CHAPTER 8
Comparisons of eastern Australian beaches with beaches world wide

8.1 Introduction and aim

Chapter 6 has shown that macrofaunal species number, abundance and biomass on eastern Australian beaches are related to physical processes expressed as Ω or BSI. Species number, in particular, is commonly controlled by physical beach processes, including tides, across the latitudinal spectrum. However, although exhibiting a wide range of beach types, not all morphodynamic beach states existed within the present study regions (see figure 8.1). The present faunal data combined with comparable data from the missing beach types would complete the picture and potentially allow for a ubiquitous scheme for beaches and macrofauna world-wide.

Unfortunately, sandy beach sampling for macrofauna communities has not been standardised and no studies using the particular specifications of the present sampling method have been published. Nevertheless, to see how beach macrofauna and morphodynamics compare on a global scale, three recent papers with reasonably similar sampling regimes have been chosen to add to the present data in lieu of a combined regression. New data uses beaches from:

a) McLachlan (1990) - including beaches from the United States of America, South Africa and Western Australia; sampled using 11-12 tidal levels, 2 x $0.1m^2$ quadrats at each to 25cm depth, 1.5mm mesh sieve.

b) McLachlan *et al.* (1993) - including beaches from southern Chile; sampled using 10 tidal levels, 4 x $0.03m^2$ cores to 30cm depth at each, 1mm mesh sieve.

c) McLachlan *et al.* (1996) - including beaches sampled at a different times from the cool temperate and tropical regions of this study (eastern Australia); sampled using 15 tidal levels, 3 x $0.1m^2$ quadrats at each to 25cm depth, 1mm mesh sieve.

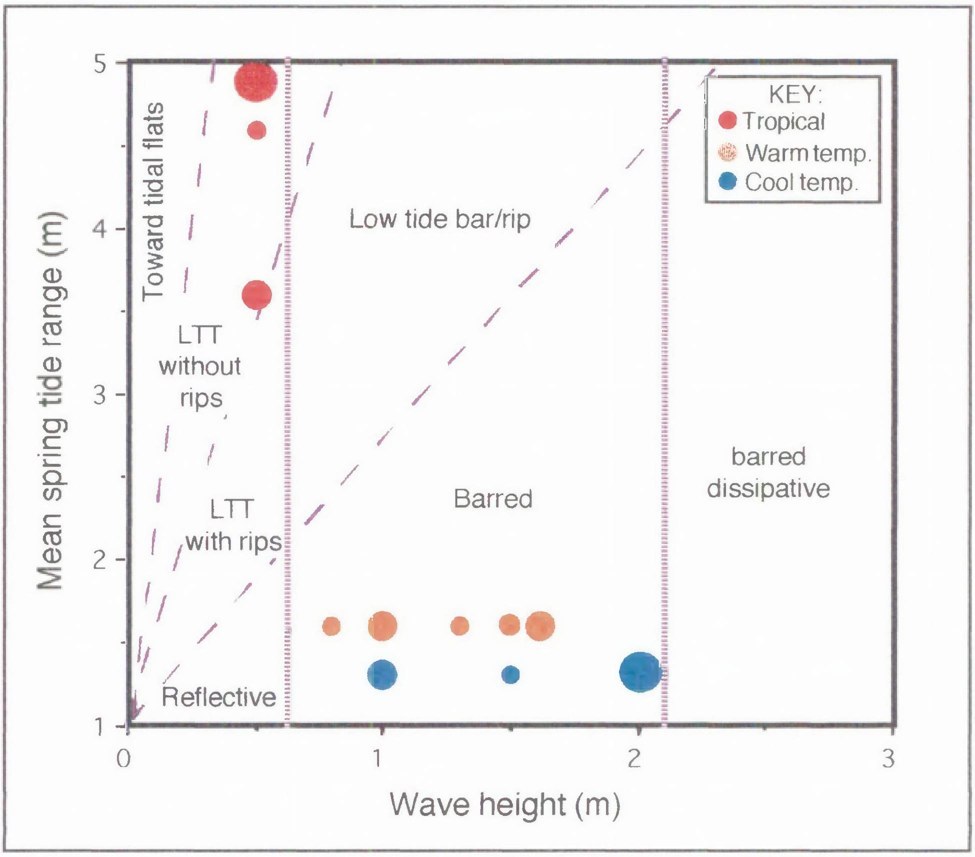


Figure 8.1: Approximate position of studied beaches within total spectrum of beach types (refer fig.1.3).
Spot size represents approximate proportion of beaches studied.
(based on wave period = 8 seconds, sediment fall velocity = 0.04m/s)
Boundaries between beach types will shift with changes in wave height and sediment.
LTT= Low Tide Terrace [After Masselink and Short, 1992].

8.2 Materials and methods

Present data and data published in McLachlan (1990), McLachlan *et al.* (1993) and McLachlan *et al.* (1996) were compared and tested for similarity using analysis of co-variance (t-test) in a similar manner to the between province comparisons of Chapter 7.

"Other" data were then combined with that for the present study on eastern Australian beaches and the joined data set linearly regressed against BSI. As for local beaches alone, normal probability plots of residuals suggested log transformation of the raw abundance and biomass combined data to form a straight line relationship; species numbers remaining untransformed. Regression statistics and equations were determined by Minitab Release 9.2 (1993).

Multiple regressions including latitude as an independent variable were also performed in a manner similar to chapter 7. No attempt has been made to graphically present these three-dimensional models.

8.3 Results

8.3.1 Species number

The slopes of the regression lines for the above data sets were significantly different from each other using both Ω and BSI as a morphodynamic index (Ω: t_{62}=2.93, P<0.001; BSI: t_{62}=1.68, P=0.024). The data sets thus show different relationships with beach state and no statistically common regression equation can be calculated.

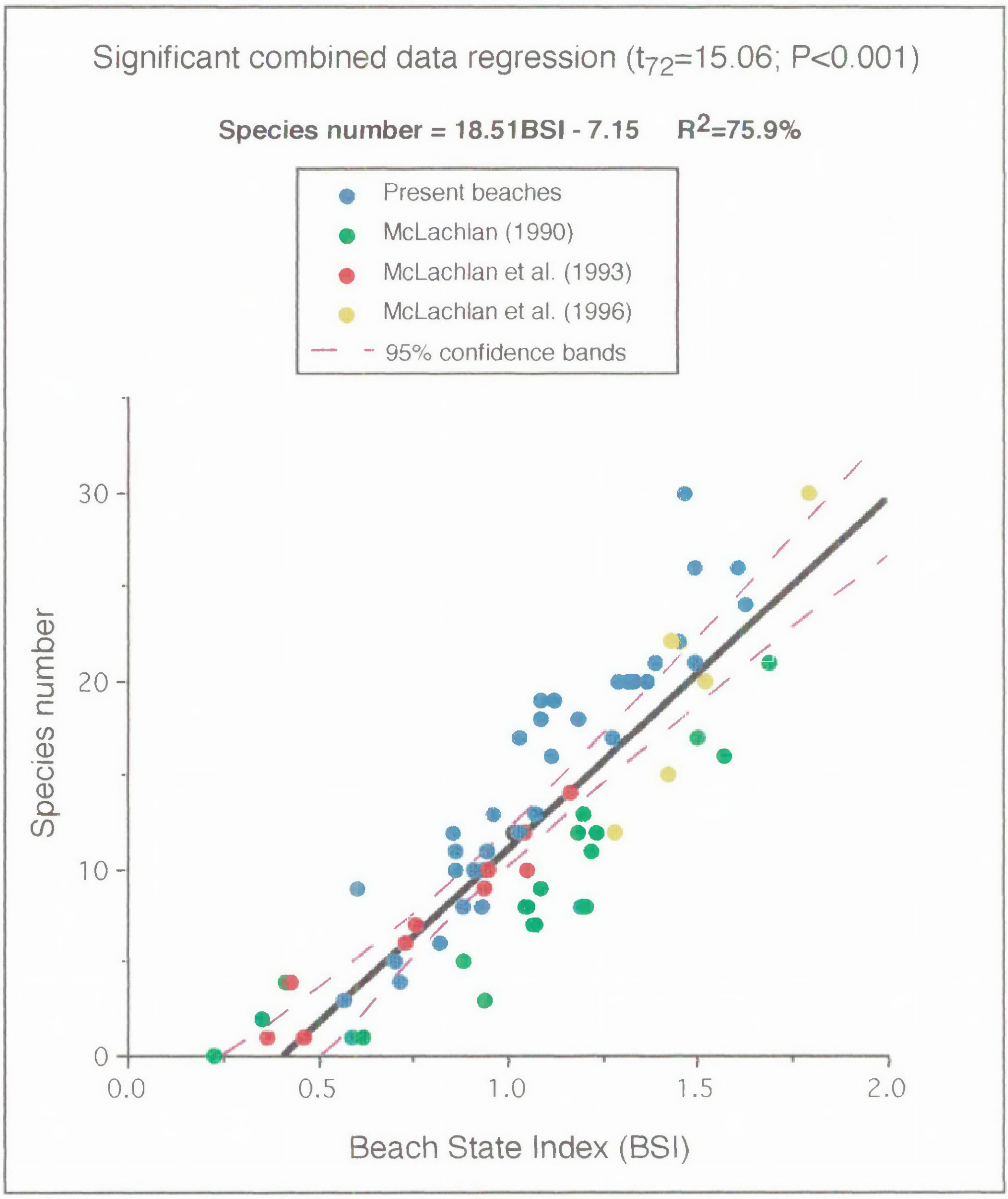
However, if BSI is considered continuum and the data pooled as a single set, a significant regression is produced (t_{72}=15.06, P<0.001; species number=18.51BSI-7.15, R^2=75.9%) (Fig 8.2). Unlike beaches of eastern Australia alone, this regression is improved by inclusion of latitude in the formula (BSI: t_{71}=12.80, P<0.001; Latitude: t_{71}=-4.22, P<0.001; species number = 3.74+16.0BSI-0.266latitude, R^2=80.5%). Correlation between latitude and BSI in this case was relatively low (Table 8.1) suggesting little problem with multi-colinearity (refer chapter 6.3). The significance of latitude in this equation indicates that it has an effect on the number of macrofaunal species present in beaches on a global scale.

A combined regression with Ω was not significant and a multiple regression using this index and latitude was less significant than the multiple regression using BSI.

Table 8.1: Correlations between independent variables: present and world data. A perfect correlation exists at values of 1.0 (+ or -), with low correlation existing at values close to 0. This table shows BSI and latitude are not greatly correlated for the present combined data.

	BSI	Ω
Ω	0.601	
Latitude	-0.457	0.259

Figure 8.2: Present and previous studies: species number vs BSI
Showing a significant combined relationship between species number and BSI world-wide. This relationship is strengthened with the inclusion of latitude (not graphically presented - see section 8.3.1)



8.3.2 Abundance

Using Ω as a beach index, there were significant differences in the slopes of the present data sets (t_{62}=2.77, P<0.001) and therefore no common response of the abundance data with dimensionless fall velocity. However, BSI as an index showed the lines to have a parallel relationship (slopes not significantly different: t_{62}=1.36, P=0.118; intercepts significantly different: t_{62}=10.63, P<0.001). This indicates that macrofaunal abundances around the world have a common response to BSI at different levels of magnitude.

A simple regression of pooled data against BSI showed a significant relationship between log animal abundance and beach state (t_{72}=9.19, P=0.001; log abundance = 2.57BSI + 0.54, R^2= 52.9%) (Fig. 8.3). This relationship was marginally improved by the inclusion of latitude in a multiple regression with BSI (BSI: t_{71}=8.95, P<0.001; Latitude: t_{71}=1.81, P<0.001; log abundance = -7.03 +3.04BSI - 0.031latitude, R^2=55.0%). The significance of latitude in the equation indicates it plays a part in determining macrofaunal abundance of beaches world-wide. There was no improvement in a multiple regression of abundance, Ω and latitude.

8.3.3 Biomass

The data sets for log biomass were also parallel using Ω as an index (slopes not significantly different: t_{62}=1.51, P=0.058; intercepts significantly different: t_{62}=6.74, P<0.001). BSI as an index showed significantly different slopes (t_{62}=1.58, P=0.039) and thus no common response of macrofaunal biomass to this description of beach state.

However, unlike biomass results against Ω, a combined data regression against BSI was significant (t_{72}=7.43, P<0.001; log biomass=2.08BSI-0.34, R_2=43.4%)(Fig. 8.4). Like the abundance results, this relationship was also strengthened by the inclusion of latitude into the formula (BSI: t_{71}=7.75, P<0.001; Latitude: t_{71}=2.21, P=0.03; log biomass = -1.73+2.38BSI-0.34latitude, R_2=46.8%). A multiple regression with Ω and latitude showed no improvement over the single BSI/biomass relationship.

Figure 8.3: Present and previous studies: abundance vs BSI
Showing a significant combined relationship between abundance and BSI world-wide. This relationship is strengthened by the inclusion of latitude in the formula (not graphically presented - see section 8.3.2)

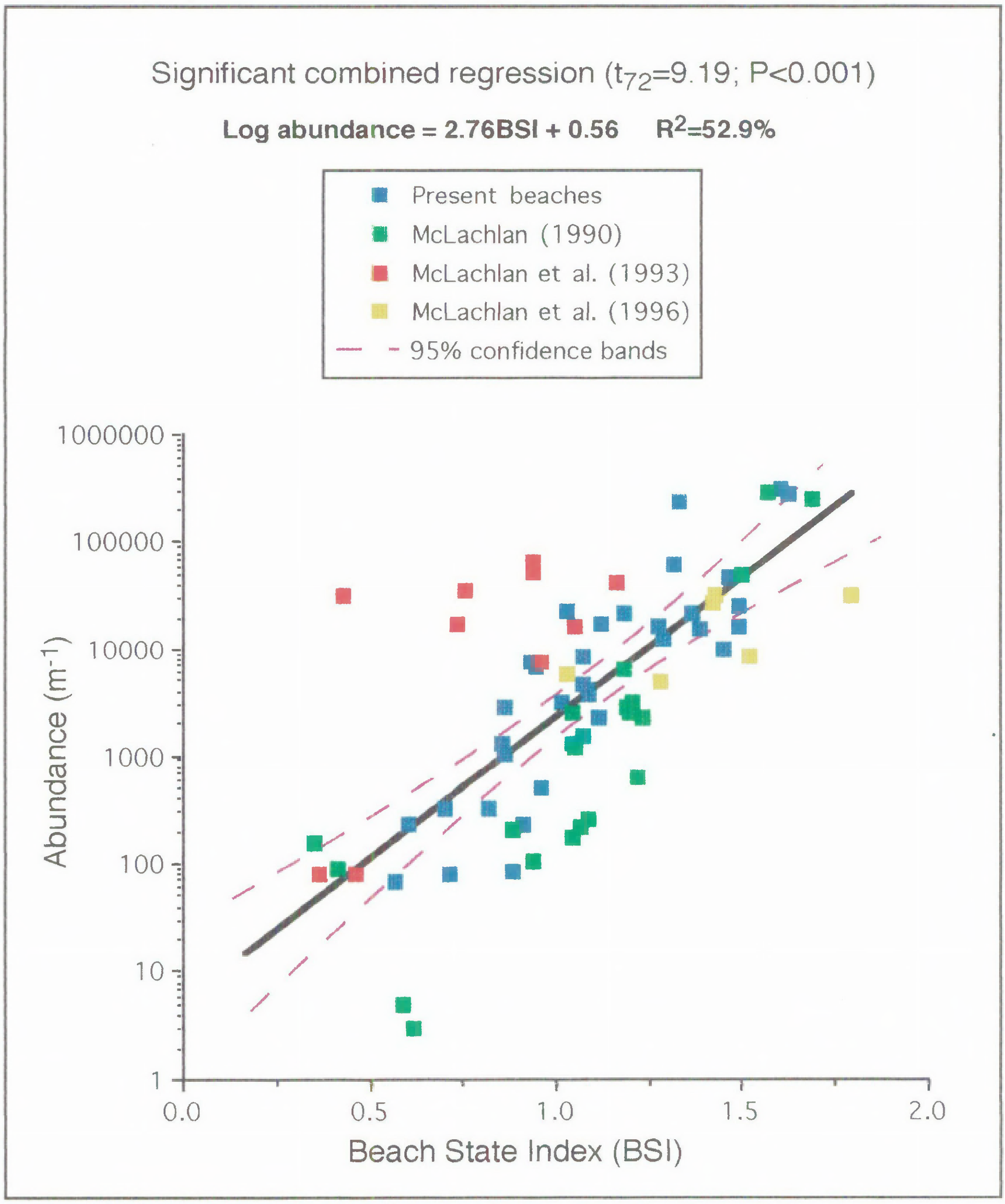
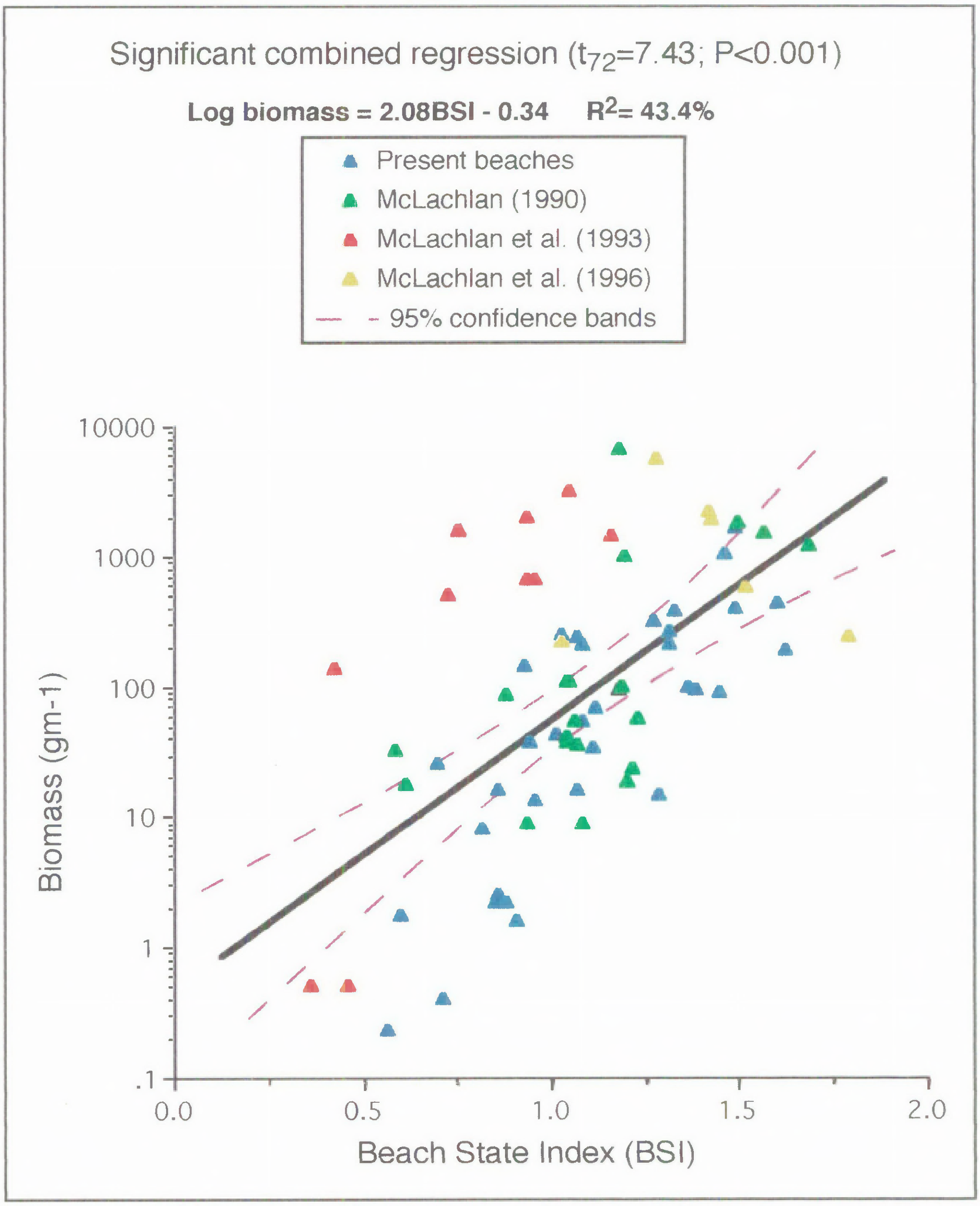


Figure 8.4: Present and previous studies: Biomass vs BSI
Showing a significant combined relationship between log biomass and BSI world-wide. This relationship is strengthened with the inclusion of latitude (not graphically presented - see section 8.3.3)



8.4 Discussion

Differences between the "present" and "other" data in terms of their relationships with BSI seem especially distinct for species number, which showed no common response to beach state for the sets of world-wide data. This suggests that the responses of this community parameter to physical conditions varies between broadly dispersed beaches. However, a pooled data regression with BSI was significant showing species number to increase with beach state across the globe. Inclusion of latitude into the formula showed an improvement in the fit of the regression indicating that, unlike for eastern Australian beaches alone, latitude is a partial determinant of species number for beaches world-wide.

Abundance and biomass lines against BSI were parallel. This suggests that the response of these community parameters to beach state may be a broadly conservative feature of beach systems world-wide (though at differing magnitudes). Combined regressions of these data were also significant, though could be strengthened by the inclusion of latitude. This again suggests that, globally, macrofaunal abundance and biomass is decided to a large degree by a combination of physical beach processes and latitudinal locality.

However, actual variations between data sets and the influence of independent variables in the multiple regressions were very likely confounded by the differing sampling methods and seasons in which the world data were obtained. For example, faunal values of McLachlan (1990) are generally lower with BSI than similar values calculated for the present study (Figs 7.2, 7.3 and 7.4). The lower counts of these "other" data are most likely due to the larger mesh aperture and more shallow sample depth used in the survey. Seasonal effects on species populations at the time of sampling may also be involved in differences between the global data. Thus elucidation of local weather effects on beach macrofauna related to BSI is a necessary direction for future research. Because of the sampling differences between the world data sets, little confidence can be placed in the accuracy of the above analyses. The issue of latitudinal effect on beach macrofaunal communities across the globe thus remains unresolved.

Nevertheless, the combined regressions of the present and "other" with BSI were all significant and support the swash exclusion hypothesis on a global scale. Species number increases consistently from reflective through dissipative to ultra-dissipative conditions, with only 24.1% of the variation attributable to factors not examined by the BSI. Like the warm temperate and tropical eastern Australian data, global trends hint at a logarithmic increase in species number towards conditions dominated by the tide - the linearity of the global regression possibly an artefact of under-sampling in macro-tidal situations (refer chapter 7.4). The acceptance of this idea, however, requires future research to involve much larger sampling areas .

Similarly, abundance and biomass values around the world increased significantly with BSI - demonstrating that these community attributes are also largely regulated by the physical beach climate. However, combining of global species numbers, abundances and biomasses decreased the strength of the relationships with BSI next to those for eastern Australian beaches alone. In the present study, where all beaches were sampled similarly and during a like season, fauna/beach state relationships were tightened when regions were combined to include all the morphodynamic states. Given the separating coastline distances between these localities, there is little reason why other beaches should not respond to morphodynamic state in a similar way. Although local oceanographic, latitudinal, seasonal and biological differences within the beaches would undoubtedly contribute to macrofaunal variations between them, the degree of this combined influence world-wide cannot be ascertained without standardisation of the sampling procedure.

Nevertheless, the finding that blending of such varied data produces such significant relationships ($p<0.001$ for all combined regressions) suggests that compound beach state indices afford, to some extent, large scale predictability of macrofaunal community structure for all natural, exposed sandy beaches. Increases in this predictability may be possible in the future with further understanding of the effect of latitude and the measurement of physical beach processes; including the additional combined effects of swash measurements, sand bars and degree of beach embayment on the morphodynamics of the system (refer section 1.1.6). In this event, appropriate modifications of beach index formulae may disclose additional dependencies of beach macrofaunal communities on their physical surrounds.