CHAPTER 3
General Materials and Methods

3.1 Design of study

This study has been constructed with the aim of broadly comparing beach macrofaunal communities and morphodynamic states both within and between regions on the east coast of Australia. Thirty five beaches were sampled overall - ten from each of two temperate areas and fifteen in the tropics (see chapter 1.4). Sampling of the beaches took place during the Australian summer months of December and January in order to counter any effects of season. Summer is also the time that beach macrofauna is potentially most abundant (see section 1.2.3c). This chapter gives an overview of the general sampling procedure undertaken for all these beaches. The procedure is based on the pilot studies of Chapter 2. Specific information on regions and the sampled beaches is included later in the relevant individual chapters.

3.2 Site selection

Within each of the provinces, a range of exposed morphodynamic beach types pertinent to the area was selected. These ranged from reflective to dissipative in the temperate latitudes and from dissipative to ultradissipative in the tropics. The beaches were, as far as known, free from pollution and large amounts of stranded kelp which have been shown to affect the composition beach macrofauna communities (Stenton-Dozey and Koop, 1983; Robertson, 1984; McLachlan, 1985; Tarr and Bally, 1985; Van der Merwe and McLachlan, 1987). The sampling transects were also located as centrally as possible on each beach - away from headlands, rocky outcrops and estuarine creeks that may have run across the beach face. Likewise, sampling sites were placed away from areas of large human use (e.g. four-wheel driving, bait collecting and other human induced sediment disturbances).

3.3 Sampling procedure

3.3.1 Transect sampling for fauna

Each beach was investigated once at low tide (on consecutive days within regions) in a method akin to McLachlan et al. (1993) (see section 2.2). It is important to remember that the transects sampled in this study are intended to reflect only the morphodynamic characteristics of a particular section of beach and not the beach in its entirety. The entire transect thus constitutes the sampling unit for Part B of this study (compare Part C where differences in macrofauna are examined within each transect across the tidal gradient).

At each beach a transect was drawn perpendicular to the horizon from above the high tide drift-line to the low tide swash. The transect was divided into ten equally spaced tidal levels: level 1 positioned above the drift line, level 2 on the drift line and the lowest level, level 10, situated in the low tide swash. At each of the beach levels, three replicate 0.11m^2 samples were taken approximately 1 m apart to a depth of 35 cm (Figs 3.1 and 3.2). The samples were regulated using a 33x33x35 cm metal box frame which could be pushed into the sediment and the sample removed from within (Fig. 3.3). Each sample was sieved in the surf on site (Fig. 3.4) through a 1mm mesh (as deemed acceptable in section 2.1). This mesh had been previously built into a wide stainless steel tray which was easily transported across the shore by means of an associated trolley (Fig. 3.5). Using this sieve/trolley system, negligible sediment/fauna was lost during the washing process.

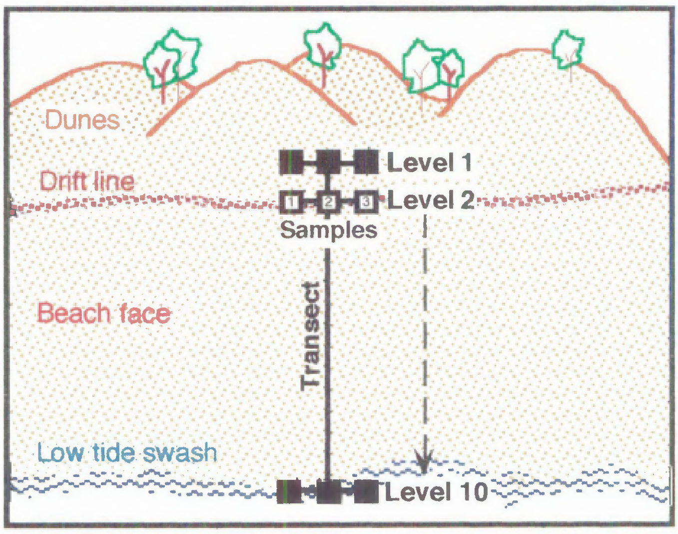

Figure 3.1: Position of beach transect for sampling
Consisting of 3 samples at 10 levels running perpendicular to the shoreline

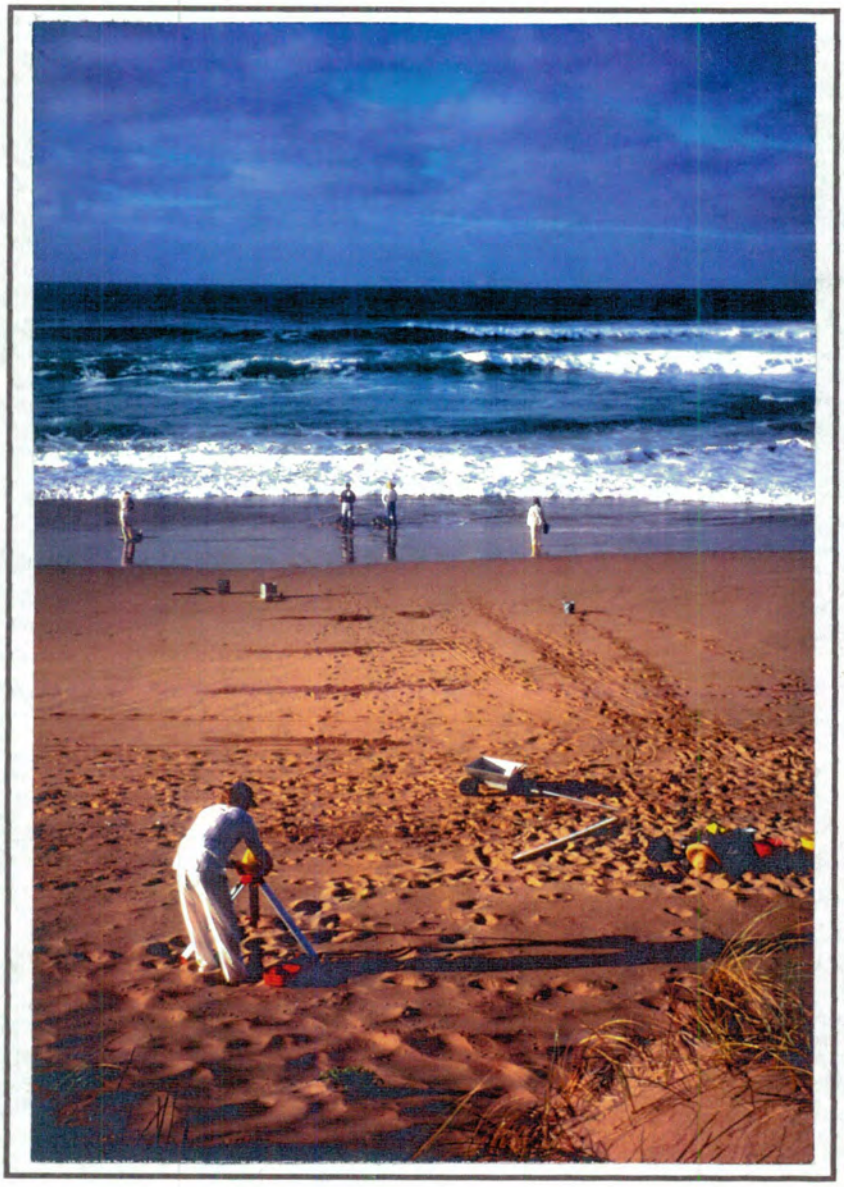

Figure 3.2: View of a sampling transect from the dunes.

Note the dumpy level (positioned at level 1) for measurements of vertical displacement and subsequent plotting of the intertidal profile.

Parsons Beach, South Australia.
[Photo: N. Hacking]

Figure 3.3: Obtaining a sample for macrofauna

Note the 33x33x35 cm metal box-frame pushed into the sand, from which a sample is removed by digging. The sample is placed in a tray (on a trolley) containing a built-in 1mm stainless steel mesh.

Mackay Harbour beach, central Queensland
[Photo: N. Hacking]

Figure 3.4: Sieving samples through the 1mm mesh using the swash and surf-zone as an aid.

Goolwa beach, South Australia
[Photo: N. Hacking]

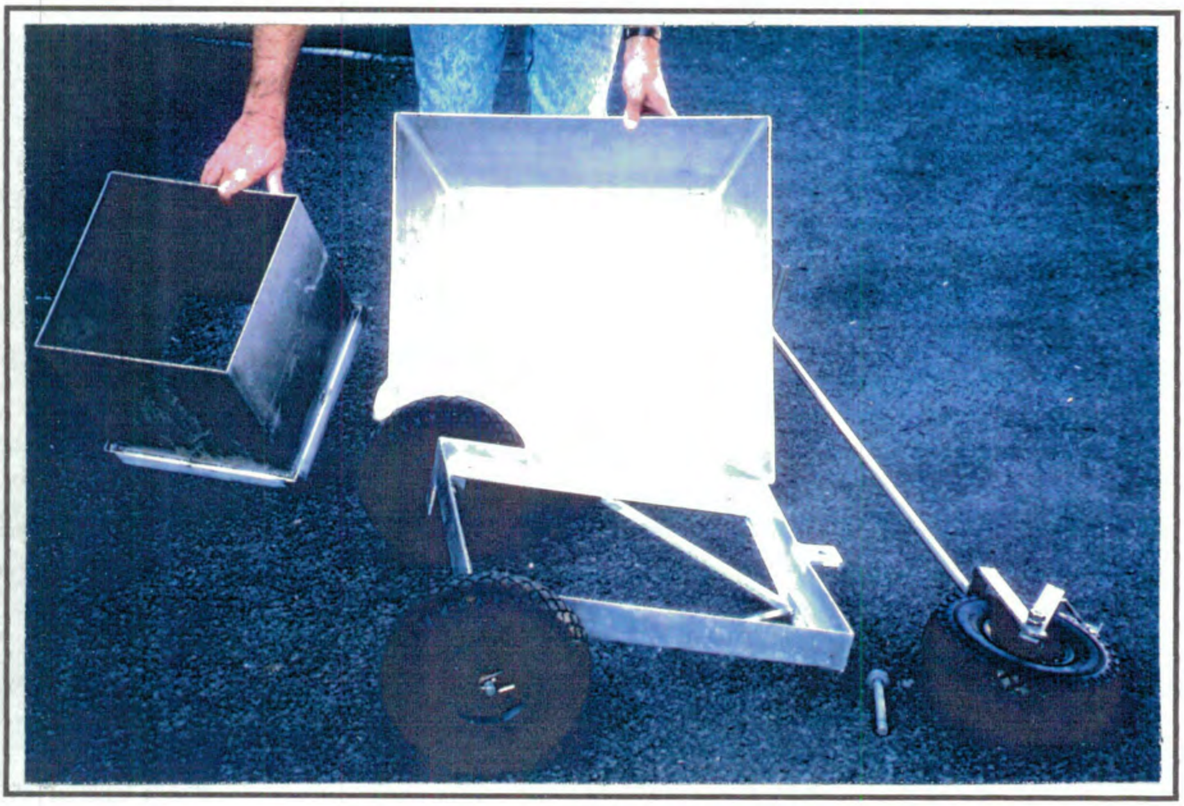

Figure 3.5: Sampling equipment (dismantled)

Showing the metal box-frame (left), tray containing 1mm mesh (back right) and trolley (main body- front right; assembly pin, front wheel and handle -front left)
[Photo: N.Hacking]

Fauna collected were preserved and stored in ~4% buffered formaldehyde in seawater and later sorted, identified, counted and weighed (see section 3.3.5). Insects and any other "terrestrial" fauna are as characteristic of beach sediment as intertidal marine species and so were included in the samples.

Where massive sediment was retained, a decantation method for fauna was employed - the end point being defined as the time when no animals occurred for three consecutive decants. Retained sediments were also checked by hand for heavier animals such as bivalve molluscs. In some instances, very large numbers of small juvenile molluscs were collected. In these cases the sieved sample was preserved in bulk and the juveniles sorted from the sediment in the laboratory.

3.3.2 Plotting beach profiles and water tables

At each beach the intertidal profile was surveyed using a dumpy level and staff. Level 1 was used as the datum point and vertical displacement of each of the subsequent sampling levels could then be calculated and thereafter plotted in a two-dimensional contour (Fig. 3.2). Using the information from these surveys, intertidal beach gradient was also calculated as:

$$\text{Beach gradient} = \frac{\text{total vertical displacement (m)}}{\text{intertidal distance (m)}} \qquad (6)$$

Position of the water table at low tide was estimated where practicable by digging. This was later plotted on the profile diagrams as the distance in centimetres below the sand surface at the beach levels, along with the position of the effluent line.

3.3.3 Estimation of wave height, wave period, tidal range and degree of beach exposure

Wave height was determined as the vertical distance between wave peaks and troughs. Wave period was determined using a stop watch as the average time in seconds between each breaking wave. These parameters were estimated on site at the time of sampling solely by the author in order to avoid potential personal variations in assessments. Wave height at the time of sampling was used in the calculations of beach indices, however wave period values for each beach were taken from long term modal data (as made available by A. Short, pers comm., and Surf Life Saving Australia).

Relative Tide Range (RTR) was calculated for each beach according to Formula 2 (section 1.1.5). Maximum tidal range was determined by extrapolation from a long term series of Australian tide tables. Use was also made of data held by A. Short (pers. comm.).

Beach exposure was rated according to the scheme of McLachlan (1980a) (refer section 1.1.2c).

3.3.4 Sediment analysis

At each beach site and level a sediment sample was taken to 35cm. This sediment was stored and later analysed using a series of graded sieves corresponding to the Wentworth scale (Buchanan, 1971) (see table 3.1). These results were averaged by weight across the beach and then expressed as sediment fall velocity (Gibbs et al., 1971, refer section 1.1.3) in order to incorporate into the beach morphodynamics formulae.

Table 3.1: The Wentworth scale of grain size characteristics

[$ø = -\log_2$ of the particle size in mm]

Grain size (mm)	**Phi (ø) scale**	**Sediment Fall Velocity (W_S)** (m sec^{-1})	**Sediment type**
256	-8	-	cobble
64	-6	-	cobble
16	-4	-	pebble
4	-2	0.300	pebble
2	-1	0.182	granule
1	0	0.110	very coarse sand
0.5	1	0.066	coarse sand
0.25	2	0.040	medium sand
0.125	3	0.024	fine sand
0.0625	4	0.015	very fine sand
0.0310	5	-	coarse silt
0.0039	8	-	silt
0.0020	9	-	silt
0.00006	14	-	clay

3.3.5 Calculations and expressions

a) Dimensionless Fall Velocity (Ω) and Beach State Index (BSI)

Each beach was indexed according to Ω and BSI using the above components inserted into formulae 1 and 3/4 respectively (see sections 1.1.3 and 1.1.5c).

b) Macrofaunal parameters

i) Species number

Species number (species richness) for each beach was determined as the total count of individual species for the faunal transect.

ii) Abundance

As most macrofaunal populations on beaches are highly mobile and undergo many migrations, population distributions and associated densities can vary greatly. For this reason abundance (and biomass) of macrofaunal communities are commonly considered by beach ecologists in metre-wide strips of beach (ie. per metre of along-shore beach) and not metres squared. For this study, abundance values per metre beach were obtained by: i) measuring the abundance per metre squared at each level by averaging the replicates; ii) multiplying these values by the metric distances between sampling levels; and iii) summing the totals. In this way the abundance data estimate whole populations of a given section of beach and may be compared with information collected during different seasonal and lunar cycles (Brown and McLachlan, 1990). This method was agreed upon by beach ecologists attending the "First International Symposium on Sandy Beaches" (1983) and was still found acceptable at "Sandy Beaches '94".

iii) Biomass

Shell-free biomass[1] was determined for each species and sample by drying at 60^{o}C for 48 hours. Where individual animals were needed whole for identification purposes, biomass was estimated as a percentage of wet weight as calculated for similar or related species (usually at around 25% as recommended by A. McLachlan pers. comm.). Biomass values per metre of beach were then calculated as for abundance (above).

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[1] "Shell-free" refers to body mass calculated after removal of animal shells (ie. as in molluscs).

iv) Simpson's Index of diversity

The most simple measure of species diversity is the number of species (species richness). However, many indices have been proposed to describe community diversity in terms of species abundance patterns (Krebs, 1985). Simpson (1949) suggested that community diversity is inversely related to the probability that two individuals picked at random will belong to the same species. This probability is expressed by the formula:

$$D = \sum p_i^2 \qquad (7)$$

(where D = Simpson's Index of diversity; p_i = the proportion of individuals of species i in the community).

To convert this probability to a measure of diversity, the complement of Simpson's original measure (1-D) has been suggested (Krebs, 1985; 1989). Thus the formula converts to:

$$D = 1\text{-}D = 1 - \sum p_i^2 \qquad (8)$$

This measure of diversity indicates the proportional abundance of species in the community, giving weight to common animals over rare. Maximum diversity is considered to exsist in communities of equally common species. Simpson's Index ranges in value from 0 (low diversity) to a maximum of (1-1/S); where S is the number of species.

For this study, Simpson's Index of diversity was calculated for each beach according to formula 8.

3.4 Statistical analysis

Each data set was checked for non-constancy of variances and outliers using residual plots determined by Minitab Release 9.2 (1993). The assumption of data normality and linearity was also checked with normal probability lots of residuals. Abundance and biomass data were subsequently log transformed for each data set[2]. Log transformation of abundance and biomass data was also later useful in fitting the present data to that of other surveys for the purpose of comparisons. There were no critical outliers in any of the data sets.

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[2] The terms "abundance" and "biomass" will forthwith be used to refer to the logged values in all cases

Examination of residuals for the linear model of species numbers indicated some heterogeneity of variances. To stabilise the variances, species number values were log transformed. However, because there was some degree of ambiguity associated with the possible heterogeneity of variances, the coefficients of variation (R^2) for the linear model and the log-transformed model were compared. Because the total sums of squares (the determinants of R^2) are not comparable between these two models, the R^2 for the linear model was compared with that for the anti-logged fitted values of the log-transformed regression. This comparison of the predictions from the log-transformed model with the linear model insures common denominators in the equation for the coefficients of determination. The larger of the two R^2's indicates the model for the best representation of the species number data.

Within each region, results for species number, abundance, species diversity (Simpson's Index) and biomass for the beaches were then regressed against Ω and BSI (significance claimed at 95%). Regression equations, coefficients of determination[3] and confidence limits[4] were calculated by Minitab Release 9.2 (1993).

Other statistical methods (e.g. analysis of covariance, multiple regressions, classification and ordination analysis) were employed where appropriate in specific chapters and are described there.

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[3] The "coefficient of determination" or "R^2" is the proportion (or percentage) of the total variation in the beach macrofaunal data (y) that is accounted for (or explained by) the fitted regression. It may be thought of a measure of the "strength" of the linear relationship (Zar, 1984).

[4] Confidence intervals are calculated using standard errors. "Confidence limits" illustrate a degree of assurance on the "correctness" of the calculated slope of the regression line (i.e. 95% confidence limits show the range within which there is no greater than 5% chance that the slope of the regression line is wrong using the given data).