

The marine benthic invertebrate assemblage recruited to artificial substratum units in shallow waters near Casey Station, Antarctica, and its utility for environmental monitoring.

Sarah Elizabeth Richards

BSc Hons I

University of New England
Armidale, New South Wales, Australia.

A thesis submitted for the degree of Doctor of Philosophy of the University of New England.

November, 2005.

Acknowledgements

I would like to thank my supervisors, Dr Steve Smith and Professor Rod Simpson from the National Marine Science Centre and Dr Martin Riddle from the Australian Antarctic Division, for the support they provided throughout the project.

The field work for this project spanned four summer seasons from October 1999 to February 2003 and the winter of 2002. Conducting research in the Antarctic presents many challenges which can only be overcome through cooperation and persistence. I owe many thanks to all the expeditioners and support staff of the 53rd, 54th, 55th and 56th ANARE at Casey and especially to my field assistants and snorkeling buddies Bob Edgar, John Rich and Nic Truchanas. I would also like to thank the Human Impacts Research Program Dive Team for collecting sediment samples, taking pictures of ASUs *in situ* and freeing some of the trays that had become caught in ice in O'Brien Bay.

Sorting macrofauna is a very labour intensive process and I spent many hours at the 'scope'. I would like to thank Debbie Lang and Trevor Bailey, who manage the AAD science laboratories, for all their help over the years. I am very grateful for the taxonomic advice provided by staff at the Australian Museum, in particular Drs Pat Hutchings, Jim Lowry, Peter Middelfart, George Wilson, Stephen Keable and Ms Anna Murray and Ms Helen Stoddart.

I would like to thank Jonny Stark for permission to use the Brown Bay metal data and infaunal species lists. I would like to thank Scott Stark for his help in analysing the marine sediment metal data. I would also like to thank the staff of the Australian Antarctic Data Centre for their help with managing GPS data and producing maps.

All along this road I have been encouraged by my family, friends and colleagues. They have been lights in times of darkness and always a solid reality for reference. At this moment I think the word 'thanks' should be longer to convey all that I mean by it!

Abstract

Community structure, diversity and faunal abundance patterns of the assemblage of marine benthic invertebrates that recruited to Artificial Substratum Units (ASUs) deployed in the shallow nearshore waters of Casey Station, East Antarctica, were investigated to determine the suitability of these ASUs as a sampling method for biological monitoring of Antarctic marine environments. The ASUs employed in this study were made of nylon mesh pot scourers.

The assemblage that recruited to the ASUs was dominated by small motile fauna including peracaridean crustaceans, gastropods and polychaetes. Crustacea were the most diverse group and gastropods were the most abundant group. Species that were often numerically dominant in the samples include *Skenella paludinoides* (Gastropoda), *Antarctogenia macrodactyla* (Amphipoda), *Munna c.f. maculata*, *Cymnodocella tubicauda* (Isopoda) and *Nototanais antarcticus* (Tanaidacea). Nematodes, nemertean, turbellarians and ophiuroids are commonly present in the assemblage. Some sessile fauna were also sampled by the units and a spirorbid polychaete commonly occurred in high abundance. Many of the taxa that recruited to the ASUs have also been recorded in other Antarctic locations.

Investigations of the physical structure of the ASU found that the colour of the scourers had no effect on the assemblage and that ASUs made of three scourers would adequately sample the available taxa in sufficient abundances for analysis. Deployment times of one year, which included an over winter period and a late summer collection, sampled an assemblage with consistent numbers of species and abundance ranges of individuals suitable for analyses.

The ASU assemblage is highly variable both within sites and between sites. Multivariate analyses found significant differences within and between all sites and between the control sites and a known impacted site. Analyses of the univariate diversity indices and abundance patterns of selected taxa also detected significant differences within sites and between sites but did not detect differences between control and impacted locations. The

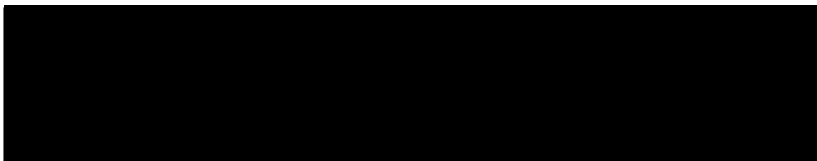
inherent natural spatial variability of the ASU assemblage makes careful choice of control locations particularly important for studies monitoring environmental impacts and change. Control locations must be as similar as possible to reduce all sources of variation that are not related to the impact or disturbance being studied.

The sensitivity of the ASU assemblage to positioning and timing of deployment mean that its use in a monitoring program must follow rigorous standardisation of deployment methods. The high frequency of ice disturbance in shallow Antarctic waters and the risks this poses for experimental units warrant further development of the deployment methods.

Certification

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.



Sarah Elizabeth Richards

I dedicate this thesis to my grandmother, Kathleen (Kit) Mary Hamilton (1907-2002), who taught me about love, thrift and endurance.

Table of Contents

Acknowledgements.....	ii
Abstract.....	iii
Certification.....	v
Dedication.....	vi
Table of Contents.....	vii
List of Tables.....	ix
List of Tables.....	x
Chapter 1.....	1
Introduction	
1.1 The Antarctic marine environment.....	1
1.2 Ecology of Antarctic shallow water benthic environments.....	2
1.3 Protection of the Antarctic environment.....	5
1.4 Environmental monitoring.....	6
1.5 Pollutants and biological effects in the marine environment.....	7
1.6 Disturbance induced change in benthic communities.....	9
1.7 Marine motile epifaunal assemblages.....	11
1.8 The use of artificial substrata in ecological studies.....	13
1.9 Aims of this study.....	16
Chapter 2.....	23
General Methods	
2.1 Study Area.....	23
2.1.1 Windmill Islands region.....	23
2.1.2 Casey Station.....	25
2.2 Sampling Locations.....	25
2.2.1 Brown Bay.....	25
2.2.2 Newcombe Bay.....	26
2.2.3 O'Brien Bay.....	27
2.2.4 Penney Bay.....	28
2.3 Sampling Unit.....	28
2.3.1 Artificial substratum unit (ASU).....	28
2.4 Study Design.....	29
2.4.1 Deployed experiments.....	29
2.4.2 Experiments retrieved and final designs.....	31
2.5 Field Methods.....	31
2.5.1 Deployment and collection of ASUs.....	31
2.5.2 Collection of marine sediments.....	33
2.6 Sample Processing.....	33
2.6.1 ASU macrofauna.....	33
2.6.2 ASU sediment.....	34
2.6.3 ASU debris.....	34
2.6.4 Marine sediment.....	34
2.7 Data Analyses.....	35
2.7.1 Multivariate methods.....	35
2.7.2 Univariate methods.....	35

Chapter 3	37
Pilot Study I: ASU Design	
3.1 Introduction.....	37
3.2 Methods.....	39
3.2.1 Effects of substratum colour on recruitment to the ASUs	39
3.2.2 Effects of unit size on recruitment to the ASUs	40
3.3 Results.....	41
3.3.1 Effects of substratum colour on recruitment to the ASUs	41
3.3.2 Effects of unit size on recruitment to the ASUs	43
3.4 Discussion	49
Chapter 4	52
Pilot Study II – ASU Deployment	
4.1 Introduction.....	52
4.2 Methods.....	54
4.3 Results.....	55
4.4 Discussion	67
Chapter 5	69
Spatial variation and contamination response in the ASU assemblage	
5.1 Introduction.....	69
5.2 Methods.....	71
5.3 Results.....	74
5.3.1 Sediment chemistry.....	74
5.3.2 Physical variables of the ASUs.....	75
5.3.3 Biotic variables	76
5.4 Discussion	96
Chapter 6	102
ASU assemblage of Brown Bay	
6.1 Introduction.....	102
6.2 Methods.....	104
6.2.1 Depth transect	104
6.2.2 Spatial variation within Brown Bay.....	104
6.2.3 Temporal variation within Brown Bay	105
6.3 Results.....	106
6.3.1 Heavy metal concentrations in Brown Bay sediments	108
6.3.2 Depth transect	109
6.3.3 Spatial variation within Brown Bay.....	113
6.3.4 Temporal variation within Brown Bay	118
6.4 Discussion	121
Chapter 7	125
General Discussion	
References.....	131
Appendix 1. Taxa list for ASU assemblage.....	146
Appendix 2. Key Taxonomic References.....	150

List of Tables

Table 1.1. Examples of studies of epifaunal assemblages from natural and artificial substrata.	17
Table 2.4.1. Details of deployment timing and temporal treatments in temporal variation experiment.....	30
Table 3.3.1. p-values for ANOVA tests of univariate diversity statistics for colour experiment.....	43
Table 3.3.2. Taxonomic summary and mean abundance for major taxonomic groups in unit size experiment.	44
Table 3.3.3. One-way ANOVA results for diversity measures in unit size treatments.	48
Table 3.3.4. Relative multivariate dispersion for unit size treatments.....	49
Table 4.2.1. Details of deployment periods and sample numbers for long term deployments.	55
Table 4.3.1. Taxonomic summary for temporal deployments.....	57
Table 4.3.2. p-values for one way ANOVAs for standard diversity measures between summer deployments and between long term deployments.	59
Table 4.3.3. Global R and p-values for ANOSIM tests of within season deployment groups.....	61
Table 4.3.4. Global R values and p-values for seasonal comparisons from one way ANOSIM test.	61
Table 4.3.5. Average dissimilarity values for within season groups.	61
Table 4.3.6. Results of SIMPER analyses comparing seasonal deployment groups.....	62
Table 5.2.1. Details of selected tray positions within sites in spatial variation experiment.	71
Table 5.2.2. Details of construction of asymmetrical ANOVA to compare control sites with impacted site.	73
Table 5.3.1. ASU taxa shared with other habitats from Casey.	77
Table 5.3.2. Mean abundance with standard error and total taxa in major taxonomic groups for sites in spatial experiment.	79
Table 5.3.3. Contribution of dominant taxa to total mean abundance (n=24).	79
Table 5.3.4. Results from two-way nested ANOSIM.	83
Table 5.3.5. Contribution to average dissimilarity for selected species from SIMPER analysis.....	84
Table 5.3.6. Asymmetrical ANOVAs comparing control vs impact treatments for diversity indices and selected taxa.	87
Table 5.3.7. One-way ANOSIM tests and pairwise comparisons within sites.....	90
Table 6.3.1. Mean total individuals, taxa and abundance for major taxonomic groups and total taxa for depth transect points and spatial variation experiments from 2001 and 2002 for Brown Bay.....	107
Table 6.3.2. ANOSIM pairwise comparisons of depth treatments.....	111

List of Figures

Figure 2.1.1. Antarctica showing location of Casey Station.....	24
Figure 2.1.2. Casey Station	25
Figure 2.2.1. Brown Bay showing Thalla Valley tip site in 2002	26
Figure 2.2.2. Newcombe Bay.	27
Figure 2.2.3. O'Brien Bay.	27
Figure 2.2.4. Penney Bay.....	28
Figure 2.3.1. Four Artificial Substratum Units (ASUs) <i>in situ</i>	29
Figure 2.4.1. Spatial variation experiment within site deployment plan.	30
Figure 2.4.2. Trays and ASUs damaged and disturbed by ice.....	31
Figure 2.5.1. Raising trays using on-board manual winch and davit.....	32
Figure 2.5.2. Removing ASUs from trays.	32
Figure 3.2.1. Number of scourers used in size treatments for unit size experiment.	40
Figure 3.3.1. nMDS ordination for colour treatments	42
Figure 3.3.2 nMDS ordinations for colour treatments from presence/absence data.....	42
Figure 3.3.3. Entrained sediment in ASUs for unit size treatments.....	43
Figure 3.3.4. Patterns of taxa occurrence in unit size treatments	46
Figure 3.3.5. Species accumulation curve for increasing unit size	47
Figure 3.3.6. Mean total number of individuals and standard errors for unit size treatments and expected total individuals.....	48
Figure 4.3.1. Mean diversity measures for temporal treatments.....	58
Figure 4.3.2. nMDS ordination for all temporal deployments.....	59
Figure 4.3.3. nMDS ordination for summer only deployments.....	60
Figure 4.3.4. nMDS ordination for long term deployments	60
Figure 4.3.5. Mean abundance and standard errors for persistent pioneer specie	65
Figure 4.3.6. Mean abundance and standard errors for secondary settlers	66
Figure 5.3.1. Mean concentration of metals in sediments showing significance of one- way ANOVA tests between sites.....	74
Figure 5.3.2. Percentage occurrence of debris types	75
Figure 5.3.3. Mean ASU sediment weight and standard error for sites in spatial variation experiment.....	76
Figure 5.3.4. Site dominance as percentage abundance for major taxonomic groups and showing contribution of the most abundant taxa	80
Figure 5.3.5. Standard diversity indices for sites.....	81
Figure 5.3.6 nMDS of ASU fourth root transformed species abundance data for sites in spatial variation experiment.....	82
Figure 5.3.7. nMDS ordinations of fourth root transformed abundance data at taxonomic resolution of class (a) and phyla (b) for sites in spatial variation experiment.	82
Figure 5.3.8. Mean abundance of selected taxa for sites showing significance of one-way ANOVAs between site groups.....	85
Figure 5.3.9. MDS ordinations of fourth root transformed abundance data for sites	89
Figure 5.3.10. Regression line of average dissimilarity from SIMPER tray comparisons and relative depth for a. Newcombe Bay and b. Penney Bay.....	91
Figure 5.3.11. Mean abundance per tray of selected taxa for Newcombe Bay and significance of one-way ANOVA tests between trays	92

Figure 5.3.12. Mean abundance per tray of selected taxa for O'Brien Bay and significance of one-way ANOVA tests between trays	93
Figure 5.3.13. Mean abundance per tray of selected taxa for Penney Bay and significance of one-way ANOVA tests between trays.....	94
Figure 5.3.14. Mean abundance per tray of selected taxa for Brown Bay and significance of one-way ANOVA tests between trays.....	95
Figure 6.3.1. Metal concentrations in parts per million from sediments in Brown Bay collected by Stark et al.(2005)	108
Figure 6.3.2. Mean and standard error for diversity indices along depth transect.....	109
Figure 6.3.3. nMDS ordination for Brown Bay depth transect.....	110
Figure 6.3.4. Mean abundance, standard errors and significance of one way ANOVA test between depths for selected taxa.....	112
Figure 6.3.5. Mean abundance and standard errors for diversity indices for plots within groups in Brown Bay spatial variation experiment.....	113
Figure 6.3.6. nMDS ordination of ASUs in Brown Bay spatial variation experiment showing groups 100 m apart and plots within groups 10 m apart	114
Figure 6.3.7. ASU sediment weight for trays deployed in 2002 spatial variation experiment.....	115
Figure 6.3.8. Mean abundance, standard error and significance of two way nested ANOVA comparing groups and trays within groups for selected taxa in Brown Bay spatial variation experiment.....	117
Figure 6.3.9. Mean and standard errors for diversity indices for temporal comparison between 2001 and 2002 in Brown Bay	118
Figure 6.3.10. nMDS ordination of ASUs from Brown Bay in 2001 and 2002	119
Figure 6.3.11. Mean abundance, standard errors and significance of one way ANOVA test between 2001 and 2002 for selected taxa.....	120
Figure 6.3.12. ASU sediment weight for trays deployed in 2001 and 2002	121