SPATIAL VARIABILITY IN MANGROVE FORESTS AROUND THE BRISBANE WATER ESTUARY

PREPARED FOR

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TABLE OF CONTENTS

INTRODUCTION

Mangroves are salt-tolerant plants that are generally found growing along the shorelines and creeks within estuaries. Mangroves are important in cycling of nutrients in estuaries and are considered to provide important habitats for birds, fish, invertebrates and a range of macro-fauna (Clarke and Hannon, 1969; Clough, 1982, Mitchell and Adam, 1989).

There have been large-scale declines in the extent of mangrove forests within NSW estuaries (Stricker, 1995; Streever, 1999). The importance of mangroves to the Brisbane Water estuary was highlighted by Harty (1994), and their subsequent conservation was given a high priority by council. There are two species of mangroves found within the Brisbane Water estuary; *Avicennia marina* (grey mangrove) and *Aegiceras corniculatum* (river mangrove). There are significant areas of mangrove forests within the estuary and large-scale mapping of their distribution has been done (West et al., 1985; Harty, 1994; Harty and Cheng, 2003). The most recent mapping of mangroves was completed by DPI Fisheries (see Fig. 1). The spatial extent of mangroves in the estuary has fluctuated as a result of urbanisation and encroachment into saltmarshes (Harty and Cheng, 2003). Harty and Cheng (2003) estimated that there had been an overall increase (approximately 4%) in the spatial extent of mangroves within the estuary up until 1995, with a subsequent large decline in the extent of saltmarshes.

In this study, we focussed on quantifying the patterns in a range of variables associated with mangrove forests at a hierarchy of spatial scales. These variables included the density, height and canopy cover of the mangrove forest as well as the number of seedlings, pneumatophores and crab holes within each of the forests. The collection of data on crab holes and pneumatophores was used to assess relative health of the forest floor (Skilleter and Warren, 2000). The collection of these data on patterns was a necessary first step in developing models about ecological processes occurring within the mangroves of the estuary (Underwood et al., 2000).

METHODS

The marine vegetation map produced by DPI Fisheries was used to identify large areas of mangroves within the estuary (Fig. 1). Fifteen locations were sampled at low tide (Table 1) to examine the variability in mangroves at the scales of kilometres, 100s of metres and metres in the estuary (Fig. 2). Two randomly nested sites were sampled at each location at similar elevations throughout the estuary. Many of the mangrove locations were situated on the edge of the estuary and at some locations the fringing forest was relatively narrow. Therefore, each site was generally chosen to cover an area of approximately 50 m of shoreline, extending back around 30 m into the forest. Within each site, three 10 m^2 plots were randomly selected.

The number of adult mangrove trees (*Avicennia marina* and *Aegiceras corniculatum*) were counted in each plot. An estimate of the height (m) of the forest canopy and its percentage cover (Specht Classification) was also made from within each plot. Furthermore, within each 10 m^2 plot, five randomly placed 0.25 m^2 quadrats were used to estimate the number of mangrove seedlings, pneumatophores (aerial roots) and crab holes. Univariate (ANOVA) statistical routines were used to analyse the data. Prior to analysis of variance, the data sets were examined for homogeneity of variances using Cochran’s test (Winer et al., 1991) and, if necessary, transformations were used to stabilise the variances (Underwood, 1981). Student-Newman-Keuls (SNK) tests were used to compare means (Underwood, 1981).

Table 1. Mangrove sampling locations.

Location	Number	Latitude	Longitude
Fagan’s Bay	1	33° 25’ 54.17’’	151° 19’ 36.31’’
Caroline Bay	2	33° 26’ 23.93’’	151° 20’ 59.82’’
Erina Creek	3	33° 26’ 17.94’’	151° 21’ 40.20’’
Egan Creek	4	33° 27’ 54.24’’	151° 21’ 34.83’’
Saratoga Wetland	5	33° 28’ 28.62’’	151° 20’ 12.52’’
Lintern Channel	6	33° 28’ 51.40’’	151° 21’ 09.43’’
Davistown Wetland	7	33° 29’ 02.60’’	151° 21’ 57.41’’
Saratoga Saltmarsh	8	33° 28’ 44.66’’	151° 21’ 47.87’’
Kincumber	9	33° 28’ 20.92’’	151° 22’ 57.65’’
Bensville	10	33° 29’ 29.09’’	151° 22’ 58.11’’
Cockle Bay Nature Reserve	11	33° 30’ 02.30’’	151° 22’ 22.44’’
Cockle Bay Wetland	12	33° 29’ 49.93’’	151° 22’ 01.38’’
Empire Bay Wetland	13	33° 29’ 28.00’’	151° 21’ 16.09’’
Rileys Island	14	33° 29’ 12.99’’	151° 20’ 44.81’’
Pelican Island	15	33° 29’ 32.68’’	151° 20’ 14.46’’

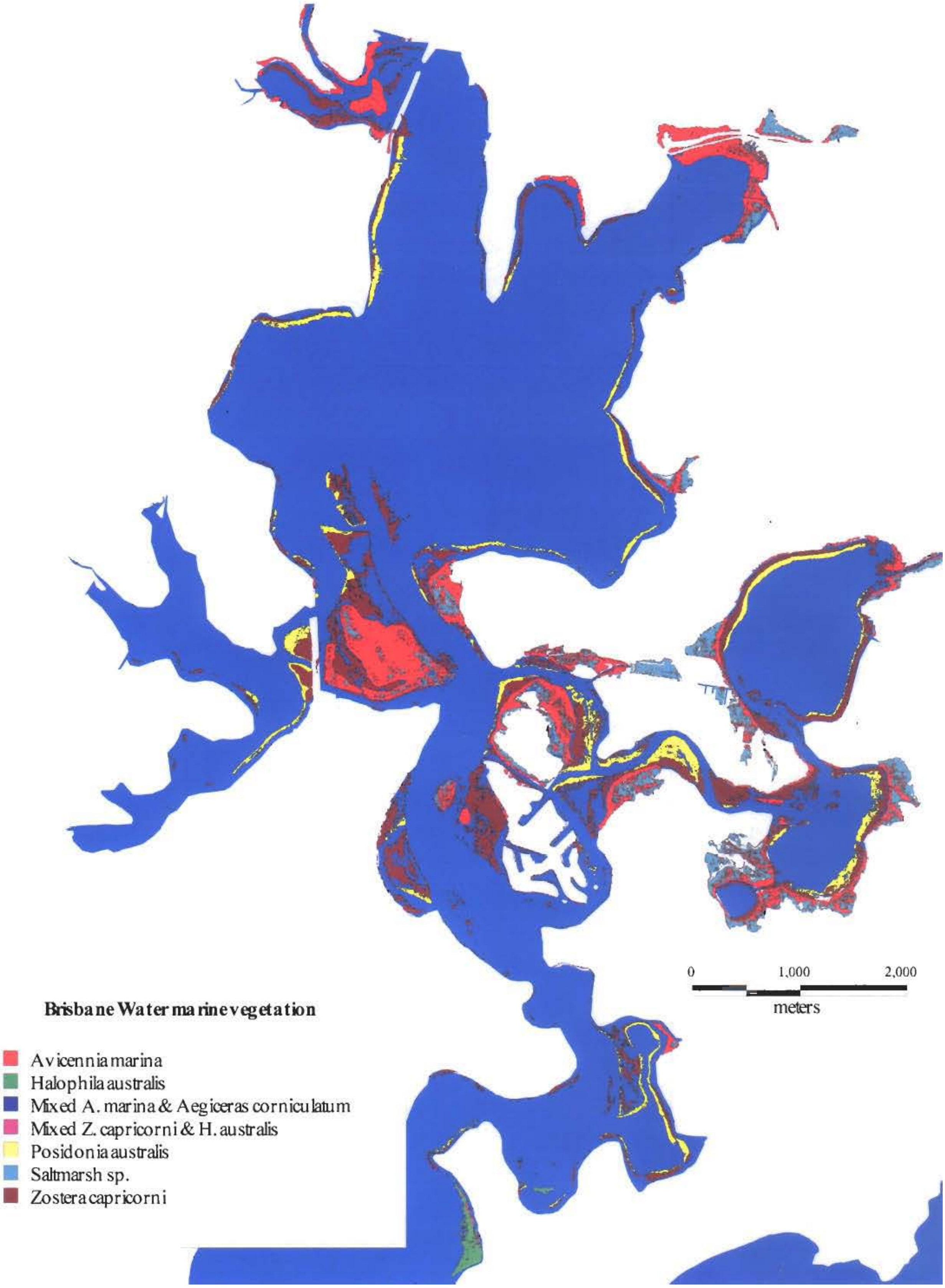

Figure 1. Marine vegetation in Brisbane Water (source: DPI Fisheries).

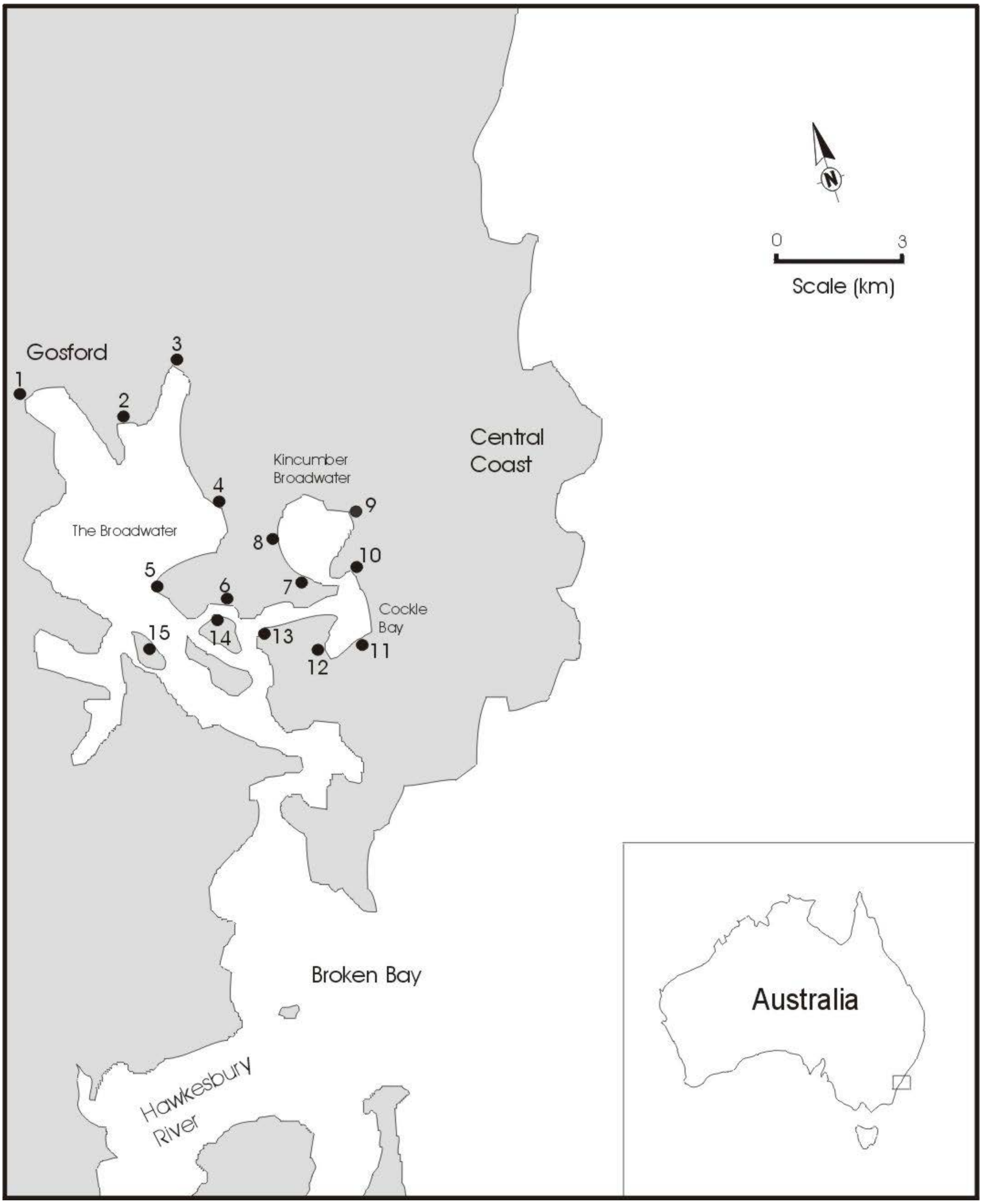

Figure 2. Mangrove sampling locations in Brisbane Water (see table 1 for locations).

RESULTS

Mangrove forests within the estuary were highly variable in terms of their density, height and canopy cover depending on which location was examined. Two mangrove species were identified; the grey mangrove *Avicennia marina* (Fig. 3) and the river mangrove *Aegiceras corniculatum* (Fig. 4). The grey mangrove was the dominant canopy forming species and the following results were based on sampling within the *Avicennia marina* forest.

There were no significant differences in the density of mangroves between the fifteen locations sampled however there were significant differences among sites nested within locations (Fig. 5, Table 2). The height of the mangrove forest and its canopy cover was found to be significantly different at the spatial scales examined, however there were no clear pattern with respect to its location within the estuary (Fig. 6 & 7, Table 2).

The number of *Avicennia marina* seedlings was found to be significantly different at all spatial scales with the greatest numbers recorded in locations 8 and 9 within the Kincumber Broadwater (Fig. 8, Table 3). The number of *Avicennia marina* pneumatophores was found to be significantly different between locations (Fig. 9, Table 3), however there were no differences among sites within a location (Table 3).

The highest densities of pneumatophores were recorded at locations in The Broadwater and Kincumber Creek (Fig. 9), whilst the lowest were recorded at locations in Cockle Channel, The Broadwater and on Pelican Island (Fig. 9). The number of crab holes also varied between locations and among plots within sites, with the greatest numbers recorded within the estuarine channel locations including the two locations on Pelican and Rileys Island (Fig. 10, Table 3).

Table 2. Summary of ANOVAs comparing the density, canopy height and canopy cover of mangroves in Brisbane Water (ns = not significant (P > 0.05); * significant (P < 0.05); ** significant (P < 0.01).

		Density		Height		Cover	
Source of variation	**df**	**MS**	***F***	**MS**	***F***	**MS**	***F***
Location	14	90.97	1.1ns	30.18	7.18**	2368.15	4.53**
Site (Location)	15	87.02	1.9*	4.20	3.72**	522.78	3.83**
Residual	60	45.18		1.13		136.67	
Total	89						
Cochran’s test			0.189ns		0.207*		0.270**
Transformation			none		none		none

Table 3. Summary of ANOVAs comparing the number of seedlings, pneumatophores and crab holes in the mangroves in Brisbane Water (ns = not significant (*P* > 0.05); * significant (*P* < 0.05); ** significant (*P* < 0.01).

		Seedlings		Pneumatophores		Crab Holes	
Source of variation	**df**	**MS**	***F***	**MS**	***F***	**MS**	***F***
Location	14	4.06	3.73**	616.81	2.93*	17.20	15.26**
Site (Location)	15	1.09	3.31**	210.77	1.75ns	1.13	1.12ns
Plot (Location x Site)	60	0.33	1.38*	120.40	2.30**	1.06	2.82**
Residual	360	0.24		52.39		0.36	
Total	449						
Cochran’s test			0.038ns		0.121**		0.053ns
Transformation			ln (x+1)		none		ln (x+1)

Figure 3. Mangrove forest dominated by the grey mangrove *Avicennia marina*.

Figure 4. The river mangrove *Aegiceras corniculatum*.

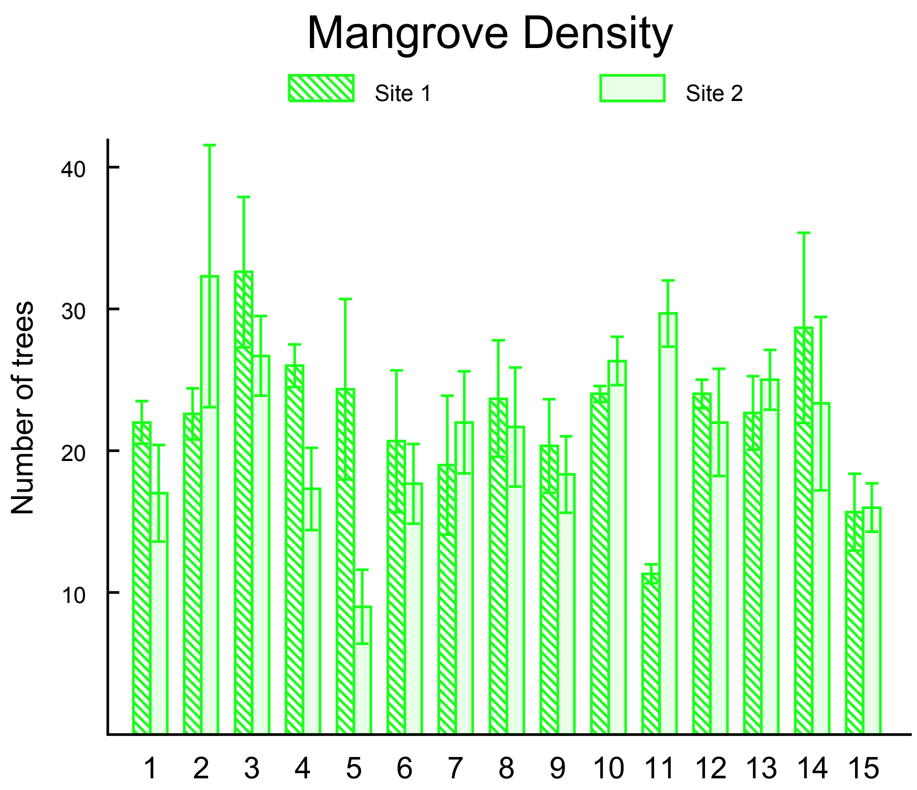

Figure 5. Mean (+SE) number (density) of mangrove trees at each site and location.

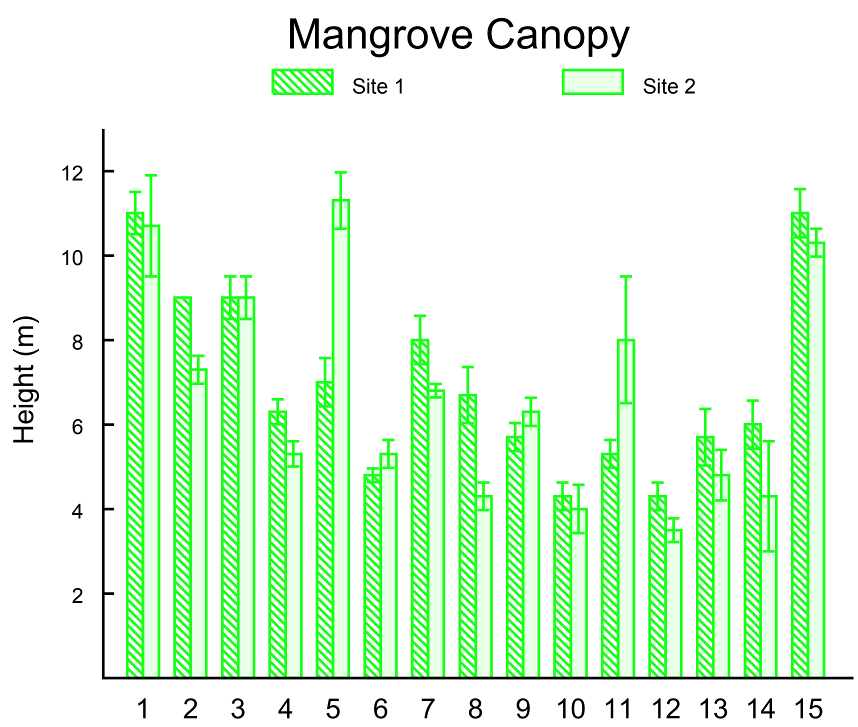

Figure 6. Mean (+SE) canopy height (m) of mangrove trees at each site and location.

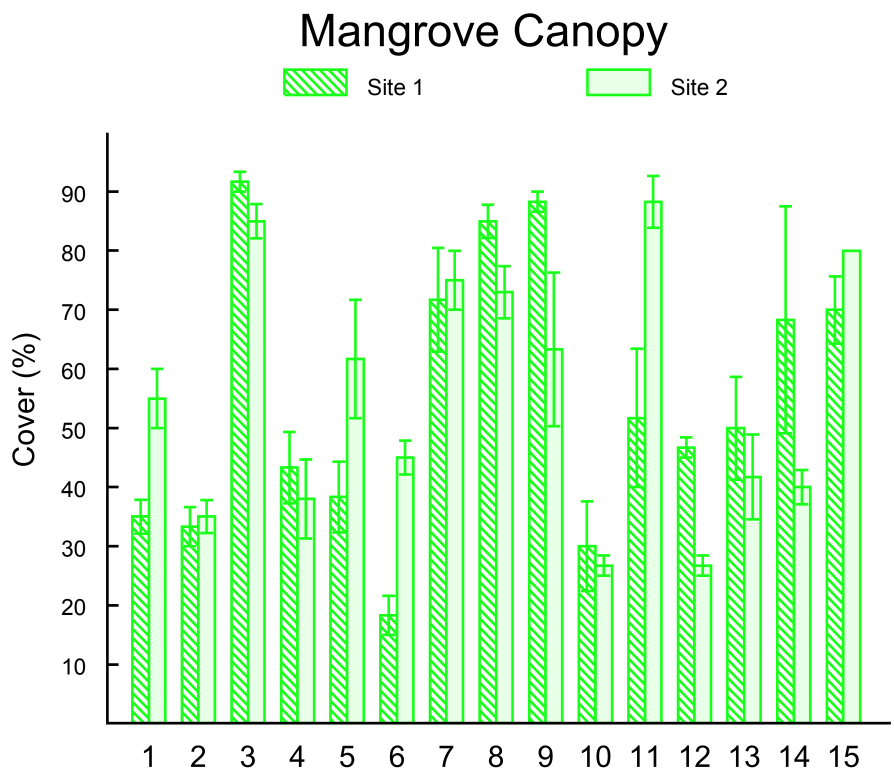

Figure 7. Mean (±SE) canopy cover (%) of mangrove trees at each site and location.

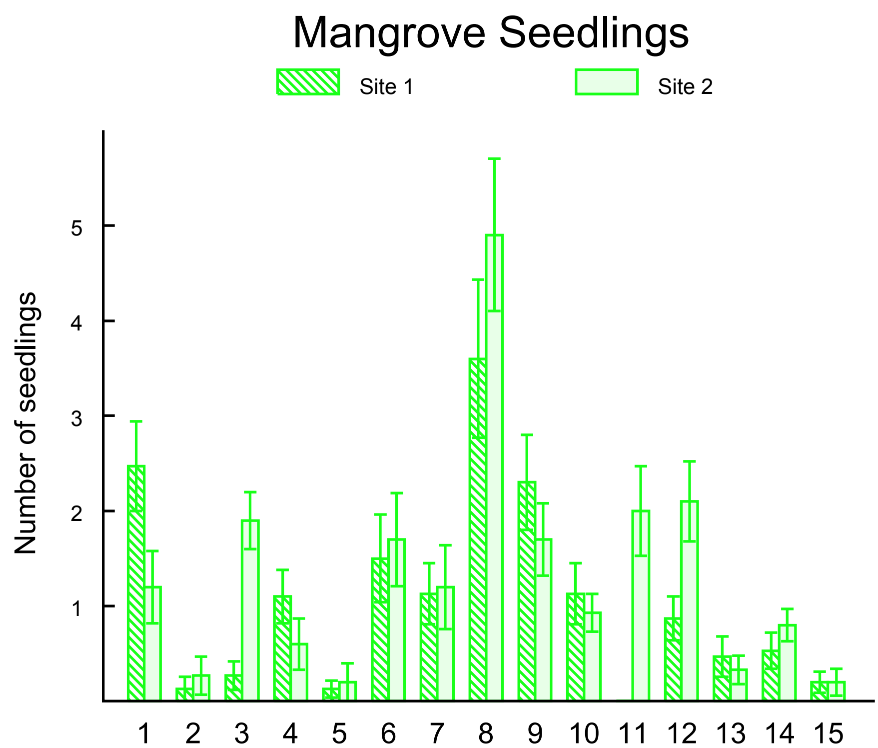

Figure 8. Mean (±SE) number of seedlings within each mangrove site and location.

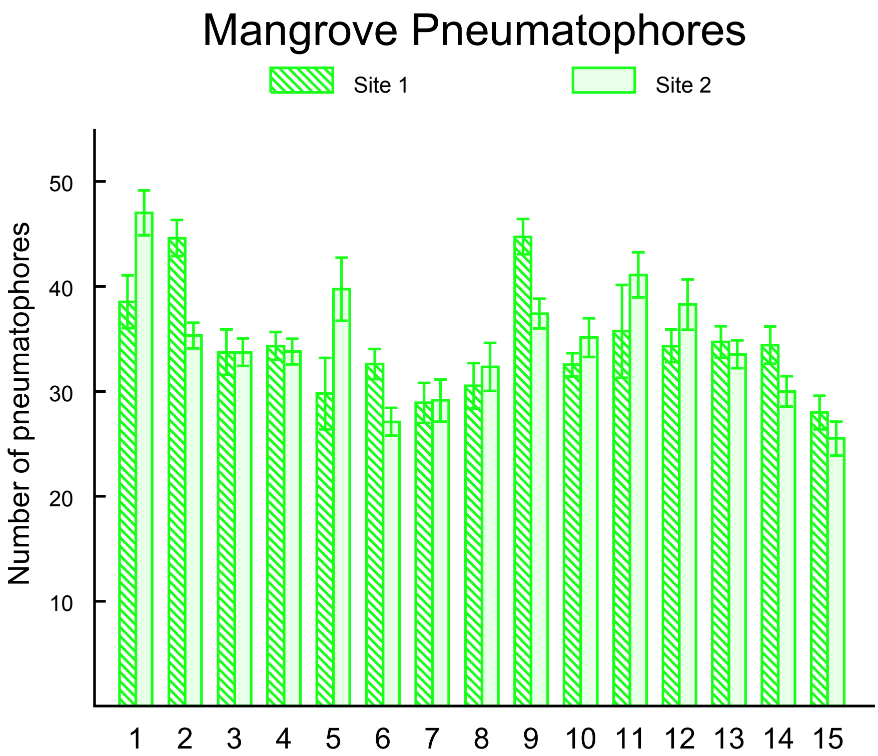

Figure 9. Mean (+SE) number of pneumatophores within each mangrove site and location.

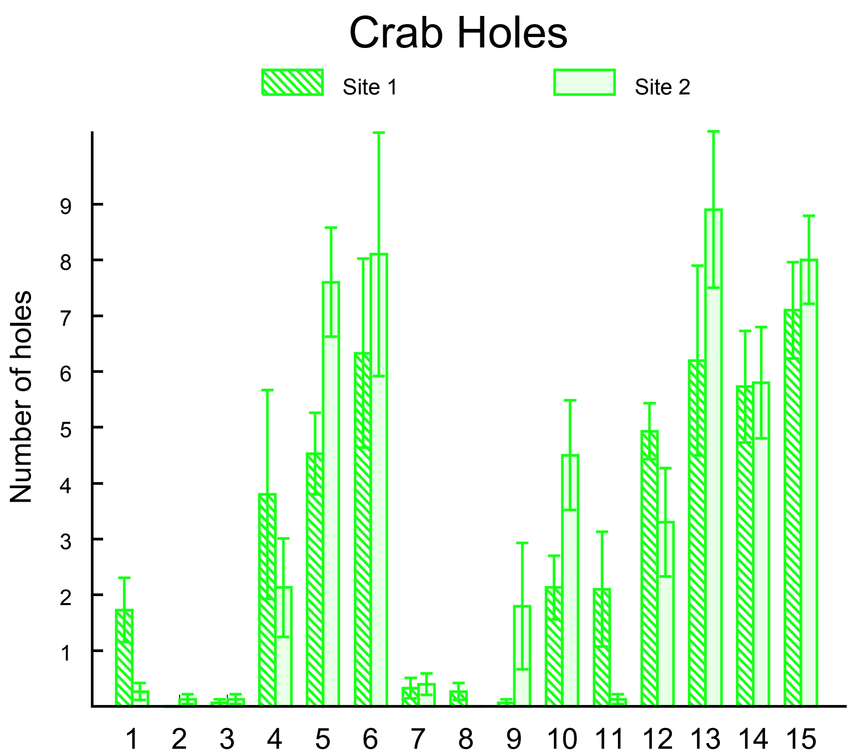

Figure 10. Mean (+SE) number of crab holes within each mangrove site and location.

DISCUSSION

The mangrove forests within Brisbane Water were comprised of two species, the grey mangrove *Avicennia marina* and the river mangrove *Aegiceras corniculatum*. There were significant differences in the derived variables for mangroves at most of the spatial scales that were sampled. The dominant species within Brisbane Water was *Avicennia marina*, which tends to form extensive forests adjacent to the shallow edges of the estuary. The river mangrove, *Aegiceras corniculatum* was primarily found growing along creek lines and occasionally within the *Avicennia marina* forest but in much smaller densities.

Whilst the density of mature *Avicennia marina* trees within the forests did not vary at the scale of locations around the estuary there were differences among these locations at smaller spatial scales. There were also differences in the height of the forest and its canopy cover at various scales. These differences may reflect hydrodynamic processes operating within a location and/or the effects of anthropogenic disturbance at these scales. The physico-chemical factors that help to structure and maintain mangroves in estuaries was described by Clarke and Hannon (1969). Tidal inundation is probably one of the most important physical factors that have allowed mangroves to be successful within estuarine systems. Their reproductive strategy of producing seeds that float with tidal currents helps to spread mangroves throughout the estuary and between different estuaries.

Mangroves grow within soft muddy and water logged sediments within estuaries. The sediments in these places are highly water logged and generally low in oxygen. The peg roots (pneumatophores) of *Avicennia marina* have evolved to provide oxygen to the tree under these anaerobic and water logged conditions. The number and condition of pneumatophores has been used as an indicator of the "health" of mangrove forests (Warren, 1999; Breitfuss, 2003). Some studies have also shown that if the pneumatophores are damaged or smothered then the mangroves may die (Skilleter and Warren, 2000). The pneumatophores of *Avicennia marina* within Brisbane Water were found at all locations. In general, the pneumatophores were in good condition and did not show any symptoms of stress.

The floor and sediments of the mangrove forest provides habitat for extensive numbers of macrobenthic invertebrates, which include crabs, molluscs and worms. A diverse assemblage of benthic macrofauna is considered to be essential for a healthy estuarine system. Crabs and other macrofauna are important components of estuarine systems as they provide food for fish and birds. The number of crab holes (burrows) has been used as a surrogate indicator for the diversity of crabs within estuarine environments. In general, there appeared to be some patterns in the number of crab holes at different mangrove locations within the estuary. The greatest number of crab holes was generally found in mangrove forests within the highly flushed channels and on the islands. The mangrove forests at these locations are more likely to experience greater tidal flushing, providing potentially greater amounts of food for animals such as crabs. This model would however need to be tested.

Anthropogenic disturbance can also produce impacts at small spatial scales thus altering the ecological processes that are operating at those scales. For example, changes to the structure of mangroves have been linked with changes to the macrofauna that inhabit the forest (Skilleter, 1996; Skilleter and Warren, 2000). There were significant interactions at small spatial scales for many of the mangrove variables that were examined. These interactions are ecologically important and show how assemblages experience patchiness in their distributions at different spatial scales.

The incorporation of a hierarchy of spatial scales into sampling programmes was discussed by Andrew and Mapstone (1987), whilst Underwood et al. (2003) highlighted the need for appropriate spatial scales in order to detect the effects of anthropogenic disturbance. This study was an important first step in identifying spatial scales of importance within the mangroves forests in Brisbane Water. Identifying temporal changes within these forests would be useful for future managerial decisions regarding mangroves and wetlands within the estuary.

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