waters.

It is likely that such periods of hypoxic waters disturb the benthic community. The large *k*-selected species die out due to the lack of oxygen. When the O_2 levels return to tolerable levels small, opportunistic *r*-selected species recolonise the areas. Caswell (1976) suggests that as the community becomes more and more stable, competitive interactions might finally succeed in squeezing out a set of species which previously had existed only marginally, or temporarily because of disturbance. Thus the community again becomes dominated by the large *k*-selected species.

This interaction between the *k*- and *r*-selected species would be reflected in the values of the diversity indices used to describe the benthic community (see Figure 3.5, section 3.2.1.C).

CHAPTER 6

CONCLUSION

CONCLUSION

This study analyses biotic data using univariate and distributional techniques (as absolute measures of disturbance) and then applies the results to explain patterns in the biotic data found by multivariate analyses (comparative methods) of the same data.

Univariate techniques reduce the full set of species abundances for a sample into a single coefficient, for example a diversity index. Distributional techniques form a class of methods which summarise the set of species abundances for a single sample by a curve or histogram. Warwick (1986) suggested that the distribution of numbers and biomass of individuals among species in marine macrobenthic communities show a differential response to disturbance. This response can be clearly demonstrated by the comparison of *k*-dominance curves for abundance and biomass which results in Abundance Biomass Comparison (ABC) curves. Both of these aforementioned techniques are species-independent, which may result in two samples having exactly the same diversity or distributional structure without possessing a single taxon in common. Multivariate ordination or clustering methods preserve taxon-specific information and will generally be rather sensitive in detecting changing community patterns (Warwick *et al.* 1990). Distributional and univariate summaries may, however, hope to extract universal features which are not a function of the specific taxa present, and may therefore be related to levels of biological "stress" (Clarke 1990). The ABC method is not necessarily more sensitive than diversity indices in detecting disturbance, and is certainly less sensitive than multivariate methods in discriminating differences in community structure (Warwick *et al.* 1990, Warwick and Clarke 1991). It does, however, have the advantage of providing an absolute rather than a comparative measure of disturbance, and is based on the theory of *r*- and *k*-selection (Warwick 1993).

The main findings for the six aims of this study are summarised below.

1. To test the hypothesis that there are differences among unmined sites (i.e. natural site-to-site variability) from the northern and southern research areas (sections 3.2.1A and 4.2.1A).

Univariate analysis: The graphical representations of the mean diversity indices (with 95 percent confidence intervals) and statistical testing (ANOVA and Tukey tests) of the indices indicated no north/south differences among the unmined sites. Only site 7 (from a different area to sites 1-6) was indicated as significantly different from all the sites 1-5 but not site 6.

Distributional analysis: The graphical representations (ABC curves) and statistical testing (ANOVA and Tukey tests) of the W-statistic highlighted some differences among the northern and southern unmined sites but suggested no definite north-south distinctions.

2. To test the hypothesis that there are differences between unmined and mined groups in (i) the northern research area (sections 3.2.1B and 4.2.1B) and (ii) the southern research area (sections 3.2.1C and 4.2.1C).

Northern area:

Univariate analysis: The graphs of some indices ('total genera', 'genus richness', 'Shannon diversity') suggested a difference between only the unmined samples and the samples mined 15-19 months previously. The statistical analyses indicated no significant differences between the unmined and mined samples in the northern area. This was interpreted as an indication that some other disturbance (besides mining) may have afffected the northern research area before the mining disturbance.

Distributional analysis: The ABC curves indicated that the unmined site showed characteristics of disturbance (A curve above B curve). The statistical analyses of the W-statistic confirmed no differences between unmined and mined samples in the northern area (both unmined and mined samples showed characteristics of disturbance).

Southern area:

Univariate analysis: The graphs of the mean indices all indicated a clear separation of the unmined site from the mined sites. The graphs of 'total genera' and 'genus richness' indices indicated a recovery in the community 15-19 months after mining followed by a disturbance at 22-24 months after mining. Statistical analyses of the univariate indices indicated significant differences between unmined and mined samples. Statistical analyses of the 'total genera' and 'genus richness' indices confirmed the indication of another disturbance on the community 22-24 months after mining.

Distributional analysis: The ABC curves show an ideal "undisturbed" ABC curve (biomass curve above the abundance curve with no cross-overs) for the unmined site and "disturbed" ABC curves for all the mined sites. Furthermore, the ABC curves suggest the effects of a disturbance other than mining acting on the benthic community 22-24 months after mining (W= -0.061) after evidence of a recovery at 15-19 months after mining (W= 0.020). Analysis of the W-statistic indicates that the unmined site was also statistically differentiated from all the mined sites, but that there were no differences among the mined sites.

3. To compare the observed diversity with predictions from Caswell's neutral model, a univariate technique for assessing stress levels (section 3.2.2).

Frequencies of positive and negative V-statistics show a difference in community diversity between the northern and southern research areas. None of the other analyses of indices or ABC curves have indicated such a definite difference between the northern and southern areas.

For the northern area sites, the frequencies of the V-statistics indicate that both the unmined and mined sites are inclined to negative V-statistics and both therefore have a lower diversity than predicted by Caswell's model. This confirms the results of the statistical analyses of the univariate indices for the northern area (i.e. no differences between the unmined and mined sites).

For the southern area sites the frequencies of positive and negative V-statistics indicated a distinct difference between the unmined and mined sites, the mined sites having a lower diversity than the unmined sites. This confirms the results of the analyses of the indices above.

4. To assess stress levels in the benthic community by interpretation of the value of the W-statistic (a summary statistic of the ABC curves) (section 4.2.2).

The interpretations of the histograms of the average W-statistic among sites (Figure 4.7) confirmed the interpretations of the ABC curves (Figures 4.4, 4.5 & 4.6) and the statistical analyses (ANOVA and Tukey tests). A few differences were indicated among the unmined sites (indicating the heterogeneity of the benthic environment) but no definite north-south distinctions. The northern unmined site shows indications of disturbance before mining and no differences between unmined and mined sites is apparent. In the southern area data, there are significant differences between the unmined and mined sites and there are indications (among the mined sites) of another disturbance (possibly hypoxic water) acting on the community 22 months after mining.

5. To test whether there is a relationship between the sedimentology of the area and the indices (sections 3.2.3 and 4.2.3).

Correlations were used to elucidate relationships between the values of the indices (as indicators of the influence of disturbance on community structure) on the one hand, and the environmental indicators of disturbance (percentage gravel, sand, mud) on the other.

A few significant results were found by correlating the diversity indices with the environmental variables (see section 3.2.3). These significant correlations were mostly from the unmined sites and mostly weak correlations ($p<0.05$). The 'total individuals', 'total genera' and 'evenness' indices had the most significant correlations with sediment parameters but these correlations were found to be uninformative due to the over-condensed nature of the index variables.

Significant correlations were found between the W-statistic and the environmental variables. The W-statistic is negative (disturbed) when the percentage sand in the sediment of the sample increases (characterising a disturbed sample). The W-statistic is positive (undisturbed) when the percentage gravel or mud increases in the sediment of the sample (characterising an undisturbed sample). This agrees with the description of the undisturbed sediments as being bimodal in character with mud and gravel layers (Rogers (1995), section 2.1 and Figure 2.2).

6. To compare the univariate and distributional results obtained in this study with each other and with the results of a multivariate analysis of the same data (Chapter 5).

Multivariate analyses (taxon-specific, comparative methods) have shown that there are differences or discontinuities in the benthic communities, but they do not suggest causality, nor are they based on theory.

The univariate (V-statistic and W-statistic) and distributional (ABC plots) analyses (absolute methods based on the theory of *r*- and *k*-selection), on the other hand, indicated differences due to the mining disturbance and an additional stress (22-24 months after mining) without the need for controls.

Finally, the results of the statistical analyses (ANOVA, Tukey tests and Chi-squared tests) of the diversity indices, the V-statistic and the W-statistic (as a representative of distributional techniques) confirmed that:

- there are some differences among the unmined sites (indicating the heterogeneity of the benthic communities) but no definite north-south distinction in the unmined sites,
- the northern unmined site shows indications of disturbance before mining and no differences between unmined and mined sites are apparent, and
- in the southern area, there are significant differences between the unmined and mined sites and there are indications of another disturbance (possibly hypoxic water) acting on the community 22 months after mining.

Graphical representations of mean diversity indices have indicated change in the benthic community after mining, the mined categories having reduced mean values compared with the unmined category.

The ABC curves have proved to be successful as absolute measures of disturbance in the benthic community. They have:

- provided the easiest identification of differences among the unmined sites (the two curves of each ABC plot acting as an 'internal control' against each other),
- shown that the northern unmined site was a "disturbed" site before mining, and thus explain why no significant differences were found (by statistical analyses) between unmined and mined samples in the northern area, and
- indicated that, in the southern area, there are significant differences between the unmined and mined sites and shown evidence of a disturbance, other than mining, acting on the benthic community 22 months post-mining after initial signs of recovery 15 months post-mining.

The multivariate analyses provided a sensitive, comparative description of biotic differences among sites and between areas, but did not explain any possible causes for these differences or provide a theoretical underpinning which the ABC method and the V- and W-statistics have done. The V-statistic, W-statistic and ABC plots have thus been successful (as absolute indicators of disturbance) in explaining, in terms of biological "stress", the results of multivariate analyses of the same data.

REFERENCES

REFERENCES

Austen, M.C., Warwick, R.M. and Rosado, M.C. (1989). Meiobenthic and macrobenthic community structure along a putative pollution gradient in southern Portugal. *Mar. Pollut. Bull.* 20: 398-405.

Bartlett, M.S. (1937). Some examples of statistical methods of research in agriculture and applied biology. *J. Royal Statist. Soc. Suppl.* 4: 137-170.

Beukema, J.J. (1988). An evaluation of the ABC-method (abundance-biomass comparison) as applied to macrozoobenthic communities living on tidal flats in the Dutch Wadden Sea. *Mar. Biol.* 99: 425-433.

Bilyard, G.R. (1987). The value of benthic infauna in marine pollution monitoring studies. *Mar. Pollut. Bull.* 18: 581-85.

Caswell, H. (1976). Community structure: a neutral model analysis. *Ecol. Monogr.* 46: 327-354.

Clarke, K.R. (1990). Comparison of dominance curves. *J. Exp. Mar. Biol. Ecol.* 138: 143-157.

Clarke, K.R. and Warwick, R.M. (1994). *Change in marine communities: an approach to statistical analysis and interpretation.* Plymouth: Plymouth Marine Laboratory, 144pp.

Connell, J.H. (1978). Diversity in tropical rain forests and coral reefs. *Science* 199: 1302-1310.

Environmental Evaluation Unit (1995). *DBM Deep Sea Diamond Mining - Initial monitoring Report (Phase 2).* EEU Report No. 11/95/143, University of Cape Town. Prepared for De Beers Marine (Pty) Ltd.

Environmental Evaluation Unit (1996). *Impacts of Deep Sea Diamond Mining, in the Atlantic 1 Mining Licence Area in Namibia, on the Natural Systems of the Marine Environment.* EEU Report No. 11/96/158, University of Cape Town. Prepared for De Beers Marine (Pty) Ltd.

Ellis, D. (1985). Taxonomic sufficiency in pollution assessment. *Mar. Pollut. Bull.* 16: 459.

Ewens, W.J. (1972). The sampling theory of selectively neutral alleles. *Theoret. Pop. Biol.* 3: 87-112.

Field, J.G., Clarke, K.R. and Warwick, R.M. (1982). A practical strategy for analysing multispecies distribution patterns. *Mar. Ecol. Prog. Ser.* 8: 37-52.

Goldman, N. and Lambshead, P.J.D. (1989). Optimization of the Ewens/Caswell neutral model program for community diversity analysis. *Mar. Ecol. Prog. Ser.* 50: 255-261.

Gray, J.S., Aschan, M., Carr, M.R., Clarke, K.R., Green, R.H., Pearson, T.H., Rosenberg, R., and Warwick, R.M. (1988). Analysis of community attributes of the benthic macrofauna of Frierfjord/Langesundfjord and in a mesocosm experiment. *Mar. Ecol. Prog. Ser.* 46: 151-165.

Gray, J.S., Clarke, K.R., Warwick, R.M. and Hobbs, G. (1990). Detection of initial effects of pollution on marine benthos: an example from the Ekofisk and Eldfisk oilfields, North Sea. *Mar. Ecol. Prog. Ser.* 66: 285-299.

Heip, C., Warwick, R.M., Carr, M.R., Herman, P.M.J., Huys, R., Smol, N. and van Holsbeke, K. (1988). Analysis of community attributes of the benthic meiofauna of Frierfjord/Langesundfjord. *Mar. Ecol. Prog. Ser.* 46: 171-180.

Huston, M. (1979). A general hypothesis of species diversity. *Am. Nat.* 113: 81-101.

Ibanez, F. and Dauvin, J.C. (1988). Long term changes (1977-1987) in a muddy fine san Abra alba-Melimna palmata community from the Western English Channel: multivariate time-series analysis. *Mar. Ecol. Prog. Ser.* 49: 65-81.

Johnson, C. (1994). *Design and analysis of ecological experiments. Notes for a short course.* Zoology department, University of Cape Town.

Lambshead, P.J. and Platt, H.M. (1988). Analysing disturbance with the Ewens/Caswell neutral model: theoretical review and practical assessment. *Mar. Ecol. Prog. Ser.* 43: 31-41.

Lambshead, P.J., Platt, H.M. and Shaw, K.M. (1983). The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. *J. Nat. Hist.* 17: 859-874.

Mardia, K.V., Kent, J.T. and Bibby, J.M. (1979). *Multivariate Analysis.* Academic Press, London.

Margalef, D.R. (1958). Information theory in Ecology. *General Systems* 3: 36-71.

Mc Manus, J.W. and Pauly, D. (1990). Measuring ecological stress: variations on a theme by R.M. Warwick. *Mar. Biol.* 106: 305-308.

Meire, P.M. and Dereu, J. (1990). Use of the abundance/biomass comparison method for detecting environmental stress: some considerations based on intertidal macrozoobenthos and bird communities. *J. appl. Ecol.* 27: 210-223.

Pielou, E.C. (1974). *Population and Community Ecology:Pprinciples and Methods.* Gordon and Breach, Science Publishers, New York.

Rogers, J. (1995). *Final report to De Beers Marine (Pty) Ltd on the environmental impact of diamond mining on surficial continental-shelf sediments off Southern Namibia.* Report submitted to the Environmental Evaluation Unit, University of Cape Town.

Savage, C. (1996). *Multivariate analyses of the impact of offshore marine mining on the benthic macrofauna off the west coast of Southern Africa.* Unpublished M.Sc. thesis. University of Cape Town.

Savage, C., Field, J.G. and Warwick, R.M. (1999). Comparative analysis of the impact of offshore marine mining on macrobenthic communities versus organic pollution studies using a meta-analysis. *Mar. Ecol. Prog. Ser.* (submitted).

Shannon, C.E. and Weaver, W. (1949). *The Mathematical Theory of Communication.* University of Illinois Press, Urbana.

Tukey, J.W. (1953). *The Problem of Multiple Comparisons.* Department of Statistics, Princeton University. (unpublished).

Van der Merwe, K. (1996). *Assessing the rate of recovery of benthic macrofauna after marine mining off the Namibian coast.* Unpublished M.Sc. thesis. University of Cape Town.

Warwick, R.M. (1986). A new method for detecting pollution effects on marine macrobenthic communities. *Mar. Biol.* 92: 557-562.

Warwick, R.M. (1988). The level of taxonomic discrimination required to detect pollution effects on marine benthic communities. *Mar. Pollut. Bull.* 19: 259-268.

Wawick, R.M. (1993). Environmental impact studies on marine communities: Pragmatical considerations. *Aust. J. Ecol.* 18: 63-80.

Warwick, R.M. and Clarke, K.R. (1991). A comparison of some methods for analysing changes in benthic community structure. *J. Mar. Biol. Assoc. U.K.* 71:225-244.

Warwick, R.M. and Clarke, K.R. (1994). Relearning the ABC: taxonomic changes and abundance/biomass relationships in disturbed benthic communities. *Mar. Biol.* 118: 739-744.

Warwick, R.M., Pearson, T.H. and Ruswahyuni (1987). Detection of pollution effects on marine macrobenthos: further evaluation of the species abundance-biomass method. *Mar. Biol.* 95: 193-200.

Warwick, R.M., Platt, H.M., Clarke, K.R., Agard, J. and Gobin, J. (1990). Analysis of macrobenthic and meiobenthic community structure in relationto polllution and disturbance in Hamilton Harbour, Bermuda. *J. Exp. Mar. Biol. Ecol.* 138: 119-142.

Weston, D.P. (1990). Quantitative examination of macrobenthic community changes along an organic enrichment gradient. *Mar.Ecol. Prog. Ser.* 61: 233-244.

Zar, J.H. (1984). *Biostatistical Analysis (second edition).* Prentice-Hall International, Inc., New Jersey.

APPENDICES

APPENDIX I

Abundance Data

MACROFAUNA ABUNDANCE DATA FOR ALL SAMPLES

FROM THE NORTHERN RESEARCH AREA

TAXA	R1.1	R1.2	R1.3	R1.4	R1.5	R1.6	R1.7	R1.8
PHYLUM PORIFERA								
Porifera A					1			
PHYLUM CNIDARIA								
Scyphozoa A								
Anthozoa A								
Anthozoa B								
Anthozoa D								
PHYLUM NEMERTEA								
Cerebratulus spp.		2	8				5	1
Lineus spp.		2						
Nemertea B								
Nemertea C					1		1	
Nemertea D								
Siphunculid A								
Siphunculid B								
PHYLUM ANNELIDA								
Lumbrineris spp.	15	20	35	6	27	36	48	34
Arabella spp.	1	1		2			1	
Diopatra spp.			2	2	1			1
Glyceridae							1	
Nereidae								
Nereis spp.	2					1		
Perinereis/Pseudonereis spp.								
Nephtys spp.	2	1	1		1			9
Spionidae								
Prionospio pinnata	68	35	39	29	47	47	116	19
Spio spp.								
Spiophanes spp.			4					
Laonice cirrata			2		2	3	8	
Spionid O								3
Spionid P								
Polydora spp.				1				
Orbiniidae		4	11		15			4
Haploscoloplos spp.						19	20	
Scoloplos spp.								
Phylo spp.		1	4	2			1	
Naineris spp.								
Orbiniidae B								
Orbinia angrapaquensis						1		
Poly BB								
Poly WW								
Paraonidae			2					

TAXA	R1.1	R1.2	R1.3	R1.4	R1.5	R1.6	R1.7	R1.8
Cirrophorus branchiatus				3				
Ophelia spp.	5							
Capitellidae spp. (heteromastus)								
Notomastus spp.	1							
Maldanidae		5	48				6	62
Maldaninae A					14			
Maldaninae B				2				
Euclymene luderitziana				5			19	
Petaloproctus spp.				1				
Rhodine gracilior								
Sabellides spp.	2							
Ampharetidae		4						
Amphicteis gunneri			5			6	1	
Ampharete spp. A								
Terebellidae			1					
Trichobranchus glacialis								
Terebellides spp.	3				2			
Amaeana trilobata/Polycirrus								
Flabelligera spp.								
Pectinariidae								19
Poly UU								
PHYLUM ARTHROPODA								
Copepoda A								
Myodocopa								
Isopod A								
Arcturidae								
Arcturidae A			1					
Arcturid B						1		
Arcturid C								
Arcturid D							1	
Cirolana spp.								
Microarcturus quadriconus								
New amphipod								
Ampelisca spp.	3	7	7	1	7	10	5	15
Aoro kergeuleni								
Aorcho delgadus		2				1		
Corophiid A (Gammaropsis)				1			1	
Corophiid Q								
Atylus swammerdamei								
Guernea rhomba								
Paramoera capensis								
Maera spp.								
Urothoe spp.	1	1					1	
Leucothoe spp.			1					
Acidostoma obesum					2			
Hippomedon longimanus	23	17	21	22	24	23	28	3
Euonyx biscayensis								

TAXA	R1.1	R1.2	R1.3	R1.4	R1.5	R1.6	R1.7	R1.8
Socarnopsis crenulata								
Monoculodopsis longimana								
Oediceroides cinderella								
Perioculodes spp.								1
Westwoodilla manta								
Paraphoxus oculatus							1	
Platyischnopus herdmani								
Podocerus brasiliensis								
Podoceropsis sophiae								
Eupariambus fallax		1	2				1	
Phtisca marina					1			
Hyperiidae					2			
Hyperiid B								
Ingolfiellid A			1					
Ingolfiellid B								
Ingolfiellid C						1		
Cumacea A					1			
Cumacea B								
Cumacea C								
Leptostraca A								
Pterygosquilla armata								
Stomatopoda B								
Stomatopod juvenile								
Mysidacea spp.								
Gastrosaccus psammodytes					1			
ORDER EUPHAUSIACEA	5	1	2		2	3	1	6
Penaeid A								
Penaeid B								
Penaeid C								
Carida B								
Carida C (Mysidaea)		1						
Carida F			1					
Anomura								
Calocaris barnardi			1					
Callianassa spp.	2		6		2	1		5
Anomura A								
Goneplax angulata	1	2	1	4	5		1	3
Mursia cristimanus		1						
Brachyura A								
Brachyura B								
Brachyura C					1			
PHYLUM BRACHIOPODA								
Terebratulina meridionalis								
PHYLUM MOLLUSCA								
Ischnochiton bergoti				2				
Macoma spp.	2	8	18	4	29		11	8
Tellina spp.	1							

TAXA	R1.1	R1.2	R1.3	R1.4	R1.5	R1.6	R1.7	R1.8
Dosinia spp.	2	3	2		8	5	4	3
Nucula nucleus				1				
Bivalve F								
Bivalve M								
Alvania fenestrata								
Bullia digitalis								
Charitodoron euphrosyne								
Epitonium kraussi			1					
Gibbula spp.								
Heliacus variegata								
Marginella spp.		7	2		1	2		1
Melanella sp.								
Nassarius spp.		6	3		5	1	1	1
Natica tecta								
Ocenebra spp.								
Protomella capensis								
Pyramidella spp.								
Solariella agulhasensis								
Tricolia capensis			1		2		3	
Triphora africana								
Turris spp.								
Turritella spp.								
Volutocorbis abyssicola								
V olvarina capensis								
Sepia spp.								
Cucumaria spp.								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta					1			
Henricia spp.								

TAXA	R1.9	R1.10	R1.11	R2.1	R2.2	R2.3	R2.4	R2.5	R2.6
PHYLUM PORIFERA									
Porifera A									
PHYLUM CNIDARIA									
Scyphozoa A									
Anthozoa A						1			
Anthozoa B									
Anthozoa D									
PHYLUM NEMERTEA									
Cerebratulus spp.				1	2			1	
Lineus spp.		5						1	
Nemertea B									
Nemertea C					3				
Nemertea D									
Siphunculid A									
Siphunculid B									
PHYLUM ANNELIDA									
Lumbrineris spp.	33	25	31	57	24	8	33	61	24
Arabella spp.									
Diopatra spp.				1		1			1
Glyceridae									
Nereidae				1	1				
Nereis spp.									
Perinereis/Pseudonereis spp.									
Nephtys spp.		2		1	2	1			1
Spionidae									
Prionospio pinnata	39	9	77	123	98	38	112	83	148
Spio spp.									
Spiophanes spp.									
Laonice cirrata	8		1	14					7
Spionid O						1		7	
Spionid P									
Polydora spp.									
Orbiniidae		13		19	14		17		
Haploscoloplos spp.	11		6			11			20
Scoloplos spp.							1		
Phylo spp.		1							1
Naineris spp.									
Orbiniidae B								14	
Orbinia angrapaquensis									
Poly BB						1			
Poly WW									
Paraonidae									
Cirrophorus branchiatus									
Ophelia spp.									
Capitellidae spp.									
Notomastus spp.					1				
Maldanidae		51	8	1	2		2		

TAXA	R1.9	R1.10	R1.11	R2.1	R2.2	R2.3	R2.4	R2.5	R2.6
Maldaninae A									
Maldaninae B									
Euclymene luderitziana	19								
Petaloproctus spp.									
Rhodine gracilior									
Sabellides spp.									
Ampharetidae									
Amphicteis gunneri	1	11	1						
Ampharete spp. A									
Terebellidae					1		1		
Trichobranchus glacialis									
Terebellides spp.				2		3	2		
Amaeana trilobata/Polycirrus									2
Flabelligera spp.								1	
Pectinariidae									
Poly UU									
PHYLUM ARTHROPODA									
Copepoda A									
Myodocopa									
Isopod A									
Arcturidae									
Arcturidae A			2						
Arcturid B									
Arcturid C									
Arcturid D									
Cirolana spp.									
Microarcturus quadriconus									
New amphipod									
Ampelisca spp.	3	6	4	51	12	7	27	43	24
Aoro kergeuleni									
Aorcho delgadus									
Corophiid A (Gammaropsis)					1			2	
Corophiid Q									
Atylus swammerdamei									
Guernea rhomba									
Paramoera capensis								4	
Maera spp.				1	1				
Urothoe spp.	1	3	1		1				1
Leucothoe spp.			1					3	1
Acidostoma obesum					1				
Hippomedon longimanus	8	15	19	6	17	2	11		4
Euonyx biscayensis									
Socarnopsis crenulata									
Monoculodopsis longimana									
Oediceroides cinderella			1						
Perioculodes spp.									
Westwoodilla manta	1			1			3		

TAXA	R1.9	R1.10	R1.11	R2.1	R2.2	R2.3	R2.4	R2.5	R2.6
Paraphoxus oculatus	1								
Platyischnopus herdmani									
Podocerus brasiliensis									
Podoceropsis sophiae									
Eupariambus fallax									
Phtisca marina									
Hyperiidae	1					1		1	
Hyperiid B									
Ingolfiellid A		1		1	1				
Ingolfiellid B						1			
Ingolfiellid C									
Cumacea A			1				1	2	
Cumacea B									
Cumacea C									
Leptostraca A								1	
Pterygosquilla armata									
Stomatopoda B									
Stomatopod juvenile							1		
Mysidacea spp.									
Gastrosaccus psammodytes									
ORDER EUPHAUSIACEA	2	2		1			2	10	3
Penaeid A									
Penaeid B									
Penaeid C									
Carida B					10				
Carida C (Mysidaea)									
Carida F									
Anomura									
Calocaris barnardi		8							
Callianassa spp.			6	2	3	2	1		4
Anomura A					1	3	1	2	
Goneplax angulata	2	3		10	2	5	5	6	7
Mursia cristimanus			1						
Brachyura A									
Brachyura B									
Brachyura C									1
PHYLUM BRACHIOPODA									
Terebratulina meridionalis									
PHYLUM MOLLUSCA									
Ischnochiton bergoti									
Macoma spp.	10	9	4	2	16	37	12	3	22
Tellina spp.		1		1			1		
Dosinia spp.	4	2	5	6	2	2		2	1
Nucula nucleus									
Bivalve F							1		1
Bivalve M									
Alvania fenestrata									

TAXA	R1.9	R1.10	R1.11	R2.1	R2.2	R2.3	R2.4	R2.5	R2.6
Bullia digitalis									
Charitodoron euphrosyne									
Epitonium kraussi									
Gibbula spp.									
Heliacus variegata					1				
Marginella spp.				5	6			12	
Melanella sp.									
Nassarius spp.		3	1	9	8		1		
Natica tecta									
Ocenebra spp.									
Protomella capensis									
Pyramidella spp.									
Solariella agulhasensis									
Tricolia capensis									
Triphora africana									
Turris spp.					1				
Turritella spp.									
Volutocorbis abyssicola									
V olvarina capensis									
Sepia spp.									
Cucumaria spp.									
PHYLUM ECHINODERMATA									
Amphipholis squamata									
Ophionereis porrecta		1							
Henricia spp.									

TAXA	R2.7	R2.8	R2.9	R2.10	R3.1	R3.2	R3.3	R3.4	R3.5
PHYLUM PORIFERA									
Porifera A									
PHYLUM CNIDARIA									
Scyphozoa A			1						
Anthozoa A									4
Anthozoa B							1		
Anthozoa D					1				
PHYLUM NEMERTEA									
Cerebratulus spp.		4			1				
Lineus spp.									
Nemertea B									
Nemertea C		2							
Nemertea D					1				
Siphunculid A					3				
Siphunculid B					1				
PHYLUM ANNELIDA									
Lumbrineris spp.	28	18	8	37	25	1	11		
Arabella spp.	1	6							1
Diopatra spp.	1	1							
Glyceridae									
Nereidae									
Nereis spp.									
Perinereis/Pseudonereis spp.									
Nephtys spp.	1	3			8				
Spionidae									
Prionospio pinnata	125	105	5	70	2		32	1	1
Spio spp.		1					1		
Spiophanes spp.	13						1		
Laonice cirrata	11			2	1		2		
Spionid O									
Spionid P	1								
Polydora spp.									
Orbiniidae	3			15	3				
Haploscoloplos spp.	21	12	4						
Scoloplos spp.	1								
Phylo spp.									1
Naineris spp.									
Orbiniidae B					1				
Orbinia angrapaquensis									
Poly BB									
Poly WW									
Paraonidae	1								
Cirrophorus branchiatus									
Ophelia spp.							3		
Capitellidae spp.									
Notomastus spp.	7	3				1			
Maldanidae									

TAXA	R2.7	R2.8	R2.9	R2.10	R3.1	R3.2	R3.3	R3.4	R3.5
Maldaninae A									
Maldaninae B									
Euclymene luderitziana	4								
Petaloproctus spp.									
Rhodine gracilior									
Sabellides spp.									
Ampharetidae								1	
Amphicteis gunneri									
Ampharete spp. A									
Terebellidae									
Trichobranchus glacialis									
Terebellides spp.	2	1		16	3		6		2
Amaeana trilobata/Polycirrus		4							
Flabelligera spp.									
Pectinariidae									
Poly UU	2								
PHYLUM ARTHROPODA									
Copepoda A									
Myodocopa			1						
Isopod A									
Arcturidae									
Arcturidae A	2	1							
Arcturid B									
Arcturid C		1							
Arcturid D									
Cirolana spp.		2					2	3	
Microarcturus quadriconus									
New amphipod					1				
Ampelisca spp.	45	36	3	48	5		9	5	
Aoro kergeuleni	1								
Aorcho delgadus		1	15				1		
Corophiid A (Gammaropsis)									
Corophiid Q	1								
Atylus swammerdamei									
Guernea rhomba									
Paramoera capensis									
Maera spp.									
Urothoe spp.		1							
Leucothoe spp.		1		1	2				
Acidostoma obesum		1	4					146	
Hippomedon longimanus	16	15	1		19				
Euonyx biscayensis									
Socarnopsis crenulata									
Monoculodopsis longimana									
Oediceroides cinderella			1						
Perioculodes spp.				1					
Westwoodilla manta									

TAXA	R2.7	R2.8	R2.9	R2.10	R3.1	R3.2	R3.3	R3.4	R3.5
Paraphoxus oculatus	3	2							
Platyischnopus herdmani		1							
Podocerus brasiliensis				1					
Podoceropsis sophiae			1						
Eupariambus fallax									
Phtisca marina		1							
Hyperiidae		3		1				1	
Hyperiid B									
Ingolfiellid A		1							
Ingolfiellid B									
Ingolfiellid C									
Cumacea A		1							
Cumacea B									
Cumacea C									
Leptostraca A									
Pterygosquilla armata									
Stomatopoda B									
Stomatopod juvenile									
Mysidacea spp.									
Gastrosaccus psammodytes									
ORDER EUPHAUSIACEA	9	6	9	1	2		1	4	
Penaeid A									
Penaeid B									
Penaeid C									
Carida B		4		1			1	1	
Carida C (Mysidaea)		1							
Carida F									
Anomura									
Calocaris barnardi									
Callianassa spp.	4	3		1					
Anomura A	1			1	2	1	9	1	2
Goneplax angulata	8	4	1	10	11	2	1	12	
Mursia cristimanus									
Brachyura A									1
Brachyura B									
Brachyura C									
PHYLUM BRACHIOPODA									
Terebratulina meridionalis			2						
PHYLUM MOLLUSCA									
Ischnochiton bergoti									
Macoma spp.	1	13		22	137	1	2		
Tellina spp.									
Dosinia spp.	2	3		1	5		1		
Nucula nucleus									
Bivalve F		1	1	1	3				
Bivalve M									
Alvania fenestrata									

TAXA	R2.7	R2.8	R2.9	R2.10	R3.1	R3.2	R3.3	R3.4	R3.5
Bullia digitalis									
Charitodoron euphrosyne									
Epitonium kraussi									
Gibbula spp.									
Heliacus variegata				1					
Marginella spp.		17	2	3	5	4	10	2	
Melanella sp.									
Nassarius spp.		22	1	5	21	5	1	10	
Natica tecta		1							
Ocenebra spp.									
Protomella capensis									
Pyramidella spp.					1				
Solariella agulhasensis					1				
Tricolia capensis					4	1			
Triphora africana					1				
Turris spp.									
Turritella spp.		1							
Volutocorbis abyssicola									
V olvarina capensis									
Sepia spp.									
Cucumaria spp.									
PHYLUM ECHINODERMATA									
Amphipholis squamata									
Ophionereis porrecta							1		
Henricia spp.									

TAXA	R3.6	R3.7	R3.8	R3.9	R3.10	R4.1	R4.2	R4.3	R4.4
PHYLUM PORIFERA									
Porifera A									
PHYLUM CNIDARIA									
Scyphozoa A									
Anthozoa A			4						
Anthozoa B			1						
Anthozoa D									
PHYLUM NEMERTEA									
Cerebratulus spp.	4		1		1				
Lineus spp.									
Nemertea B								1	
Nemertea C			1						
Nemertea D									
Siphunculid A									
Siphunculid B									
PHYLUM ANNELIDA									
Lumbrineris spp.	41	5	27	12	13	6	1	19	7
Arabella spp.									1
Diopatra spp.									
Glyceridae									
Nereidae									
Nereis spp.				1	1				
Perinereis/Pseudonereis spp.									
Nephtys spp.			5	7	4		1	5	9
Spionidae									
Prionospio pinnata	17	13	89	50	43	28	1	41	35
Spio spp.									
Spiophanes spp.									
Laonice cirrata	16		6	4		1		2	
Spionid O									
Spionid P									
Polydora spp.									
Orbiniidae	11		27						
Haploscoloplos spp.		2	1	8	7	1		6	
Scoloplos spp.									
Phylo spp.									
Naineris spp.									
Orbiniidae B									
Orbinia angrapaquensis									
Poly BB									
Poly WW									
Paraonidae									
Cirrophorus branchiatus									
Ophelia spp.									
Capitellidae spp.									
Notomastus spp.									
Maldanidae									

TAXA	R3.6	R3.7	R3.8	R3.9	R3.10	R4.1	R4.2	R4.3	R4.4
Maldaninae A									
Maldaninae B									
Euclymene luderitziana					14				
Petaloproctus spp.	1								
Rhodine gracilior									
Sabellides spp.									
Ampharetidae									
Amphicteis gunneri	2		4						
Ampharete spp. A									
Terebellidae									
Trichobranchus glacialis									
Terebellides spp.	5	2	2	1	4	1	1	4	
Amaeana trilobata/Polycirrus									
Flabelligera spp.									
Pectinariidae									
Poly UU									
PHYLUM ARTHROPODA									
Copepoda A				1					
Myodocopa									
Isopod A								1	
Arcturidae	2								
Arcturidae A									
Arcturid B									
Arcturid C									
Arcturid D									
Cirolana spp.									
Microarcturus quadriconus						2			
New amphipod									
Ampelisca spp.	77		22	26	27	28		34	3
Aoro kergeuleni									
Aorcho delgadus	8								
Corophiid A (Gammaropsis)									
Corophiid Q									
Atylus swammerdamei						1			3
Guernea rhomba						1			
Paramoera capensis									
Maera spp.									
Urothoe spp.									
Leucothoe spp.	8		1		1				
Acidostoma obesum			1	1			3		
Hippomedon longimanus	1		14	7	18				4
Euonyx biscayensis									
Socarnopsis crenulata									
Monoculodopsis longimana						1			
Oediceroides cinderella									
Perioculodes spp.			1						
Westwoodilla manta			1					2	

TAXA	R3.6	R3.7	R3.8	R3.9	R3.10	R4.1	R4.2	R4.3	R4.4
Paraphoxus oculatus				1	1				
Platyischnopus herdmani									
Podocerus brasiliensis									
Podoceropsis sophiae									
Eupariambus fallax									
Phtisca marina	1								
Hyperiidae	1		4	1		1		1	
Hyperiid B									
Ingolfiellid A									
Ingolfiellid B									
Ingolfiellid C									
Cumacea A									
Cumacea B									
Cumacea C									
Leptostraca A									
Pterygosquilla armata									
Stomatopoda B					1				
Stomatopod juvenile									
Mysidacea spp.									
Gastrosaccus psammodytes									
ORDER EUPHAUSIACEA	5		1		4	2		4	1
Penaeid A									
Penaeid B	1								
Penaeid C									
Carida B				1					
Carida C (Mysidaea)									
Carida F									
Anomura									
Calocaris barnardi									
Callianassa spp.			3	1	1			4	2
Anomura A	2		3	1					
Goneplax angulata	3		15	7	7	1	6	15	6
Mursia cristimanus									1
Brachyura A									
Brachyura B									
Brachyura C									
PHYLUM BRACHIOPODA									
Terebratulina meridionalis									
PHYLUM MOLLUSCA									
Ischnochiton bergoti				5					
Macoma spp.	24		63	39	31	27	57	38	71
Tellina spp.									
Dosinia spp.			6		2			2	2
Nucula nucleus				3		7		3	
Bivalve F	3		1	7					
Bivalve M									
Alvania fenestrata									

TAXA	R3.6	R3.7	R3.8	R3.9	R3.10	R4.1	R4.2	R4.3	R4.4
Bullia digitalis									
Charitodoron euphrosyne									
Epitonium kraussi									
Gibbula spp.									
Heliacus variegata									
Marginella spp.	20		18	3	4	7		1	1
Melanella sp.									
Nassarius spp.	3		13	1	2		14	41	
Natica tecta									
Ocenebra spp.									
Protomella capensis									
Pyramidella spp.									
Solariella agulhasensis									
Tricolia capensis									
Triphora africana									
Turris spp.			1						
Turritella spp.									
Volutocorbis abyssicola									
V olvarina capensis									
Sepia spp.									
Cucumaria spp.									
PHYLUM ECHINODERMATA									
Amphipholis squamata									
Ophionereis porrecta	3								
Henricia spp.									

TAXA	R4.5	R4.6	R4.7	R4.8	R4.9	R4.10	S1.1	S1.5	S1.11
PHYLUM PORIFERA									
Porifera A									
PHYLUM CNIDARIA									
Scyphozoa A									
Anthozoa A									
Anthozoa B									
Anthozoa D									
PHYLUM NEMERTEA									
Cerebratulus spp.	1			1					
Lineus spp.									
Nemertea B									
Nemertea C				1					
Nemertea D									
Siphunculid A	3								
Siphunculid B	1						1		
PHYLUM ANNELIDA									
Lumbrineris spp.	12	2	9	6	2	2	3	6	10
Arabella spp.		2							
Diopatra spp.		1		2					
Glyceridae									
Nereidae									
Nereis spp.	1	1		2					
Perinereis/Pseudonereis spp.								3	
Nephtys spp.	1	2	1	8					1
Spionidae									
Prionospio pinnata	18	5	7	2	1	1	20	12	7
Spio spp.									
Spiophanes spp.				1					
Laonice cirrata		1	2			2			1
Spionid O				2					
Spionid P									
Polydora spp.									
Orbiniidae				11		1			
Haploscoloplos spp.	5						2	2	8
Scoloplos spp.									
Phylo spp.									
Naineris spp.									
Orbiniidae B									
Orbinia angrapaquensis									
Poly BB									
Poly WW	2								
Paraonidae									
Cirrophorus branchiatus									
Ophelia spp.	1	1							
Capitellidae spp.									
Notomastus spp.						1			2
Maldanidae				1					1

TAXA	R4.5	R4.6	R4.7	R4.8	R4.9	R4.10	S1.1	S1.5	S1.11
Maldaninae A									
Maldaninae B									
Euclymene luderitziana									
Petaloproctus spp.									
Rhodine gracilior									1
Sabellides spp.				3					
Ampharetidae				2					
Amphicteis gunneri		6	1						
Ampharete spp. A									
Terebellidae									
Trichobranchus glacialis									
Terebellides spp.	2	7	3	18	2	1			5
Amaeana trilobata/Polycirrus									
Flabelligera spp.									
Pectinariidae									
Poly UU									
PHYLUM ARTHROPODA									
Copepoda A							1		
Myodocopa									
Isopod A									
Arcturidae									
Arcturidae A									
Arcturid B									
Arcturid C									
Arcturid D									
Cirolana spp.				1					
Microarcturus quadriconus				2					
New amphipod									
Ampelisca spp.	1	2	4	8					1
Aoro kergeuleni									
Aorcho delgadus		1		1					
Corophiid A (Gammaropsis)									
Corophiid Q									
Atylus swammerdamei									
Guernea rhomba									
Paramoera capensis									
Maera spp.									
Urothoe spp.									
Leucothoe spp.	3		1	3					1
Acidostoma obesum		1		1					
Hippomedon longimanus		1	28	41	3		10	5	11
Euonyx biscayensis									
Socarnopsis crenulata									
Monoculodopsis longimana									
Oediceroides cinderella									
Perioculodes spp.									
Westwoodilla manta									

TAXA	R4.5	R4.6	R4.7	R4.8	R4.9	R4.10	S1.1	S1.5	S1.11
Paraphoxus oculatus									1
Platyischnopus herdmani									
Podocerus brasiliensis									
Podoceropsis sophiae									
Eupariambus fallax				2					
Phtisca marina									
Hyperiidae	1								
Hyperiid B									
Ingolfiellid A									
Ingolfiellid B									
Ingolfiellid C									
Cumacea A								1	
Cumacea B									
Cumacea C									
Leptostraca A									
Pterygosquilla armata		1							
Stomatopoda B									
Stomatopod juvenile									
Mysidacea spp.									
Gastrosaccus psammodytes									
ORDER EUPHAUSIACEA									
Penaeid A									
Penaeid B	1								
Penaeid C									
Carida B									
Carida C (Mysidaea)				1				1	
Carida F									
Anomura									
Calocaris barnardi	1								
Callianassa spp.									
Anomura A	1		2	2					
Goneplax angulata	5	6	5	18	2				
Mursia cristimanus				2					
Brachyura A									
Brachyura B									
Brachyura C									
PHYLUM BRACHIOPODA									
Terebratulina meridionalis									
PHYLUM MOLLUSCA									
Ischnochiton bergoti						1			
Macoma spp.	18	123	32	153	8	11	4	1	12
Tellina spp.				10					3
Dosinia spp.	1	2		8			1	1	
Nucula nucleus	5				2	1			
Bivalve F	1								1
Bivalve M									
Alvania fenestrata				3	1				1

TAXA	R4.5	R4.6	R4.7	R4.8	R4.9	R4.10	S1.1	S1.5	S1.11
Bullia digitalis							9	2	
Charitodoron euphrosyne									1
Epitonium kraussi				6				1	2
Gibbula spp.							1		
Heliacus variegata							1		
Marginella spp.	14	2		4	3		15	3	1
Melanella sp.							2		
Nassarius spp.	4	11	2	102	1		28	99	22
Natica tecta									
Ocenebra spp.				5			2	4	1
Protomella capensis							6	1	
Pyramidella spp.				2					
Solariella agulhasensis				42			1	9	2
Tricolia capensis		1		31	4		19	9	14
Triphora africana									
Turris spp.									
Turritella spp.									
Volutocorbis abyssicola									
V olvarina capensis									
Sepia spp.									
Cucumaria spp.									
PHYLUM ECHINODERMATA									
Amphipholis squamata									
Ophionereis porrecta				3					
Henricia spp.				1					

TAXA	S1.14	S1.15	S1.17	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7
PHYLUM PORIFERA									
Porifera A									
PHYLUM CNIDARIA									
Scyphozoa A									
Anthozoa A									
Anthozoa B									
Anthozoa D									
PHYLUM NEMERTEA									
Cerebratulus spp.		1							
Lineus spp.		1							
Nemertea B									
Nemertea C									1
Nemertea D									
Siphunculid A									
Siphunculid B									
PHYLUM ANNELIDA									
Lumbrineris spp.	13	21	12	9	10	4	12	3	7
Arabella spp.		1							
Diopatra spp.									1
Glyceridae									
Nereidae									
Nereis spp.		1							
Perinereis/Pseudonereis spp.									
Nephtys spp.	2	1			1	2	3		
Spionidae		1					9		
Prionospio pinnata	21	1	24	30	36	52	47	30	36
Spio spp.									
Spiophanes spp.	12		6						
Laonice cirrata		1	1	4			1	2	
Spionid O									
Spionid P									
Polydora spp.									
Orbiniidae							3		
Haploscoloplos spp.	12	41	13	7	3		10	3	
Scoloplos spp.									
Phylo spp.		1							
Naineris spp.									
Orbiniidae B		1							
Orbinia angrapaquensis	2								2
Poly BB									
Poly WW									
Paraonidae									
Cirrophorus branchiatus	1								
Ophelia spp.									
Capitellidae spp.									1
Notomastus spp.	1								
Maldanidae	4	1	1						

TAXA	S1.14	S1.15	S1.17	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7
Maldaninae A									
Maldaninae B									
Euclymene luderitziana									
Petaloproctus spp.									
Rhodine gracilior		2							
Sabellides spp.									
Ampharetidae									
Amphicteis gunneri		1							1
Ampharete spp. A									
Terebellidae									
Trichobranchus glacialis									
Terebellides spp.				5		2			
Amaeana trilobata/Polycirrus							1		
Flabelligera spp.									
Pectinariidae									
Poly UU									
PHYLUM ARTHROPODA									
Copepoda A						1		1	
Myodocopa									
Isopod A									
Arcturidae	1	1							
Arcturidae A									
Arcturid B									1
Arcturid C									
Arcturid D									
Cirolana spp.									
Microarcturus quadriconus									
New amphipod									
Ampelisca spp.	4		1	5	4	19	4	11	9
Aoro kergeuleni									
Aorcho delgadus		1						1	
Corophiid A (Gammaropsis)									
Corophiid Q									
Atylus swammerdamei									
Guernea rhomba									
Paramoera capensis									
Maera spp.									
Urothoe spp.									
Leucothoe spp.	2	2	1			3	1	4	2
Acidostoma obesum	1	6							
Hippomedon longimanus	27		39	1		14			6
Euonyx biscayensis							3		
Socarnopsis crenulata									
Monoculodopsis longimana									
Oediceroides cinderella									
Perioculodes spp.			1						
Westwoodilla manta					1		4		

TAXA	S1.14	S1.15	S1.17	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7
Paraphoxus oculatus									
Platyischnopus herdmani				1					
Podocerus brasiliensis									
Podoceropsis sophiae									
Eupariambus fallax									
Phtisca marina		1							
Hyperiidae	1	2		1			1		
Hyperiid B		1						2	
Ingolfiellid A		2							
Ingolfiellid B									
Ingolfiellid C									
Cumacea A	2			1					
Cumacea B									
Cumacea C									
Leptostraca A						1			
Pterygosquilla armata									
Stomatopoda B									
Stomatopod juvenile		1							
Mysidacea spp.									
Gastrosaccus psammodytes									
ORDER EUPHAUSIACEA			1			2			1
Penaeid A					1	1			
Penaeid B									
Penaeid C	1			4					
Carida B								1	
Carida C (Mysidaea)				1			4		
Carida F									
Anomura							1		
Calocaris barnardi									
Callianassa spp.						3			
Anomura A									
Goneplax angulata					1	4	3		1
Mursia cristimanus									
Brachyura A									
Brachyura B						1			
Brachyura C									
PHYLUM BRACHIOPODA									
Terebratulina meridionalis						1		1	1
PHYLUM MOLLUSCA									
Ischnochiton bergoti									
Macoma spp.	21	1	9	2		2	2	2	4
Tellina spp.									
Dosinia spp.		1						1	1
Nucula nucleus									
Bivalve F	1		1	6			2		
Bivalve M									
Alvania fenestrata	1	2							

TAXA	S1.14	S1.15	S1.17	S2.2	S2.3	S2.4	S2.5	S2.6	S2.7
Bullia digitalis									
Charitodoron euphrosyne	1								
Epitonium kraussi			1						
Gibbula spp.									
Heliacus variegata									
Marginella spp.	2	1		1	1	1			6
Melanella sp.									
Nassarius spp.	6	20	14		1	8		3	12
Natica tecta									
Ocenebra spp.			1						
Protomella capensis									
Pyramidella spp.									
Solariella agulhasensis			1						
Tricolia capensis	2	3	6						
Triphora africana									
Turris spp.									
Turritella spp.			1						
Volutocorbis abyssicola									
V olvarina capensis		1							
Sepia spp.									
Cucumaria spp.							1		
PHYLUM ECHINODERMATA									
Amphipholis squamata								1	
Ophionereis porrecta									
Henricia spp.									

TAXA	S3.1	S3.2	S3.3	S3.4	S3.5	S3.7	S4.2	S4.6	S4.8
PHYLUM PORIFERA									
Porifera A									
PHYLUM CNIDARIA									
Scyphozoa A									
Anthozoa A									
Anthozoa B									
Anthozoa D									
PHYLUM NEMERTEA									
Cerebratulus spp.							1		
Lineus spp.									
Nemertea B									
Nemertea C									
Nemertea D									
Siphunculid A									
Siphunculid B		3							
PHYLUM ANNELIDA									
Lumbrineris spp.	1	8	11	15	3	4	10	1	7
Arabella spp.									
Diopatra spp.		1							
Glyceridae									
Nereidae									
Nereis spp.									
Perinereis/Pseudonereis spp.									
Nephtys spp.									
Spionidae									
Prionospio pinnata	6	2		16	1	1	5	1	6
Spio spp.									
Spiophanes spp.									
Laonice cirrata	1	2	2	3	2	1	5		3
Spionid O									
Spionid P									
Polydora spp.									
Orbiniidae									
Haploscoloplos spp.	1	3	8	2	1				
Scoloplos spp.									2
Phylo spp.									
Naineris spp.		6							
Orbiniidae B									
Orbinia angrapaquensis									
Poly BB									
Poly WW									
Paraonidae									
Cirrophorus branchiatus									
Ophelia spp.									
Capitellidae spp.									
Notomastus spp.		1	1						
Maldanidae									

TAXA	S3.1	S3.2	S3.3	S3.4	S3.5	S3.7	S4.2	S4.6	S4.8
Maldaninae A									
Maldaninae B									
Euclymene luderitziana									
Petaloproctus spp.									
Rhodine gracilior									
Sabellides spp.									
Ampharetidae									
Amphicteis gunneri							1		
Ampharete spp. A		1							
Terebellidae									
Trichobranchus glacialis						1			
Terebellides spp.			1		1		15		9
Amaeana trilobata/Polycirrus									
Flabelligera spp.							1		
Pectinariidae									
Poly UU									
PHYLUM ARTHROPODA									
Copepoda A		1			2				
Myodocopa									
Isopod A						1			
Arcturidae									
Arcturidae A									
Arcturid B									
Arcturid C									
Arcturid D									
Cirolana spp.									
Microarcturus quadriconus									
New amphipod									
Ampelisca spp.			1	3	2		10		
Aoro kergeuleni			1	1					
Aorcho delgadus		1			3				1
Corophiid A (Gammaropsis)									
Corophiid Q									
Atylus swammerdamei									
Guernea rhomba									
Paramoera capensis									
Maera spp.		6	2			1			
Urothoe spp.									
Leucothoe spp.		8	2	1	2	1		1	1
Acidostoma obesum		1	2	1	3	1			
Hippomedon longimanus				2	1		1		
Euonyx biscayensis									
Socarnopsis crenulata			1						
Monoculodopsis longimana									
Oediceroides cinderella									
Perioculodes spp.									
Westwoodilla manta							1		

TAXA	S3.1	S3.2	S3.3	S3.4	S3.5	S3.7	S4.2	S4.6	S4.8
Paraphoxus oculatus									
Platyischnopus herdmani									
Podocerus brasiliensis									
Podoceropsis sophiae									
Eupariambus fallax									
Phtisca marina									
Hyperiidae			1	1	1				
Hyperiid B		1				1			
Ingolfiellid A									
Ingolfiellid B									
Ingolfiellid C									
Cumacea A									
Cumacea B									
Cumacea C		1					1		
Leptostraca A									
Pterygosquilla armata									
Stomatopoda B									
Stomatopod juvenile					1				
Mysidacea spp.									1
Gastrosaccus psammodytes									
ORDER EUPHAUSIACEA			1						
Penaeid A									
Penaeid B									
Penaeid C			1	2		1	2		3
Carida B					2				
Carida C (Mysidaea)									
Carida F									
Anomura		1	2	2	1				
Calocaris barnardi									
Callianassa spp.				1					
Anomura A						1			
Goneplax angulata			3	2		4			2
Mursia cristimanus									
Brachyura A									
Brachyura B									
Brachyura C									
PHYLUM BRACHIOPODA									
Terebratulina meridionalis									
PHYLUM MOLLUSCA									
Ischnochiton bergoti		4							
Macoma spp.	4	5	17	35	8	4	49		12
Tellina spp.		6	2		3				
Dosinia spp.		1							
Nucula nucleus	1					10			2
Bivalve F						2			
Bivalve M		1							
Alvania fenestrata		1							

TAXA	S3.1	S3.2	S3.3	S3.4	S3.5	S3.7	S4.2	S4.6	S4.8
Bullia digitalis									
Charitodoron euphrosyne									
Epitonium kraussi			1						
Gibbula spp.		2							
Heliacus variegata									
Marginella spp.	1	1				1	1		5
Melanella sp.									
Nassarius spp.	1	47	50	40	21	5	31		54
Natica tecta									
Ocenebra spp.		2	1						1
Protomella capensis									
Pyramidella spp.				1					1
Solariella agulhasensis			1	2	3				
Tricolia capensis		11	2	5	1		2		10
Triphora africana									
Turris spp.						2			
Turritella spp.									
Volutocorbis abyssicola							1		
V olvarina capensis									
Sepia spp.				1					
Cucumaria spp.									
PHYLUM ECHINODERMATA									
Amphipholis squamata									
Ophionereis porrecta									
Henricia spp.									

TAXA	S4.9	S4.13	S4.14	S4.15
PHYLUM PORIFERA				
Porifera A				
PHYLUM CNIDARIA				
Scyphozoa A				
Anthozoa A				
Anthozoa B				
Anthozoa D				
PHYLUM NEMERTEA				
Cerebratulus spp.		2	1	
Lineus spp.				
Nemertea B				
Nemertea C				
Nemertea D				
Siphunculid A				
Siphunculid B				
PHYLUM ANNELIDA				
Lumbrineris spp.		11	10	3
Arabella spp.			2	
Diopatra spp.				
Glyceridae				
Nereidae				
Nereis spp.				
Perinereis/Pseudonereis spp.			1	
Nephtys spp.		3	7	
Spionidae				
Prionospio pinnata	12	10	21	
Spio spp.				
Spiophanes spp.				
Laonice cirrata			1	
Spionid O				
Spionid P				
Polydora spp.				
Orbiniidae				1
Haploscoloplos spp.		4	1	
Scoloplos spp.			1	1
Phylo spp.				
Naineris spp.				
Orbiniidae B				
Orbinia angrapaquensis				
Poly BB				
Poly WW				
Paraonidae				
Cirrophorus branchiatus				
Ophelia spp.				
Capitellidae spp.				
Notomastus spp.				
Maldanidae				

TAXA	S4.9	S4.13	S4.14	S4.15
Maldaninae A				
Maldaninae B				
Euclymene luderitziana				
Petaloproctus spp.				
Rhodine gracilior				
Sabellides spp.				
Ampharetidae				
Amphicteis gunneri				
Ampharete spp. A				
Terebellidae				
Trichobranchus glacialis				
Terebellides spp.		1		
Amaeana trilobata/Polycirrus				
Flabelligera spp.		1		
Pectinariidae				
Poly UU				
PHYLUM ARTHROPODA				
Copepoda A				
Myodocopa				
Isopod A				
Arcturidae				
Arcturidae A				
Arcturid B				
Arcturid C				
Arcturid D				
Cirolana spp.		1		
Microarcturus quadriconus				
New amphipod				
Ampelisca spp.		13	1	
Aoro kergeuleni				
Aorcho delgadus		1		
Corophiid A (Gammaropsis)				
Corophiid Q				
Atylus swammerdamei				
Guernea rhomba				
Paramoera capensis				
Maera spp.		17		
Urothoe spp.				
Leucothoe spp.		3		
Acidostoma obesum		19		
Hippomedon longimanus		5	2	
Euonyx biscayensis				
Socarnopsis crenulata				
Monoculodopsis longimana				
Oediceroides cinderella				
Perioculodes spp.				
Westwoodilla manta				

TAXA	S4.9	S4.13	S4.14	S4.15
Paraphoxus oculatus				
Platyischnopus herdmani				
Podocerus brasiliensis				
Podoceropsis sophiae				
Eupariambus fallax				
Phtisca marina				
Hyperiidae				
Hyperiid B				
Ingolfiellid A				
Ingolfiellid B				
Ingolfiellid C				
Cumacea A				
Cumacea B				
Cumacea C				
Leptostraca A				
Pterygosquilla armata				
Stomatopoda B				
Stomatopod juvenile				
Mysidacea spp.				
Gastrosaccus psammodytes				
ORDER EUPHAUSIACEA				
Penaeid A				
Penaeid B				
Penaeid C				
Carida B				
Carida C (Mysidaea)				
Carida F				
Anomura				
Calocaris barnardi				
Callianassa spp.				
Anomura A				
Goneplax angulata			4	
Mursia cristimanus				
Brachyura A				
Brachyura B				
Brachyura C				
PHYLUM BRACHIOPODA				
Terebratulina meridionalis				
PHYLUM MOLLUSCA				
Ischnochiton bergoti				
Macoma spp.		40	2	1
Tellina spp.			5	
Dosinia spp.			3	
Nucula nucleus				
Bivalve F		1		
Bivalve M				
Alvania fenestrata				1

TAXA	S4.9	S4.13	S4.14	S4.15
Bullia digitalis				
Charitodoron euphrosyne				
Epitonium kraussi			1	
Gibbula spp.				
Heliacus variegata				
Marginella spp.				2
Melanella sp.				
Nassarius spp.	4	4	55	48
Natica tecta				
Ocenebra spp.				1
Protomella capensis				
Pyramidella spp.				1
Solariella agulhasensis	1		20	10
Tricolia capensis			16	9
Triphora africana				
Turris spp.				
Turritella spp.				
Volutocorbis abyssicola				
V olvarina capensis				
Sepia spp.				
Cucumaria spp.				
PHYLUM ECHINODERMATA				
Amphipholis squamata				
Ophionereis porrecta				
Henricia spp.				

MACROFAUNA ABUNDANCE DATA FOR ALL SAMPLES

FROM THE SOUTHERN RESEARCH AREA

TAXON	R5.1	R5.3	R5.4	R5.5	R5.6	R5.7	R5.8	R5.9
PHYLUM CNIDARIA								
Anthozoa A								
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.	2		1	1			1	1
Lineus spp.	3			2				
Nemertea B								
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)								
Lumbrineris spp.	17	4	6	13	12	6	8	19
Arabella spp.				1		2		1
Diopatra spp.	71	26	7	3	25	2		9
Epidiopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.		5		1				
Perinereis/Pseudonereis spp.								
Micronereides capensis				1				
Nephtyidae	4		2				9	
Nephtys spp.				3	2	7		2
Spionidae								
Prionospio pinnata	43	2	2	61	43	58	16	91
Laonice cirrata		10						1
Haploscoloplos spp.					2			3
Phylo spp.								4
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp. (heteromastus)								
Notomastus spp.		3						
Maldanidae	4				1			
Euclymene luderitziana		2						
Maldanella capensis								
Petaloproctus spp.								
Sabellides spp.		2						
Ampharetidae			4	1				
Amphicteis gunneri		6						
Terebellides spp.	21	287	4	3	2			17
Amaeana trilobata/Polycirrus						1	1	

TAXON	R5.1	R5.3	R5.4	R5.5	R5.6	R5.7	R5.8	R5.9
Ancistrosyllis parva								
Flabelligeridae			2					
Flabelligera spp.								
Pectinaria capensis								
Cossura coasta								
PHYLUM ARTHROPODA								
Tanaid A								
Copepoda A						1	7	
Isopod A								
Ampelisca spp.			1	1	14	17	24	41
Aoro kergeuleni								
Aorcho delgadus		1						
Corophiid Q								1
Guernea rhomba								
Rhachotropis spp.						1		
Elasmopus affinis			2					
Ceradocus natalensis								
Maera spp.					1			
Urothoe spp.								
Leucothoe spp.				5				
Listriella lindae		2			3		1	
Acidostoma obesum		1		2				
Hippomedon longimanus				1	1		2	
Westwoodilla manta				2	10	10	21	
Paraphoxus oculatus			2					1
Platyischnopus herdmani					1			
Podocerus brasiliensis								
Eupariambus fallax								
Hyperiidae					3	1	4	1
Hyperiid B								
Cumacea B								
Pterygosquilla armata	4	1		1	4	1		
Stomatopod juvenile							1	2
Meiosquilla desmarestii								
ORDER EUPHAUSIACEA			1	12	15		4	3
Carida A							2	
Carida B		2						
Carida C (Mysidaea)		1			1	1	4	
Carida D		1				7		
Carida F				2	1		1	
Calocaris barnardi	4	9		3	11	2		1
Callianassa spp.	7	1	1	10	12	5	6	4
Anomura A		3						
Goneplax angulata	3			3	2	6	4	3
Mursia cristimanus								
Brachyura A								

TAXON	R5.1	R5.3	R5.4	R5.5	R5.6	R5.7	R5.8	R5.9
PHYLUM MOLLUSCA								
Macoma spp.	10	11		10	14	5	10	27
Tellina spp.								
Dosinia spp.								
Nucula nucleus			4			1		1
Bivalve F			1					
Bivalve I								
Alvania fenestrata								
Clanculus sp.								
Epitonium kraussi								
Marginella spp.				1		1		
Nassarius spp.	1	48	9	6		7		3
Ocenebra spp.								
Pyramidella spp.								
Solariella agulhasensis								
Tricolia capensis								
Turris spp.						1		
Volutocorbis abyssicola				1				
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta		2						

TAXON	R5.10	R6.6	R6.7	R6.8	R6.9	R6.10	S5.2	S5.3
PHYLUM CNIDARIA								
Anthozoa A								
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.	1					1		
Lineus spp.								
Nemertea B								
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)								
Lumbrineris spp.	4	3	15	6	7	14	8	8
Arabella spp.			1					1
Diopatra spp.	26	3	34	37	8	57	10	48
Epidiopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.								4
Perinereis/Pseudonereis spp.							2	6
Micronereides capensis								
Nephtyidae								
Nephtys spp.			4	2	2	5	3	6
Spionidae								
Prionospio pinnata	12	2	59	23	21	43	31	25
Laonice cirrata								
Haploscoloplos spp.				1				1
Phylo spp.								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp. (heteromastus)								
Notomastus spp.			2					
Maldanidae							9	6
Euclymene luderitziana								
Maldanella capensis								
Petaloproctus spp.								
Sabellides spp.								
Ampharetidae						1		
Amphicteis gunneri				1				
Terebellides spp.	8		1	10		47	10	4
Amaeana trilobata/Polycirrus	1	1						
Ancistrosyllis parva			1					
Flabelligeridae								
Flabelligera spp.				1				
Pectinaria capensis								
Cossura coasta								
PHYLUM ARTHROPODA								
Tanaid A								
Copepoda A								
Isopod A					1			
Ampelisca spp.	3	1	14	11		33	3	2

TAXON	R5.10	R6.6	R6.7	R6.8	R6.9	R6.10	S5.2	S5.3
Aoro kergeuleni								
Aorcho delgadus				1		1		
Corophiid Q								
Guernea rhomba								
Rhachotropis spp.								
Elasmopus affinis								
Ceradocus natalensis								
Maera spp.								
Urothoe spp.				1		1		
Leucothoe spp.								2
Listriella lindae			1					
Acidostoma obesum								
Hippomedon longimanus			1					
Westwoodilla manta			1			6	1	
Paraphoxus oculatus		1	1					
Platyischnopus herdmani								
Podocerus brasiliensis								
Eupariambus fallax								
Hyperiidae			4	1		1		1
Hyperiid B								
Cumacea B								
Pterygosquilla armata			3			2	2	1
Stomatopod juvenile			1					1
Meiosquilla desmarestii			1					
ORDER EUPHAUSIACEA	1		8	3	1	2	1	1
Carida A			1					
Carida B						3	1	
Carida C (Mysidaea)								
Carida D								
Carida F								
Calocaris barnardi	3		4	2		7	16	15
Callianassa spp.			5		1		6	7
Anomura A								
Goneplax angulata	1		1	4		10		
Mursia cristimanus								
Brachyura A								
PHYLUM MOLLUSCA								
Macoma spp.		6	6	32		44	17	87
Tellina spp.						2		1
Dosinia spp.				4		3		
Nucula nucleus					3			1
Bivalve F						1		2
Bivalve I								1
Alvania fenestrata								4
Clanculus sp.								1
Epitonium kraussi								2
Marginella spp.								
Nassarius spp.	1	1	5		34	37	11	207
Ocenebra spp.					1			2
Pyramidella spp.								
Solariella agulhasensis							1	

TAXON	R5.10	R6.6	R6.7	R6.8	R6.9	R6.10	S5.2	S5.3
Tricolia capensis								2
Turris spp.					1			
Volutocorbis abyssicola	1							
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								

TAXON	S5.5	S5.6	S5.9	S5.11	S6.1	S6.2	S6.3	S6.4
PHYLUM CNIDARIA								
Anthozoa A			1					
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.								
Lineus spp.					2			1
Nemertea B								
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)								
Lumbrineris spp.	13	2	9	8	7	9	11	9
Arabella spp.							1	
Diopatra spp.	1	12	19			33	40	28
Epidiopatra spp.			2					2
Glyceridae								
Nereidae			3					
Nereis spp.					5			
Perinereis/Pseudonereis spp.	4	1					7	
Micronereides capensis								
Nephtyidae								
Nephtys spp.	5	4		1	3	1	2	2
Spionidae			1	2				
Prionospio pinnata	37	46	13	90	52	34	7	20
Laonice cirrata								
Haploscoloplos spp.	3			4				
Phylo spp.								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp. (heteromastus)								
Notomastus spp.								
Maldanidae			3					
Euclymene luderitziana								
Maldanella capensis	4							
Petaloproctus spp.	4							
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri							4	
Terebellides spp.	7	9	3	6	3	1	10	12
Amaeana trilobata/Polycirrus								
Ancistrosyllis parva								
Flabelligeridae								
Flabelligera spp.								
Pectinaria capensis								
Cossura coasta								
PHYLUM ARTHROPODA								
Tanaid A				1				
Copepoda A		1		3	1	2	1	14
Isopod A								
Ampelisca spp.	3	17	1	13		4	2	38

TAXON	S5.5	S5.6	S5.9	S5.11	S6.1	S6.2	S6.3	S6.4
Aoro kergeuleni							3	
Aorcho delgadus							3	2
Corophiid Q								2
Guernea rhomba				1				
Rhachotropis spp.								
Elasmopus affinis								
Ceradocus natalensis								
Maera spp.							7	
Urothoe spp.								
Leucothoe spp.	1							
Listriella lindae								
Acidostoma obesum								
Hippomedon longimanus								
Westwoodilla manta	1	1		4				10
Paraphoxus oculatus					1		2	1
Platyischnopus herdmani								
Podocerus brasiliensis								1
Eupariambus fallax	1							
Hyperiidae			1					3
Hyperiid B				2	1			
Cumacea B								1
Pterygosquilla armata	1		3		2	1	3	
Stomatopod juvenile						1		1
Meiosquilla desmarestii								
ORDER EUPHAUSIACEA				3				2
Carida A				1				
Carida B								
Carida C (Mysidaea)								23
Carida D								
Carida F								
Calocaris barnardi	3	16	5		8	25	6	3
Callianassa spp.		4	6	5		5		
Anomura A								
Goneplax angulata	2	1		5	3			
Mursia cristimanus								
Brachyura A								
PHYLUM MOLLUSCA								
Macoma spp.	23	24	12	6	11	11	50	6
Tellina spp.					1			
Dosinia spp.	1						2	
Nucula nucleus				3	1	1	1	
Bivalve F	1				1		1	
Bivalve I								
Alvania fenestrata								
Clanculus sp.								
Epitonium kraussi							1	
Marginella spp.								
Nassarius spp.	27	5	6	38	4	13	44	
Ocenebra spp.							3	
Pyramidella spp.							1	
Solariella agulhasensis								

TAXON	S5.5	S5.6	S5.9	S5.11	S6.1	S6.2	S6.3	S6.4
Tricolia capensis							6	
Turris spp.				1			3	
Volutocorbis abyssicola								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								

TAXON	S6.5	S6.6	D1.1	D1.2	D1.3	D1.4	D1.5	D1.6
PHYLUM CNIDARIA								
Anthozoa A								
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.						1		
Lineus spp.								
Nemertea B		1						
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)		1						
Lumbrineris spp.	6	6	2	5	2	2		5
Arabella spp.		1					2	
Diopatra spp.	12	2	3	3	1		2	2
Epidiopatra spp.								
Glyceridae								
Nereidae		1						
Nereis spp.								
Perinereis/Pseudonereis spp.		2						
Micronereides capensis								
Nephtyidae								
Nephtys spp.			1	1	1	3		3
Spionidae								
Prionospio pinnata	12	9		1				
Laonice cirrata		1						
Haploscoloplos spp.								
Phylo spp.								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp. (heteromastus)		1						
Notomastus spp.								
Maldanidae								
Euclymene luderitziana								
Maldanella capensis								
Petaloproctus spp.								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri								
Terebellides spp.	7							
Amaeana trilobata/Polycirrus								
Ancistrosyllis parva								
Flabelligeridae								
Flabelligera spp.	2							
Pectinaria capensis								
Cossura coasta					1			
PHYLUM ARTHROPODA								
Tanaid A								
Copepoda A								
Isopod A								
Ampelisca spp.	2							

TAXON	S6.5	S6.6	D1.1	D1.2	D1.3	D1.4	D1.5	D1.6
Aoro kergeuleni	2							
Aorcho delgadus		1	1					
Corophiid Q								
Guernea rhomba								
Rhachotropis spp.								
Elasmopus affinis								
Ceradocus natalensis		10						
Maera spp.	1	4						
Urothoe spp.								
Leucothoe spp.								
Listriella lindae								
Acidostoma obesum								
Hippomedon longimanus								
Westwoodilla manta								
Paraphoxus oculatus	1							
Platyischnopus herdmani								
Podocerus brasiliensis								
Eupariambus fallax								
Hyperiidae		1						
Hyperiid B								
Cumacea B								
Pterygosquilla armata				1		2		1
Stomatopod juvenile								
Meiosquilla desmarestii								
ORDER EUPHAUSIACEA	1							
Carida A								
Carida B								
Carida C (Mysidaea)								
Carida D								
Carida F								
Calocaris barnardi	5	3		2			2	4
Callianassa spp.	1			1				
Anomura A								
Goneplax angulata	1	2						
Mursia cristimanus		1						
Brachyura A								
PHYLUM MOLLUSCA								
Macoma spp.	10	1						
Tellina spp.								
Dosinia spp.								
Nucula nucleus								
Bivalve F		1						
Bivalve I								
Alvania fenestrata								
Clanculus sp.								
Epitonium kraussi								
Marginella spp.								
Nassarius spp.	11	5	34	6	22	11	89	21
Ocenebra spp.		1						
Pyramidella spp.								
Solariella agulhasensis								

TAXON	S6.5	S6.6	D1.1	D1.2	D1.3	D1.4	D1.5	D1.6
Tricolia capensis								
Turris spp.	1							
Volutocorbis abyssicola				1			1	
PHYLUM ECHINODERMATA								
Amphipholis squamata		2						
Ophionereis porrecta								

TAXON	D2.1	D2.2	D2.3	D2.4	D2.5	D2.6	D3.1	D3.2
PHYLUM CNIDARIA								
Anthozoa A								
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.				3				
Lineus spp.								
Nemertea B								
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)								
Lumbrineris spp.	3		3	2	3	1	1	2
Arabella spp.						1		
Diopatra spp.	2	4	1	2	3			
Epidiopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.								
Perinereis/Pseudonereis spp.								
Micronereides capensis								
Nephtyidae								
Nephtys spp.	1	3	1	1	3			8
Spionidae								
Prionospio pinnata	2	25	4	8	52	1	8	55
Laonice cirrata								
Haploscoloplos spp.								
Phylo spp.								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp. (heteromastus)								
Notomastus spp.								
Maldanidae								
Euclymene luderitziana								
Maldanella capensis								
Petaloproctus spp.								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri								
Terebellides spp.								
Amaeana trilobata/Polycirrus								
Ancistrosyllis parva								
Flabelligeridae								
Flabelligera spp.								
Pectinaria capensis					3	1		
Cossura coasta		3						1
PHYLUM ARTHROPODA								
Tanaid A								
Copepoda A								
Isopod A								
Ampelisca spp.				1	1			3

TAXON	D2.1	D2.2	D2.3	D2.4	D2.5	D2.6	D3.1	D3.2
Aoro kergeuleni								
Aorcho delgadus			1	1		1		2
Corophiid Q								
Guernea rhomba								
Rhachotropis spp.								
Elasmopus affinis								
Ceradocus natalensis								
Maera spp.								
Urothoe spp.								
Leucothoe spp.								
Listriella lindae								
Acidostoma obesum								
Hippomedon longimanus								
Westwoodilla manta								
Paraphoxus oculatus		1						1
Platyischnopus herdmani								
Podocerus brasiliensis								
Eupariambus fallax								
Hyperiidae								
Hyperiid B								
Cumacea B								
Pterygosquilla armata	3	2	1	2	3			
Stomatopod juvenile								
Meiosquilla desmarestii								
ORDER EUPHAUSIACEA								
Carida A			1		1			
Carida B								
Carida C (Mysidaea)								
Carida D								
Carida F								
Calocaris barnardi		4		1	4	1		2
Callianassa spp.		1	1					
Anomura A								
Goneplax angulata								
Mursia cristimanus								
Brachyura A								
PHYLUM MOLLUSCA								
Macoma spp.								
Tellina spp.								1
Dosinia spp.								
Nucula nucleus								
Bivalve F								
Bivalve I								
Alvania fenestrata								
Clanculus sp.								
Epitonium kraussi								1
Marginella spp.					1			
Nassarius spp.	23	66	36	50	118	17	21	217
Ocenebra spp.								
Pyramidella spp.								
Solariella agulhasensis								

TAXON	D2.1	D2.2	D2.3	D2.4	D2.5	D2.6	D3.1	D3.2
Tricolia capensis								
Turris spp.								
Volutocorbis abyssicola								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								

TAXON	D3.3	D3.4	D3.5	D3.6	D4.1	D4.2	D4.3	D4.4
PHYLUM CNIDARIA								
Anthozoa A								
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.		2			2	1		1
Lineus spp.								
Nemertea B								
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)								
Lumbrineris spp.	1		4	1	5	3	5	5
Arabella spp.								
Diopatra spp.					4	7	7	2
Epidiopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.								
Perinereis/Pseudonereis spp.								
Micronereides capensis								
Nephtyidae								
Nephtys spp.		3	6	2	1			2
Spionidae								
Prionospio pinnata	39	3	26	38	4	2	4	8
Laonice cirrata								
Haploscoloplos spp.								
Phylo spp.								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp. (heteromastus)								
Notomastus spp.								
Maldanidae								
Euclymene luderitziana								
Maldanella capensis								
Petaloproctus spp.								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri								
Terebellides spp.								
Amaeana trilobata/Polycirrus								
Ancistrosyllis parva								
Flabelligeridae								
Flabelligera spp.								
Pectinaria capensis			2					
Cossura coasta								
PHYLUM ARTHROPODA								
Tanaid A								
Copepoda A								
Isopod A								
Ampelisca spp.	1		1					

TAXON	D3.3	D3.4	D3.5	D3.6	D4.1	D4.2	D4.3	D4.4
Aoro kergeuleni								
Aorcho delgadus						2	4	1
Corophiid Q								
Guernea rhomba								
Rhachotropis spp.								
Elasmopus affinis								
Ceradocus natalensis								
Maera spp.								
Urothoe spp.								
Leucothoe spp.								
Listriella lindae								
Acidostoma obesum								
Hippomedon longimanus								
Westwoodilla manta								
Paraphoxus oculatus								
Platyischnopus herdmani								
Podocerus brasiliensis								
Eupariambus fallax								
Hyperiidae						1		
Hyperiid B								
Cumacea B								
Pterygosquilla armata	2	1			2	1	1	
Stomatopod juvenile								
Meiosquilla desmarestii								
ORDER EUPHAUSIACEA								
Carida A								
Carida B								
Carida C (Mysidaea)								
Carida D								
Carida F								
Calocaris barnardi	4	1	3		3	1	3	4
Callianassa spp.					6	1	6	4
Anomura A								
Goneplax angulata								
Mursia cristimanus								
Brachyura A								
PHYLUM MOLLUSCA								
Macoma spp.								
Tellina spp.			1					
Dosinia spp.								
Nucula nucleus								
Bivalve F								
Bivalve I								
Alvania fenestrata								
Clanculus sp.								
Epitonium kraussi								
Marginella spp.								
Nassarius spp.	38	11	4	17	4			3
Ocenebra spp.								
Pyramidella spp.								
Solariella agulhasensis								

TAXON	D3.3	D3.4	D3.5	D3.6	D4.1	D4.2	D4.3	D4.4
Tricolia capensis								
Turris spp.								
Volutocorbis abyssicola								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								

TAXON	D4.5	D4.6	D5.1	D5.2	D5.3	D5.4	D5.5	D5.6
PHYLUM CNIDARIA								
Anthozoa A								
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.								
Lineus spp.								
Nemertea B								
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)								
Lumbrineris spp.	4	4		3		2		
Arabella spp.		2	1			2		1
Diopatra spp.	10	12	1	2		1	1	
Epidiopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.								
Perinereis/Pseudonereis spp.								
Micronereides capensis								
Nephtyidae								
Nephtys spp.	1							
Spionidae								
Prionospio pinnata	2	5				3		
Laonice cirrata								
Haploscoloplos spp.								
Phylo spp.								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp. (heteromastus)								
Notomastus spp.								
Maldanidae								
Euclymene luderitziana								
Maldanella capensis								
Petaloproctus spp.								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri								
Terebellides spp.								
Amaeana trilobata/Polycirrus								
Ancistrosyllis parva		1						
Flabelligeridae								
Flabelligera spp.								
Pectinaria capensis								
Cossura coasta								
PHYLUM ARTHROPODA								
Tanaid A								
Copepoda A								
Isopod A								
Ampelisca spp.								2

TAXON	D4.5	D4.6	D5.1	D5.2	D5.3	D5.4	D5.5	D5.6
Aoro kergeuleni								
Aorcho delgadus		2						
Corophiid Q								
Guernea rhomba								
Rhachotropis spp.								
Elasmopus affinis								
Ceradocus natalensis								
Maera spp.								
Urothoe spp.								
Leucothoe spp.								
Listriella lindae								
Acidostoma obesum								
Hippomedon longimanus								
Westwoodilla manta								1
Paraphoxus oculatus								
Platyischnopus herdmani								
Podocerus brasiliensis								
Eupariambus fallax								
Hyperiidae								
Hyperiid B								
Cumacea B								
Pterygosquilla armata	3			3			1	
Stomatopod juvenile								
Meiosquilla desmarestii								
ORDER EUPHAUSIACEA								
Carida A								
Carida B								
Carida C (Mysidaea)								
Carida D								
Carida F								
Calocaris barnardi	3	3						
Callianassa spp.	6	2						
Anomura A								
Goneplax angulata								
Mursia cristimanus								
Brachyura A								
PHYLUM MOLLUSCA								
Macoma spp.								
Tellina spp.				1				1
Dosinia spp.								
Nucula nucleus								
Bivalve F								
Bivalve I								
Alvania fenestrata								
Clanculus sp.								
Epitonium kraussi								
Marginella spp.								
Nassarius spp.	1	1	35	24		9	7	22
Ocenebra spp.								
Pyramidella spp.								
Solariella agulhasensis								

TAXON	D4.5	D4.6	D5.1	D5.2	D5.3	D5.4	D5.5	D5.6
Tricolia capensis								
Turris spp.								
Volutocorbis abyssicola								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								

TAXON	UD4.5	UD4.6
PHYLUM CNIDARIA		
Anthozoa A		
Anthozoa B		
PHYLUM NEMERTEA		
Cerebratulus spp.		
Lineus spp.		
Nemertea B		
PHYLUM ANNELIDA		
Eunicidae		
Eunicidae spp. (drilonereis)		
Lumbrineris spp.	4	4
Arabella spp.		2
Diopatra spp.	10	12
Epidiopatra spp.		
Glyceridae		
Nereidae		
Nereis spp.		
Perinereis/Pseudonereis spp.		
Micronereides capensis		
Nephtyidae		
Nephtys spp.	1	
Spionidae		
Prionospio pinnata	2	5
Laonice cirrata		
Haploscoloplos spp.		
Phylo spp.		
Poly BB		
Poly WW		
Paraonidae		
Cirrophorus branchiatus		
Capitellidae spp. (heteromastus)		
Notomastus spp.		
Maldanidae		
Euclymene luderitziana		
Maldanella capensis		
Petaloproctus spp.		
Sabellides spp.		
Ampharetidae		
Amphicteis gunneri		
Terebellides spp.		
Amaeana trilobata/Polycirrus		
Ancistrosyllis parva		
Flabelligeridae		
Flabelligera spp.		
Pectinaria capensis		
Cossura coasta		
PHYLUM ARTHROPODA		
Tanaid A		
Copepoda A		
Isopod A		
Ampelisca spp.		

TAXON	UD4.5	UD4.6
Aoro kergeuleni		2
Aorcho delgadus		
Corophiid Q		
Guernea rhomba		
Rhachotropis spp.		
Elasmopus affinis		
Ceradocus natalensis		
Maera spp.		
Urothoe spp.		
Leucothoe spp.		
Listriella lindae		
Acidostoma obesum		
Hippomedon longimanus		
Westwoodilla manta		
Paraphoxus oculatus		
Platyischnopus herdmani		
Podocerus brasiliensis		
Eupariambus fallax		
Hyperiidae		
Hyperiid B		
Cumacea B	3	
Pterygosquilla armata		
Stomatopod juvenile		
Meiosquilla desmarestii		
ORDER EUPHAUSIACEA		
Carida A		
Carida B		
Carida C (Mysidaea)		
Carida D		
Carida F	3	3
Calocaris barnardi	6	2
Callianassa spp.		
Anomura A		
Goneplax angulata		
Mursia cristimanus		
Brachyura A		
PHYLUM MOLLUSCA		
Macoma spp.		
Tellina spp.		
Dosinia spp.		
Nucula nucleus		
Bivalve F		
Bivalve I		
Alvania fenestrata		
Clanculus sp.		
Epitonium kraussi	1	1
Marginella spp.		
Nassarius spp.		
Ocenebra spp.		
Pyramidella spp.		
Solariella agulhasensis		

TAXON	UD4.5	UD4.6
Tricolia capensis		
Turris spp.		
Volutocorbis abyssicola		
PHYLUM ECHINODERMATA		
Amphipholis squamata		
Ophionereis porrecta		

APPENDIX II

Biomass Data

MACROFAUNA BIOMASS DATA FOR ALL SAMPLES

FROM THE NORTHERN RESEARCH AREA

TAXA	R1.1	R1.2	R1.3	R1.4	R1.5	R1.6	R1.7	R1.8	R1.9	R1.10
PHYLUM PORIFERA										
Porifera A					0.1					
PHYLUM CNIDARIA										
Scyphozoa A										
Anthozoa A										
Anthozoa B										
Anthozoa D										
PHYLUM NEMERTEA										
Cerebratulus spp.		0.31	0.31				0.8	0.4		
Lineus spp.		0.4								0.6
Nemertea B										
Nemertea C					0.3		0.1			
Nemertea D										
Siphunculid A										
Siphunculid B										
PHYLUM ANNELIDA										
Lumbrineris spp.	1.18	0.93	0.27	0.3	2.1	0.82	0.62	0.28	2.67	0.26
Arabella spp.	0.9	0.7		0.1			0.9			
Diopatra spp.			0.29	1.8	0.1			0.4		
Glyceridae							0.2			
Nereidae										
Nereis spp.	0.2					0.1				
Perinereis/Pseudonereis spp.										
Nephtys spp.	0.5	0.2	0.3		0.3			0.3		0.12
Spionidae										
Prionospio pinnata	0.43	0.14	0.23	0.13	0.25	0.25	0.8	0.19	0.4	0.4
Spio spp.										
Spiophanes spp.			0.2							
Laonice cirrata			0.1		0.1	0.2	0.4		0.6	
Spionid O								0.2		
Spionid P										
Polydora spp.				0.1						
Orbiniidae		0.1	0.3		0.4			0.1		0.12
Haploscoloplos spp.						0.2	0.5		0.3	
Scoloplos spp.										
Phylo spp.		0.19	1.12	0.8			0.5			0.2
Naineris spp.										
Orbiniidae B										
Orbinia angrapaquensis						0.1				
Poly BB										
Poly WW										
Paraonidae			0.1							
Cirrophorus branchiatus				0.1						
Ophelia spp.	0.1									
Capitellidae spp.										
Notomastus spp.	0.13									

TAXA	R1.1	R1.2	R1.3	R1.4	R1.5	R1.6	R1.7	R1.8	R1.9	R1.10
Maldanidae		0.2	0.16				0.2	0.2		0.16
Maldaninae A					0.4					
Maldaninae B				0.1						
Euclymene luderitziana				0.5			0.3		0.4	
Petaloproctus spp.				0.1						
Rhodine gracilior										
Sabellides spp.	0.2									
Ampharetidae		0.4								0.9
Amphicteis gunneri			0.7			0.9	0.1		0.1	
Ampharete spp. A										
Terebellidae			0.1							
Trichobranchus glacialis										
Terebellides stroemi	0.39				0.5					
Amaeana trilobata/Polycirrus										
Flabelligera spp.										
Pectinariidae								0.2		
Poly UU										
PHYLUM ARTHROPODA										
Copepoda A										
Myodocopa										
Isopod A										
Arcturidae										
Arcturidae A			0.1							
Arcturid B						0.1				
Arcturid C										
Arcturid D							0.1			
Cirolana spp.										
Microarcturus quadriconus										
New amphipod										
Ampelisca spp.	0.1	0.3	0.2	0.1	0.1	0.5	0.3	0.3	0.1	0.3
Aora kergeuleni										
Aorcho delgadus		0.1				0.1				
Corophiid A (Gammaropsis)				0.1			0.1			
Corophiid Q										
Atylus swammerdamei										
Guernea rhomba										
Paramoera capensis										
Maera spp.										
Urothoe spp.	0.1	0.1					0.1		0.1	0.1
Leucothoe spp.			0.1							
Acidostoma obesum					0.1					
Hippomedon longimanus	0.7	0.4	0.8	0.6	0.6	0.4	0.6	0.1	0.1	0.4
Euonyx biscayensis										
Socarnopsis crenulata										
Monoculodopsis longimana										
Oediceroides cinderella										
Perioculodes spp.								0.1		
Westwoodilla manta									0.1	
Paraphoxus oculatus							0.1		0.1	
Platyischnopus herdmani										
Podocerus brasiliensis										
Podoceropsis sophiae										

TAXA	R1.1	R1.2	R1.3	R1.4	R1.5	R1.6	R1.7	R1.8	R1.9	R1.10
Eupariambus fallax		0.1	0.1				0.1			
Phtisca marina					0.1					
Hyperiidae					0.2				0.1	
Hyperiid B										
Ingolfiellid A			0.1							0.1
Ingolfiellid B										
Ingolfiellid C						0.1				
Cumacea A					0.1					
Cumacea C										
Leptostraca A										
Pterygosquilla armata										
Stomatopoda B										
Stomatopod juvenile										
Mysidacea spp.										
Gastrosaccus psammodytes					0.1					
ORDER EUPHAUSIACEA	0.1	0.1	0.1		0.2	0.1	0.1	0.2	0.1	0.2
Penaeid A										
Penaeid B										
Penaeid C										
Carida B										
Carida C (Mysidaea)		0.1								
Carida F			0.1							
Anomura										
Calocaris barnardi			0.1							0.1
Callianassa spp.	0.1		0.1		0.1	0.1		0.2		
Anomura A										
Goneplax angulata	0.1	0.34	0.1	0.8	0.83		0.12	0.99	0.2	0.31
Mursia cristimanus		7.55								
Brachyura A										
Brachyura B										
Brachyura C					0.1					
PHYLUM BRACHIOPODA										
Terebratulina meridionalis										
PHYLUM MOLLUSCA										
Ischnochiton bergoti				0.1						
Macoma spp.	0.1	0.1	0.8	0.1	0.8		0.4	0.1	0.3	0.15
Tellina spp.	0.8									0.14
Dosinia spp.	0.1	0.3	0.4		0.19	0.6	0.4	0.1	0.6	0.1
Nucula nucleus				0.5						
Bivalve F										
Bivalve M										
Alvania fenestrata										
Bullia digitalis										
Charitodoron euphrosyne										
Epitonium kraussi			0.7							
Gibbula spp.										
Heliacus variegata										
Marginella spp.		1.37	0.2		0.1	0.3		0.8		
Melanella sp.										
Nassarius spp.		0.49	0.71		0.87	0.22	0.1	0.39		0.2
Natica tecta										
Ocenebra spp.										

TAXA	R1.1	R1.2	R1.3	R1.4	R1.5	R1.6	R1.7	R1.8	R1.9	R1.10
Protomella capensis										
Pyramidella spp.										
Solariella agulhasensis										
Tricolia capensis			0.1		0.1		0.4			
Triphora africana										
Turris spp.										
Turritella spp.										
Volutocorbis abyssicola										
V olvarina capensis										
Sepia spp.										
Cucumaria spp.										
PHYLUM ECHINODERMATA										
Amphipholis squamata										
Ophionereis porrecta					0.1					0.5
Henricia spp.										

TAXA	R1.11	R2.1	R2.2	R2.3	R2.4	R2.5	R2.6	R2.7
PHYLUM PORIFERA								
Porifera A								
PHYLUM CNIDARIA								
Scyphozoa A								
Anthozoa A				0.14				
Anthozoa B								
Anthozoa D								
PHYLUM NEMERTEA								
Cerebratulus spp.		0.3	0.15			0.5		
Lineus spp.						0.2		
Nemertea B								
Nemertea C			0.9					
Nemertea D								
Siphunculid A								
Siphunculid B								
PHYLUM ANNELIDA								
Lumbrineris spp.	0.52	2.18	0.76	2.63	1.22	1.39	1.27	0.43
Arabella spp.								0.3
Diopatra spp.		0.44		0.3			0.96	1.9
Glyceridae								
Nereidae		0.1	0.4					
Nereis spp.								
Perinereis/Pseudonereis spp.								
Nephtys spp.		0.6	0.4	0.8			0.2	0.8
Spionidae								
Prionospio pinnata	0.24	0.43	0.44	0.19	0.75	0.43	1.73	0.51
Spio spp.								
Spiophanes spp.								0.1
Laonice cirrata	0.1	0.9					0.8	0.6
Spionid O				0.1		0.5		
Spionid P								0.1
Polydora spp.								
Orbiniidae		0.13	0.22		0.5			0.1
Haploscoloplos spp.	0.1			0.3			0.9	0.7
Scoloplos spp.					0.1			0.1
Phylo spp.							0.39	
Naineris spp.								
Orbiniidae B						0.8		
Orbinia angrapaquensis								
Poly BB				0.21				
Poly WW								
Paraonidae								0.1
Cirrophorus branchiatus								
Ophelia spp.								
Capitellidae spp.								
Notomastus spp.			0.12					0.2
Maldanidae	0.2	0.1	0.1		0.3			
Maldaninae A								
Maldaninae B								
Euclymene luderitziana								0.1
Petaloproctus spp.								

TAXA	R1.11	R2.1	R2.2	R2.3	R2.4	R2.5	R2.6	R2.7
Rhodine gracilior								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri	0.1							
Ampharete spp. A								
Terebellidae			0.23		0.12			
Trichobranchus glacialis								
Terebellides stroemi		0.26		0.39	0.44			0.5
Amaeana trilobata/Polycirrus							0.5	
Flabelligera spp.						0.18		
Pectinariidae								
Poly UU								0.1
PHYLUM ARTHROPODA								
Copepoda A								
Myodocopa								
Isopod A								
Arcturidae								
Arcturidae A	0.1							0.1
Arcturid B								
Arcturid C								
Arcturid D								
Cirolana spp.								
Microarcturus quadriconus								
New amphipod								
Ampelisca spp.	0.2	0.11	0.3	0.3	0.7	0.7	0.7	0.7
Aora kergeuleni								0.1
Aorcho delgadus								
Corophiid A (Gammaropsis)			0.1			0.1		
Corophiid Q								0.1
Atylus swammerdamei								
Guernea rhomba								
Paramoera capensis						0.1		
Maera spp.		0.1	0.1					
Urothoe spp.	0.1		0.1				0.1	
Leucothoe spp.	0.1					0.1	0.1	
Acidostoma obesum			0.1					
Hippomedon longimanus	0.4	0.1	0.4	0.1	0.3		0.1	0.4
Euonyx biscayensis								
Socarnopsis crenulata								
Monoculodopsis longimana								
Oediceroides cinderella	0.1							
Perioculodes spp.								
Westwoodilla manta		0.1			0.1			
Paraphoxus oculatus								0.1
Platyischnopus herdmani								
Podocerus brasiliensis								
Podoceropsis sophiae								
Eupariambus fallax								
Phtisca marina								
Hyperiidae				0.1		0.1		
Hyperiid B								

TAXA	R1.11	R2.1	R2.2	R2.3	R2.4	R2.5	R2.6	R2.7
Ingolfiellid A		0.1	0.1					
Ingolfiellid B				0.1				
Ingolfiellid C								
Cumacea A	0.1				0.1	0.1		
Cumacea C								
Leptostraca A						0.1		
Pterygosquilla armata								
Stomatopoda B								
Stomatopod juvenile					0.1			
Mysidacea spp.								
Gastrosaccus psammodytes								
ORDER EUPHAUSIACEA		0.1			0.1	0.4	0.3	0.5
Penaeid A								
Penaeid B								
Penaeid C								
Carida B			0.7					
Carida C (Mysidaea)								
Carida F								
Anomura								
Calocaris barnardi								
Callianassa spp.	0.1	0.1	0.1	0.1	0.1		0.1	0.2
Anomura A			0.5	0.19	0.1	0.3		0.1
Goneplax angulata		0.5	1.12	1.19	0.23	0.5	0.5	0.9
Mursia cristimanus	5							
Brachyura A								
Brachyura B								
Brachyura C							0.1	
PHYLUM BRACHIOPODA								
Terebratulina meridionalis								
PHYLUM MOLLUSCA								
Ischnochiton bergoti								
Macoma spp.	0.1	0.1	0.5	0.11	0.2	0.1	0.4	0.1
Tellina spp.		0.1			0.1			
Dosinia spp.	0.8	0.8	0.28	0.1		0.1	0.1	0.14
Nucula nucleus								
Bivalve F					0.1		0.1	
Bivalve M								
Alvania fenestrata								
Bullia digitalis								
Charitodoron euphrosyne								
Epitonium kraussi								
Gibbula spp.								
Heliacus variegata			0.14					
Marginella spp.		0.4	0.6			0.23		
Melanella sp.								
Nassarius spp.	0.1	2.17	1.23		0.18			
Natica tecta								
Ocenebra spp.								
Protomella capensis								
Pyramidella spp.								
Solariella agulhasensis								

TAXA	R1.11	R2.1	R2.2	R2.3	R2.4	R2.5	R2.6	R2.7
Tricolia capensis								
Triphora africana								
Turris spp.			0.45					
Turritella spp.								
Volutocorbis abyssicola								
V olvarina capensis								
Sepia spp.								
Cucumaria spp.								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								
Henricia spp.								

TAXA	R2.8	R2.9	R2.10	R3.1	R3.2	R3.3	R3.4	R3.5
PHYLUM PORIFERA								
Porifera A								
PHYLUM CNIDARIA								
Scyphozoa A		0.1						
Anthozoa A								0.83
Anthozoa B						0.8		
Anthozoa D				0.2				
PHYLUM NEMERTEA								
Cerebratulus spp.	0.6			0.9				
Lineus spp.								
Nemertea B								
Nemertea C	0.2							
Nemertea D				0.1				
Siphunculid A				0.39				
Siphunculid B				0.73				
PHYLUM ANNELIDA								
Lumbrineris spp.	1.75	0.3	0.16	3.81	0.15	0.76		
Arabella spp.	0.74							0.4
Diopatra spp.	0.4							
Glyceridae								
Nereidae								
Nereis spp.								
Perinereis/Pseudonereis spp.								
Nephtys spp.	0.8			0.13				
Spionidae								
Prionospio pinnata	0.5	0.2	0.36	0.1		0.3	0.1	0.1
Spio spp.	0.1					0.1		
Spiophanes spp.						0.1		
Laonice cirrata			0.2	0.1		0.3		
Spionid O								
Spionid P								
Polydora spp.								
Orbiniidae			0.7	0.1				
Haploscoloplos spp.	0.3	0.2						
Scoloplos spp.								
Phylo spp.								0.35
Naineris spp.								
Orbiniidae B				0.9				
Orbinia angrapaquensis								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Ophelia spp.						0.2		
Capitellidae spp.								
Notomastus spp.	0.34				0.1			
Maldanidae								
Maldaninae A								
Maldaninae B								
Euclymene luderitziana								
Petaloproctus spp.								

TAXA	R2.8	R2.9	R2.10	R3.1	R3.2	R3.3	R3.4	R3.5
Rhodine gracilior								
Sabellides spp.								
Ampharetidae							0.1	
Amphicteis gunneri								
Ampharete spp. A								
Terebellidae								
Trichobranchus glacialis								
Terebellides stroemi	0.3		1.22	0.12		0.8		0.39
Amaeana trilobata/Polycirrus	1.57							
Flabelligera spp.								
Pectinariidae								
Poly UU								
PHYLUM ARTHROPODA								
Copepoda A								
Myodocopa		0.1						
Isopod A								
Arcturidae								
Arcturidae A	0.1							
Arcturid B								
Arcturid C	0.1							
Arcturid D								
Cirolana spp.	0.2					0.3	0.3	
Microarcturus quadriconus								
New amphipod				0.1				
Ampelisca spp.	0.5	0.2	0.6	0.2		0.3	0.1	
Aora kergeuleni								
Aorcho delgadus	0.1	0.1				0.1		
Corophiid A (Gammaropsis)								
Corophiid Q								
Atylus swammerdamei								
Guernea rhomba								
Paramoera capensis								
Maera spp.								
Urothoe spp.	0.1							
Leucothoe spp.	0.1		0.1	0.1				
Acidostoma obesum	0.1	0.1					1.2	
Hippomedon longimanus	0.4	0.1		0.2				
Euonyx biscayensis								
Socarnopsis crenulata								
Monoculodopsis longimana								
Oediceroides cinderella		0.1						
Perioculodes spp.			0.1					
Westwoodilla manta								
Paraphoxus oculatus	0.1							
Platyischnopus herdmani	0.1							
Podocerus brasiliensis			0.1					
Podoceropsis sophiae		0.1						
Eupariambus fallax								
Phtisca marina	0.1							
Hyperiidae	0.1		0.1				0.1	
Hyperiid B								

TAXA	R2.8	R2.9	R2.10	R3.1	R3.2	R3.3	R3.4	R3.5
Ingolfiellid A	0.1							
Ingolfiellid B								
Ingolfiellid C								
Cumacea A	0.1							
Cumacea C								
Leptostraca A								
Pterygosquilla armata								
Stomatopoda B								
Stomatopod juvenile								
Mysidacea spp.								
Gastrosaccus psammodytes								
ORDER EUPHAUSIACEA	0.2	0.5	0.1	0.1		0.1	0.1	
Penaeid A								
Penaeid B								
Penaeid C								
Carida B	0.3		0.1			0.1	0.1	
Carida C (Mysidaea)	0.1							
Carida F								
Anomura								
Calocaris barnardi								
Callianassa spp.	2.1		0.1					
Anomura A			0.1	0.1	0.5	0.1	0.1	0.1
Goneplax angulata	0.28	0.1	0.8	3.56	0.1	0.25	0.4	
Mursia cristimanus								
Brachyura A								0.31
Brachyura B								
Brachyura C								
PHYLUM BRACHIOPODA								
Terebratulina meridionalis		0.3						
PHYLUM MOLLUSCA								
Ischnochiton bergoti								
Macoma spp.	0.3		0.5	0.53	0.1	0.1		
Tellina spp.								
Dosinia spp.	0.44		0.1	0.6		0.5		
Nucula nucleus								
Bivalve F	0.1	0.2	0.1	0.5				
Bivalve M								
Alvania fenestrata								
Bullia digitalis								
Charitodoron euphrosyne								
Epitonium kraussi								
Gibbula spp.								
Heliacus variegata			0.15					
Marginella spp.	0.29	0.5	0.2	0.5	0.3	0.91	0.2	
Melanella sp.								
Nassarius spp.	4.46	0.3	0.28	0.64	0.2	0.11	0.47	
Natica tecta	0.17							
Ocenebra spp.								
Protomella capensis								
Pyramidella spp.				0.2				
Solariella agulhasensis				0.1				

TAXA	R2.8	R2.9	R2.10	R3.1	R3.2	R3.3	R3.4	R3.5
Tricolia capensis				0.2	0.1			
Triphora africana				0.1				
Turris spp.								
Turritella spp.	0.9							
Volutocorbis abyssicola								
V olvarina capensis								
Sepia spp.								
Cucumaria spp.								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta						0.1		
Henricia spp.								

TAXA	R3.6	R3.7	R3.8	R3.9	R3.10	R4.1	R4.2	R4.3
PHYLUM PORIFERA								
Porifera A								
PHYLUM CNIDARIA								
Scyphozoa A								
Anthozoa A			1.75					
Anthozoa B			0.11					
Anthozoa D								
PHYLUM NEMERTEA								
Cerebratulus spp.	0.8		0.7		0.5			
Lineus spp.								
Nemertea B								0.86
Nemertea C			0.1					
Nemertea D								
Siphunculid A								
Siphunculid B								
PHYLUM ANNELIDA								
Lumbrineris spp.	0.11	0.1	3.17	1.75	1.54	0.2	0.1	1.81
Arabella spp.								
Diopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.				0.1	0.7			
Perinereis/Pseudonereis spp.								
Nephtys spp.			0.41	0.15	0.42		0.1	0.7
Spionidae								
Prionospio pinnata	0.8	0.5	0.47	0.33	0.27	0.13	0.1	0.18
Spio spp.								
Spiophanes spp.								
Laonice cirrata	0.1		0.1	0.2		0.1		0.1
Spionid O								
Spionid P								
Polydora spp.								
Orbiniidae	0.5		0.5					
Haploscoloplos spp.		0.1	0.1	0.3	0.1	0.1		0.1
Scoloplos spp.								
Phylo spp.								
Naineris spp.								
Orbiniidae B								
Orbinia angrapaquensis								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Ophelia spp.								
Capitellidae spp.								
Notomastus spp.								
Maldanidae								
Maldaninae A								
Maldaninae B								
Euclymene luderitziana					0.5			
Petaloproctus spp.	0.8							

TAXA	R3.6	R3.7	R3.8	R3.9	R3.10	R4.1	R4.2	R4.3
Rhodine gracilior								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri	0.6		0.5					
Ampharete spp. A								
Terebellidae								
Trichobranchus glacialis								
Terebellides stroemi	0.58	0.1	0.34	0.14	0.5	0.9	0.1	0.33
Amaeana trilobata/Polycirrus								
Flabelligera spp.								
Pectinariidae								
Poly UU								
PHYLUM ARTHROPODA								
Copepoda A				0.1				
Myodocopa								
Isopod A								0.1
Arcturidae	0.1							
Arcturidae A								
Arcturid B								
Arcturid C								
Arcturid D								
Cirolana spp.								
Microarcturus quadriconus						0.1		
New amphipod								
Ampelisca spp.	0.13		0.2	0.3	0.3	0.4		0.4
Aora kergeuleni								
Aorcho delgadus	0.1							
Corophiid A (Gammaropsis)								
Corophiid Q								
Atylus swammerdamei						0.1		
Guernea rhomba						0.1		
Paramoera capensis								
Maera spp.								
Urothoe spp.								
Leucothoe spp.	0.1		0.1		0.1			
Acidostoma obesum			0.1	0.1			0.1	
Hippomedon longimanus	0.1		0.1	0.1	0.3			
Euonyx biscayensis								
Socarnopsis crenulata								
Monoculodopsis longimana						0.1		
Oediceroides cinderella								
Perioculodes spp.			0.1					
Westwoodilla manta			0.1					0.1
Paraphoxus oculatus				0.1	0.1			
Platyischnopus herdmani								
Podocerus brasiliensis								
Podoceropsis sophiae								
Eupariambus fallax								
Phtisca marina	0.1							
Hyperiidae	0.1		0.1	0.1		0.1		0.1
Hyperiid B								

TAXA	R3.6	R3.7	R3.8	R3.9	R3.10	R4.1	R4.2	R4.3
Ingolfiellid A								
Ingolfiellid B								
Ingolfiellid C								
Cumacea A								
Cumacea C								
Leptostraca A								
Pterygosquilla armata								
Stomatopoda B					0.1			
Stomatopod juvenile								
Mysidacea spp.								
Gastrosaccus psammodytes								
ORDER EUPHAUSIACEA	0.2		0.1		0.1	0.2		0.1
Penaeid A								
Penaeid B	0.2							
Penaeid C								
Carida B				0.1				
Carida C (Mysidaea)								
Carida F								
Anomura								
Calocaris barnardi								
Callianassa spp.			0.5	0.1	0.1			0.1
Anomura A	0.1		0.1	0.1				
Goneplax angulata	0.1		1.6	0.9	1.14	0.1	0.5	1.63
Mursia cristimanus								
Brachyura A								
Brachyura B								
Brachyura C								
PHYLUM BRACHIOPODA								
Terebratulina meridionalis								
PHYLUM MOLLUSCA								
Ischnochiton bergoti				0.83				
Macoma spp.	0.12		0.24	0.6	0.4	0.1	0.53	0.8
Tellina spp.								
Dosinia spp.			0.13		0.3			0.2
Nucula nucleus				0.61		2.1		0.68
Bivalve F	0.2		0.2	0.11				
Bivalve M								
Alvania fenestrata								
Bullia digitalis								
Charitodoron euphrosyne								
Epitonium kraussi								
Gibbula spp.								
Heliacus variegata								
Marginella spp.	1.91		0.2	0.3	0.4	0.6		0.1
Melanella sp.								
Nassarius spp.	0.2		0.64	0.1	0.13		3.8	6.3
Natica tecta								
Ocenebra spp.								
Protomella capensis								
Pyramidella spp.								
Solariella agulhasensis								

TAXA	R3.6	R3.7	R3.8	R3.9	R3.10	R4.1	R4.2	R4.3
Tricolia capensis								
Triphora africana								
Turris spp.			0.4					
Turritella spp.								
Volutocorbis abyssicola								
V olvarina capensis								
Sepia spp.								
Cucumaria spp.								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta	0.1							
Henricia spp.								

TAXA	R4.4	R4.5	R4.6	R4.7	R4.8	R4.9	R4.10	S1.1
PHYLUM PORIFERA								
Porifera A								
PHYLUM CNIDARIA								
Scyphozoa A								
Anthozoa A								
Anthozoa B								
Anthozoa D								
PHYLUM NEMERTEA								
Cerebratulus spp.		0.2			0.1			
Lineus spp.								
Nemertea B								
Nemertea C					0.7			
Nemertea D								
Siphunculid A		0.65						
Siphunculid B		1						0.9
PHYLUM ANNELIDA								
Lumbrineris spp.	2.73	4.11	0.1	1.59	0.14	0.1	0.1	0.1
Arabella spp.	0.1		0.41					
Diopatra spp.			0.5		0.18			
Glyceridae								
Nereidae								
Nereis spp.		0.2	0.1		0.21			
Perinereis/Pseudonereis spp.								
Nephtys spp.	0.9	0.2	0.15	0.4	0.9			
Spionidae								
Prionospio pinnata	0.2	0.6	0.2	0.4	0.1	0.1	0.1	0.15
Spio spp.								
Spiophanes spp.					0.1			
Laonice cirrata			0.1	0.2			0.4	
Spionid O					0.2			
Spionid P								
Polydora spp.								
Orbiniidae					0.3		0.1	
Haploscoloplos spp.		0.3						0.1
Scoloplos spp.								
Phylo spp.								
Naineris spp.								
Orbiniidae B								
Orbinia angrapaquensis								
Poly BB								
Poly WW		0.1						
Paraonidae								
Cirrophorus branchiatus								
Ophelia spp.		0.1	0.1					
Capitellidae spp.								
Notomastus spp.							0.4	
Maldanidae					0.1			
Maldaninae A								
Maldaninae B								
Euclymene luderitziana								
Petaloproctus spp.								

TAXA	R4.4	R4.5	R4.6	R4.7	R4.8	R4.9	R4.10	S1.1
Rhodine gracilior								
Sabellides spp.					0.13			
Ampharetidae					0.9			
Amphicteis gunneri			0.8	0.1				
Ampharete spp. A								
Terebellidae								
Trichobranchus glacialis								
Terebellides stroemi		0.2	0.31	0.7	1.88	0.16	0.1	
Amaeana trilobata/Polycirrus								
Flabelligera spp.								
Pectinariidae								
Poly UU								
PHYLUM ARTHROPODA								
Copepoda A								0.1
Myodocopa								
Isopod A								
Arcturidae								
Arcturidae A								
Arcturid B								
Arcturid C								
Arcturid D								
Cirolana spp.					0.2			
Microarcturus quadriconus					0.1			
New amphipod								
Ampelisca spp.	0.1	0.1	0.1	0.3	0.3			
Aora kergeuleni								
Aorcho delgadus			0.1		0.1			
Corophiid A (Gammaropsis)								
Corophiid Q								
Atylus swammerdamei	0.1							
Guernea rhomba								
Paramoera capensis								
Maera spp.								
Urothoe spp.								
Leucothoe spp.		0.1		0.1	0.1			
Acidostoma obesum			0.1		0.1			
Hippomedon longimanus	0.1		0.1	0.9	0.13	0.1		0.3
Euonyx biscayensis								
Socarnopsis crenulata								
Monoculodopsis longimana								
Oediceroides cinderella								
Perioculodes spp.								
Westwoodilla manta								
Paraphoxus oculatus								
Platyischnopus herdmani								
Podocerus brasiliensis								
Podoceropsis sophiae								
Eupariambus fallax					0.1			
Phtisca marina								
Hyperiidae		0.1						
Hyperiid B								

TAXA	R4.4	R4.5	R4.6	R4.7	R4.8	R4.9	R4.10	S1.1
Ingolfiellid A								
Ingolfiellid B								
Ingolfiellid C								
Cumacea A								
Cumacea C								
Leptostraca A								
Pterygosquilla armata			0.69					
Stomatopoda B								
Stomatopod juvenile								
Mysidacea spp.								
Gastrosaccus psammodytes								
ORDER EUPHAUSIACEA	0.1							
Penaeid A								
Penaeid B		0.2						
Penaeid C								
Carida B								
Carida C (Mysidaea)					0.1			
Carida F								
Anomura								
Calocaris barnardi		0.1						
Callianassa spp.	0.1							
Anomura A		0.1		0.1	0.1			
Goneplax angulata	0.7	0.62	0.17	0.56	0.34	0.1		
Mursia cristimanus	1.83				5.31			
Brachyura A								
Brachyura B								
Brachyura C								
PHYLUM BRACHIOPODA								
Terebratulina meridionalis								
PHYLUM MOLLUSCA								
Ischnochiton bergoti							0.27	
Macoma spp.	0.49	0.7	0.82	0.44	1.8	0.4	0.6	0.2
Tellina spp.					0.18			
Dosinia spp.	0.1	0.1	0.2		0.9			0.1
Nucula nucleus		1.1				0.42	0.56	
Bivalve F		0.1						
Bivalve M								
Alvania fenestrata					0.1	0.1		
Bullia digitalis								0.1
Charitodoron euphrosyne								
Epitonium kraussi					0.2			
Gibbula spp.								0.1
Heliacus variegata								0.1
Marginella spp.	0.1	0.11	0.1		0.1	0.3		0.12
Melanella sp.								0.2
Nassarius spp.		0.42	0.8	0.1	0.44			0.2
Natica tecta								
Ocenebra spp.					0.2			0.1
Protomella capensis								0.6
Pyramidella spp.					0.2			
Solariella agulhasensis					0.22			0.1

TAXA	R4.4	R4.5	R4.6	R4.7	R4.8	R4.9	R4.10	S1.1
Tricolia capensis			0.1		0.13	0.2		0.8
Triphora africana								
Turris spp.								
Turritella spp.								
Volutocorbis abyssicola								
V olvarina capensis								
Sepia spp.								
Cucumaria spp.								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta					0.1			
Henricia spp.					0.53			

TAXA	S1.5	S1.11	S1.14	S1.15	S1.17	S2.2	S2.3	S2.4
PHYLUM PORIFERA								
Porifera A								
PHYLUM CNIDARIA								
Scyphozoa A								
Anthozoa A								
Anthozoa B								
Anthozoa D								
PHYLUM NEMERTEA								
Cerebratulus spp.				0.3				
Lineus spp.				0.1				
Nemertea B								
Nemertea C								
Nemertea D								
Siphunculid A								
Siphunculid B								
PHYLUM ANNELIDA								
Lumbrineris spp.	0.2	0.12	0.3	0.57	0.7	0.4	3.26	0.44
Arabella spp.				0.1				
Diopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.				0.1				
Perinereis/Pseudonereis spp.	0.4							
Nephtys spp.		0.8	0.3	0.1			0.1	0.94
Spionidae				0.1				
Prionospio pinnata	0.8	0.3	0.3	0.1	0.19	0.31	0.4	0.25
Spio spp.								
Spiophanes spp.			0.1		0.1			
Laonice cirrata		0.1		0.1	0.1	0.5		
Spionid O								
Spionid P								
Polydora spp.								
Orbiniidae								
Haploscoloplos spp.	0.1	0.4	0.13	0.19	0.7	0.5	0.2	
Scoloplos spp.								
Phylo spp.				0.1				
Naineris spp.								
Orbiniidae B				0.31				
Orbinia angrapaquensis			0.2					
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus			0.1					
Ophelia spp.								
Capitellidae spp.								
Notomastus spp.		0.1	0.5					
Maldanidae		0.1	0.1	0.1	0.1			
Maldaninae A								
Maldaninae B								
Euclymene luderitziana								
Petaloproctus spp.								

TAXA	S1.5	S1.11	S1.14	S1.15	S1.17	S2.2	S2.3	S2.4
Rhodine gracilior		0.1		0.1				
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri				0.2				
Ampharete spp. A								
Terebellidae								
Trichobranchus glacialis								
Terebellides stroemi		0.8				0.6		0.39
Amaeana trilobata/Polycirrus								
Flabelligera spp.								
Pectinariidae								
Poly UU								
PHYLUM ARTHROPODA								
Copepoda A								0.1
Myodocopa								
Isopod A								
Arcturidae			0.1	0.1				
Arcturidae A								
Arcturid B								
Arcturid C								
Arcturid D								
Cirolana spp.								
Microarcturus quadriconus								
New amphipod								
Ampelisca spp.		0.1	0.2		0.1	0.1	0.2	0.6
Aora kergeuleni								
Aorcho delgadus				0.1				
Corophiid A (Gammaropsis)								
Corophiid Q								
Atylus swammerdamei								
Guernea rhomba								
Paramoera capensis								
Maera spp.								
Urothoe spp.								
Leucothoe spp.		0.1	0.1	0.1	0.1			0.1
Acidostoma obesum			0.1	0.1				
Hippomedon longimanus	0.2	0.3	0.1		0.18	0.1		0.2
Euonyx biscayensis								
Socarnopsis crenulata								
Monoculodopsis longimana								
Oediceroides cinderella								
Perioculodes spp.					0.1			
Westwoodilla manta							0.1	
Paraphoxus oculatus		0.1						
Platyischnopus herdmani						0.1		
Podocerus brasiliensis								
Podoceropsis sophiae								
Eupariambus fallax								
Phtisca marina				0.1				
Hyperiidae			0.1	0.1		0.1		
Hyperiid B				0.1				

TAXA	S1.5	S1.11	S1.14	S1.15	S1.17	S2.2	S2.3	S2.4
Ingolfiellid A				0.1				
Ingolfiellid B								
Ingolfiellid C								
Cumacea A	0.1		0.1			0.1		
Cumacea C								
Leptostraca A								0.1
Pterygosquilla armata								
Stomatopoda B								
Stomatopod juvenile				0.1				
Mysidacea spp.								
Gastrosaccus psammodytes								
ORDER EUPHAUSIACEA					0.1			0.2
Penaeid A							0.6	0.3
Penaeid B								
Penaeid C			0.3			0.12		
Carida B								
Carida C (Mysidaea)	0.1					0.1		
Carida F								
Anomura								
Calocaris barnardi								
Callianassa spp.								1.29
Anomura A								
Goneplax angulata							0.21	0.2
Mursia cristimanus								
Brachyura A								
Brachyura B								0.1
Brachyura C								
PHYLUM BRACHIOPODA								
Terebratulina meridionalis								0.9
PHYLUM MOLLUSCA								
Ischnochiton bergoti								
Macoma spp.	0.3	0.7	0.43	0.1	0.21	0.1		0.2
Tellina spp.		0.1						
Dosinia spp.	0.5			0.4				
Nucula nucleus								
Bivalve F		0.1	0.1		0.1	0.14		
Bivalve M								
Alvania fenestrata		0.1	0.1	0.1				
Bullia digitalis	0.29							
Charitodoron euphrosyne		0.1	0.2					
Epitonium kraussi	0.5	0.3			0.5			
Gibbula spp.								
Heliacus variegata								
Marginella spp.	0.1	0.1	0.1	0.1		0.1	1.14	0.96
Melanella sp.								
Nassarius spp.	2.99	0.35	0.38	0.56	0.26		0.14	1.34
Natica tecta								
Ocenebra spp.	0.6	0.1			0.2			
Protomella capensis	0.1							
Pyramidella spp.								
Solariella agulhasensis	0.5	0.3			0.1			

TAXA	S1.5	S1.11	S1.14	S1.15	S1.17	S2.2	S2.3	S2.4
Tricolia capensis	0.9	0.11	0.1	0.1	0.5			
Triphora africana								
Turris spp.								
Turritella spp.					0.4			
Volutocorbis abyssicola								
V olvarina capensis				0.1				
Sepia spp.								
Cucumaria spp.								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								
Henricia spp.								

TAXA	S2.5	S2.6	S2.7	S3.1	S3.2	S3.3	S3.4	S3.5
PHYLUM PORIFERA								
Porifera A								
PHYLUM CNIDARIA								
Scyphozoa A								
Anthozoa A								
Anthozoa B								
Anthozoa D								
PHYLUM NEMERTEA								
Cerebratulus spp.								
Lineus spp.								
Nemertea B								
Nemertea C			0.2					
Nemertea D								
Siphunculid A								
Siphunculid B					3.72			
PHYLUM ANNELIDA								
Lumbrineris spp.	1.55	0.3	1.38	0.1	1.42	1.5	0.7	0.2
Arabella spp.								
Diopatra spp.			1.5		0.3			
Glyceridae								
Nereidae								
Nereis spp.								
Perinereis/Pseudonereis spp.								
Nephtys spp.	0.57							
Spionidae	0.2							
Prionospio pinnata	0.39	0.35	0.17	0.5	0.1		0.11	0.1
Spio spp.								
Spiophanes spp.								
Laonice cirrata	0.1	0.2		0.1	0.1	0.2	0.3	0.1
Spionid O								
Spionid P								
Polydora spp.								
Orbiniidae	0.3							
Haploscoloplos spp.	0.4	0.1		0.1	0.2	0.4	0.2	0.1
Scoloplos spp.								
Phylo spp.								
Naineris spp.					0.29			
Orbiniidae B								
Orbinia angrapaquensis			0.6					
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Ophelia spp.								
Capitellidae spp.			0.33					
Notomastus spp.					0.2	0.2		
Maldanidae								
Maldaninae A								
Maldaninae B								
Euclymene luderitziana								
Petaloproctus spp.								

TAXA	S2.5	S2.6	S2.7	S3.1	S3.2	S3.3	S3.4	S3.5
Rhodine gracilior								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri			0.2					
Ampharete spp. A					0.1			
Terebellidae								
Trichobranchus glacialis								
Terebellides stroemi						0.1		0.3
Amaeana trilobata/Polycirrus	0.12							
Flabelligera spp.								
Pectinariidae								
Poly UU								
PHYLUM ARTHROPODA								
Copepoda A		0.1			0.1			0.1
Myodocopa								
Isopod A								
Arcturidae								
Arcturidae A								
Arcturid B			0.1					
Arcturid C								
Arcturid D								
Cirolana spp.								
Microarcturus quadriconus								
New amphipod								
Ampelisca spp.	0.1	0.4	0.4			0.1	0.1	0.2
Aora kergeuleni						0.1	0.1	
Aorcho delgadus		0.1			0.1			0.1
Corophiid A (Gammaropsis)								
Corophiid Q								
Atylus swammerdamei								
Guernea rhomba								
Paramoera capensis								
Maera spp.					0.5	0.1		
Urothoe spp.								
Leucothoe spp.	0.1	0.1	0.1		0.2	0.1	0.1	0.2
Acidostoma obesum					0.1	0.1	0.1	0.2
Hippomedon longimanus			0.1				0.1	0.1
Euonyx biscayensis	0.2							
Socarnopsis crenulata						0.1		
Monoculodopsis longimana								
Oediceroides cinderella								
Perioculodes spp.								
Westwoodilla manta	0.1							
Paraphoxus oculatus								
Platyischnopus herdmani								
Podocerus brasiliensis								
Podoceropsis sophiae								
Eupariambus fallax								
Phtisca marina								
Hyperiidae	0.1					0.1	0.1	0.1
Hyperiid B		0.1			0.1			

TAXA	S2.5	S2.6	S2.7	S3.1	S3.2	S3.3	S3.4	S3.5
Ingolfiellid A								
Ingolfiellid B								
Ingolfiellid C								
Cumacea A								
Cumacea C					0.1			
Leptostraca A								
Pterygosquilla armata								
Stomatopoda B								
Stomatopod juvenile								0.1
Mysidacea spp.								
Gastrosaccus psammodytes								
ORDER EUPHAUSIACEA			0.1			0.2		
Penaeid A								
Penaeid B								
Penaeid C						0.7	0.5	
Carida B		0.1						0.2
Carida C (Mysidaea)	0.1							
Carida F								
Anomura								
Calocaris barnardi								
Callianassa spp.							0.1	
Anomura A								
Goneplax angulata	1.61		0.7			0.29	0.6	
Mursia cristimanus								
Brachyura A								
Brachyura B								
Brachyura C								
PHYLUM BRACHIOPODA								
Terebratulina meridionalis		0.1	0.1					
PHYLUM MOLLUSCA								
Ischnochiton bergoti					0.69			
Macoma spp.	0.1	0.1	0.2	0.3	0.5	0.9	0.9	0.4
Tellina spp.					0.5	0.1		0.1
Dosinia spp.		0.1	0.1		0.1			
Nucula nucleus				0.28				
Bivalve F	0.4							
Bivalve M					0.2			
Alvania fenestrata					0.1			
Bullia digitalis								
Charitodoron euphrosyne								
Epitonium kraussi						0.7		
Gibbula spp.					0.15			
Heliacus variegata								
Marginella spp.			0.5	0.1	0.1			
Melanella sp.								
Nassarius spp.		0.53	2.21	0.1	3.48	9.82	0.34	2.11
Natica tecta								
Ocenebra spp.					0.5	0.1		
Protomella capensis								
Pyramidella spp.							0.1	
Solariella agulhasensis						0.1	0.1	0.1

TAXA	S2.5	S2.6	S2.7	S3.1	S3.2	S3.3	S3.4	S3.5
Tricolia capensis					0.7	0.3	0.3	0.1
Triphora africana								
Turris spp.								
Turritella spp.								
Volutocorbis abyssicola								
V olvarina capensis								
Sepia spp.							0.12	
Cucumaria spp.	2.19							
PHYLUM ECHINODERMATA								
Amphipholis squamata		0.1						
Ophionereis porrecta								
Henricia spp.								

TAXA	S3.7	S4.2	S4.6	S4.8	S4.9	S4.13	S4.14	S4.15
PHYLUM PORIFERA								
Porifera A								
PHYLUM CNIDARIA								
Scyphozoa A								
Anthozoa A								
Anthozoa B								
Anthozoa D								
PHYLUM NEMERTEA								
Cerebratulus spp.		0.23				0.8	0.2	
Lineus spp.								
Nemertea B								
Nemertea C								
Nemertea D								
Siphunculid A								
Siphunculid B								
PHYLUM ANNELIDA								
Lumbrineris spp.	0.7	0.4	0.1	0.15		1.1	0.2	0.3
Arabella spp.							0.41	
Diopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.								
Perinereis/Pseudonereis spp.							0.1	
Nephtys spp.						0.28	0.89	
Spionidae								
Prionospio pinnata	0.1	0.5	0.1	0.2	0.13	0.6	0.12	
Spio spp.								
Spiophanes spp.								
Laonice cirrata	0.1	0.6		0.2			0.1	
Spionid O								
Spionid P								
Polydora spp.								
Orbiniidae								0.12
Haploscoloplos spp.						0.3	0.1	
Scoloplos spp.				0.1			0.15	0.16
Phylo spp.								
Naineris spp.								
Orbiniidae B								
Orbinia angrapaquensis								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Ophelia spp.								
Capitellidae spp.								
Notomastus spp.								
Maldanidae								
Maldaninae A								
Maldaninae B								
Euclymene luderitziana								
Petaloproctus spp.								

TAXA	S3.7	S4.2	S4.6	S4.8	S4.9	S4.13	S4.14	S4.15
Rhodine gracilior								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri		0.1						
Ampharete spp. A								
Terebellidae								
Trichobranchus glacialis	0.14							
Terebellides stroemi		0.45		0.14		0.3		
Amaeana trilobata/Polycirrus								
Flabelligera spp.		0.16				0.25		
Pectinariidae								
Poly UU								
PHYLUM ARTHROPODA								
Copepoda A								
Myodocopa								
Isopod A	0.1							
Arcturidae								
Arcturidae A								
Arcturid B								
Arcturid C								
Arcturid D								
Cirolana spp.						0.3		
Microarcturus quadriconus								
New amphipod								
Ampelisca spp.		0.3				0.1	0.1	
Aora kergeuleni								
Aorcho delgadus				0.1		0.1		
Corophiid A (Gammaropsis)								
Corophiid Q								
Atylus swammerdamei								
Guernea rhomba								
Paramoera capensis								
Maera spp.	0.1					0.5		
Urothoe spp.								
Leucothoe spp.	0.1		0.1	0.1		0.1		
Acidostoma obesum	0.1					0.11		
Hippomedon longimanus		0.1				0.1	0.1	
Euonyx biscayensis								
Socarnopsis crenulata								
Monoculodopsis longimana								
Oediceroides cinderella								
Perioculodes spp.								
Westwoodilla manta		0.1						
Paraphoxus oculatus								
Platyischnopus herdmani								
Podocerus brasiliensis								
Podoceropsis sophiae								
Eupariambus fallax								
Phtisca marina								
Hyperiidae								
Hyperiid B	0.1							

TAXA	S3.7	S4.2	S4.6	S4.8	S4.9	S4.13	S4.14	S4.15
Ingolfiellid A								
Ingolfiellid B								
Ingolfiellid C								
Cumacea A								
Cumacea C		0.1						
Leptostraca A								
Pterygosquilla armata								
Stomatopoda B								
Stomatopod juvenile								
Mysidacea spp.				0.1				
Gastrosaccus psammodytes								
ORDER EUPHAUSIACEA								
Penaeid A								
Penaeid B								
Penaeid C	0.8	0.11		0.18				
Carida B								
Carida C (Mysidaea)								
Carida F								
Anomura								
Calocaris barnardi								
Callianassa spp.								
Anomura A	0.1							
Goneplax angulata	0.38			0.23			1.5	
Mursia cristimanus								
Brachyura A								
Brachyura B								
Brachyura C								
PHYLUM BRACHIOPODA								
Terebratulina meridionalis								
PHYLUM MOLLUSCA								
Ischnochiton bergoti								
Macoma spp.	0.3	0.14		0.28		0.13	0.1	0.1
Tellina spp.							0.2	
Dosinia spp.							0.9	
Nucula nucleus	3			0.18				
Bivalve F	0.2					0.1		
Bivalve M								
Alvania fenestrata								0.1
Bullia digitalis								
Charitodoron euphrosyne								
Epitonium kraussi							0.2	
Gibbula spp.								
Heliacus variegata								
Marginella spp.	0.1	0.1		2.9				0.2
Melanella sp.								
Nassarius spp.	0.78	6.12		1.4	0.4	1.1	6.3	1.42
Natica tecta								
Ocenebra spp.				0.2				0.3
Protomella capensis								
Pyramidella spp.				0.1				0.1
Solariella agulhasensis					0.1		0.12	0.4

TAXA	S3.7	S4.2	S4.6	S4.8	S4.9	S4.13	S4.14	S4.15
Tricolia capensis		0.1		0.11			0.9	0.6
Triphora africana								
Turris spp.	0.84							
Turritella spp.								
Volutocorbis abyssicola		19.92						
V olvarina capensis								
Sepia spp.								
Cucumaria spp.								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								
Henricia spp.								

MACROFAUNA BIOMASS DATA FOR ALL SAMPLES

FROM THE SOUTHERN RESEARCH AREA

TAXON	R5.1	R5.3	R5.4	R5.5	R5.6	R5.7	R5.8	R5.9	R5.10	R6.6
PHYLUM CNIDARIA										
Anthozoa A										
Anthozoa B										
PHYLUM NEMERTEA										
Cerebratulus spp.	0.65		0.16	0.1			0.64	0.3	0.85	
Lineus spp.	0.5			0.6						
Nemertea B										
PHYLUM ANNELIDA										
Eunicidae										
Eunicidae spp. (drilonereis)										
Lumbrineris spp.	3.69	0.58	1.7	3.96	1.93	1.24	2.1	0.85	0.54	2.18
Arabella spp.				1.1		0.69		0.34		
Diopatra spp.	6.23	2.9	0.2	0.19	2.74	1.65		0.8	1.8	0.6
Epidiopatra spp.										
Glyceridae										
Nereidae										
Nereis spp.		0.34		0.24						
Perinereis/Pseudonereis spp.										
Micronereides capensis				0.1						
Nephtyidae	0.4		0.1				0.48			
Nephtys spp.				0.61	0.2	0.21		0.1		
Spionidae										
Prionospio pinnata	0.2	0.2	0.1	0.53	0.37	0.54	0.17	0.86	0.17	0.1
Laonice cirrata		0.1						0.1		
Haploscoloplos spp.					0.2			0.4		
Phylo spp.								0.87		
Poly BB										
Poly WW										
Paraonidae										
Cirrophorus branchiatus										
Capitellidae spp.										
Notomastus spp.		0.1								
Maldanidae	0.1				0.1					
Euclymene luderitziana		0.1								
Maldanella capensis										
Petaloproctus spp.										
Sabellides spp.		0.8								
Ampharetidae			0.39	0.3						
Amphicteis gunneri		0.36								
Terebellides spp.	1.44	12.27	0.49	0.49	0.61			2.6	1.34	
Amaeana trilobata/Polycirrus						0.5	0.5		0.3	0.2
Ancistrosyllis parva										
Flabelligeridae			0.58							
Flabelligera spp.										
Pectinaria capensis										

TAXON	R5.1	R5.3	R5.4	R5.5	R5.6	R5.7	R5.8	R5.9	R5.10	R6.6
Cossura coasta										
PHYLUM ARTHROPODA										
Tanaid A										
Copepoda A						0.1	0.1			
Isopod A										
Ampelisca spp.			0.1	0.1	0.3	0.2	0.3	0.7	0.1	0.1
Aora kergeuleni										
Aorcho delgadus		0.1								
Corophiid Q								0.1		
Guernea rhomba										
Rhachotropis spp.						0.1				
Elasmopus affinis			0.1							
Ceradocus natalensis										
Maera spp.					0.1					
Urothoe spp.										
Leucothoe spp.				0.4						
Listriella lindae		0.1			0.3		0.1			
Acidostoma obesum		0.1		0.1						
Hippomedon longimanus				0.1	0.1		0.1			
Westwoodilla manta				0.1	0.1	0.1	0.3			
Paraphoxus oculatus			0.1					0.1		0.1
Platyischnopus herdmani					0.1					
Podocerus brasiliensis										
Eupariambus fallax										
Hyperiidae					0.1	0.1	0.1	0.1		
Hyperiid B										
Cumacea B										
Cumacea C										
Leptostraca A										
Pterygosquilla armata	6.7	2.15		1.46	24.7	0.5				
Stomatopod juvenile							0.1	0.1		
Meiosquilla desmarestii										
ORDER EUPHAUSIACEA			0.1	0.5	0.6		0.1	0.1	0.1	
Carida A							0.14			
Carida B		0.1								
Carida C (Mysidaea)		0.1			0.1	0.1	0.1			
Carida D		0.1				0.2				
Carida F				0.3	0.1		0.5			
Calocaris barnardi	0.76	2.34		0.8	0.58	0.31		0.16	0.12	
Callianassa spp.	3.14	0.2	0.1	3.67	2.35	1.9	1.26	0.1		
Anomura A		0.1								
Goneplax angulata	2.99			1.53	0.2	0.9	0.65	2.1	0.1	
Mursia cristimanus										
Brachyura A										
PHYLUM MOLLUSCA										
Macoma spp.	0.4	0.6		0.3	0.3	0.1	0.2	0.6		0.1
Tellina spp.										
Dosinia spp.										
Nucula nucleus			0.78			0.13		0.1		
Bivalve F			0.1							
Bivalve I										

TAXON	R5.1	R5.3	R5.4	R5.5	R5.6	R5.7	R5.8	R5.9	R5.10	R6.6
Alvania fenestrata										
Clanculus sp.										
Epitonium kraussi										
Marginella spp.				0.1		0.3				
Nassarius spp.	0.1	0.8	0.26	0.23		0.25		0.2	0.2	0.2
Ocenebra spp.										
Pyramidella spp.										
Solariella agulhasensis										
Tricolia capensis										
Turris spp.						0.17				
Volutocorbis abyssicola				6.82					9.42	
PHYLUM ECHINODERMATA										
Amphipholis squamata										
Ophionereis porrecta		0.1								

TAXON	R6.7	R6.8	R6.9	R6.10	S5.2	S5.3	S5.5	S5.6
PHYLUM CNIDARIA								
Anthozoa A								
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.				0.16				
Lineus spp.								
Nemertea B								
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)								
Lumbrineris spp.	1.11	0.7	0.2	0.88	0.8	0.27	0.34	0.15
Arabella spp.	0.53					0.84		
Diopatra spp.	2.36	1.45	0.8	2.4	0.68	2.82	0.3	0.67
Epidiopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.						0.16		
Perinereis/Pseudonereis spp.					0.5	0.1	0.1	0.6
Micronereides capensis								
Nephtyidae								
Nephtys spp.	0.3	0.7	0.4	0.1	0.8	0.5	0.5	0.13
Spionidae								
Prionospio pinnata	0.12	0.15	0.14	0.48	0.29	0.16	0.24	0.33
Laonice cirrata								
Haploscoloplos spp.		0.1				0.1	0.2	
Phylo spp.								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp.								
Notomastus spp.	0.1							
Maldanidae					0.2	0.2		
Euclymene luderitziana								
Maldanella capensis							0.81	
Petaloproctus spp.							0.28	
Sabellides spp.								
Ampharetidae				0.1				
Amphicteis gunneri		0.3						
Terebellides spp.	0.4	0.72		5.95	1.49	0.53	0.76	0.79
Amaeana trilobata/Polycirrus								
Ancistrosyllis parva	0.1							
Flabelligeridae								
Flabelligera spp.		0.2						
Pectinaria capensis								
Cossura coasta								
PHYLUM ARTHROPODA								

TAXON	R6.7	R6.8	R6.9	R6.10	S5.2	S5.3	S5.5	S5.6
Tanaid A								
Copepoda A								0.1
Isopod A			0.2					
Ampelisca spp.	0.2	0.1		0.5	0.2	0.2	0.1	0.2
Aora kergeuleni								
Aorcho delgadus		0.1		0.1				
Corophiid Q								
Guernea rhomba								
Rhachotropis spp.								
Elasmopus affinis								
Ceradocus natalensis								
Maera spp.								
Urothoe spp.		0.1		0.1				
Leucothoe spp.						0.1	0.1	
Listriella lindae	0.1							
Acidostoma obesum								
Hippomedon longimanus	0.1							
Westwoodilla manta	0.1			0.1	0.1		0.1	0.1
Paraphoxus oculatus	0.1							
Platyischnopus herdmani								
Podocerus brasiliensis								
Eupariambus fallax							0.1	
Hyperiidae	0.1	0.1		0.1		0.1		
Hyperiid B								
Cumacea B								
Cumacea C								
Leptostraca A								
Pterygosquilla armata	5.2			0.36	0.77	0.19	1.41	
Stomatopod juvenile	0.1					0.1		
Meiosquilla desmarestii	0.4							
ORDER EUPHAUSIACEA	0.1	0.1	0.1	0.1	0.1	0.1		
Carida A	0.22							
Carida B				0.2	0.1			
Carida C (Mysidaea)								
Carida D								
Carida F								
Calocaris barnardi	0.2	0.1		0.3	0.97	1.7	0.4	0.52
Callianassa spp.	1.81		0.6		0.3	0.72		0.1
Anomura A								
Goneplax angulata	0.1	0.32		1.79			0.4	0.7
Mursia cristimanus								
Brachyura A								
PHYLUM MOLLUSCA								
Macoma spp.	0.2	0.12		0.17	0.11	0.9	0.17	0.14
Tellina spp.				0.3		0.1		
Dosinia spp.		0.1		0.3			0.1	
Nucula nucleus			0.33			0.1		

TAXON	R6.7	R6.8	R6.9	R6.10	S5.2	S5.3	S5.5	S5.6
Bivalve F				0.2		0.1	0.1	
Bivalve I						0.12		
Alvania fenestrata						0.1		
Clanculus sp.						0.1		
Epitonium kraussi						0.4		
Marginella spp.								
Nassarius spp.	0.8		1	1.14	0.1	0.96	0.15	0.2
Ocenebra spp.			0.1			0.5		
Pyramidella spp.								
Solariella agulhasensis					0.1			
Tricolia capensis						0.1		
Turris spp.			0.76					
Volutocorbis abyssicola								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								

TAXON	S5.9	S5.11	S6.1	S6.2	S6.3	S6.4	S6.5	S6.6
PHYLUM CNIDARIA								
Anthozoa A	0.21							
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.								
Lineus spp.			0.6			0.2		
Nemertea B								0.14
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)								0.9
Lumbrineris spp.	1.68	0.5	0.94	1.65	1.13	0.15	0.18	0.2
Arabella spp.					0.18			0.15
Diopatra spp.	1.51			2.51	1.44	1.7	0.74	0.75
Epidiopatra spp.	0.5					0.1		
Glyceridae								
Nereidae	0.9							0.1
Nereis spp.			0.32					
Perinereis/Pseudonereis spp.					0.13			0.7
Micronereides capensis								
Nephtyidae								
Nephtys spp.		0.1	0.12	0.3	0.1	0.1		
Spionidae	0.1	0.2						
Prionospio pinnata	0.1	1.7	0.6	0.29	0.4	0.2	0.9	0.6
Laonice cirrata								0.1
Haploscoloplos spp.		0.3						
Phylo spp.								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp.								0.1
Notomastus spp.								
Maldanidae	0.1							
Euclymene luderitziana								
Maldanella capensis								
Petaloproctus spp.								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri					0.13			
Terebellides spp.	0.92	0.35	0.52	0.1	0.45	0.95	0.85	
Amaeana trilobata/Polycirrus								
Ancistrosyllis parva								
Flabelligeridae								
Flabelligera spp.							0.75	
Pectinaria capensis								
Cossura coasta								
PHYLUM ARTHROPODA								

TAXON	S5.9	S5.11	S6.1	S6.2	S6.3	S6.4	S6.5	S6.6
Tanaid A		0.2						
Copepoda A		0.1	0.1	0.1	0.1	0.2		
Isopod A								
Ampelisca spp.	0.1	0.2		0.1	0.1	0.4	0.1	
Aora kergeuleni					0.1		0.1	
Aorcho delgadus					0.1	0.1		0.1
Corophiid Q						0.1		
Guernea rhomba		0.1						
Rhachotropis spp.								
Elasmopus affinis								
Ceradocus natalensis								0.1
Maera spp.					0.6		0.2	0.6
Urothoe spp.								
Leucothoe spp.								
Listriella lindae								
Acidostoma obesum								
Hippomedon longimanus								
Westwoodilla manta		0.1				0.1		
Paraphoxus oculatus			0.1		0.1	0.1	0.1	
Platyischnopus herdmani								
Podocerus brasiliensis						0.1		
Eupariambus fallax								
Hyperiidae	0.1					0.1		0.1
Hyperiid B		0.1	0.1					
Cumacea B						0.1		
Cumacea C								
Leptostraca A								
Pterygosquilla armata	1.66		4.75	3.77	7.3			
Stomatopod juvenile				0.1		0.1		
Meiosquilla desmarestii								
ORDER EUPHAUSIACEA		0.2				0.1	0.2	
Carida A		0.18						
Carida B								
Carida C (Mysidaea)						0.3		
Carida D								
Carida F								
Calocaris barnardi	0.17		0.13	2.8	0.11	0.3	0.4	0.2
Callianassa spp.	3.41	0.28		0.38			0.1	
Anomura A								
Goneplax angulata		3.36	0.47				0.9	0.38
Mursia cristimanus								3.99
Brachyura A								
PHYLUM MOLLUSCA								
Macoma spp.	0.9	0.2	0.7	0.14	0.3	0.3	0.9	0.1
Tellina spp.			0.1					
Dosinia spp.					0.2			
Nucula nucleus		0.4	0.22	0.5	0.1			

TAXON	S5.9	S5.11	S6.1	S6.2	S6.3	S6.4	S6.5	S6.6
Bivalve F			0.1		0.1			0.4
Bivalve I								
Alvania fenestrata								
Clanculus sp.								
Epitonium kraussi					0.4			
Marginella spp.								
Nassarius spp.	0.1	1.39	0.5	0.36	3.38		0.26	0.64
Ocenebra spp.					0.55			0.1
Pyramidella spp.					0.1			
Solariella agulhasensis								
Tricolia capensis					0.17			
Turris spp.		0.62			0.87		0.86	
Volutocorbis abyssicola								
PHYLUM ECHINODERMATA								
Amphipholis squamata								0.1
Ophionereis porrecta								

TAXON	D1.1	D1.2	D1.3	D1.4	D1.5	D1.6	D2.1	D2.2
PHYLUM CNIDARIA								
Anthozoa A								
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.				0.21				
Lineus spp.								
Nemertea B								
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)								
Lumbrineris spp.	0.5	0.88	0.88	0.41		2.58	1.8	
Arabella spp.					0.8			
Diopatra spp.	0.15	0.25	0.2		0.7	0.22	0.32	2.31
Epidiopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.								
Perinereis/Pseudonereis spp.								
Micronereides capensis								
Nephtyidae								
Nephtys spp.	0.3	0.1	0.7	0.53		0.4	0.5	0.2
Spionidae								
Prionospio pinnata		0.1					0.2	0.1
Laonice cirrata								
Haploscoloplos spp.								
Phylo spp.								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp.								
Notomastus spp.								
Maldanidae								
Euclymene luderitziana								
Maldanella capensis								
Petaloproctus spp.								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri								
Terebellides spp.								
Amaeana trilobata/Polycirrus								
Ancistrosyllis parva								
Flabelligeridae								
Flabelligera spp.								
Pectinaria capensis								
Cossura coasta			0.1					
PHYLUM ARTHROPODA								

TAXON	D1.1	D1.2	D1.3	D1.4	D1.5	D1.6	D2.1	D2.2
Tanaid A								
Copepoda A								
Isopod A								
Ampelisca spp.								
Aora kergeuleni								
Aorcho delgadus	0.1							
Corophiid Q								
Guernea rhomba								
Rhachotropis spp.								
Elasmopus affinis								
Ceradocus natalensis								
Maera spp.								
Urothoe spp.								
Leucothoe spp.								
Listriella lindae								
Acidostoma obesum								
Hippomedon longimanus								
Westwoodilla manta								
Paraphoxus oculatus								0.1
Platyischnopus herdmani								
Podocerus brasiliensis								
Eupariambus fallax								
Hyperiidae								
Hyperiid B								
Cumacea B								
Cumacea C								
Leptostraca A								
Pterygosquilla armata		1.7		0.64		4.74	18.2	0.74
Stomatopod juvenile								
Meiosquilla desmarestii								
ORDER EUPHAUSIACEA								
Carida A								
Carida B								
Carida C (Mysidaea)								
Carida D								
Carida F								
Calocaris barnardi		0.2			0.26	0.19		0.14
Callianassa spp.		1.14						0.8
Anomura A								
Goneplax angulata								
Mursia cristimanus								
Brachyura A								
PHYLUM MOLLUSCA								
Macoma spp.								
Tellina spp.								
Dosinia spp.								
Nucula nucleus								

TAXON	D1.1	D1.2	D1.3	D1.4	D1.5	D1.6	D2.1	D2.2
Bivalve F								
Bivalve I								
Alvania fenestrata								
Clanculus sp.								
Epitonium kraussi								
Marginella spp.								
Nassarius spp.	1.8	1.1	0.96	0.36	2.54	1.31	1.44	2.87
Ocenebra spp.								
Pyramidella spp.								
Solariella agulhasensis								
Tricolia capensis								
Turris spp.								
Volutocorbis abyssicola		2.49			7.2			
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								

TAXON	D2.3	D2.4	D2.5	D2.6	D3.1	D3.2	D3.3	D3.4
PHYLUM CNIDARIA								
Anthozoa A								
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.		1.47						1.3
Lineus spp.								
Nemertea B								
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)								
Lumbrineris spp.	0.85	0.32	0.77	0.31	0.31	1.15	0.43	
Arabella spp.				0.8				
Diopatra spp.	0.1	0.4	0.39					
Epidiopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.								
Perinereis/Pseudonereis spp.								
Micronereides capensis								
Nephtyidae								
Nephtys spp.	0.1	0.1	0.6			0.16		0.3
Spionidae								
Prionospio pinnata	0.1	0.3	0.17	0.1	0.5	0.22	0.21	0.2
Laonice cirrata								
Haploscoloplos spp.								
Phylo spp.								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp.								
Notomastus spp.								
Maldanidae								
Euclymene luderitziana								
Maldanella capensis								
Petaloproctus spp.								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri								
Terebellides spp.								
Amaeana trilobata/Polycirrus								
Ancistrosyllis parva								
Flabelligeridae								
Flabelligera spp.								
Pectinaria capensis			0.8	0.1				
Cossura coasta						0.1		
PHYLUM ARTHROPODA								

TAXON	D2.3	D2.4	D2.5	D2.6	D3.1	D3.2	D3.3	D3.4
Tanaid A								
Copepoda A								
Isopod A								
Ampelisca spp.		0.1	0.1			0.1	0.1	
Aora kergeuleni								
Aorcho delgadus	0.1	0.1		0.1		0.3		
Corophiid Q								
Guernea rhomba								
Rhachotropis spp.								
Elasmopus affinis								
Ceradocus natalensis								
Maera spp.								
Urothoe spp.								
Leucothoe spp.								
Listriella lindae								
Acidostoma obesum								
Hippomedon longimanus								
Westwoodilla manta								
Paraphoxus oculatus						0.1		
Platyischnopus herdmani								
Podocerus brasiliensis								
Eupariambus fallax								
Hyperiidae								
Hyperiid B								
Cumacea B								
Cumacea C								
Leptostraca A								
Pterygosquilla armata	0.36	15.66	0.63				4.84	1.25
Stomatopod juvenile								
Meiosquilla desmarestii								
ORDER EUPHAUSIACEA								
Carida A	0.1		0.13					
Carida B								
Carida C (Mysidaea)								
Carida D								
Carida F								
Calocaris barnardi		0.5	0.9	0.7		0.7	0.16	0.1
Callianassa spp.	0.3							
Anomura A								
Goneplax angulata								
Mursia cristimanus								
Brachyura A								
PHYLUM MOLLUSCA								
Macoma spp.								
Tellina spp.						0.1		
Dosinia spp.								
Nucula nucleus								

TAXON	D2.3	D2.4	D2.5	D2.6	D3.1	D3.2	D3.3	D3.4
Bivalve F								
Bivalve I								
Alvania fenestrata								
Clanculus sp.								
Epitonium kraussi						0.1		
Marginella spp.			2.13					
Nassarius spp.	1.52	2.41	4.22	0.88	0.86	4.77	1.24	0.67
Ocenebra spp.								
Pyramidella spp.								
Solariella agulhasensis								
Tricolia capensis								
Turris spp.								
Volutocorbis abyssicola								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								

TAXON	D3.5	D3.6	D4.1	D4.2	D4.3	D4.4	D4.5	D4.6
PHYLUM CNIDARIA								
Anthozoa A								
Anthozoa B								
PHYLUM NEMERTEA								
Cerebratulus spp.			0.96	0.17		0.29		
Lineus spp.								
Nemertea B								
PHYLUM ANNELIDA								
Eunicidae								
Eunicidae spp. (drilonereis)								
Lumbrineris spp.	0.57	0.19	4.39	1.67	2.39	1.48	0.74	1.39
Arabella spp.								0.2
Diopatra spp.			2.59	3.96	1.6	0.14	1.12	1.65
Epidiopatra spp.								
Glyceridae								
Nereidae								
Nereis spp.								
Perinereis/Pseudonereis spp.								
Micronereides capensis								
Nephtyidae								
Nephtys spp.	0.7	0.3	0.4			0.2	0.2	
Spionidae								
Prionospio pinnata	0.14	0.22	0.4	0.1	0.4	0.3	0.1	0.4
Laonice cirrata								
Haploscoloplos spp.								
Phylo spp.								
Poly BB								
Poly WW								
Paraonidae								
Cirrophorus branchiatus								
Capitellidae spp.								
Notomastus spp.								
Maldanidae								
Euclymene luderitziana								
Maldanella capensis								
Petaloproctus spp.								
Sabellides spp.								
Ampharetidae								
Amphicteis gunneri								
Terebellides spp.								
Amaeana trilobata/Polycirrus								
Ancistrosyllis parva								0.1
Flabelligeridae								
Flabelligera spp.								
Pectinaria capensis	0.7							
Cossura coasta								
PHYLUM ARTHROPODA								

TAXON	D3.5	D3.6	D4.1	D4.2	D4.3	D4.4	D4.5	D4.6
Tanaid A								
Copepoda A								
Isopod A								
Ampelisca spp.	0.1							
Aora kergeuleni								
Aorcho delgadus				0.2	0.3	0.1		0.2
Corophiid Q								
Guernea rhomba								
Rhachotropis spp.								
Elasmopus affinis								
Ceradocus natalensis								
Maera spp.								
Urothoe spp.								
Leucothoe spp.								
Listriella lindae								
Acidostoma obesum								
Hippomedon longimanus								
Westwoodilla manta								
Paraphoxus oculatus								
Platyischnopus herdmani								
Podocerus brasiliensis								
Eupariambus fallax								
Hyperiidae				0.1				
Hyperiid B								
Cumacea B								
Cumacea C								
Leptostraca A								
Pterygosquilla armata			0.5	0.56	0.48		3.28	
Stomatopod juvenile								
Meiosquilla desmarestii								
ORDER EUPHAUSIACEA								
Carida A								
Carida B								
Carida C (Mysidaea)								
Carida D								
Carida F								
Calocaris barnardi	0.16		0.45	0.8	0.48	0.24	0.74	0.89
Callianassa spp.			3.88	1.34	5.39	5.47	3.19	1.72
Anomura A								
Goneplax angulata								
Mursia cristimanus								
Brachyura A								
PHYLUM MOLLUSCA								
Macoma spp.								
Tellina spp.	0.1							
Dosinia spp.								
Nucula nucleus								

TAXON	D3.5	D3.6	D4.1	D4.2	D4.3	D4.4	D4.5	D4.6
Bivalve F								
Bivalve I								
Alvania fenestrata								
Clanculus sp.								
Epitonium kraussi								
Marginella spp.								
Nassarius spp.	0.46	0.59	0.17			0.8	0.1	0.6
Ocenebra spp.								
Pyramidella spp.								
Solariella agulhasensis								
Tricolia capensis								
Turris spp.								
Volutocorbis abyssicola								
PHYLUM ECHINODERMATA								
Amphipholis squamata								
Ophionereis porrecta								

TAXON	D5.1	D5.2	D5.3	D5.4	D5.5	D5.6
PHYLUM CNIDARIA						
Anthozoa A						
Anthozoa B						
PHYLUM NEMERTEA						
Cerebratulus spp.						
Lineus spp.						
Nemertea B						
PHYLUM ANNELIDA						
Eunicidae						
Eunicidae spp. (drilonereis)						
Lumbrineris spp.		0.32		0.4		
Arabella spp.	0.5			0.6		0.23
Diopatra spp.	0.1	0.9		0.6	0.14	
Epidiopatra spp.						
Glyceridae						
Nereidae						
Nereis spp.						
Perinereis/Pseudonereis spp.						
Micronereides capensis						
Nephtyidae						
Nephtys spp.						
Spionidae						
Prionospio pinnata				0.1		
Laonice cirrata						
Haploscoloplos spp.						
Phylo spp.						
Poly BB						
Poly WW						
Paraonidae						
Cirrophorus branchiatus						
Capitellidae spp.						
Notomastus spp.						
Maldanidae						
Euclymene luderitziana						
Maldanella capensis						
Petaloproctus spp.						
Sabellides spp.						
Ampharetidae						
Amphicteis gunneri						
Terebellides spp.						
Amaeana trilobata/Polycirrus						
Ancistrosyllis parva						
Flabelligeridae						
Flabelligera spp.						
Pectinaria capensis						
Cossura coasta						
PHYLUM ARTHROPODA						

TAXON	D5.1	D5.2	D5.3	D5.4	D5.5	D5.6
Tanaid A						
Copepoda A						
Isopod A						
Ampelisca spp.						0.1
Aora kergeuleni						
Aorcho delgadus						
Corophiid Q						
Guernea rhomba						
Rhachotropis spp.						
Elasmopus affinis						
Ceradocus natalensis						
Maera spp.						
Urothoe spp.						
Leucothoe spp.						
Listriella lindae						
Acidostoma obesum						
Hippomedon longimanus						
Westwoodilla manta						0.1
Paraphoxus oculatus						
Platyischnopus herdmani						
Podocerus brasiliensis						
Eupariambus fallax						
Hyperiidae						
Hyperiid B						
Cumacea B						
Cumacea C						
Leptostraca A						
Pterygosquilla armata		1.12			0.39	
Stomatopod juvenile						
Meiosquilla desmarestii						
ORDER EUPHAUSIACEA						
Carida A						
Carida B						
Carida C (Mysidaea)						
Carida D						
Carida F						
Calocaris barnardi						
Callianassa spp.						
Anomura A						
Goneplax angulata						
Mursia cristimanus						
Brachyura A						
PHYLUM MOLLUSCA						
Macoma spp.						
Tellina spp.		0.7				0.1
Dosinia spp.						
Nucula nucleus						

TAXON	D5.1	D5.2	D5.3	D5.4	D5.5	D5.6
Bivalve F						
Bivalve I						
Alvania fenestrata						
Clanculus sp.						
Epitonium kraussi						
Marginella spp.						
Nassarius spp.	1.71	1.66		2.32	0.21	0.64
Ocenebra spp.						
Pyramidella spp.						
Solariella agulhasensis						
Tricolia capensis						
Turris spp.						
Volutocorbis abyssicola						
PHYLUM ECHINODERMATA						
Amphipholis squamata						
Ophionereis porrecta						