Part B

Australian beach macrofaunal communities and their relation to beach morphodynamics

The "spiney-eyed" ghost crab, *Ocypode ceratopthalma.*
[Photo: G. Gerber]

CHAPTER 4
Community structure on cool temperate Australian beaches

4.1 Introduction

4.1.1 Physical characteristics of cool temperate Australian beaches

The south-eastern coast of South Australia possesses one of the world's most dynamic shorelines. Aligned with the Southern Ocean, the coast receives the full force of the dominant south-west waves, swell and accompanying winds. The persistently high swell and onshore westerlies has lead to the development of high-energy beach systems and extensive coastal dune fields in the area. In addition, and unlike the easterly-facing coast of Australia, the beaches here are primarily composed of carbonate sediments that have been moved shoreward of the continental shelf by the high deep-water wave energy (Short and Hesp, 1984).

Within this area, however, there is also a high degree of variation in small scale local beach environments. This is a result of spatial and temporal variations in wave power and the erosional effects of periodic severe storms. Thus, although most of the beaches are generally wide and flat, sandy shorelines of this region also exist in other widths and shapes. The overall tides here are small in range (<2m) and semi-diurnal, with some inequalities and discrepancies in the twice-daily cycle due to periodic changes in sea-level. Changes in sea-level may occur over days, weeks or months as dictated by weather patterns acting on the Southern Ocean (Short and Hesp, 1984). Beaches of this dynamic area were chosen for the cool temperate component of this study.

4.1.2 Aim

The aim was to investigate trends in species richness, species diversity (Simpsons Index), abundance and biomass for a morphodynamic series of sandy beaches (classified and compared according to Ω and BSI) in cool temperate South Australia.

4.2 Materials and Methods

Ten beaches were selected for study from the Fleurieu Peninsula to slightly east of Cape Jaffa in South Australia. The beaches are (from west to east): Parsons, Waitpinga, Chiton Rocks, Bashams, Goolwa (west), Goolwa, Coorong, Granites, Longbeach and Evans Cave (Fig. 4.1).

The above beaches were sampled at low tide each day from 29th December, 1994 to 7th January, 1995 according to the method outlined in Chapter 3. Although a "summer storm" preceded our arrival (local residents, pers comm.), local weather at this time was mostly clear with variable winds and some cloudy days. Statistical analysis was according to section 3.4.

4.3 Results

Thirty-four macrofaunal species were found at the cool temperate beaches studied - over one third of these in the form of insects and insect larvae (Table 4.1). Other macrofauna included amphipods, isopods, bivalve molluscs, polychaetes, nemertea, oligochaetes and an arachnid (spider). No decapod crustaceans, mysids, stomatopods or gastropod molluscs were detected.

The ten beaches studied were all classified as exposed (McLachlan, 1980a) and represented a micro-tidal range from almost fully reflective to fully dissipative (Table 4.2). Relative Tide Ranges (RTR's) were all less than 2 indicating the dominance of swash and wave processes on the intertidal beach.

Using Ω as a beach classification index produced the most significant regressions for each of species number (t_8=4.10, P=0.003, R^2=67.8%), log abundance (t_8=2.68, P=0.028, R^2=47.3%) and log biomass (t_8=4.30, P=0.003, R^2=69.8%). In each case, values increased from reflective to dissipative beach state (Figs 4.2, 4.3 and 4.4 respectively). There was no significant relationship between Ω and Simpsons Index of species diversity (t_8= -0.13, P=0.899, R^2=0.2%)(Fig 4.5).

The BSI also showed significant relationships, with the macrofaunal communities increasing in species number, abundance and biomass from reflective to dissipative conditions. However, these relationships were not as significant as those using Ω (Figs 4.6, 4.7 and 4.8). Simpsons Index of diversity remained non-significant (t_8=-0.25, P=0.811, R^2=0.8%) (Fig. 4.9).

Figure 4.1: Location of cool temperate study sites (South Australia)

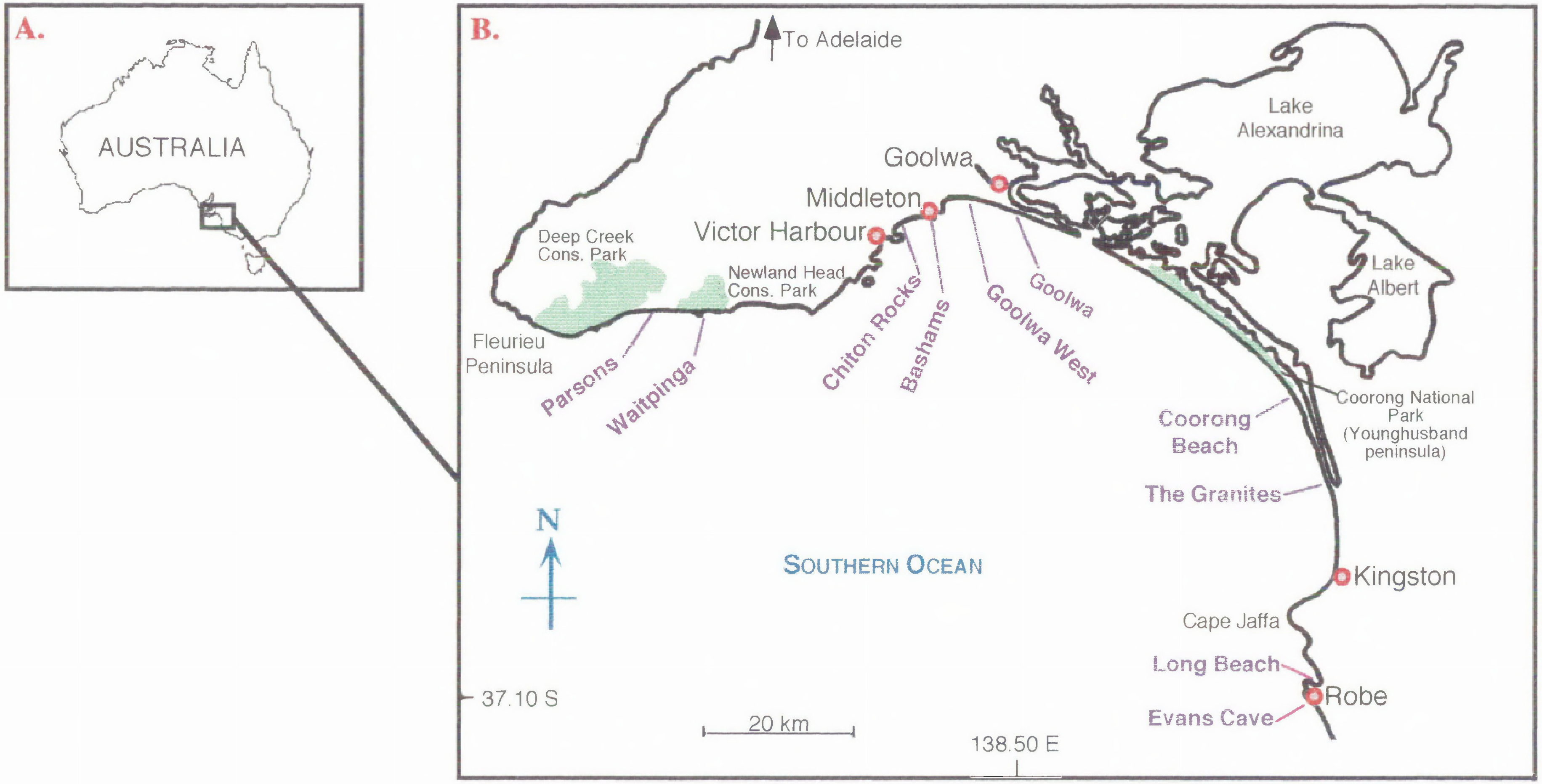


Table 4.1: Species composition at cool temperate Australian beaches (South Australia)
(Star (*) indicates presence)

	Chiton Rocks	Basham	Evans Cave	Goolwa (west)	Wait-pinga	Long-beach	Goolwa	Parsons	Coorong	Granites
MOLLUSCA										
Bivalvia										
Donax deltoides				*		*	*		*	*
Paphies elongata						*	*		*	*
POLYCHAETA										
Arabella iricolor iricolor						*				
Dispio glabrillamellata						*				
Hemipodus australiensis		*		*	*		*	*	*	
Nephtys longipes				*		*	*			*
Notomastus cf. torquatus						*			*	
Orbinia papillosa										*
Scolelepis carunculata					*					
Sigalion cf. oviger									*	*
OLIGOCHAETA										
Oligochaete		*								
NEMERTEA										
Nemertean					*					
CRUSTACEA										
Isopoda										
Actaecia thomsoni	*	*		*	*	*	*	*	*	*
Pseudolana concinna	*	*	*	*	*	*	*	*	*	
?Aenigmathura sp.	*									
Amphipoda										
Exoediceroides latrans		*			*	*		*	*	*
Talorchestia quadrimana			*	*	*		*	*	*	
Urohaustorius halei						*		*	*	
Urohaustorius metungi								*		
INSECTA										
Coleoptera #1		*			*			*		*
Coleoptera #2					*					*
Coleoptera #3		*						*		*
Coleoptera #4					*					
Coleoptera larvae #1		*								
Coleoptera larvae #2					*		*			
Coleoptera (F: Staphylinidae)										*
Coleoptera (F:Curculivnidae)			*						*	*
Diptera larvae #1									*	
Diptera larvae #2		*			*			*	*	*
Hemiptera (Largidae)										*
Hemiptera (Lygaeidae)										*
Lepidoptera larvae										
ARACHNIDS										
Aranaea			*			*				*

Table 4.2: Raw data for cool temperate Australian beaches (South Australia)

Beach	Beach State Index (BSI)	Deans Value (Ω)	Slope of beach face	Number of species	Abundance m^{-1}	Simpsons Index (*D*)	Biomass gm^{-1}	Sediment fall velocity $cm\ s^{-1}$	Av. wave height (cm)	Av. wave period (s)	Maximum tide range (m)	Relative Tide Range	Exposure rating (McLachlan 1980a)
Chiton Rocks	0.563	1.77	0.104	3	69.00	0.474	0.23	0.047	100	12	1.6	1.30	15
Bashams	0.599	1.98	0.099	9	225.00	0.257	1.78	0.042	100	12	1.6	1.30	14
Evans cave	0.712	2.77	0.089	4	78.75	0.744	0.40	0.060	100	12	1.6	1.30	14
Goolwa west	0.816	3.79	0.068	6	322.50	0.446	7.95	0.045	200	12	1.6	0.65	11
Waitpinga	0.850	4.06	0.070	12	1291.50	0.557	2.24	0.041	200	12	1.6	0.65	12
Longbeach	0.859	4.16	0.043	11	1018.50	0.561	2.59	0.030	150	12	1.6	0.87	11
Goolwa	0.879	4.38	0.047	8	82.50	0.178	2.23	0.038	200	12	1.6	0.65	13
Parsons	0.911	4.76	0.060	10	225.00	0.204	1.60	0.035	200	12	1.6	0.65	14
Coorong	0.957	5.37	0.038	13	492.75	0.181	13.49	0.031	200	12	1.6	0.65	11
Granites	1.110	7.93	0.026	16	2244.00	0.572	34.00	0.021	200	12	1.6	0.65	11

Figure 4.2:

Cool temperate Australian beaches: Species number vs Ω

Showing a significant increase in number of species with the dimensionless fall velocity (Ω)

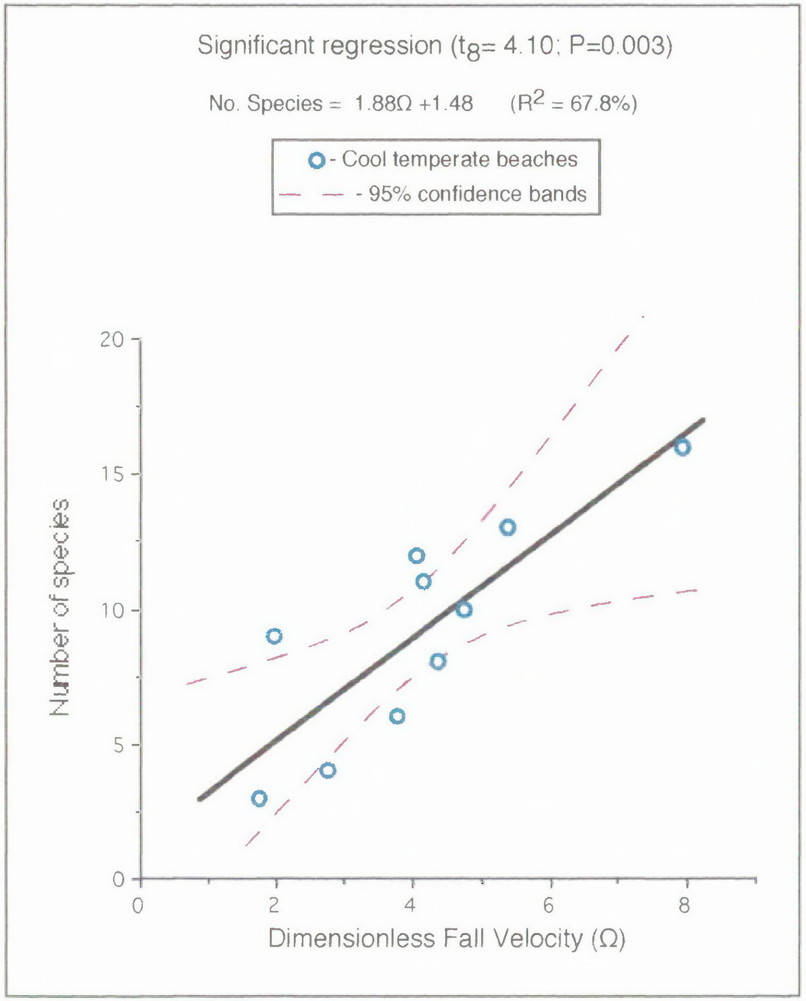


Figure 4.3:

Cool temperate Australian beaches: Abundance vs Ω.

Showing a significant logarithmic increase in total organism abundance (per metre of beach) with the dimensionless fall velocity (Ω)

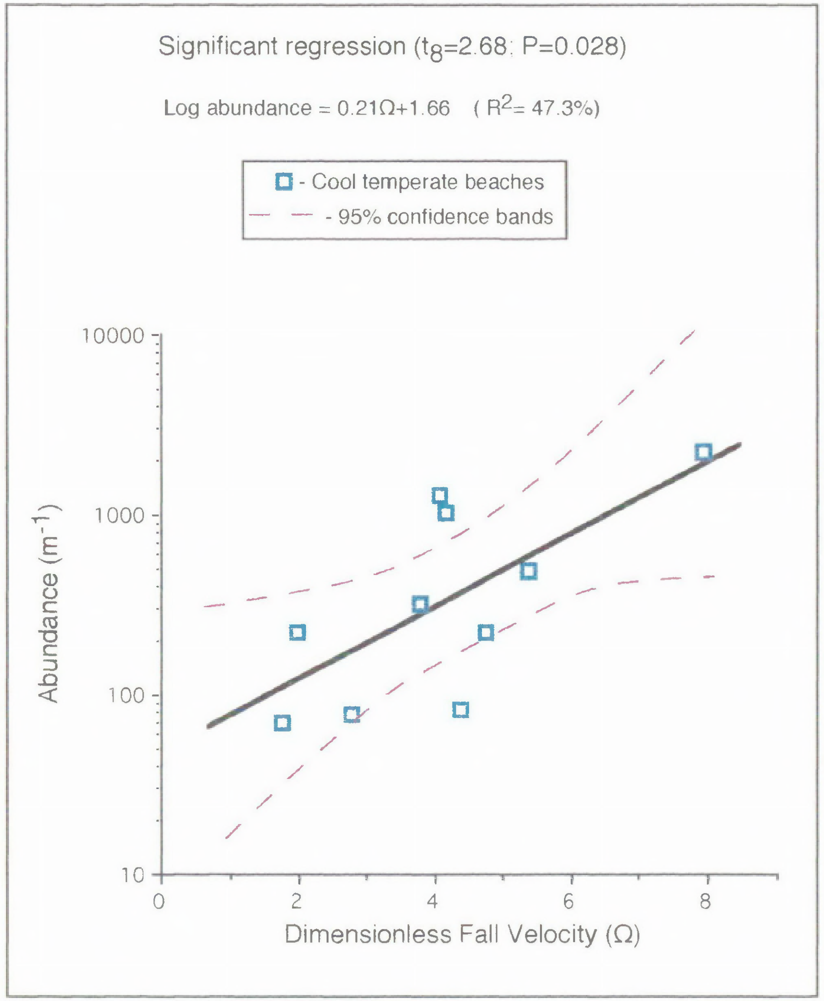


Figure 4.4:

Cool temperate Australian beaches: Biomass vs Ω

Showing a significant increase in total macrofaunal biomass (per metre of beach) with dimensionless fall velocity (Ω)

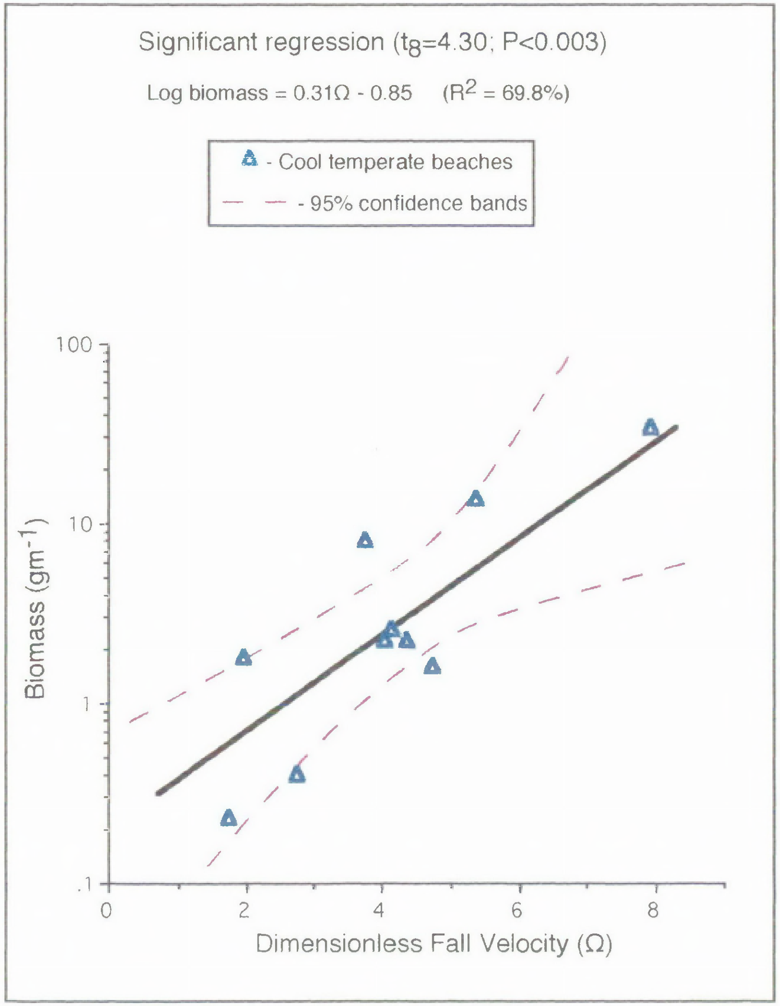


Figure 4.5:

Cool temperate Australian beaches: Simpson's Index vs Ω

Showing no significant relationship between animal diversity (Simpson's Index) and the dimensionless fall velocity (Ω)

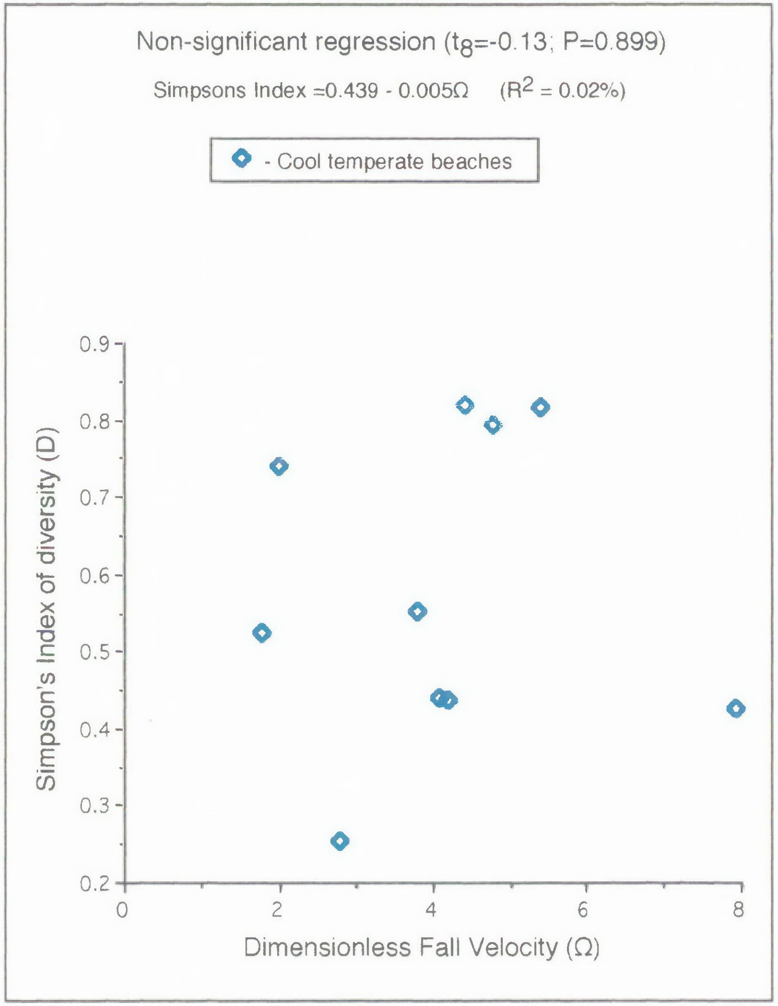


Figure 4.6:

Cool temperate Australian beaches: Species number vs BSI

Showing a significant increase in number of species with Beach State Index (BSI)

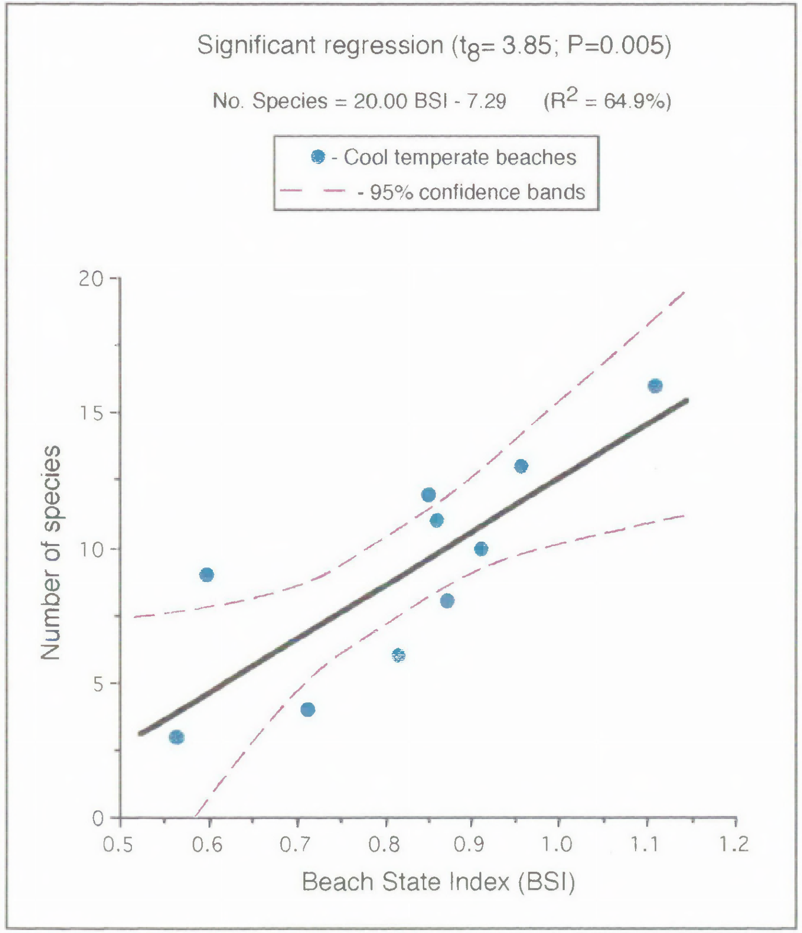


Figure 4.7:

Cool temperate Australian beaches: Abundance vs BSI

Showing a significant logarithmic increase in total animal abundance (per metre of beach) with Beach State Index (BSI)

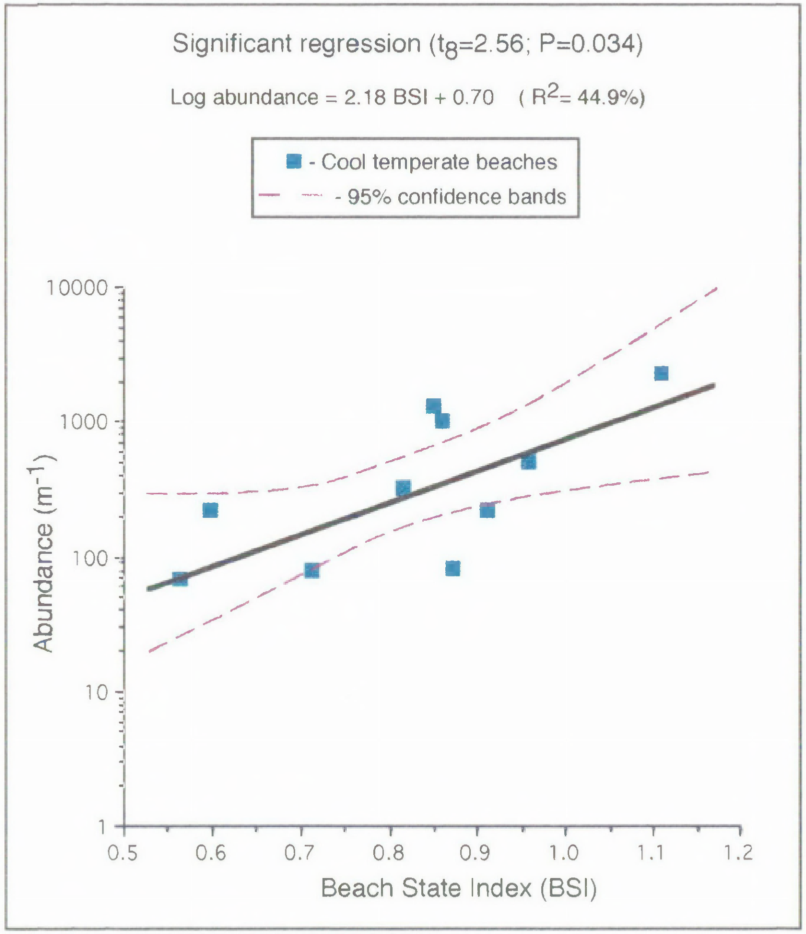


Figure 4.8:

Cool temperate Australian beaches: Biomass vs BSI

Showing a significant logarithmic increase in biomass (per metre of beach) with Beach State Index (BSI)

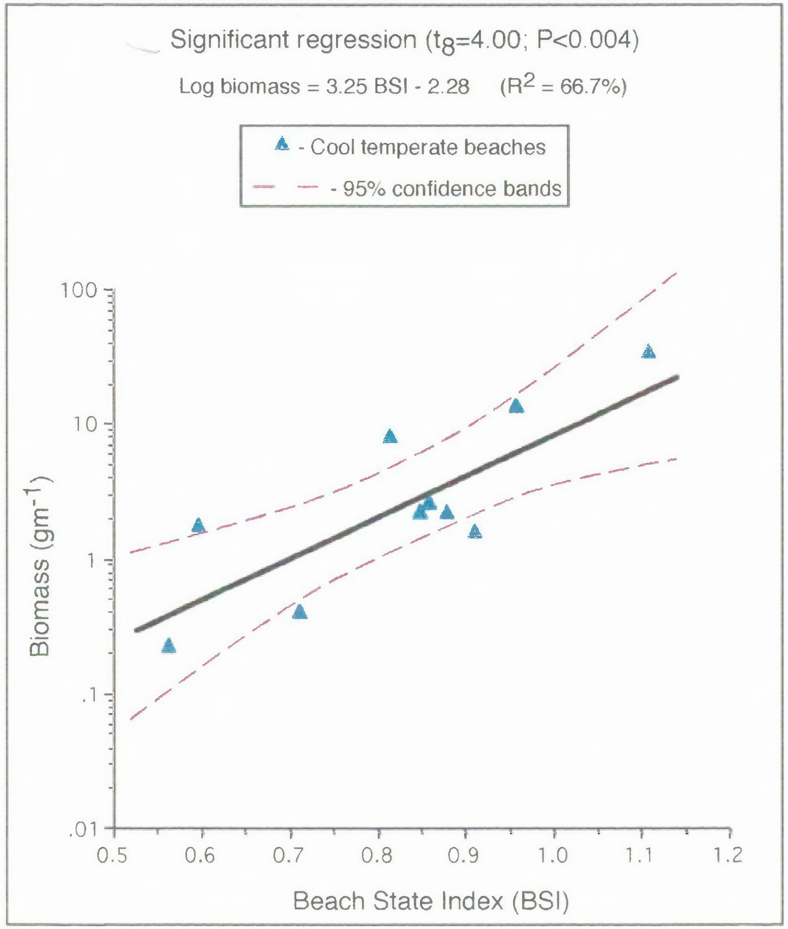
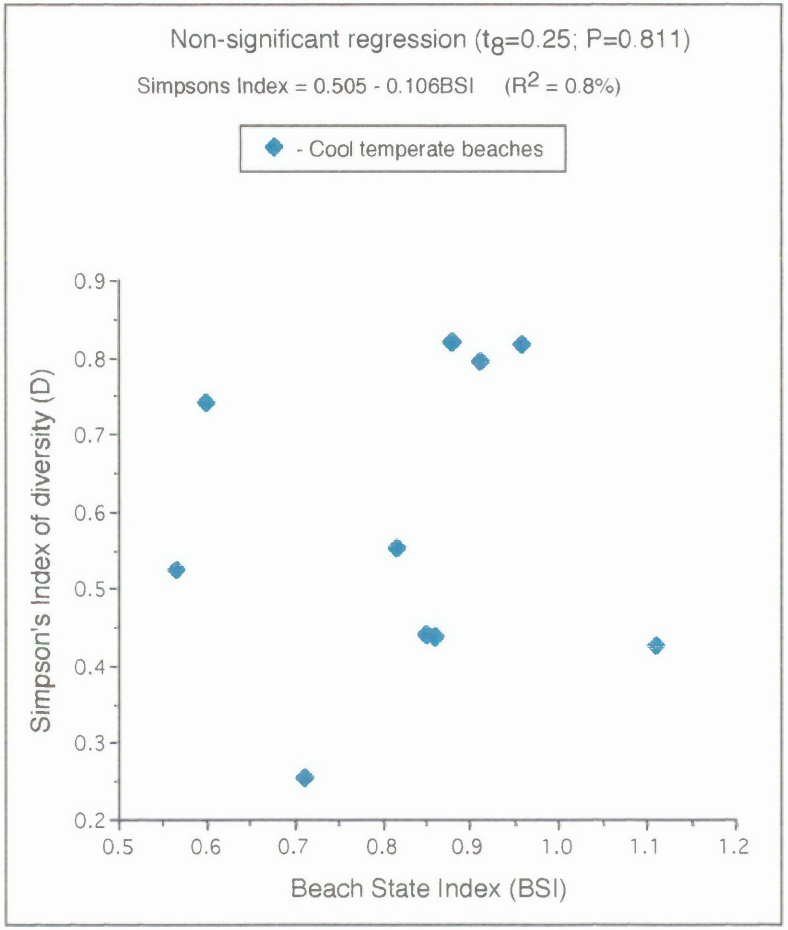


Figure 4.9:

Cool temperate Australian beaches: Simpson's Index vs BSI

Showing no significant relationship between animal diversity (Simpson's Index) and Beach State Index (BSI)



Residuals for species number against Ω and BSI were ambiguous in indicating heterogeneity of variances (refer section 3.4). However, the logarithmic model showed no improvement in the relationship with either beach index (as indicated by comparisons of the R^2's for the anti-logged predicted values with those for the linear models). Therefore, a linear relationship between species numbers and Ω/BSI is the most representative for the South Australian beach macrofauna data.

4.4 Discussion

Within the cool temperate area, beaches showed a significant increase in species number, abundance and biomass with dissipativeness of the sampling site. This occurred using both Ω and BSI. Best results were achieved within the locality using Ω, suggesting that the tide is of little importance in beach state indexing when comparing beaches within a region of similar tidal range.

Although only a small spectrum of beach types was ultimately sampled, the results of the present study support past conclusions that more dissipative beaches generally harbour richer fauna. For the present beaches, species number, abundance and biomass consistently increase from low to high beach energy with species number the most predictable parameter using either Ω or BSI. This trend of increase resembles that reported in similar, previous studies (refer chapter 1.3.2).

The significance of the above regressions supports the premise that physical aspects of beaches are of major importance in determining the species number, abundance and biomass composition of the macrofaunal communities present. Rather than respond to changes in any single parameter, the fauna seem to respond to combinations of sand size, wave regime and tidal range (McLachlan, 1990; McLachlan et al., 1993). These results also support the swash exclusion hypothesis of McArdle and McLachlan (1992) (refer chapter 1.3.2) in that species, abundance and biomass increase with habitat dissipativeness and its intrinsic effect on the prevailing swash environment.

The swash climate itself is determined by the physical factors that are used in the morphodynamics formulae to classify beaches (principally wave height and sediment size, which together influence beach slope). Dissipative beaches mostly have a long even swash activity across a low gradient beach face. In contrast, reflective beaches display more violent swash features with waves often breaking directly on the steep intertidal beach face and running rapidly back out into the surf zone (refer chapter 1.1.4). These features have different implications in terms of the conditions experienced by the macrofauna living in the intertidal sand.

Swash climate is probably the most important consideration of the beach face habitat encountered by sandy beach macrofauna. Most species move, feed, burrow and reproduce in the swash (McArdle and McLachlan, 1992) and therefore must be affected by it. Thus it is likely that the reduced species, abundance and biomass numbers on reflective beaches are a result of strong swash on the beach face providing little feeding or movement opportunity for the animals present. There is also an increased risk of animals becoming stranded or washed out to sea (McLachlan et al., 1993). Thus, only the most specialised macrofaunal species can exist on reflective beaches. Alternatively, more dissipative beach states exhibit a longer, gentler, more "hospitable" swash which can be tolerated and utilised by a wider range of animals. Dissipative beaches also seem to experience more varied processes on the beach face as a result of the characteristics of their swash climate. This potentially allows for greater habitat complexity which can be exploited by a larger number of species.

In the most reflective South Australian beach, there were no macrofaunal animals other than small, robust, fast-moving isopods (Table 4.1). These were probably the only animals capable of surviving the harsh swash conditions caused by large waves breaking directly on the beach face. This may indicate the relative sturdiness of the variety of South Australian isopod species in terms of ability to survive various swash strengths. As the beaches became more dissipative, these isopods were still present with polychaetes and insects beginning to appear and increase, followed closely by bivalve molluscs (Table 4.1). These results support the swash exclusion hypothesis in equating BSI with harshness of the swash environment.

Both Goolwa and Coorong beaches have been sampled before by McLachlan et al. (1996). The BSI values for these beaches at their time of sampling were much higher than the values calculated here, illustrating temporal changes in beach morphodynamics. Correspondingly, McLachlan et al. (1996) also found a higher species count than demonstrated by these beaches in the present study. This points to the importance of physical characteristics acting on beach macrofauna at a place and time. In terms of predicting beach macrofaunal communities, physical data at the time of sampling (especially sediment size) are clearly essential.

Simpson's index of diversity is unrelated to physical beach processes expressed as Ω or BSI in cool temperate eastern Australia. However, a number of factors can influence the value diversity indices, making comparisons between sites unreliable. These might include: time, spatial heterogeneity, competition and predation, sample size and sampling method, level of taxonomic identification, stability, productivity, nich structure and evolution (Heip and Engels, 1974; Menge and Sutherland, 1976; Hughes, 1978;

Smith, 1993). Thus, although the summarisation of community data into one such value is an appealing feature of diversity indices for ecological studies, species richness (number of species) is more easily correlated with the physical environment of sandy beaches.

In any case, despite the potentially confounding spatial variation within the beach system (as demonstrated in chapter 2.2), significant trends in species number, abundance and biomass with the morphodynamic state of the sample transect have been found for the cool temperate eastern Australian beaches.