The effect of habitat variables on bird density and species richness in Newcastle and Lake Macquarie mangrove forests

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This study aimed to determine whether the size of a temperate mangrove patch had any effect on bird density or bird species richness (number of species). Four isolated mangrove patches were chosen: two large (Black Neds Bay, 116 ha; Sandgate, 82 ha) and two small (Swansea, 4 ha; Carrington, 2.8 ha). A sampling area of 2 ha was used, and counts lasted 40 minutes. Mean canopy height was much greater at Sandgate than at the other three locations. Percent canopy cover was similar at all locations. The bird species richness was highest at Carrington, the site with the smallest patch size. Bird species richness increased with increasing canopy height variation. The presence of a second mangrove species at Carrington probably increased canopy height variation at that site. Patch size had no effect on bird density. Patch size did, however, change the species composition. There was a general shift from specialist feeders to generalists as patch size decreased. Two species were only found in the large patches: the Rufous Whistler *Pachycephala rufiventris* and the Grey Fantail *Rhipidura albiscapa*. These species probably require areas larger than 4 ha of a single non-fragmented habitat type to sustain them.

INTRODUCTION

Mangrove ecosystems support essential ecological functions (Valiela *et al.* 2001). They intercept land-derived nutrients, pollutants, and suspended matter before these contaminants reach deeper water, and they export materials that support near-shore food webs, including shrimp and prawns (Rodelli 1984, cited in Valiela *et al.* 2001). They serve as a nursery for marine species and support a great abundance of fish and invertebrates (Beck *et al.* 2001).

Australia has a fairly large number of species and subspecies of birds, mostly passerines, confined to or largely dependent on mangroves, which occur discontinuously as a narrow chain for thousands of kilometres along tropical and subtropical coasts (Ford 1982). Mangroves dominate the seaward fringe of many estuaries, more so in the tropics where many species and zones of recognisable mangrove communities exist (Simpson & Day 1986). In the temperate latitudes of the central coast of New South Wales, however, mangrove forests are structurally depauperate (Ford 1982), consisting mostly of one species, the Grey Mangrove *Avicennia marina*.

One species of bird that is largely dependent on mangroves is the Mangrove Gerygone *Gerygone levigaster*. They are small birds, attaining a size of just 11cm (Simpson & Day 1986). It is one of the most widely-distributed of the 16 bird species confined to mangroves in Australia (Noske 1996, cited in Noske 2001). It occurs as far south as the Central Coast of New South Wales in the east and the southern Kimberley in the west, as well as southern New Guinea. In the extensive mangals of the Darwin region, Woinarski *et al.* (1988, cited in Noske 2001) reported it in densities of 0.24-0.91 birds ha^{-1}. It is a foliage-gleaning insectivore.

Mangrove forests occur discontinuously along tropical and subtropical coasts (Ford 1982) and can be viewed as habitat islands. The formation of a habitat island on the mainland creates an edge effect (Krohne 2001). This involves a change in the physical and biological parameters of a habitat at its boundaries relative to what is found at its centre.

Within vegetation there are typically several layers. The whole structure represents a vertical zonation (Briggs & Smithson 1985) within which a varied wildlife frequently exists. This, too, shows a vertical structure related to the character of the vegetation. Linkages between diversity above ground and below ground may be functionally important at the ecosystem scale in terms of the maintenance and stability of ecosystem processes and the persistence of keystone species or other species with strong ecosystem effects (Hooper *et al.* 2000).

There is a strong correlation between the structural heterogeneity of a habitat and species diversity (Krohne 2001). This suggests that in more structurally diverse systems species can specialise to a greater extent on differences in microhabitat. There is considerable evidence to suggest that for avian species diversity increases with the diversity of the foliage structure in the habitat. As habitat structure (measured by variation in the height of vegetation) becomes more complex, more species of birds are present (Krohne 2001).

This study will aim to determine whether various habitat variables have any significant effect on bird density or bird species richness in temperate mangroves. The habitat variables that will be used are mangrove patch size, height of mangrove canopy, percent foliage cover, and number of mangrove species present.

METHODS

Four isolated patches of temperate mangrove forest were chosen for the study. Two patches, one large and one small, were chosen in the Hunter Estuary. Similarly, one large and one small patch were chosen at the entrance channel to Lake Macquarie, as shown in **Figure 1**.

In the Hunter Estuary the large mangrove patch was located at Sandgate. It comprised 82ha of isolated mangrove forest (**Figure 1**). The small mangrove patch in the Hunter Estuary of 2.8ha was located at Carrington. It is just 3km from the Newcastle CBD, and is surrounded by industrial and urban development. A boardwalk has been constructed through it (**Figure 1**). The large mangrove patch in Lake Macquarie was located at Black Neds Bay Nature Reserve, which is on the southern shore of the entrance channel. It comprised 116ha of mangrove forest (**Figure 1**). The small mangrove patch, 4ha in size, was located on the northern side of the entrance channel at Swansea.

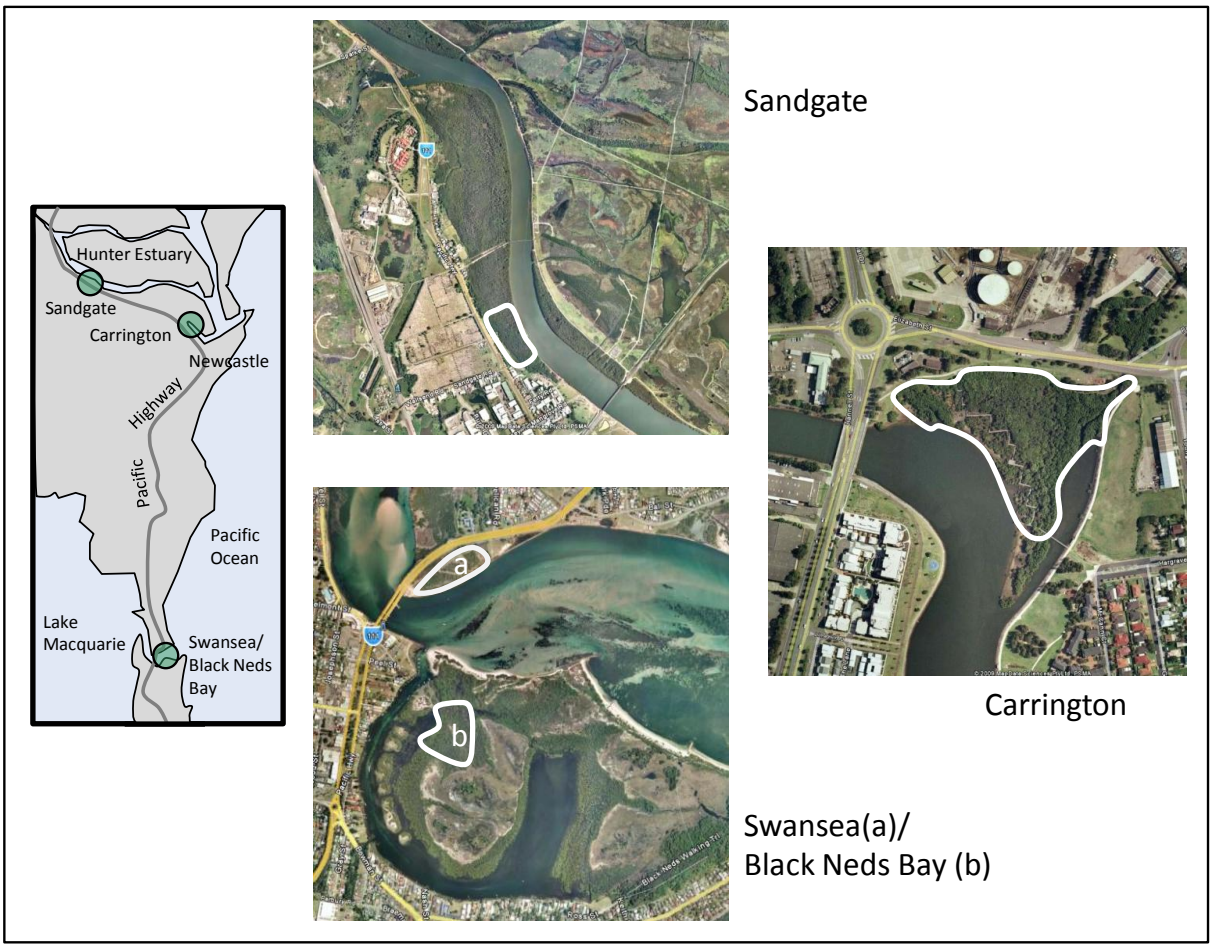

Figure 1. Locations of mangrove patches in the Hunter Estuary at Sandgate and Carrington and patches in Lake Macquarie at Black Neds Bay and Swansea.

At Sandgate, Swansea and Black Neds Bay, the only plant species present in the sites was the Grey Mangrove *Avicennia marina* var. *australasica*. At Carrington, *A. marina australasica* dominated the forest vegetation, but the River Mangrove *Aegiceras corniculatum* was also present, and was in flower at the time of sampling.

The study was carried out in September and October, 2003. At each location a 2ha (200m x 100m) site was haphazardly chosen and pegged out. The sampling area measurements were the same as that recommended by Silcocks (1998), but different to the size of sites used by Date *et al.* (2002). They sampled plots of 1.2ha (200m x 60m). Sampling area measurements followed those recommended by Silcocks (1998) because this study involved all habitats whereas Date *et al.* (2002) was studying birds only in woodlands. Thus it was thought that the patch size dimensions recommended by Silcocks (1998) would be more appropriate for mangrove habitats than those used by Date *et al.* (2002).

The boundaries of each plot were at least 10m inside the edge of the mangrove forest. This was done to try to minimise edge effects. The edge of the mangrove forest was defined as where the grass or herb line began or, where grasses or herbs were absent by the start of the mangrove canopy.

Habitat structure was assessed at 11 randomly selected points within the site at Black Neds Bay, and at six randomly selected points at each of the other three sites. At each point, height of the canopy and percent canopy cover were measured. Canopy height was measured with a surveying staff. The staff was placed on the point, and the tallest part of the vegetation was recorded within an imaginary cylinder with radius 1m and vertical axis of revolution centered on the point. Percent canopy cover was measured with a mirror. A grid containing 100 x 1cm squares was drawn on the mirror. At each random point, the mirror was placed horizontally on top of the pneumatophores projecting from the mud. The number of grid squares that were more than half shaded from the sun by the canopy equaled the percent canopy cover at that point.

Birds were sampled before 10:30am within the 3 hour window either side of low tide. Each count lasted 40 minutes. Sampling time was different to that recommended by Silcocks (1998). In that study Birds Australia (BA) conducted a volunteer-based survey of the distribution of Australia's birds. While a number of surveying methods were accommodated, the preferred method that was recommended was a 2ha search for 20 minutes. The BA survey protocol was designed as a constant effort sampling procedure expected to find most but not all the birds at a site. It was decided for this study that in a dense habitat like a mangrove forest 20 minutes was not long enough to record all the birds within a 2ha area. Also, if multiple species move about an area larger than 2ha in the mangrove forest as a foraging flock, a longer survey interval would increase the probability that the flock is recorded in the survey site during sampling, and hence at the location.

Sampling during the 40 minutes involved making three line searches within the site. These line searches across the 100m wide site occurred at 40, 100, and 160m along the 200m long transect. On each line search, all species and the number of individuals per species seen or heard within 30-40m of the line were recorded. Birds flying over the site were only recorded if they were deemed to be using the flying space specifically because of the habitat or potential prey or food within the site. The cumulative abundance and species richness from the three line searches became the density and species richness for the sample.

Each site was sampled on two separate days. On each day, two replicate counts were made. The time between replicates was no longer than 15 minutes. Thus, each location was sampled 4 times, and mean density and species richness were then calculated.

RESULTS

The canopy height was significantly higher at Sandgate than at the other 3 locations ($p<0.01$, **Figure 2**). Carrington had the greatest variation in canopy height (**Figure 2**). Mean canopy cover was found to be similar at all locations (**Figure 3**). Within each site except Sandgate a large variation in percent canopy cover was measured (**Figure 3**).

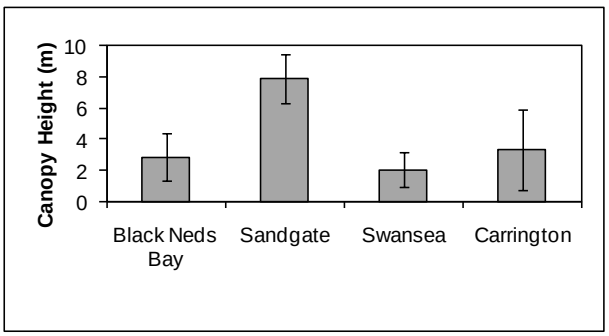

Figure 2. Mean canopy height and its variation (shown by error bars) at each location.

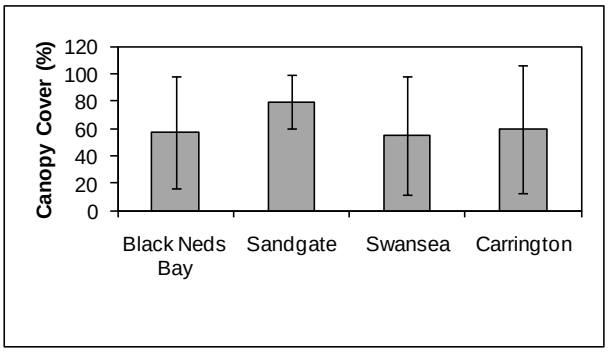

Figure 3. Mean percent canopy cover and its variation (shown by error bars) at each location.

A total of 41 species was recorded during the study (**Table 1**). At Black Neds Bay, 12 species were recorded, compared with 15 at Sandgate and Swansea, and 30 at Carrington. Four species were recorded in all locations: These were the Silvereye *Zosterops lateralis*; Yellow-faced Honeyeater *Lichenostomus chrysops*; Brown Honeyeater *Lichmera indistincta*; and Black-faced Cuckoo-shrike *Coracina novaehollandiae*. The Mangrove Gerygone was only recorded in the locations with the three largest patch sizes. Four species were recorded in only the two large mangrove patches. These were the Eastern Rosella *Platycercus elegans*; Rufous Whistler; Brown Thornbill *Acanthiza pusilla*; and Grey Fantail. Six species were recorded in only the two small mangrove patches. These were the Welcome Swallow *Hirundo neoxena*; Galah *Eolophus roseicapillus*; Eastern Great Egret *Egretta modesta*; Magpie-lark *Grallina cyanoleuca*; Red Wattlebird *Anthochaera carunculata*; and Spotted Dove *Streptopelia chinensis*.

Table 1. Species recorded at the sampling locations (# indicates presence).

Common Name	**Scientific Name**	**Black Neds Bay**	**Sandgate**	**Swansea**	**Carrington**
Silvereye	*Zosterops lateralis*	#	#	#	#
Yellow-faced Honeyeater	*Lichenostomus chrysops*	#	#	#	#
Brown Honeyeater	*Lichmera indistincta*	#	#	#	#
Black-faced Cuckoo-Shrike	*Coracina novaehollandiae*	#	#	#	#
Mangrove Gerygone	*Gerygone levigaster*	#	#	#	
Eastern Rosella	*Platycercus elegans*	#	#		
Rufous Whistler	*Pachycephala rufiventris*	#	#		
Brown Thornbill	*Acanthiza pusilla*	#	#		
Grey Fantail	*Rhipidura albiscapa*	#	#		
Yellow Thornbill	*Acanthiza nana*	#	#		#
White-breasted Woodswallow	*Artamus leucorynchus*	#			#
Willie Wagtail	*Rhipidura leucophrys*	#			#
Sacred Ibis	*Threskiornis molucca*		#		#
Australian Raven	*Corvus coronoides*		#		#
Sacred Kingfisher	*Todiramphus sancta*		#		#
Sulphur-crested Cockatoo	*Cacatua galerita*		#		
Spotted Pardalote	*Pardalotus punctatus*		#		
Welcome Swallow	*Hirundo neoxena*			#	#
Galah	*Eolophus roseicapillus*			#	#
Eastern Great Egret	*Ardea modesta*			#	#
Magpie-lark	*Grallina cyanoleuca*			#	#
Red Wattlebird	*Anthochaera carunculata*			#	#
Spotted Dove	*Streptopelia chinensis*			#	#
Common Mynah	*Acridotheres tristis*			#	
Pied Oystercatcher	*Haematopus ostralegus*			#	
Whimbrel	*Numenius phaeopus*			#	
Eastern Curlew	*Numenius madagascariensis*			#	
Rufous Night Heron	*Nycticorax caledonicus*				#
Little Pied Cormorant	*Phalacrocorax melanoleucos*				#
Common Starling	*Sturnus vulgaris*				#
Little Black Cormorant	*Phalacrocorax sulcirostris*				#
Figbird	*Sphecotheres viridis*				#
Laughing Kookaburra	*Dacelo gigas*				#
Crested Pigeon	*Ocyphaps lophotes*				#
Little Egret	*Egretta garzetta*				#
Darter	*Anhinga melanogaster*				#
Australian Pelican	*Pelecanus conspicillatus*				#
Superb Fairy-wren	*Malurus cyaneus*				#
Silver Gull	*Larus novaehollandiae*				#
Striated Heron	*Butorides striatus*				#
Brown Goshawk	*Accipiter fasciatus*				#

Figure 4 shows the mean bird density recorded at each location. The variation in counts is much higher at Sandgate than at the other three locations.

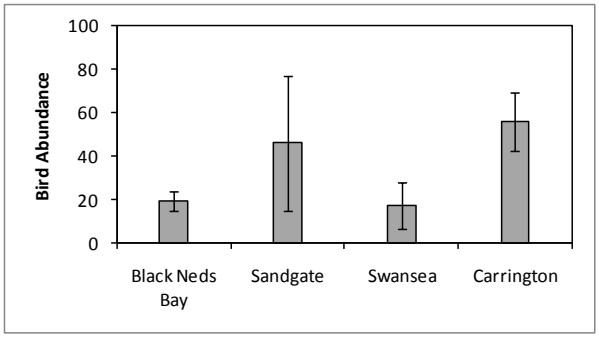

Figure 4. Mean bird abundance per hectare and the variation (shown by error bars).

Mean species richness per count at each of the locations is shown in **Figure 5**. The average variation in species recorded per survey increased as mangrove patch size decreased.

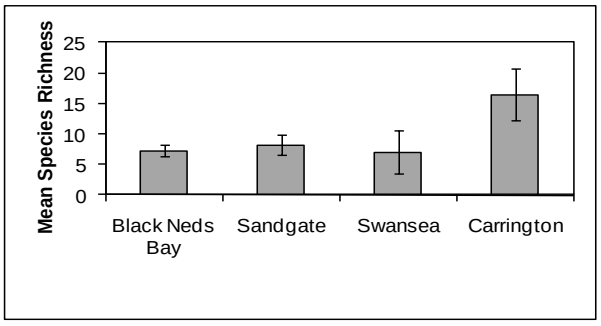

Figure 5. Mean number of species and the variation (shown by error bars) counted per survey.

Mean bird density in large mangrove patches was 33 per hectare compared with 36 per hectare in small patches. This was not significantly different at the 5% level. The average number of bird species recorded per count was eight in large mangrove patches and 12 in small ones. This was not significantly different at the 5% level.

The Mangrove Gerygone was recorded in densities in the range 0 to 2 birds ha^{-1}. Mean density was 1.09 birds ha^{-1}. Three species were recorded as breeding during the surveys, all of which were at Carrington. These were the White-breasted Woodswallow *Artamus leucorynchus*, Magpie-lark, and Australian Raven *Corvus coronoides*.

DISCUSSION

The structure of the mangroves at the Sandgate site was different from the other three sites. The trees, on average, were taller (**Figure 2**). Also, the relatively small variation of percent cover within the Sandgate site (**Figure 3**) shows that there is a more homogeneous cover. The greater height of these mangroves may be because they are protected from the southerly wind by elevated terrain on Sandgate Road.

The large variation in bird density at Sandgate (s^2=965.5) was because migrating Yellow-faced Honeyeaters were recorded on the first sampling day, but were not moving through the site on the second occasion. Variation in numbers of Yellow-faced Honeyeaters (s^2=836.92) contributed 87 percent to the total variation in density at Sandgate. Variation in counts of the other 14 species (s^2=127.58) accounted for the remaining 13 percent.

The Mangrove Gerygone was not recorded at Carrington, the smallest mangrove patch. As it is confined to mangroves, it may be that the critical minimum patch size needed to support this species in temperate latitudes is greater than 2.8 hectares. Mean density recorded for this species (1.09 birds ha^{-1}) was higher than was recorded in the Darwin region (0.24 to 0.91 birds ha^{-1}, Woinarski *et al.* 1988 cited in Noske 2001).

One species that was only found in the two small mangrove patches was the Red Wattlebird. Being one of the largest honeyeaters, it may be better able to survive in a range of habitats than the smaller honeyeaters.

Four species were found at all locations. These were the Silvereye, Yellow-faced Honeyeater, Brown Honeyeater and Black-faced Cuckoo-shrike. In this study mangrove patch size does not seem to affect these species.

The data in this study supports the strong correlation between the structural heterogeneity of a habitat and species richness (Krohne 2001). If structural heterogeneity in this study is measured by the standard error of mean canopy height at the four locations (**Figure 2**), then mean bird species richness (**Figure 5**) increases with increasing habitat structural heterogeneity. Both are greatest at Carrington.

Despite its small size, the Carrington site is important as a habitat for birds. The presence of the River Mangrove is significant to the richness of birdlife recorded compared to the other three locations. It may be the co-existence of the two mangrove species at Carrington that creates the

greater structural heterogeneity (**Figure 2**) required for greater species richness. However, it may just be important for birds in general given its location, as some of the species are not mangrove-dependent (e.g., Magpie-lark, Spotted Dove). A patch of its size is probably all edge habitat, which is accessible to species from neighbouring (open) habitats (M. Newman, *pers. comm.*). This could also explain the high species richness.

The mangroves at Carrington, however, are limited by the size of the area in which they are contained. It is too small to support the habitat requirements of the Mangrove Gerygone, Rufous Whistler and Grey Fantail. These species need larger patches to sustain them.

The results of this study should add extra conservation value to the known benefits of the Carrington mangroves. Situated near the mouth of Throsby Creek, the Carrington mangroves remove sediment, pollutants, and rubbish that enter the system from many stormwater pipes located upstream. Conservation of these mangroves will become even more important as the increasing inner-city population will require local aesthetically-appealing retreats.

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