North Creek Dredging Program: Baseline shorebird survey

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Cover Photo: Eastern curlew, lesser sand plover and Pacific golden plover roosting at Chickiba Lake.

Disclaimer:

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1. Introduction

Ballina Shire Council is investigating the feasibility of dredging sections of North Creek to improve tidal exchange, navigation and obtain fill for land-based projects. Hydrosphere Consulting has been contracted by council to undertake baseline investigations into the environmental impact of proposed dredging. Sandpiper Ecological Surveys was contracted by Hydrosphere Consulting to undertake targeted baseline surveys for migratory and resident shorebirds.

The aim of the baseline shorebird survey was to determine the importance of high tide roost and foraging areas in North Creek to the (migratory and resident) shorebird community in the Richmond River Estuary. For the purpose of this report the shorebird community in the Richmond River Estuary is also referred to as the Local population. Population boundaries are defined in Section 2.

Objectives of the baseline survey include:

1. Survey shorebirds at high tide roosts to determine the abundance and species richness of the Richmond River Estuaries shorebird community.
2. Utilise abundance data to determine the value of high tide roosts potentially affected by dredging to the Richmond Estuaries shorebird community.
3. Sample shorebirds at major foraging areas within North Creek and the Richmond Estuary during low tide to determine the relative (i.e. comparison of abundance and species richness) importance of affected intertidal habitats to the local shorebird community.
4. Undertake sampling during the low tide period to determine how key indicator species of shorebird utilise the Serpentine intertidal sand flat.
5. Observe the foraging rate and type of prey consumed by key indicator species of shorebird at the Serpentine intertidal sand flat and compare attributes to other foraging habitat in the Richmond River Estuary.
6. Provide a baseline assessment on the potential impact of dredging on the local shorebird community.

1.1 Background

1.1.1 Dredging proposal

The proposal involves dredging of North Creek. Although the proposal is not finalised and is likely to be adjusted in accordance with various environmental, operational and economic constraints, there are currently four areas currently being considered for dredging as described in Hydrosphere Consulting (2016):

- Area A – encompasses approximately 13.7 ha of the North Creek navigation channel on the western foreshore from Missingham Bridge upstream;
- Area B - encompasses approximately 7 ha of The Serpentine spit (also referred to in other documentation as the ‘Middle Shoal’), which is the large sand flat area upstream of Missingham Bridge on the eastern side of North Creek;

- Area C – extends approximately 700 m downstream of Prospect Bridge and covers an area of approximately 5.8 ha; and
- Area D – the navigation channel from Prospect Bridge approximately 900 m upstream. This would cover an area of approximately 8 ha.

The in-situ dredge volume is approximately 575,000 m³ and has a combined footprint of 34.7ha.

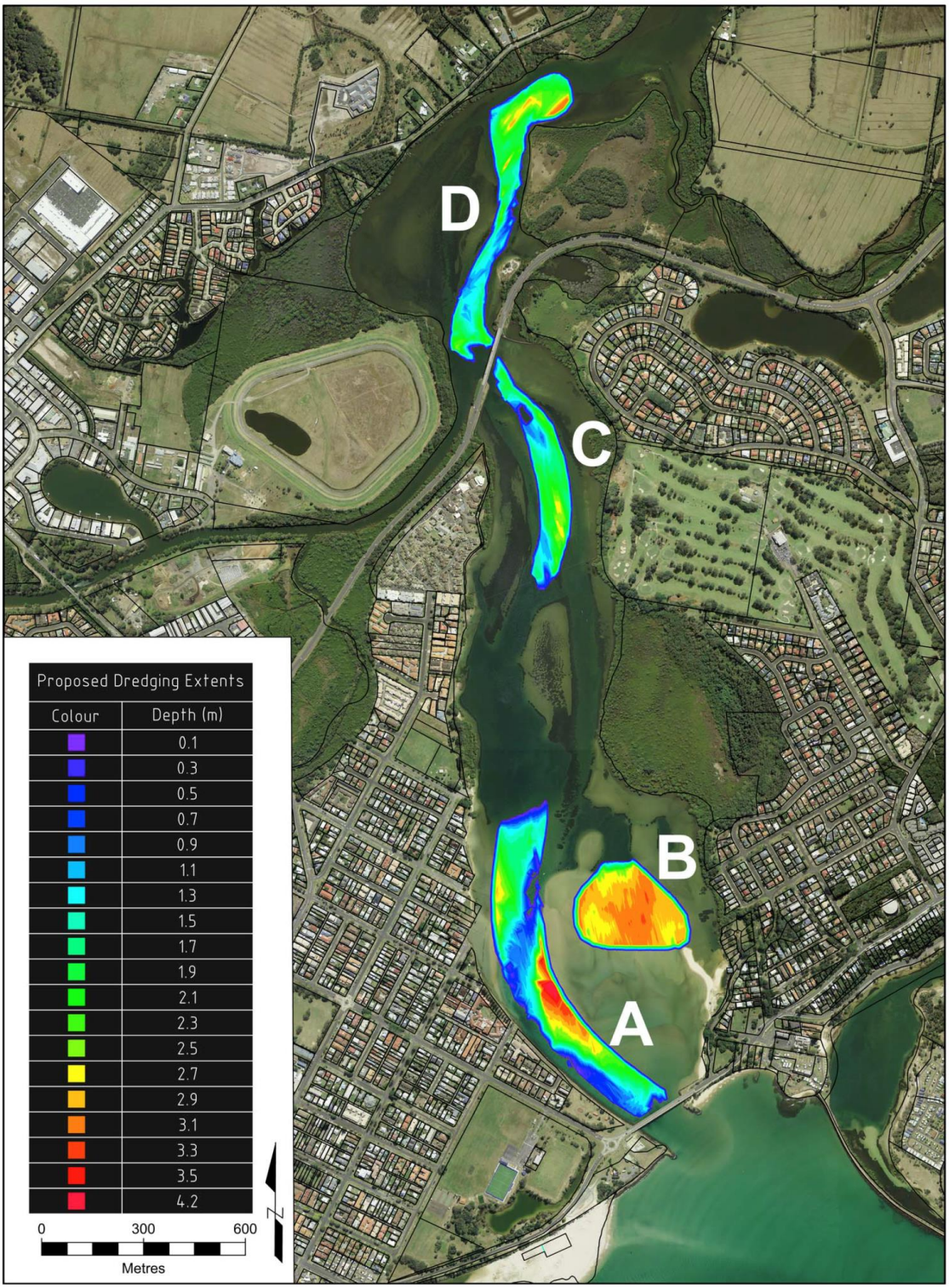

Figure 1: Proposed dredging areas in North Creek (Hydrosphere Consulting 2016).

1.1.2 Shorebirds

Shorebirds[1] are an important component of coastal ecosystems, representing a substantial proportion of vertebrate fauna within estuarine, ocean beach and rocky shore environments. Habitats relied upon by shorebirds are also used intensively for human recreation and occur within estuarine systems that are affected by industry, urban development and agriculture. Shorebirds and their habitat are protected by State (*Threatened Species Conservation (TSC) Act 1995*) and Commonwealth (*Environment Protection and Biodiversity Conservation (EPBC) Act 1999*) threatened species legislation, the Convention on Wetlands of International Importance (i.e. Ramsar Convention) and within the National Parks Estate.

Shorebirds belong to the sub-order Charadrii within the order Charadriiformes. In Australia there are nine locally occurring shorebird families and 75 species (refer Table 2.1 in Sandpiper Ecological 2010). Shorebirds can be divided into two groups, migrants, which breed elsewhere (mainly in the northern hemisphere) and spend the non-breeding season in Australia, and residents, which reside permanently in Australia. Resident shorebirds also undertake regular movements between coastal and inland wetlands and along the coast. Migratory species that come to Australia utilise the East-Asian Australasian Flyway (Priest *et al.* 2002).

In Australia, shorebirds have three basic habitat requirements:

1. Feeding areas - where they can forage in a manner that enables them to satisfy their daily energy requirements.
2. Roosts - where they can rest at high tide when foraging areas are unavailable.
3. Nesting areas - where they can nest and raise chicks.

This study is primarily concerned with roost and foraging habitats, although beach stone-curlew, Australian pied oystercatcher, and red-capped plover have previously breed in the Richmond River estuary.

The use of roost and foraging areas is governed by the tidal cycle and shorebirds forage irrespective of whether it is day or night (McNeil *et al.* 1992). At night there is evidence that some species utilise different roost and foraging areas (Rohweder and Baverstock 1996; Rohweder 2001). The reasons for changes in habitat use are complex but often relate to food availability and a desire to increase energy intake (Rohweder 1999).

At high tide shorebirds gather at sites called roosts, which are typically located just above the high water mark, have an open field of view, access to the water and occur near preferred foraging habitats. There are several types of roosts. Spring tide roosts are used during spring tides, neap tide roosts are used during neap tides and staging roosts are sites where birds coalesce into flocks during the ebb and flood tides. Shorebirds utilise a variety of habitats (and structures) for roosting and the type of roost used varies between species. Examples include; saltmarsh, sand and shingle beaches, sand bars and sand spits, mangroves, rock walls, rock platforms and oyster racks. Shorebirds are opportunistic in their selection of roosts often using recently cleared areas adjoining estuarine habitat. Roosts provide a critical function as they enable birds to rest and conserve energy at a time when they are unable to forage.

[1] Shorebirds are also called waders.

As the tide recedes and intertidal sand and mudflats become exposed, shorebirds leave roosts and begin foraging. Birds will often commence foraging at sites close to roosts and then move further away as other habitats become exposed. Shorebirds utilise a variety of intertidal habitats for foraging with individuals often selecting feeding areas where they can maximise food intake rates. Ideally foraging sites have a high abundance of preferred prey and low risk of predation and disturbance. Types of foraging sites used by shorebirds include; ocean beaches, mudflats, sand flats, seagrass beds, saltmarsh, mangrove fringes and flooded pasture. The time spent feeding varies between species with larger species foraging for less time than small species.

2. Study area

The study area encompassed the lower Richmond River estuary and adjacent coastline, extending from South Ballina Beach in the south to Flat Rock in the north and west to the Emigrant Creek wetland (Figure 2a). Major features of the study area include, the main Richmond River channel, lower North Creek, Emigrant Creek and Mobbs Bay, a sheltered embayment near the river entrance. North Creek represents a major component of the lower estuary and contains a substantial proportion of the estuaries intertidal habitat. The creek joins the Richmond River approximately 1.5km from the river mouth.

The Richmond estuary is characterised by a mosaic of different intertidal habitats. Intertidal habitat in the main river channel and lower North Creek tends to be characterised by coarse-grained sediment and strong tidal flow, while flats in Mobbs Bay, Emigrant Creek and upper North Creek are characterised by finer sediment and reduced tidal flow. Seagrass beds dominated by *Zostera* spp occur in areas of reduced tidal flow, such as Mobbs Bay and upper North Creek.

Names used to refer to sites in North Creek are shown on Figure 2b.

Figure 2a: The Richmond River estuary study area.

Figure 2b: Names used to refer to roost and feeding areas in North Creek.

3. Methods

3.1 High tide survey

High tide surveys were conducted on six occasions, three neap tide (2-4 February) and three spring tide (8-10 February). Two observers conducted each survey. During the neap tide phase both observers initially surveyed boat-based sites and then one observer surveyed Chickiba Lake and Flat Rock and the other, South Ballina Beach. During the spring tide phase one observer surveyed the boat-based sites and the other land-based sites. Surveys commenced 1.5hrs prior to high water (HW; RMS 2015) and were completed 1.5hrs after HW. A total of 17 sites were surveyed (Table 1; Figure 3). Prospect saltmarsh, Airport, Emigrant Creek and Emigrant Creek wetland were surveyed during the spring tide phase only, whilst all other sites were surveyed during both tidal phases.

Previous experience sampling shorebirds in the Richmond River was used to select the most appropriate observation point at each site. Care was taken when approaching each roost to ensure that birds were not flushed. If birds were flushed an approximate count and direction of flight was recorded to assist in determining if they were counted at another site. Data collected at each site included: number of individuals and species, wind speed and direction, tide stage, human activity, and location (easting & northing).

Table 1: High tide sample sites.

Site No.	Site Name	Habitat type	Roost type	Observation Point		Survey method
				Easting	Northing	
1	Serpentine east	Sandspit	Spring tide	555845	6806691	Land
2	Serpentine west	Sandbar	Neap tide	555851	6806885	Land
3	North Creek rocks	Rock outcrop (natural)	Neap tide	556008	6808312	Boat
4	Prospect bridge (groyne)	Rock groyne	Spring tide	555831	6808696	Boat
5	Prospect bridge rocks	Rock abutment	Neap tide	555669	6808568	Boat
6	Prospect sand bank	Sand bank	Neap tide	555738	6808910	Boat
7	Prospect saltmarsh	Saltmarsh	Spring tide	555833	6809226	Boat
8	Airport	Grassland/shoreline	Neap & spring	555781	6810543	Boat
9	Emigrant Creek	Mangroves	Spring tide	550602	6805548	Boat
10	Richmond (RSL) sandbar	Sandbar	Neap tide	554273	6806004	Land
11	Mobbs Bay island	Sand island	Neap & spring tide	555743	6805344	Land
12	Mobbs Bay rocks	Rock groyne & mangroves	Neap tide	555874	6805135	Land
13	Mobbs Bay mangroves	Mangroves	Spring tide	555823	6805408	Boat/Land
14	Chickiba Lake	Saltmarsh/grassland	Neap & spring tide	557312	6808975	Land
15	Flat Rock	Rock platform	Neap & spring tide	559244	6809276	Land
16	South Ballina Beach	Ocean beach	Neap & spring tide	556586	6805103	Land
17	Emigrant Creek wetland	Tidal lagoon	Spring	550776; 549281	6807906; 6806937	Land

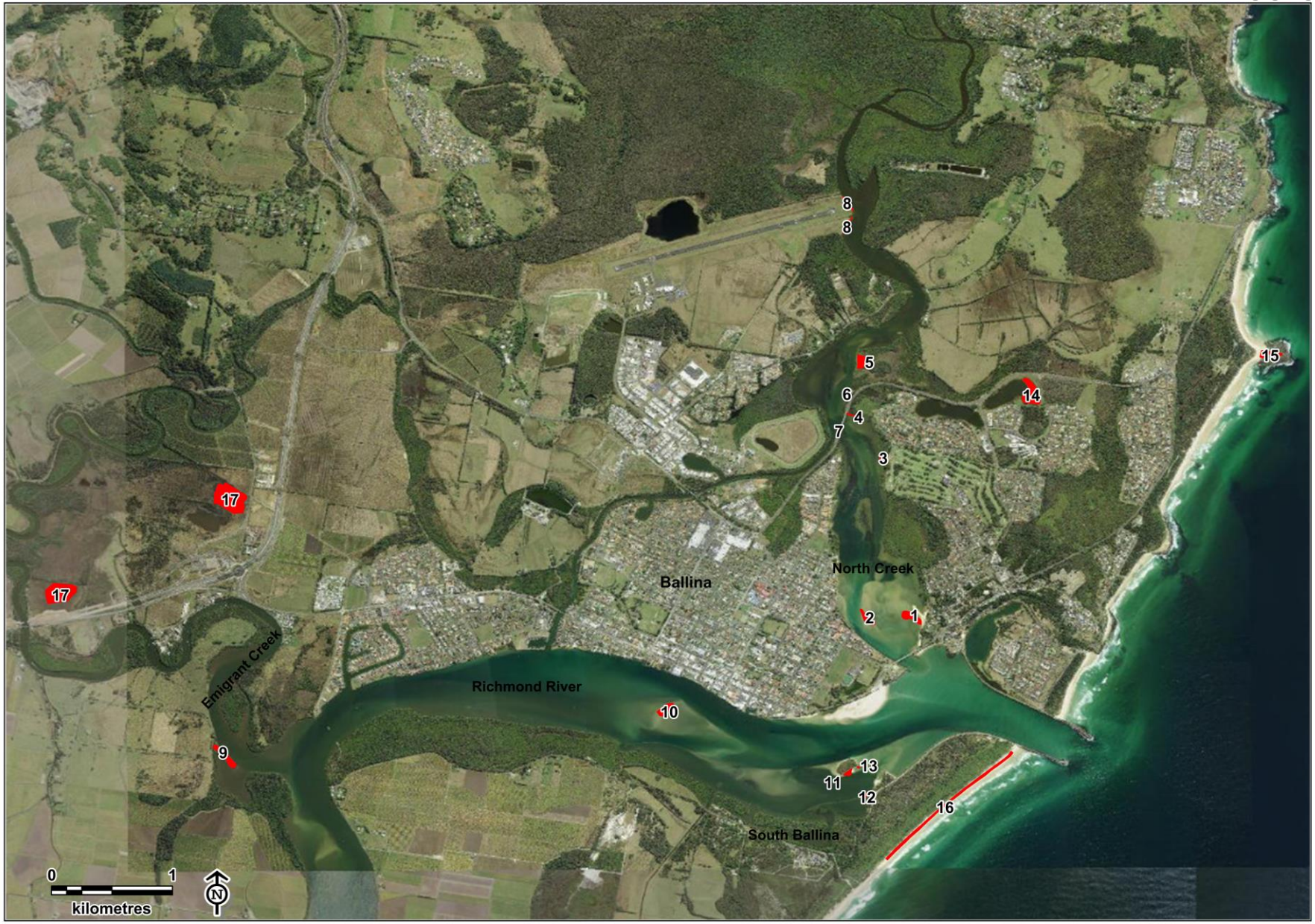

Figure 3: High tide roosts surveyed during the baseline shorebird surveys.

3.2 Low tide survey

Low tide surveys were conducted on six occasions in February 2016. The initial objective was to undertake three neap tide (2-4 February) and three spring tide (8-10 February) surveys on consecutive days, however, surveys scheduled for 9 and 10 February were cancelled due to strong wind. Subsequent low tide surveys were conducted on 14 and 22 February.

Nine sites were surveyed at low tide (Table 2; Figure 4). Surveys started at the Serpentine sand flat and ended at Mobbs Bay and were conducted within one hour of low water (LW). The tidal lag within North Creek was accounted for by starting at Serpentine. By the time North Creek upper (NCu) was surveyed the tidal stage at that site was approximately 1hr prior to mean low water. All sites were accessed by boat and observations were conducted from land using a 20-60*80mm spotting scope and pair of 10*42mm binoculars. A combination of boat and land survey was used to sample North Creek central, North Creek north and North Creek upper. Data collected at each site included: number of individuals and species, wind speed and direction, tidal stage, human activity, and location (easting & northing). A single observer conducted low tide surveys.

Table 2: Low tide sample sites

Site No.	Site Name (Area in ha)	Habitat type	Observation Point		Survey method
			Easting	Northing	
1	Serpentine (32.4)	Sandflat	555851	6806885	Land
2	Serpentine west (4.5)	Sandflat	555851	6806885	Land
3	North Creek south (5.7)	Sandflat & seagrass	555815	6807704	Land
4	North Creek central (6.7)	Mudflat & mangrove fringe	555815	6807704	Land & boat
5	North Creek north (3.8)	Oyster beds & mudflat	555788	6808615	Land & boat
6	Prospect (17.9)	Muddy sand, mudflat, seagrass	555735	6808910	Land
7	Upper North Creek (7.4)	Mudflat	556290	6809804	Land & boat
8	Richmond River mid-channel (13.1)	Sandflat	554272	6806017	Land
9	Mobbs Bay (outer sandbar) (11.8)	Sandflat & seagrass	554875	6805395	Land

Figure 4: Low tide sample sites.

3.3 Habitat use – Serpentine and Prospect

The location of individuals and flocks of five target species was recorded during the low tide period to assess foraging distribution. At Serpentine, observations were conducted from a single point (Easting 555851; Northing 6806885) near the north end of the neap tide roost and occurred at approximate 45 minute intervals during the period four hours either side of MLW. Primary target species were eastern curlew, bar-tailed godwit, Pacific golden plover and sanderling. Secondary target species were curlew sandpiper, great knot and Australian pied oystercatcher. Secondary species were recorded if time permitted. Target species were selected to represent a range of size classes and foraging strategies to provide an overall indication of how shorebirds use the sand flat.

During each observation period the location of primary and secondary target species was determined using a range finder and compass. Birds were initially located and identified using a 20-60x80mm spotting scope set over the observation point. The range finder could not detect birds at distances greater than about 125m so a series of marker pegs were installed at 150, 200, 250, 300 and 350m from the observation point on four orientations, 15°, 40°, 70° and 90° to assist with distance measures (Plate 1). The range finder was able to measure distance to larger features such as rock walls, sheds, people and pelicans and these were used to assist with distance measurement when possible.

The entire area of exposed sand was surveyed during each observation period. Because birds typically congregate on the roost or higher ground and then move over flats as the tide recedes the number of observations (i.e. individuals/flocks) increased over the ebb tide, as birds dispersed, and decreased over the flood tide as birds were pushed back to higher ground. The number of observations for each species during each observation period was dependent on the number of individuals present and their behaviour. In the early stages of the ebb tide there were typically fewer birds or most individuals were roosting which resulted in fewer observations. Data collected on each target species included: species, number of individuals, area of group (if number of individuals > 1), bearing (magnetic north), distance (m), behaviour (foraging, roosting, transit), and substrate (moist sand, dry sand, shoreline (1m either side of waters edge), in water, seagrass). Data were uploaded immediately onto an iPad.

Collection of habitat use data was concentrated at Serpentine, with one low tide period spent sampling the eastern side of the Prospect tidal flat.

3.4 Feeding rates

Data on feeding rates was collected during the low tide period at Serpentine, Mid Richmond and Prospect tidal flats. Species targeted were eastern curlew, bar-tailed godwit and Pacific golden plover. Birds were selected at random and observed continuously for five minutes, with the number and, if possible, type of prey consumed counted. Only birds that were actively foraging were selected. To reduce pseudo-replication of eastern curlews, observations were conducted once for each individual during each sample period. Feeding observations were spread over several low tide periods to capture a range of weather and tidal conditions. The target replication was 10 observations/species/site. The number (and type) of prey consumed within each five-minute period was counted. Identification of prey to species level was difficult and typically prey was assigned to broad groups, that is, crabs, polychaete worm, mollusc. Soldier crabs (*Mictyris* spp) and ghost

shrimps (*Trypaea* spp) were more easily identified. An observation was abandoned if the focal bird flew away during the observation period. Other data collected during each observation included time and substrate (i.e. moist sand, dry sand, water's edge and seagrass).

Plate 1: Serpentine sand flat at low tide showing marker pegs used to assist with the shorebird habitat use study.

3.5 Data summary and analysis

3.5.1 High and low tide

Basic summary statistics were tabulated and graphed for high and low tide data and presented as:

1. Maximum counts/site (maximum number of individuals for each species at each site);
2. Mean counts/site (all species combined and all species separate; means derived by dividing cumulative total by number of samples);
3. Proportion of population estimate present (derived by dividing a species count by the population estimate for that species and multiplying by 100).

A population estimate was derived for the sample period by summing species counts for each high tide survey to provide a cumulative total for each species/survey. Maximum counts for each species over the six samples were then used to determine a population estimate. Data collected during each sample was initially vetted to remove double-counts (i.e. same individuals counted at more than 1

site) and the cumulative species counts for each survey compared to identify potential outliers. For example, if the sample population estimate for species A across six surveys was 10, 14, 11, 10, 44 and 9. The figure of 44 would be carefully scrutinised to determine its accuracy.

Low tide counts were included in the population estimate if they were an accurate count of a single species at one site. A count was considered to be accurate if birds were confined to a small area, visibility was good (i.e. no obstructions), no individuals took flight during the count and the count occurred at close range (i.e. <200m) and movement was limited. Low tide counts used in the population estimate were:

1. Sharp-tailed sandpiper at Mid-Richmond;
2. Greenshank at Prospect;
3. Common Sandpiper within North Creek Canal;
4. Double-banded plover at Serpentine; and
5. Red-capped plover at Serpentine.

The latter two species were only recorded at low tide. Greenshank were repeatedly recorded in a single flock at Prospect and sharp-tailed sandpipers were recorded in a single roosting flock at Mid-Richmond. Other flocks of sharp-tailed sandpiper were recorded in North Creek immediately prior to the Mid-Richmond record and the population estimate of 62 individuals is regarded as conservative.

3.5.2 Habitat use – Serpentine and Prospect

Habitat use data for Serpentine and Prospect intertidal areas was summarised and mapped by Hydrosphere Consulting. Field observations were re-organised into a database format and magnetic north bearings were transformed to grid north. An equation was written to calculate geographic locations from bearings and distances generated from the known observation point. Each observation was then allocated to one of nine time periods ranging from 4 hours before LW to 4 hours after LW. Observations for each time period were then mapped using MapInfo. Initial map outputs were checked for accuracy and a small number of records, occurring on land or deep water, were adjusted. Adjustment was required in three areas, a permanent tidal pool northwest of the Serpentine oyster shed, the former dredge pool near the northern end of the Serpentine sandbar and landward records on the Serpentine west sandbar. Adjustment was necessary due to incorrect distance estimation at distances exceeding 400m from the observation point.

3.5.3 Feeding rates

Feeding rate data were square-root transformed and analysed using Analysis of Variance (ANOVA) in Systat 13.2. Site was included as the categorical variable and feeding rate as the dependent variable.

4. Results

4.1 Timing, weather conditions and logistics

The survey was timed to coincide with the latter stages of the 'stable' summer population period for migratory shorebirds and occurred prior to the departure of eastern curlew, which is typically the first species to leave north coast estuaries (D. Rohweder pers obs). The survey was also timed to avoid the peak holiday period and therefore reduce the influence of human activity on high and low tide surveys. Despite avoiding the peak holiday period human activity was recorded on the Serpentine sand flat during each low tide sample period. On the main Serpentine sand flat human activity was concentrated in the tidal pool and lower intertidal habitat northwest of the Oyster Shed across to the northern tidal pool and dredge hole. Consistent human activity in that area affected bird distribution.

Tide height ranged from a low of 0.15m to a high of 1.93m and sample periods from 0625hrs to 1821 hours (Table 3). Weather conditions were suitable for sampling shorebirds, although strong afternoon wind on 9 and 10 February forced the cancellation of low tide surveys (Table 4). Wind was not considered strong enough to alter bird behaviour or habitat selection on 9 February but the habitat use survey on 10 February was postponed until the following spring tide period. No noticeable weather related change in habitat use was observed during the sample period. Visibility was good throughout the survey period.

Table 3: Survey features. HT = high tide; LT = low tide; ns = no survey. Tide heights and times were sourced from Roads and Maritime Services 2015.

Date	Tide Height (& Time)		Survey Times		
	HT	LT	HT	LT	Habitat
2/2/2016	1.19 (1557)	0.72 (1012)	1410-1625	0930-1125	0625-1358
3/2/2016	1.18 (1711)	0.68 (1125)	1552-1811	1043-1230	0731-1519
4/2/2016	1.22 (1815)	0.60 (1227)	1639-1821	1214-1406	0831-1623
8/2/2016	1.87 (0852)	0.22 (1527)	0727-1020	1427-1645	1137-1732
9/2/2016	1.92 (0837)	0.17 (1608)	0845-1045	ns	1229-1427 & 1532-1732
10/2/2016	1.93 (1024)	0.15 (1651)	0920-1220	ns	ns
14/2/2016	1.50 (1346)	0.45 (0640)	ns	0640-0910	ns
22/2/2016	ns	0.34 (1530)	ns	1530-1700	ns
23/2/2016	ns	0.35 (1603)	ns	ns	1333-1753

Estimating distance on the Serpentine sand flat was difficult at distances greater than 375m due to limited topographic relief. Placement of marked pegs assisted in estimating distances between the limit of the range finder (i.e. about 125m) and 375m. Distance estimates beyond 375m are suspected to have a 5% margin of error. Whilst the range finder can measure distances to 1000m capability was affected by limited topographic relief and small bird size.

Table 4: Weather data. HT = high tide; LT = low tide; ns = no survey. Wind speed and direction collected during survey, other data from Ballina Airport (Source: Bureau of Meteorology).

Date	Wind Direction		Wind Speed (KpH)		Temperature		Cloud Cover (8ths)		Rain (mm)
	HT	LT	HT	LT	9am	3pm	9am	3pm	
2/2/2016	SE	SE	1-5	1-11	30.1	27	0	0	0
3/2/2016	NE	SE/N	1-11	1-5	23.4	30.2	8	2	1
4/2/2016	SE	SE	1-11	6-25	24.9	24.4	8	7	0.6
8/2/2016	SE	SE	1-19	12-19	23.4	27.1	4	2	3.2
9/2/2016	SE	ns	12-35	ns	25.9	27.1	3	4	0
10/2/2016	SE	ns	1-19	ns	22.7	25.2	8	8	0
14/2/2016	ns	S	ns	1-11	24.3	26.7	3	7	1.4
22/2/2016	na	SE	na	6-19	26.4	26.6	0	8	0
23/2/2016	na	SE	na	11-19	26.1	27.8	8	3	0.2

4.2 Species Richness and legislative status

4.2.1 Shorebirds

Twenty-seven species of shorebird were recorded during the survey, including eight resident species and 19 migratory species (Table 5). Migratory species included one trans-Tasman migrant, double-banded plover, and 18 Holarctic migrants. Twenty-five species were recorded at high tide and 21 species at low tide. Species not recorded during high tide were red-capped plover and double-banded plover. The latter species was recorded during a low tide survey on 22 February and was probably not present during high tide surveys between 2 and 10 February. Species not recorded at high tide only were beach stone-curlew, sooty oystercatcher, black-fronted dotterel, red-kneed dotterel, Latham's snipe and wandering tattler (Table 5).

Ten threatened species of shorebird were recorded during the survey, including nine species listed by the NSW *Threatened Species Conservation (TSC) Act 1995* and two species listed by the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (Table 5). One species, curlew sandpiper, is listed by both the *EPBC* and *TSC Acts*. Eighteen migratory species listed on the *EPBC Act* were also recorded. Status of the species recorded includes four critically endangered species (three commonwealth & one state), two endangered species (one commonwealth & two state) and six vulnerable species (two commonwealth & six state). Nineteen species were recorded at sites in North Creek, including two resident species, 16 migratory species and seven threatened species (Table 5).

Table 5: Species richness and status. CE = critically endangered; E = endangered; V = vulnerable; M = migratory; TSC = Threatened Species Conservation Act 1995; EPBC Act = Environment Protection and Biodiversity Conservation Act 1999.

Common name	Scientific name	Status		Recorded at High tide	Recorded at Low tide	Recorded in North Creek
		TSC Act	EPBC Act			
Beach Stone-Curlew	*Esacus magnirostris*	CE				
Aust. Pied Oystercatcher	*Haematopus longirostris*	E				
Sooty Oystercatcher	*Haematopus fuliginosus*	V				
Black-winged Stilt	*Himantopus himantopus*					
Pacific Golden Plover	*Pluvialis fulva*		M			
Red-capped Plover	*Charadrius ruficapillus*					
Double-banded Plover	*Charadrius bicinctus*					
Lesser Sand Plover	*Charadrius mongolus*	V	E, M			
Greater Sand Plover	*Charadrius leschenaultii*	V	V, M			
Black-fronted Dotterel	*Elseyornis melanops*					
Red-kneed Dotterel	*Erythrogonys cinctus*					
Masked Lapwing	*Vanellus miles*					
Latham's Snipe	*Gallinago hardwickii*		M			
Bar-tailed Godwit	*Limosa lapponica baueri*		V,M			
Whimbrel	*Numenius phaeopus*		M			
Eastern Curlew	*Numenius madagascariensis*		CE, M			
Terek Sandpiper	*Xenus cinereus*	V	M			
Common Sandpiper	*Actitis hypoleucos*		M			
Grey-tailed Tattler	*Tringa brevipes*		M			
Wandering Tattler	*Tringa incanus*		M			
Common Greenshank	*Tringa nebularia*		M			
Ruddy Turnstone	*Arenaria interpres*		M			
Great Knot	*Calidris tenuirostris*	V	CE, M			
Sanderling	*Calidris alba*	V	M			
Red-necked Stint	*Calidris ruficollis*		M			
Sharp-tailed Sandpiper	*Calidris acuminata*		M			
Curlew Sandpiper	*Calidris ferruginea*	E	CE, M			

4.3 Shorebird population estimate

The shorebird population in the Richmond River estuary between 2 and 10 February 2016 was estimated at 1162 individuals (Table 6). The estimate includes single low tide counts for sharp-tailed sandpiper, common greenshank, common sandpiper, red-capped plover and double-banded plover. The population included 148 resident shorebirds and 1014 migratory shorebirds. Black-winged stilt was the most abundant resident species (70 individuals), followed by masked lapwing (35 individuals) and Australian pied oystercatcher (26 individuals; Table 6). Pacific golden plover was the most abundant migratory species with a population estimate of 278 individuals, followed by red-necked stint (203 individuals) and bar-tailed godwit (164 individuals; Table 6). Other significant counts include 63 grey-tailed tattler, 62 sharp-tailed sandpiper, 54 whimbrel, 37 eastern curlew, 35 great knot and 34 terek sandpiper (Table 6).

4.4 High tide surveys

4.4.1 Species richness and distribution

Shorebirds were recorded at 13 of the 17 sites surveyed at high tide (Table 7). No shorebirds were recorded at Prospect rocks, Prospect Island, Prospect saltmarsh or Airport. Historically, these roosts have been secondary sites that are used occasionally, during certain conditions, and the absence of birds during this survey is not surprising. At high tide the highest diversity of shorebirds was recorded at South Ballina Beach (15 species), followed by Serpentine west (13 species) and Mid-Richmond (12 species; Table 7). Mobbs Bay Island, Mobbs Bay rocks, Serpentine east, Chickiba Lake and Flat Rock supported between seven and nine species (Table 7).

South Ballina Beach and Mid-Richmond each supported nine threatened species, Serpentine west eight threatened species and Serpentine east five threatened species at high tide. Mobbs Bay island and Mobbs Bay rocks each supported four threatened species (Table 7). Species richness of migratory shorebirds followed a similar trend to total species richness with the highest number of migratory species recorded at South Ballina Beach (12 species), followed by Serpentine west (11 species) and Mid-Richmond (10 species). Sites supporting 6-7 migratory species were Mobbs Bay Island (6), Mobbs Bay rocks (6), Serpentine east (7), Chickiba Lake (6), and Flat Rock (7).

Six of the roosts surveyed are regarded as spring and neap tide roosts, six as neap tide roosts and five as spring tide roosts. Spring and neap tide roosts include Flat Rock, Chickiba Lake, Serpentine east, South Ballina Beach and Emigrant wetland. These roosts tend to be used at all times although the Serpentine east roost had few birds during neap tides as birds prefer to use the Serpentine west roost at that time.

Primary spring tide roosts are:

- Flat Rock;
- Chickiba Lake;
- Serpentine east;
- Mobbs Bay;
- South Ballina Beach.

Primary neap tide roosts are:

Flat Rock;
Chickiba Lake;
Serpentine west;
Mobbs Bay;
South Ballina Beach.
Mid-Richmond.

Table 6: Summary of population estimates. * = species recorded opportunistically; ** a single low tide count used in the local population estimate.

Species/Count	2.2.16	3.2.16	4.2.16	8.2.16	9.2.16	10.2.16	Maximum Count/Popn Estimate	Mean	SDEVA
Beach Stone-Curlew			1				1	0.17	0.41
Aust. Pied Oystercatcher	17	21	14	20	4	26	26	17	7.54
Sooty Oystercatcher	11	11	2	10	10	7	11	8.5	3.51
Black-winged Stilt				64	7	70	70	23.5	33.86
Pacific Golden Plover	130	278	125	140	122	130	278	154.17	60.97
Red-capped Plover	1						1**	0.17	0.41
Double-banded Plover							1**	0.17	0.41
Lesser Sand Plover	4	3	4	1		1	4	2.6	1.52
Greater Sand Plover			1	2	4	2	4	1.5	1.52
Black-fronted Dotterel				2	2	2	2	1	1.09
Red-kneed Dotterel				2			2	0.33	0.82
Masked Lapwing	35	9	2				35	7.67	13.84
Latham's Snipe				1		2	2	0.5	0.84
Bar-tailed Godwit	164	156	97	94	89	132	164	122	33.22
Whimbrel	54	52	38	38	22	27	54	38.5	12.86
Eastern Curlew	37	36	33	32	34	35	37	34.5	1.87
Terek Sandpiper	30	34	16	25	19		34	20.67	12.13
Common Sandpiper							2*		
Grey-tailed Tattler	63	55	44	58	48		63	44.67	22.92
Wandering Tattler						1	1	0.17	0.41
Common Greenshank	5	6	6	1			6**	3	2.97
Ruddy Turnstone	13	7	2	13	9	11	13	9.17	4.21
Great Knot	32	35	19**	31	17	28	35	25.83	9.19
Sanderling	6	9	9	6	6	10	10	7.67	1.87
Red-necked Stint	137	139	80	202	180	203	203	156.83	47.58
Sharp-tailed Sandpiper	30	14	14	62	29	24	62**	28.83	17.69
Curlew Sandpiper	14	41	36	32	27	29	41	29.83	9.24
Sand plover spp.	1		1					0.33	0.52
Tattler/Terek				2	19	71		15.33	28.27
No. migr species	11	13	13	16	13	14	19		
No. migr individuals	684	859	498	691	625	706	1014	677.2	117.4
No. resident species	4	3	4	5	4	4	8		
No. resident individuals	64	41	19	98	23	105	148	58.3	37.1
Total no species	15	16	17	21	17	18	27		
Total no. individuals	748	900	517	789	648	811	1162	735.5	135.04

Table 7: Species occurrence and maximum counts recorded at 13 high tide roosts surveyed during the baseline surveys; ts = terek sandpiper; gtt = grey-tailed tattler; V = vulnerable; E = endangered; CE = critically endangered; M = migratory. NB: Prospect rocks (neap), Prospect Island (neap), Prospect saltmarsh (spring) and Airport (Spr&Np) have not been included as no birds were recorded at those sites.

Species & status	Mid-Richmond	MB Island	MB M'grove	MB rocks	NC rocks	Prosp groyne	Serp west	Serp east	Sth Ball Beach	Chickiba Lake	Flat Rock	Emigrant Ck	Emigrant wetland
	Neap	Neap	Spring	Neap	Neap	Spring	Neap	Spr&Np	Spr&Np	Spr&Np	Spr&Np	Spring	Spr&Np
Beach Stone-Curlew [CE]		1											
Aust. Pied Oystercatcher [E]	3	4		3			14	22	6				
Sooty Oystercatcher [V]	1	9		2					7		11		
Black-winged Stilt		2							7				68
Pacific Golden Plover [M]	25			15			62	6	157	131			
Lesser Sand Plover [V,E,M]	2						4	1	1				
Greater Sand Plover [V,V,M]	1						1		4				
Black-fronted Dotterel										2			
Red-kneed Dotterel										2			
Masked Lapwing		4			1		4			27			
Latham's Snipe [M]										2			
Bar-tailed Godwit [V,M]	84						72	31	98	2	5		
Whimbrel [M]	32	1		1			20	20	19	3		11	
Eastern Curlew [CE,M]	17	5					17	14	23				
Terek Sandpiper [V,M]	4			34									
Common Sandpiper [M]													
Grey-tailed Tattler [M]				55	26	3	14				2		
Wandering Tattler [M]											1		
Common Greenshank													1
Ruddy Turnstone [M]									4		12		
Great Knot [V,CE,M]	1						35	11	27				
Sanderling [V,M]							9		9		1		
Red-necked Stint [M]	20						18	1	182		62		
Sharp-tailed Sandpiper [M]		1		1					3	29	10		

Species & status	Mid-Richmond	MB Island	MB M'grove	MB rocks	NC rocks	Prosp groyne	Serp west	Serp east	Sth Ball Beach	Chickiba Lake	Flat Rock	Emigrant Ck	Emigrant wetland
	Neap	Neap	Spring	Neap	Neap	Spring	Neap	Spr&Np	Spr&Np	Spr&Np	Spr&Np	Spring	Spr&Np
Curlew Sandpiper [CE,M]	15			14			17		8	28			
Tattler/Terek		19	70 (ts&gtt)								2		
N^{O}. species	12	7	2	8	2	1	13	8	15	9	9	1	2
N^{0}. threatened species	8	4	1	4	0	0	7	4	8	1	2	0	0
N^{O}. migratory species	10	6	2	6	1	1	11	7	12	6	7	1	1

4.4.2 Maximum counts

Maximum counts and proportion of the estuaries population for each species at primary high tide roosts is presented in Table 8. The Serpentine west and Serpentine east roosts supported significant proportions of the local population for several species. During neap high tides the Serpentine west roost supported 100% of the local population of lesser sand plover, great knot and sanderling, all threatened species, and between 30 and 75% of the population of Australian pied oystercatcher (67%), eastern curlew (45.95%), bar-tailed godwit (43.9%) and whimbrel (37.04%). Serpentine east supported 100% of the lesser sand plover population, 84% of the Australian pied oystercatcher population and between 30 and 75% of the whimbrel (52.6%), 40% of eastern curlew and 35.4% of great knot.

Table 8: Maximum counts at major high tide roosts and proportion of population estimate present. PE = population estimate; V = vulnerable; E = endangered; CE = critically endangered; M = migratory. NB sites used only during spring or neap tides were compared to spring and neap tide counts only. Red text denotes a site that supported >75% of the species population. Orange text denotes a site that supported between 30 and 74% of a species population.

Species/Count	Serpentine west		Serpentine east		South Ballina		Chickiba Lake		Mid-Richmond		Mobbs Bay		Flat Rock	
	Max	%PEn	Max	%PEs	Max	%PE	Max	%PE	Max	%PEs	Max	%PE	Max	%PE
Beach Stone-Curlew [CE]											1	100		
Aust. Pied Oystercatcher [E]	14	67.0	22	84.6	6	23.08			3	14	4	15.39		
Sooty Oystercatcher [V]					7	63.6			1	9	10	90.9	11	100
Black-winged Stilt					7	10					2	2.86		
Pacific Golden Plover [M]	62	22	6	4.2	157	56.5	131	47.1	25	8.9	15	5.4		
Lesser Sand Plover [V,M]	4	100	4	100	1	25			2	50				
Greater Sand Plover [V,M]	1	25	1		4	100			1	25				
Black-fronted Dotterel							2	100						
Red-kneed Dotterel							2	100						
Masked Lapwing	4	11.43	4				27	77.1			4	11.43		
Latham's Snipe [M]							2	100						
Bar-tailed Godwit [M]	72	43.9	72	23.4	98	59.7	2	1.22	84	51.2			5	3.05
Whimbrel [M]	20	37.0	20	52.6	19	35.2	3	5.56	32	59.2	2	3.7		
Eastern Curlew [CE,M]	17	45.9	17	40	23	62.2			17	45.9	5	13.51		
Terek Sandpiper [V,M]									4	11.7	34	100		
Grey-tailed Tattler [M]	14	22.22									55	87.3	2	3.17
Wandering Tattler [M]													1	100
Ruddy Turnstone [M]					4	30.8							12	92.3
Great Knot [V,M]	35	100	11	35.4	27	77.1			1	2.8				
Sanderling [V,M]	9	100			9	90							1	10
Red-necked Stint [M]	18	13	1	0.5	182	89.7			20	14.3			62	30.5
Sharp-tailed Sandpiper [M]					3	4.84	29	46.8			1	1.61	10	16.13
Curlew Sandpiper [CE,M]	17	41.5			8	19.51	28	68.3	15	36.5	14	34.2		

South Ballina Beach, at times, supported 100% of greater sand plover, 90% of sanderling, 89.7% of red-necked stint, 77.1% of great knot, 63.6% of sooty oystercatcher, 62.2% of eastern curlew, 59.7% of bar-tailed godwit, 56.5% of Pacific golden plover and 35.2% of whimbrel. Significant proportions at Chickiba Lake were black-fronted dotterel (100%), red-kneed dotterel (100%), Latham's snipe (100%), masked lapwing (77.1%) and Pacific Golden Plover (47.1%). During neap tides the Mid-Richmond roost supported between 45.9 and 59.2% of eastern curlew, lesser sand plover, bar-tailed godwit and whimbrel (Table 8). Mobbs Bay supported significant proportions of beach stone-curlew, terek sandpiper, sooty oystercatcher and grey-tailed tattler and Flat Rock significant proportions of sooty oystercatcher, wandering tattler and ruddy turnstone.

Graphical comparison of maximum, mean and proportion of the shorebird community recorded at major roosts shows that South Ballina Beach, Serpentine west, Mid-Richmond and Chickiba Lake are of primary importance (Figure 5). This trend is not consistent for species richness (Figure 6). Maximum number and proportion of species was highest at South Ballina Beach but mean species richness was highest at Serpentine west followed by mid-Richmond, South Ballina Beach and Chickiba Lake. The result shows that a higher number of species are consistently recorded at Serpentine than South Ballina Beach and mid-Richmond.

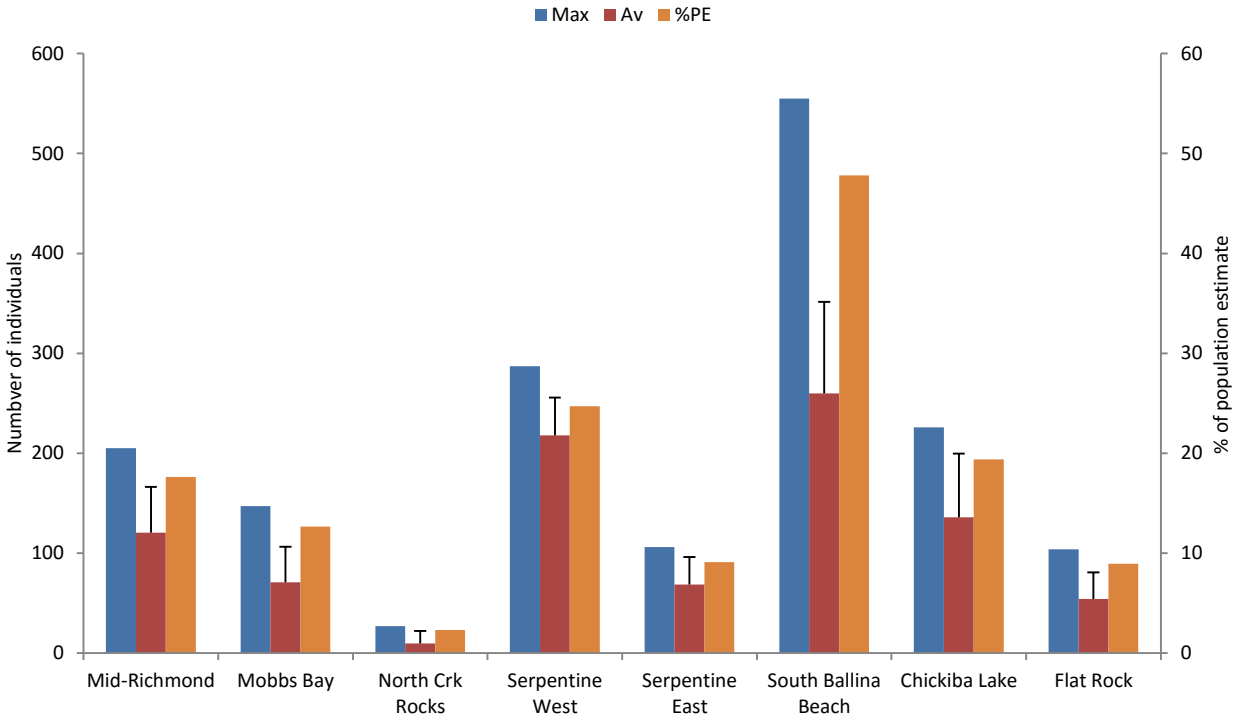

Figure 5: Comparison of maximum counts, mean counts and proportion of shorebird population estimate recorded at eight roosting areas. NB Mobbs Bay includes Mobbs Bay rocks, Mobbs Bay island and Mobbs Bay mangroves.

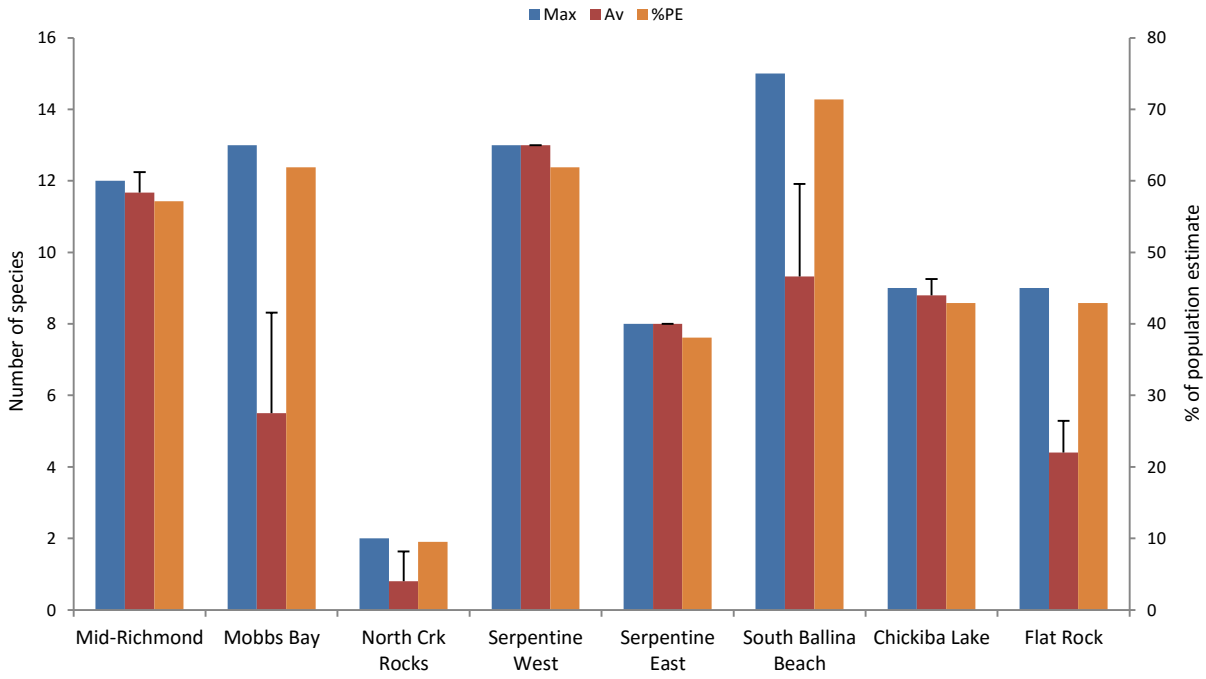

Figure 6: Comparison of maximum species richness, mean species richness and proportion of total species recorded at eight roosting areas.

4.4.3 Species analysis

Comparison of maximum, mean (+ standard deviation) and proportion of local population of priority species at key roosts highlights habitat preference of different species and important roosts (Figures 7 to 13). Serpentine west, South Ballina Beach, Mid-Richmond and Chickiba Lake are the primary roosts for most species. Serpentine west was the primary roost for great knot and secondary roost for Australian pied oystercatcher, Pacific golden plover, eastern curlew and curlew sandpiper (Figures 7, 8, 10 and 12). Serpentine east was the primary roost for Australian pied oystercatcher and a secondary roost for eastern curlew. South Ballina Beach was the primary roost for bar-tailed godwit and eastern curlew and the secondary roost for Pacific golden plover and great knot. Chickiba Lake was the primary roost for Pacific golden plover and curlew sandpiper. Although the maximum count of Pacific golden plover was highest at South Ballina Beach that species was more consistently recorded at Chickiba Lake and Serpentine west, as shown by higher mean counts and lower standard deviations (Figure 8).

Mid-Richmond was a secondary roost for bar-tailed godwit, eastern curlew and curlew sandpiper. Mean counts of eastern curlew were higher at mid-Richmond and Serpentine west but maximum count and proportion of the local population was highest at South Ballina Beach. This trend is attributed to the nature of roost use, with the former sites being used during neap tides and South Ballina used during spring and neap tides. Mobbs Bay provides the primary roosting habitat for grey-tailed tattler, with secondary habitat provided by the upper north creek roosts.

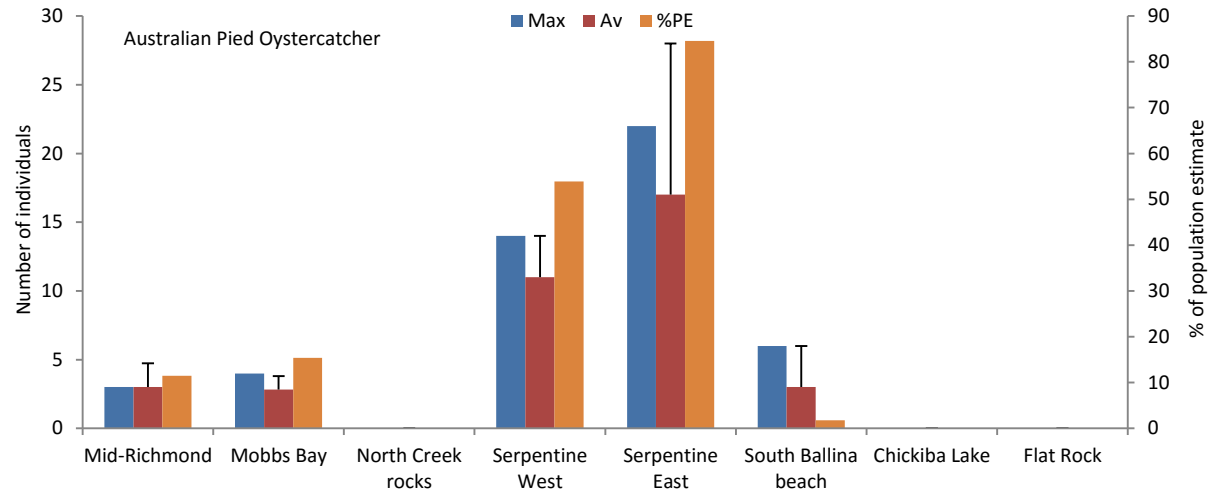

Figure 7: Maximum count, mean count and proportion of population estimate of Australian pied oystercatchers at eight roost areas.

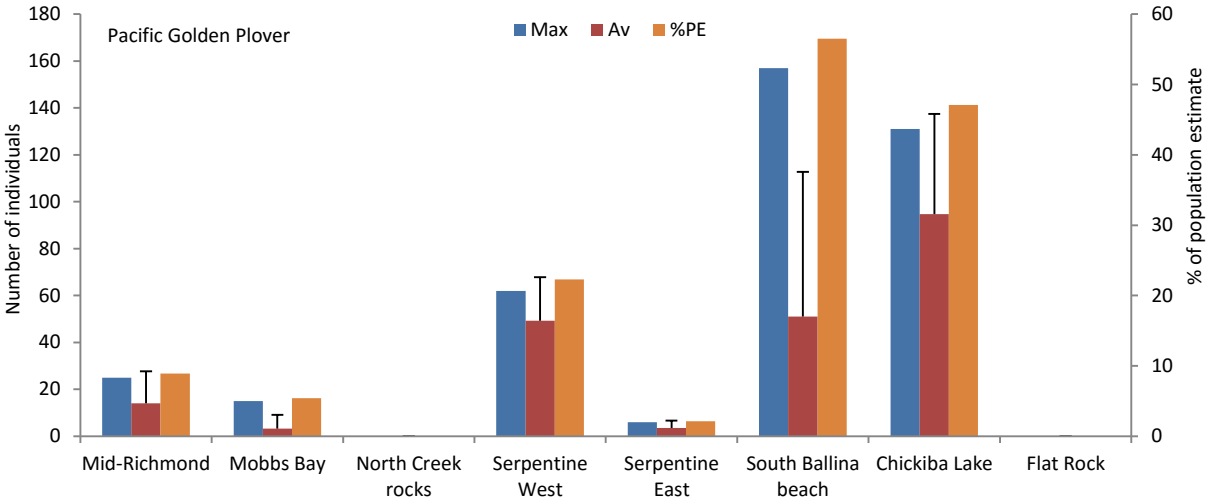

Figure 8: Maximum count, mean count and proportion of population estimate of Pacific golden plover at eight roost areas.

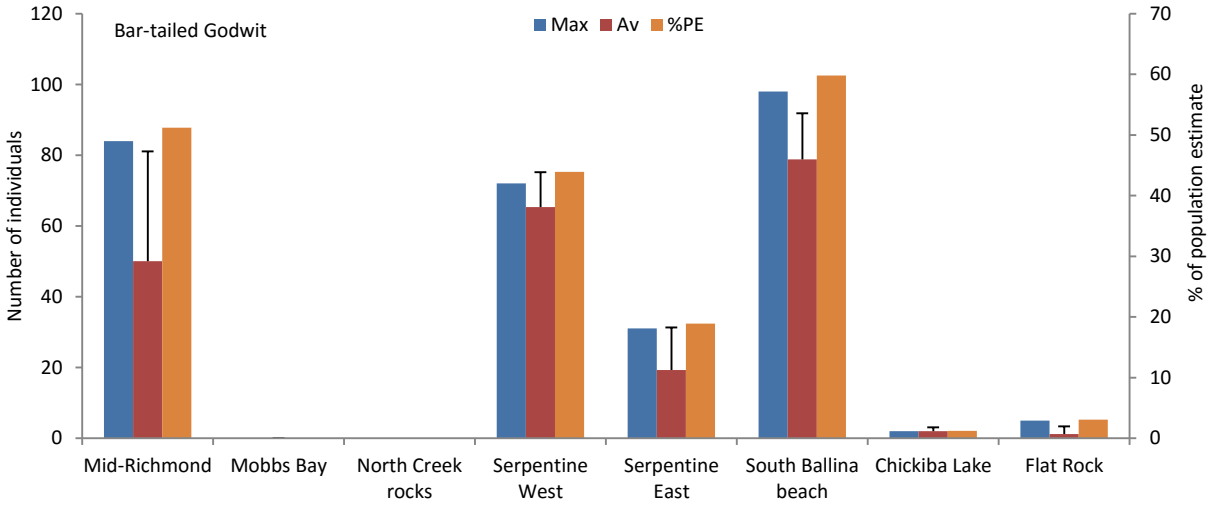

Figure 9: Maximum count, mean count and proportion of population estimate of bar-tailed godwit at eight roost areas.

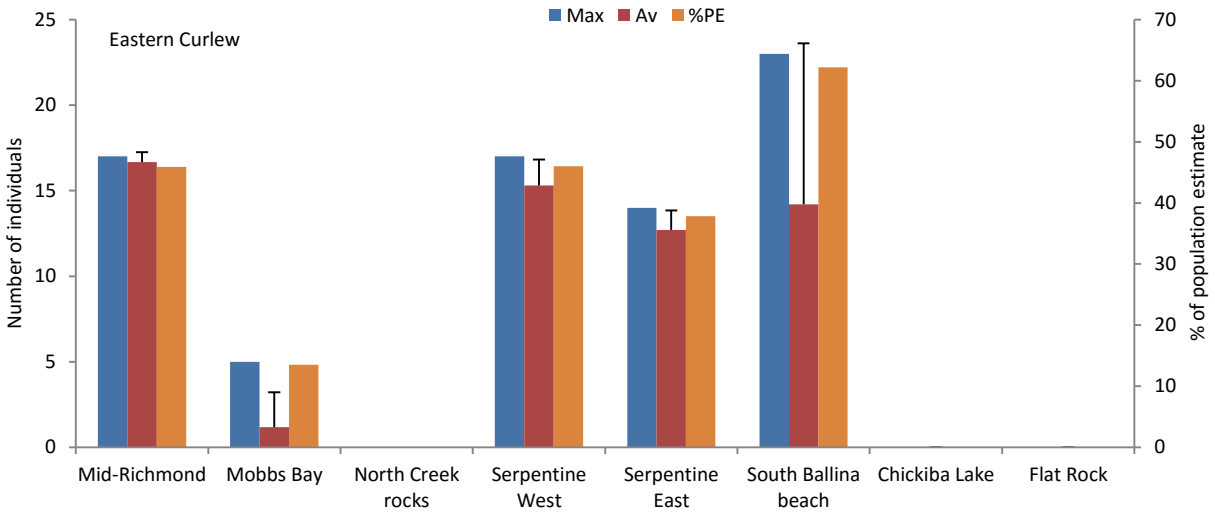

Figure 10: Maximum count, mean count and proportion of population estimate of eastern curlew at eight roost areas.

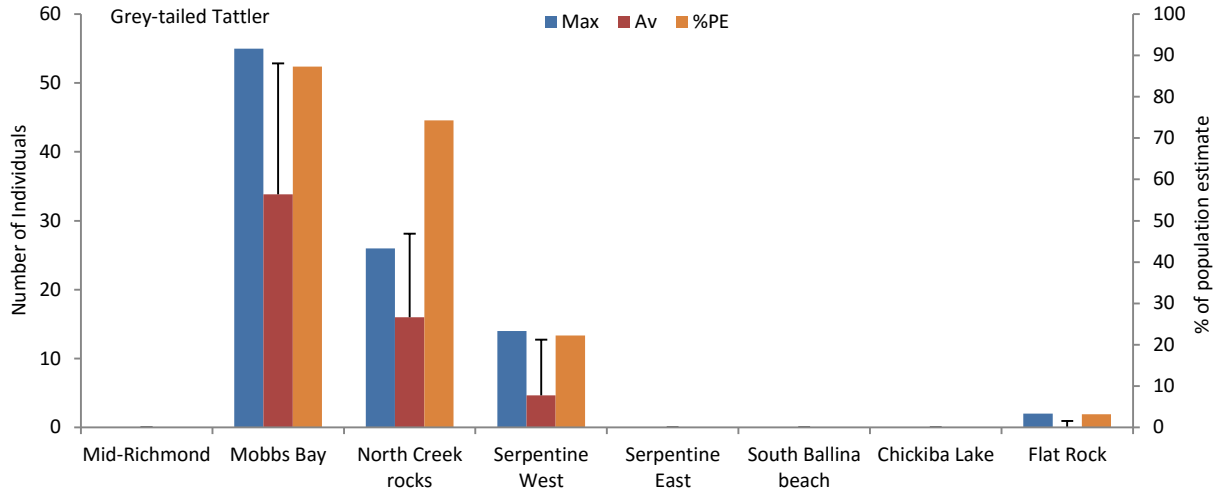

Figure 11: Maximum count, mean count and proportion of population estimate of grey-tailed tattler at eight roost areas.

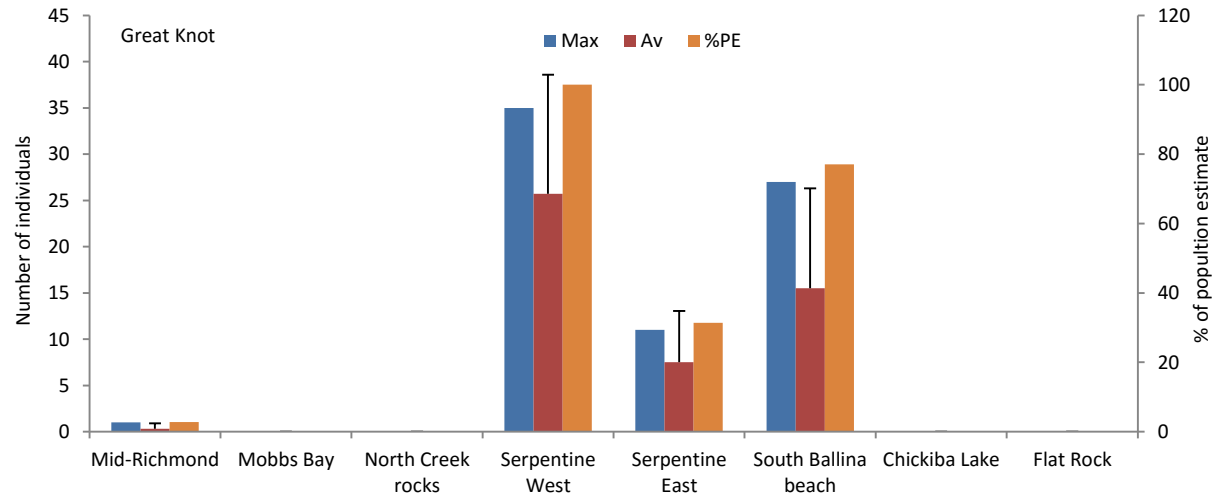

Figure 12: Maximum count, mean count and proportion of population estimate of great knot at eight roost areas.

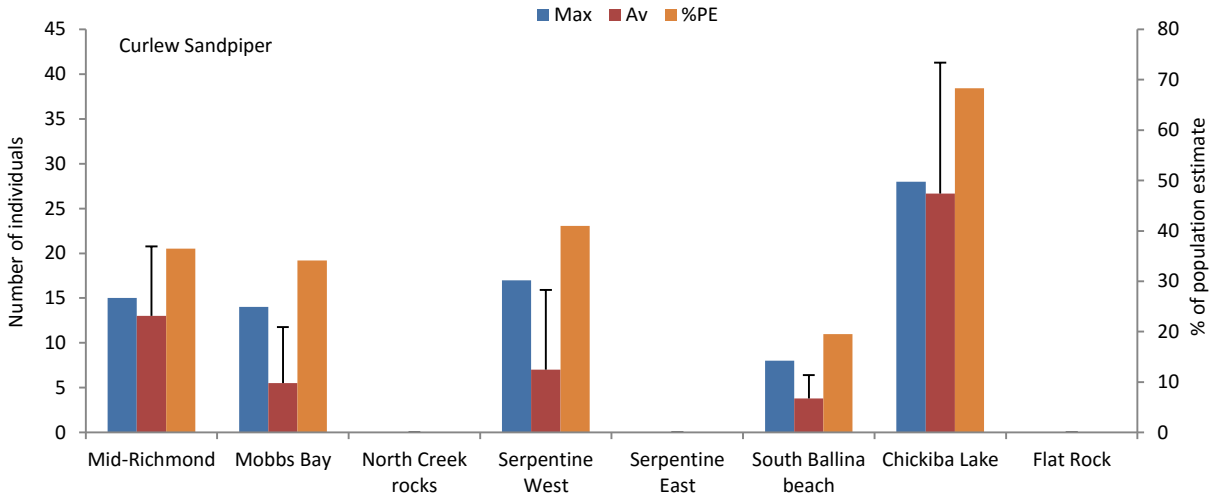

Figure 13: Maximum count, mean count and proportion of population estimate of curlew sandpiper at eight roost areas.

4.5 Low tide surveys

4.5.1 Species richness and distribution

Shorebirds were recorded at all of the low tide sample sites (Table 9). Nine threatened species were recorded at low tide. Sooty oystercatcher and lesser sand plover were each recorded at a single site, whilst greater sand plover, terek sandpiper and sanderling were recorded at two sites each. The remaining threatened species were recorded at five or more sites with curlew sandpiper recorded at seven sites (Table 9). Shorebird distribution at low tide reflects habitat preferences and habitat use. For example, sanderling, sand plovers and terek sandpipers prefer sandy substrates and are therefore primarily restricted to sandy habitats in the lower estuary. Sooty oystercatcher prefers rocky substrates and at low tide is primarily restricted to foraging along the rock walls in Mobbs Bay. In contrast, eastern curlew, great knot and curlew sandpiper display a more generalised in their habitat selection and move from sandy sites in the lower estuary to seagrass and muddy habitats in the upper estuary as the tide recedes.

Serpentine and mid-Richmond intertidal areas supported the highest diversity of shorebirds at low tide with 16 species recorded at each site (Table 9). Other foraging areas with a high diversity of species were Prospect and Mobbs Bay outer with 11 species each, North Creek south with 10 species and North Creek upper with 9 species (Table 9). The highest diversity of threatened species at low tide was recorded at Mid-Richmond (9 species) followed by Serpentine (8 species). Species richness of migratory shorebirds followed a similar pattern with 12 migratory species recorded at Mid-Richmond and Serpentine, nine each at North Creek south, Prospect and Mobbs Bay outer and eight at North Creek upper.

Table 9: Species occurrence and maximum counts (and proportion of population estimate) recorded at 8 low tide feeding areas surveyed during the baseline surveys; V = vulnerable; E = endangered; CE = critically endangered; M = migratory NB: Prospect rocks (neap), Prospect Island (neap), Prospect saltmarsh (spring) and Airport (Spr&Np) have not been included as no birds were recorded at those sites.

Species	Serpentine	NC south	NC central	NC north	Prospect	NC upper	Mid-Richmond	MB outer
Aust. Pied Oystercatcher [E]	11 (42)	1 (4)		6 (23)			3 (12)	2 (8)
Sooty Oystercatcher [V]							1 (9)	
Black-winged Stilt					1 (1)		2 (3)	
Pacific Golden Plover [M]	101 (36)	5 (2)	3 (1)	6 (2)	31 (11)	35 (12)	130 (47)	72 (26)
Red-capped Plover	1 (100)							
Double-banded Plover	1 (100)							
Lesser Sand Plover [V, M]	2 (50)							
Greater Sand Plover [V, M]	1 (25)						2 (50)	
Masked Lapwing	36 (100)			3 (9)	1 (3)	1 (3)	16 (46)	2 (6)
Bar-tailed Godwit [M]	58 (35)	16 (10)	3 (2)		8 (5)		81 (49)	43 (26)
Whimbrel [M]	16 (30)	3 (6)	4 (7)	1 (2)	3 (6)	4 (7)	20 (37)	29 (54)
Eastern Curlew [CE, M]	14 (38)	1 (3)			2 (6)	1 (3)	10 (27)	6 (16)
Terek Sandpiper [V, M]							29 (85)	11 (31)
Grey-tailed Tattler [M]	24 (38)	8 (13)	1 (1)	11 (17)	10 (16)	6 (10)	27 (43)	33 (52)
Common Greenshank [M]	3 (50)				6 (100)	1 (17)		
Great Knot [V, M]	37 (100)	20 (57)			25 (71)	33 (94)	3 (9)	
Sanderling [V, M]	8 (80)						4 (40)	
Red-necked Stint [M]	59 (29)	9 (4)					55 (27)	15 (7)
Sharp-tailed Sandpiper [M]		2 (3)		8 (13)	22 (35)	30 (48)	62 (100)	4 (6)
Curlew Sandpiper [CE, M]	22 (54)	10 (24)	4 (10)		1 (2)	15 (37)	13 (32)	10 (24)
Sand plover spp.	4							
Sandpiper spp.	4							
Tattler/Terek	2							
N^{O}. species	16	10	5	6	11	9	16	11
N^{0}. threatened species	7	4	1	1	3	3	9	5
N^{O}. migratory species	12	9	5	4	9	8	12	9

4.5.2 Maximum counts

The Serpentine and mid-Richmond intertidal habitats supported the largest number of shorebirds (Table 9). At times, Serpentine supported >30% of the local population of 14 species, including; Australian pied Oystercatcher (42%), lesser sand plover (50%), eastern curlew (38%), great knot (100%), sanderling (80%) and curlew sandpiper (54%) (Table 9). Mid-Richmond supported >30% of the local population of 10 species, including; greater sand plover (50%), terek sandpiper (85%), sanderling (40%) and curlew sandpiper (32%). Mobbs Bay outer and Prospect each supported >30% of the local population of three species (Table 9).

Graphical comparison of maximum, mean (+ standard deviation) and proportion of local population of shorebirds at eight foraging areas shows that mid-Richmond supported the highest maximum count, highest mean count and highest proportion of shorebirds, followed closely by Serpentine (Figure 14). Mid-Richmond supports larger numbers of more common species such as bar-tailed godwit and Pacific golden plover than Serpentine, whilst the latter site supports larger numbers of rare species (Table 9).

Species richness was the same at mid-Richmond and Serpentine, although mean species richness was slightly higher at the former site (Figure 15).

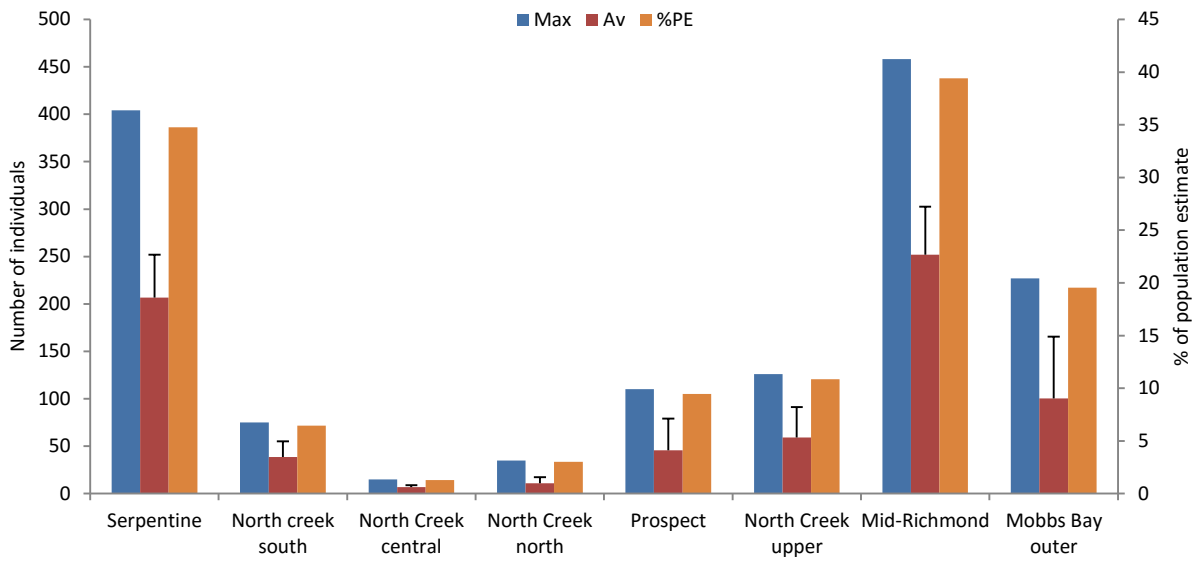

Figure 14: Comparison of maximum counts, mean counts and proportion of shorebird population estimate recorded at eight foraging areas.

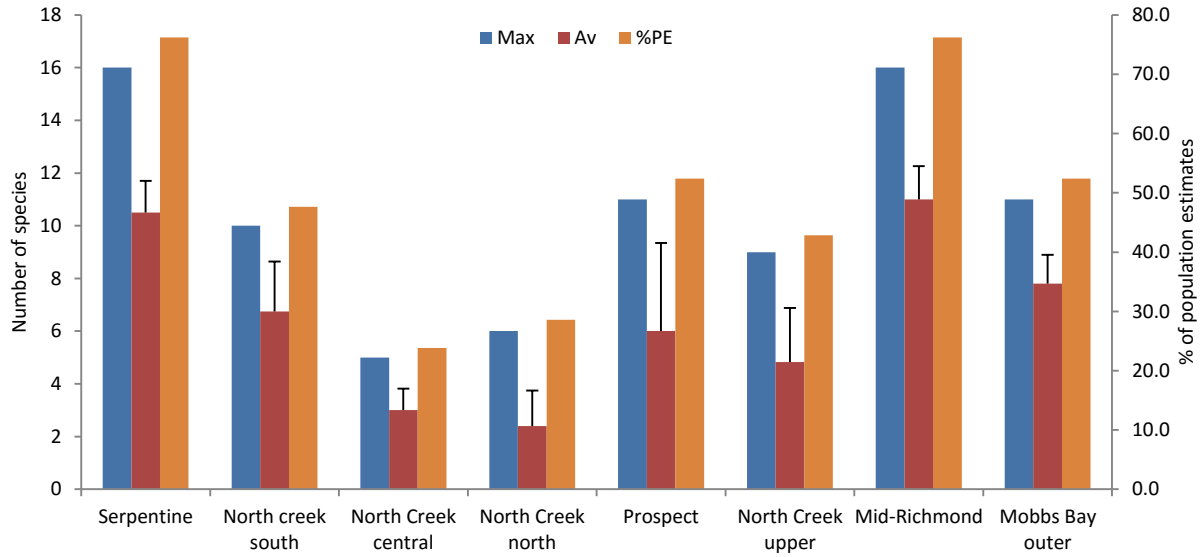

Figure 15: Comparison of maximum species richness, mean species richness (+ standard deviation) and proportion of the local shorebird population recorded at eight foraging areas.

4.5.3 Species analysis

Graphical comparison of maximum and mean counts (+ standard deviation) and proportion of local population of priority species recorded at eight foraging areas emphasises the importance of Serpentine, mid-Richmond and Mobbs Bay outer (Figures 16 to 22). Serpentine was a priority foraging area for Australian pied oystercatcher, eastern curlew, great knot and curlew sandpiper and of secondary importance for Pacific golden plover and bar-tailed godwit. The large standard deviations recorded for Australian pied oystercatcher, grey-tailed tattler, great knot and curlew

sandpiper at some sites is due to tidal variations in habitat availability and use. For example, some sites in upper North Creek are not suitable for foraging by all species during neap tides and species movement between sites during ebb spring tides contributes to variation.

A good example of intra-tidal movement between foraging areas is provided by great knot (Figure 21). Great knots commence foraging at Serpentine but progressively move upstream as the tide recedes, which explains the large standard deviations at several sites and number of secondary sites. Secondary sites for great knot include North Creek south, Prospect and North Creek upper (Figure 20). A similar trend is evident for curlew sandpiper, although that species also foraged at mid-Richmond and Mobbs Bay outer (Figure 22).

Mid-Richmond is a primary foraging area for Pacific golden plover, bar-tailed godwit, eastern curlew and curlew sandpiper. Both Serpentine and mid-Richmond are regarded as priority foraging areas for eastern curlew and curlew sandpiper as they support the highest mean counts (Figures 19 and 22).

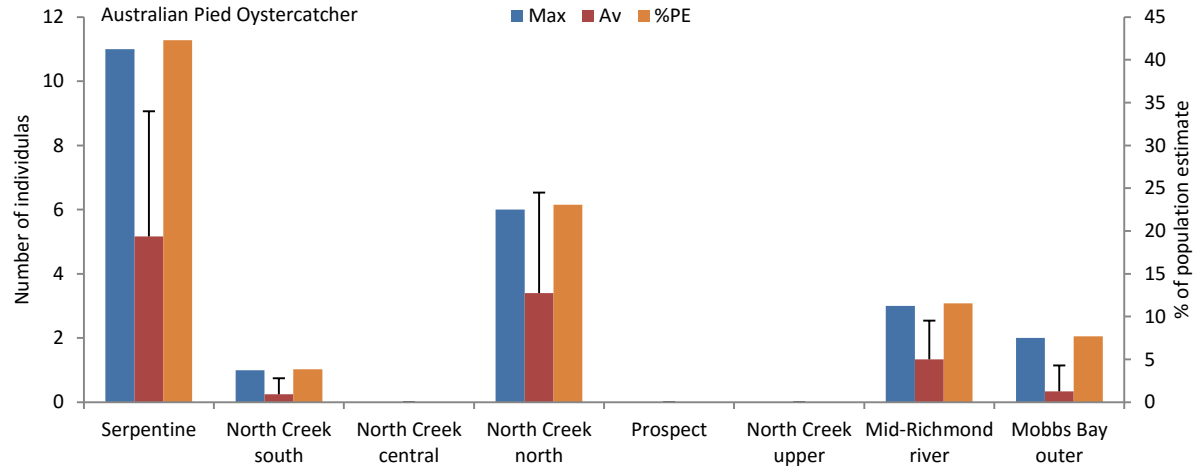

Figure 16: Comparison of maximum counts, mean counts and proportion of Australian pied oystercatcher population estimate recorded at eight foraging areas.

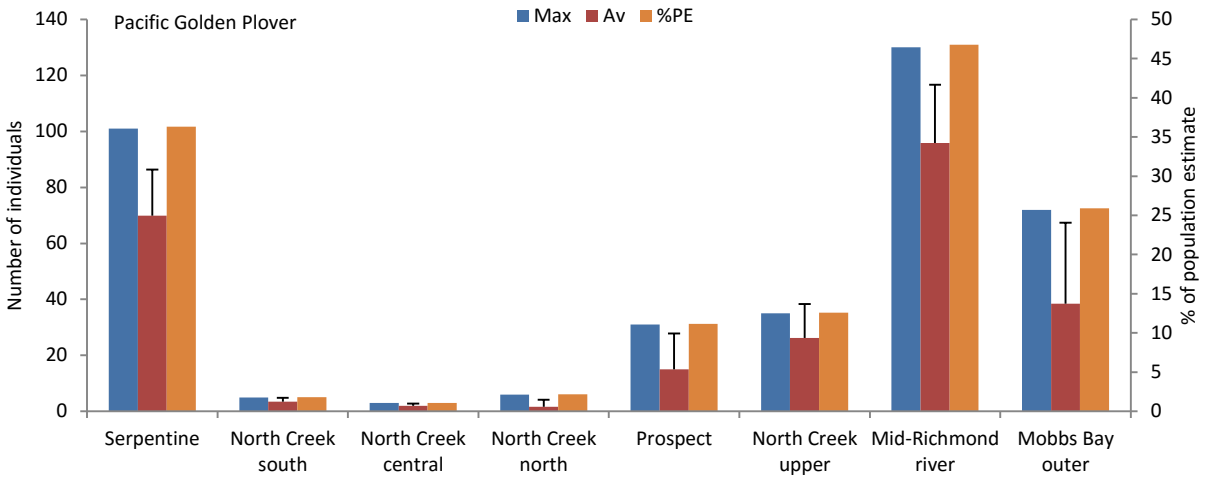

Figure 17: Comparison of maximum counts, mean counts and proportion of Pacific golden plover population estimate recorded at eight foraging areas.

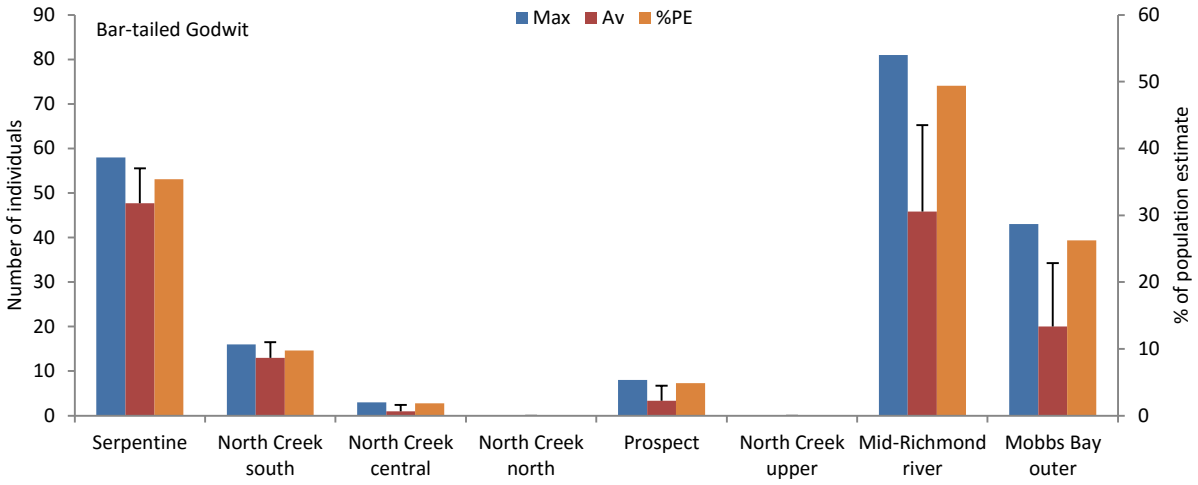

Figure 18: Comparison of maximum counts, mean counts and proportion of bar-tailed godwit population estimate recorded at eight foraging areas.

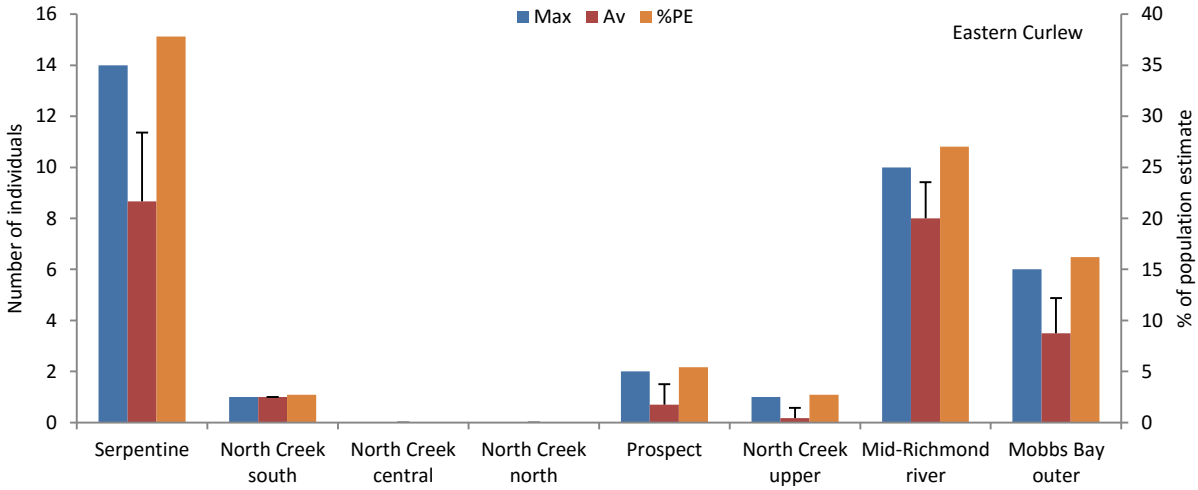

Figure 19: Comparison of maximum counts, mean counts and proportion of eastern curlew population estimate recorded at eight foraging areas.

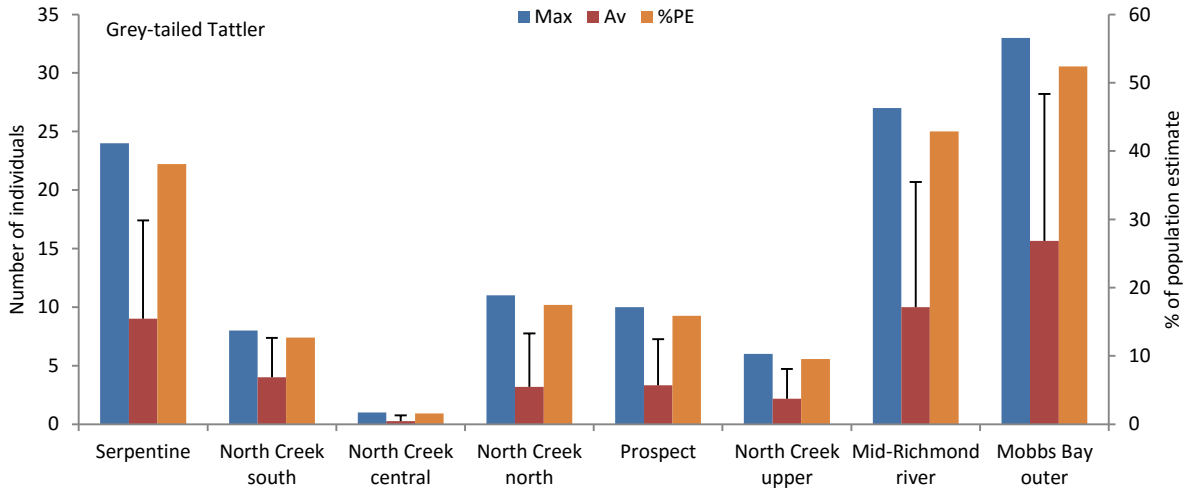

Figure 20: Comparison of maximum counts, mean counts and proportion of grey-tailed tattler population estimate recorded at eight foraging areas.

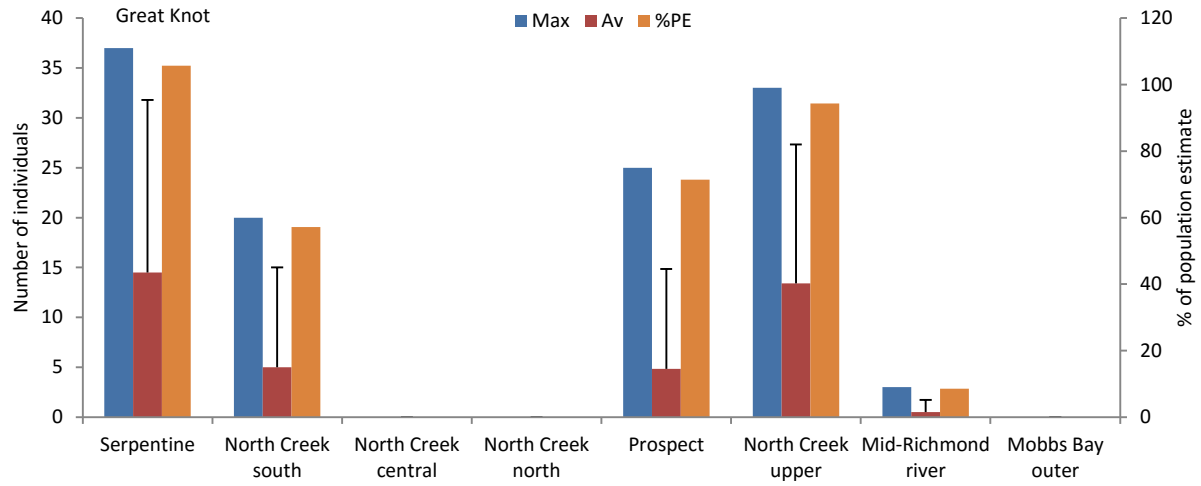

Figure 21: Comparison of maximum counts, mean counts and proportion of great knot population estimate recorded at eight foraging areas.

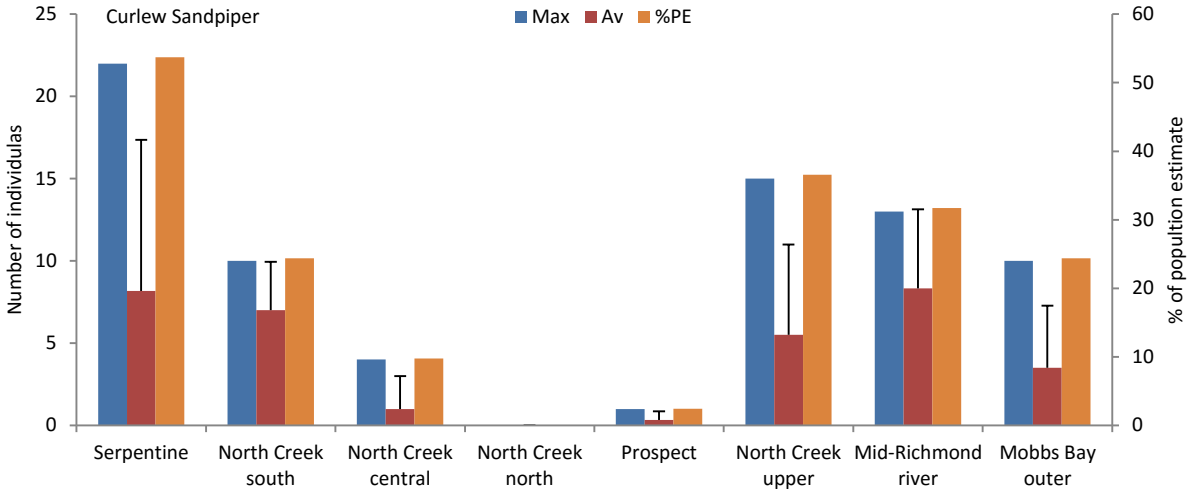

Figure 22: Comparison of maximum counts, mean counts and proportion of curlew sandpiper population estimate recorded at eight foraging areas.

4.5.4 Feeding density

The highest mean density of shorebirds at low tide was recorded at mid-Richmond (19.2 birds/ha), followed by Mobbs Bay outer (8.5 birds/ha), North Creek upper (8 birds/ha) and Serpentine (6.4 birds/ha) (Table 9). Density ranged from 13.97 to 24.73 birds/ha at mid-Richmond, 0.17 to 14.15 birds/ha at Mobbs Bay outer, 4.38 to 8.46 birds/ha at Serpentine and 0.81 to 13.51 birds/ha at North Creek upper (Table 10).

Table 10: Density of shorebirds at nine foraging areas in the Richmond River estuary. SD = standard deviation

Date	Serpentine	Serpentine west	NC south	NC central	NC north	Prospect	NC upper	Mid-Richmond	Mobbs Bay outer
2.2.16	8.46	0.00	0.00	0.00	0.00	0.28	8.38	22.14	0.17
3.2.16	7.16	5.11	0.00	0.00	0.26	0.50	0.81	24.73	11.44
4.2.16	4.38	4.67	3.16	0.75	2.89	2.96	11.08	13.97	7.63
8.2.16	6.57	7.11	9.47	0.75	5.00	2.40	7.84	20.23	13.39
14.2.16	6.02	2.89	5.96	1.19	3.16	3.18	13.51	17.40	4.32
22.2.16	5.52	0.89	8.60	1.34	2.89	5.20	6.35	17.02	14.15
Mean	6.4	3.4	4.5	0.7	2.4	2.4	8.0	19.2	8.5
SD	1.4	2.7	4.1	0.6	1.9	1.8	4.3	3.9	5.5

4.5.5 Feeding rates

Feeding rates of eastern curlew (P=0.157; df 1, 19), bar-tailed godwit (P=0.23; df 2,21) and Pacific golden plover (P=0.214; df 2,18) did not differ significantly between sites. Mean feeding rate (prey/five minutes) of eastern curlew was higher at Mid-Richmond (2.3 prey/5-minutes) than Serpentine (1.2 prey/5-minutes; Table 11). Feeding rate of bar-tailed godwit peaked at Prospect (8.3 prey/5-minutes), followed by Mid-Richmond (4.6 prey/5-minutes) and Serpentine (3.1 prey/5-minutes). At Prospect, bar-tailed godwits foraged predominantly on Polychaete worms, with soldier crabs being the dominant prey at Mid-Richmond and Serpentine (Table 11). Pacific golden plovers achieved similar feeding rates at Serpentine (2.4 prey/5-minutes) and Mid-Richmond (3 prey/five-minutes). The absence of significant differences is attributed to high variability in mean values, as shown by large standard deviations.

All three target species had lower feeding rates at Serpentine than Mid-Richmond and Prospect. This result fits with the lower feeding density of shorebirds at Serpentine and may indicate that the site is less productive than other intertidal habitats.

Table 11: Mean feeding rates and prey consumed by eastern curlew, bar-tailed godwit and Pacific golden plover at three sites in the Richmond estuary. M = mean; SD = standard deviation; n = sample size.

Species	Serpentine			Mid-Richmond			Prospect		
	M (n)	SD	Prey type	Mean	SD	Prey type	Mean	SD	Prey type
Eastern Curlew	1.2 (10)	1.9	Soldier crab.	2.3 (11)	2.2	Soldier crab; ghost shrimp.	NR	NR	NR
Bar-tailed Godwit	3.1 (8)	1.78	Soldier crab.	4.6 (10)	3.0	Soldier crab; molluscs	8.3 (6)	5.7	Polychaete worms; molluscs
Pacific Golden Plover	2.4 (10)	2.9	Soldier crabs; Sand bubbler crab	3.0 (6)	1.3	Soldier crab; shrimp	1.0 (5)	1.0	Unidentified crab

4.6 Habitat use

The purpose of habitat use sampling was to determine the extent that shorebirds utilise the Serpentine foraging area. These data could assist in identifying priority roost and foraging areas, which is essential to assess the potential effect of dredging.

4.6.1 Serpentine

Habitat use by seven species of shorebird during the low tide cycle was assessed at the Serpentine foraging area. Species surveyed included Australian pied oystercatcher, Pacific golden plover, bar-tailed godwit, eastern curlew, great knot, sanderling, and curlew sandpiper. Australian pied oystercatcher, great knot and sanderling were secondary target species, which were surveyed when time permitted. Although curlew sandpiper was a primary target species they occurred in small numbers and remained at the site only until upstream habitat was available.

The location of foraging and roosting individuals and groups is presented separately for each species (Figures 23 to 29). Dots represent individual birds or groups of birds that are foraging or roosting in a flock. The area covered by a group varied from 1 x 1m to 30 x 30m and group size was typically larger for roosting birds. All individuals in a group were displaying the same behaviour. The different coloured dots (shown on Figures 23 to 29) represent hourly stages of the low tide period, which extended from 2 hours after MHW (-4 on map) to two hours prior to MHW (i.e. 4 on map). Due to other survey commitments (i.e. low and high tide surveys & feeding surveys) most effort was expended in the -4 to (+) 2-hour sample period and greater sample effort occurred during the neap tide phase.

Some distinct patterns of habitat use were recorded, including:

1. The entire Serpentine intertidal area is used by shorebirds during low tide, with the exception of the more exposed sandspits that are used for roosting.
2. Apparent low use of the northeastern corner of the foraging area (i.e. extending from the tidal lagoon southeast to the Oyster shed) is due to human activity. Bait collectors and anglers utilised that area on most sample days.
3. Dispersal of species from primary roosts at Serpentine east and west as the tide recedes. Most common movement during the ebb tide was from Serpentine west to higher sandbanks north of that roost.
4. Use of staging (resting) areas during the early ebb (-3 & -2 hrs) and late flood (3 & 4 hr) tide periods. This pattern was displayed by all species but is most evident for bar-tailed godwit, Pacific golden plover, and eastern curlew.
5. The major staging areas occurred north of the Serpentine west roost, a central cluster of north-south aligned sandbanks and the western edge of the eastern roost.
6. Movement by a small number of individuals, of several species, to the sand flat west of North Creek during the ebb tide.

Patterns of behaviour for individual species included:

1. Australian pied oystercatcher were most commonly recorded roosting around the Serpentine east and west roosts, although individuals also roosted at the northern staging area and in the central sandbanks after being disturbed from the aforementioned areas (Figure 23). Pied oystercatchers occasionally foraged around the Serpentine west roost, on rocks at Serpentine west and on the central northern rocks. Some individuals moved upstream to forage on oyster beds at North creek north during spring low tides.
2. Pacific golden plover was one of the most common species at Serpentine and, despite some movement upstream during the ebb tide, a substantial number of individuals were present

throughout the entire low tide period. Plovers preferred to forage on dry and moist sand avoiding shallow water and immediately exposed sand. The species foraged over the entire sand flat (Figure 24). Individuals staged on the sand bank north of Serpentine west and dispersed from that area as the tide receded, returning to roost at the northern sand bank and Serpentine west during the latter stages of the flood tide. Roosting birds were also recorded throughout the central section of the sand flat.

3. Bar-tailed godwit was one of the most common species at Serpentine. Godwits displayed a broad foraging distribution that encompassed the entire sand flat (Figure 25). Individuals dispersed eastwards from the Serpentine west and northern staging roosts with small numbers moving to the western sand flat during the ebb tide. During the flood tide small flocks of godwits mainly staged at a central sandbar and the sandbank north of Serpentine west, although roosting birds were recorded throughout the area.
4. Eastern curlew typically moved from the Serpentine west roost to staging areas to the north, where they roosted briefly before foraging on recently exposed substrate and in shallow water. Curlews returned to that area to roost in the later stage of the flood tide (Figure 26). The results show that curlews forage over the entire Serpentine flat but most foraging activity occurred in the western half of the sand flat. The results are biased by neap tide data and human disturbance.
5. Great knot were recorded foraging in shallow water and recently exposed sand near staging areas and the eastern shoreline. Due to their habit of foraging in flocks most feeding records of great knots were of groups. During neap tides knots roosted at staging areas during the early ebb and late flood tides.
6. Sanderlings occurred in small numbers (8 individuals) at Serpentine. Individuals were mostly recorded roosting but some foraging activity occurred on moist substrate in the central western half of the site and birds roosted at Serpentine west and the northern staging area (Figure 28). Sanderlings did not move from Serpentine to upstream foraging areas.
7. Curlew sandpipers occurred in low numbers (22 individuals) at Serpentine. Individuals were recorded foraging in small flocks across the northern half of the site, around the Serpentine west roost and on the western sandbar (Figure 29). Most foraging activity occurred during the ebb tide and the species had typically moved to upstream habitats by MLW.

4.6.2 Prospect

Foraging observations at Prospect occurred during a single low tide period and were concentrated on the eastern third of the intertidal area. Consequently the data provide only a preliminary indication of habitat use. Pacific golden plover, bar-tailed godwit, eastern curlew and great knot were surveyed at Prospect. Data for the latter species are not included as there were only two data points.

The Prospect intertidal area contains a variety of habitats, including soft mud adjoining mangrove forest, dense seagrass beds that are exposed during spring low tides sandy mud interspersed with seagrass and muddy sand. The latter substrate occurs primarily along the eastern side. Shallow channels dominated by seagrass separate areas of bare sand and mud. During neap low tides very little foraging habitat is available and shorebird activity was concentrated along the western mangrove fringe and eastern sandbank. During spring low tides a substantial area of intertidal

habitat is exposed and birds disperse from the western fringe to central and eastern seagrass beds. Individuals moving upstream, as the tide recedes, disperse from the eastern sandbar.

Shorebirds initially commenced foraging on the eastern side of Prospect in the last hour before MLW. Foraging was initially concentrated on the higher elevation sandbank, with individuals moving into seagrass beds at MLW and in the first hour after MLW (Figures 30 to 32). Observations at Prospect ended before the site was covered by the flood tide. Based on the data collected, and previous observations, it is likely that birds would continue to forage over the entire eastern section of the prospect foraging area whilst habitat was exposed. As the tide rises birds would most likely be forced back towards the higher sandbank before moving to roosts.

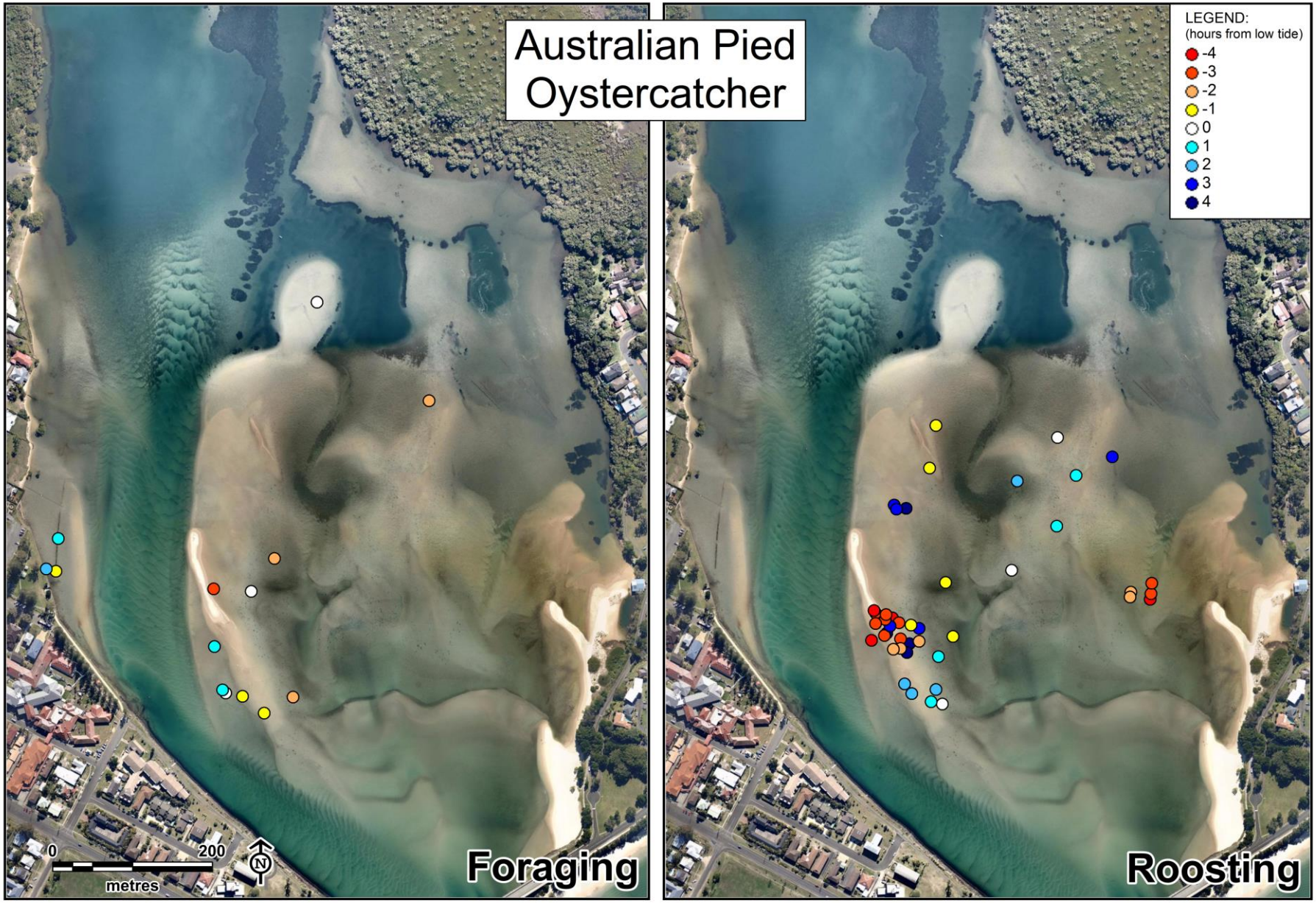

Figure 23: Habitat use by Australian pied oystercatcher at the Serpentine.

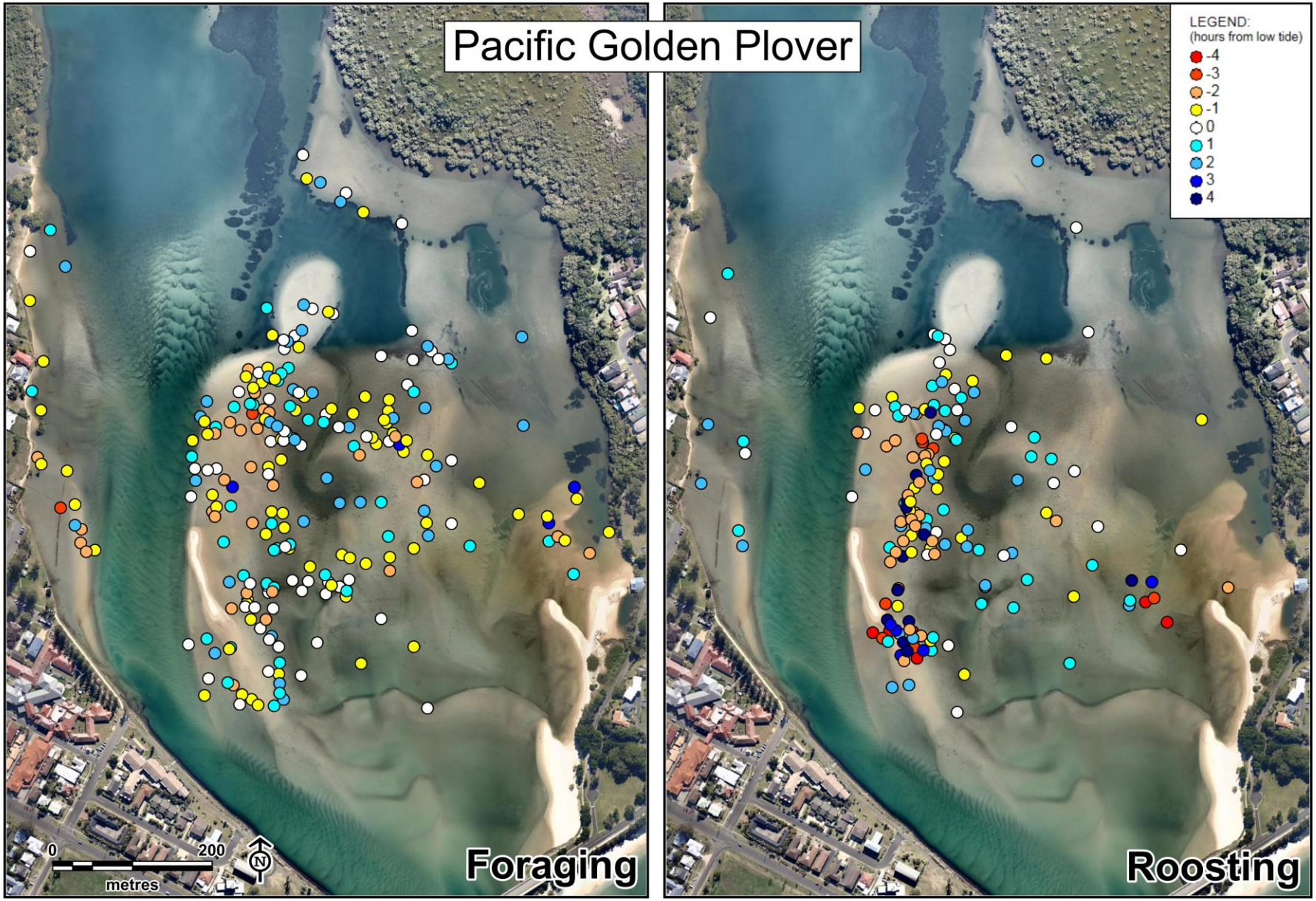

Figure 24: Habitat use by Pacific golden plover at the Serpentine.

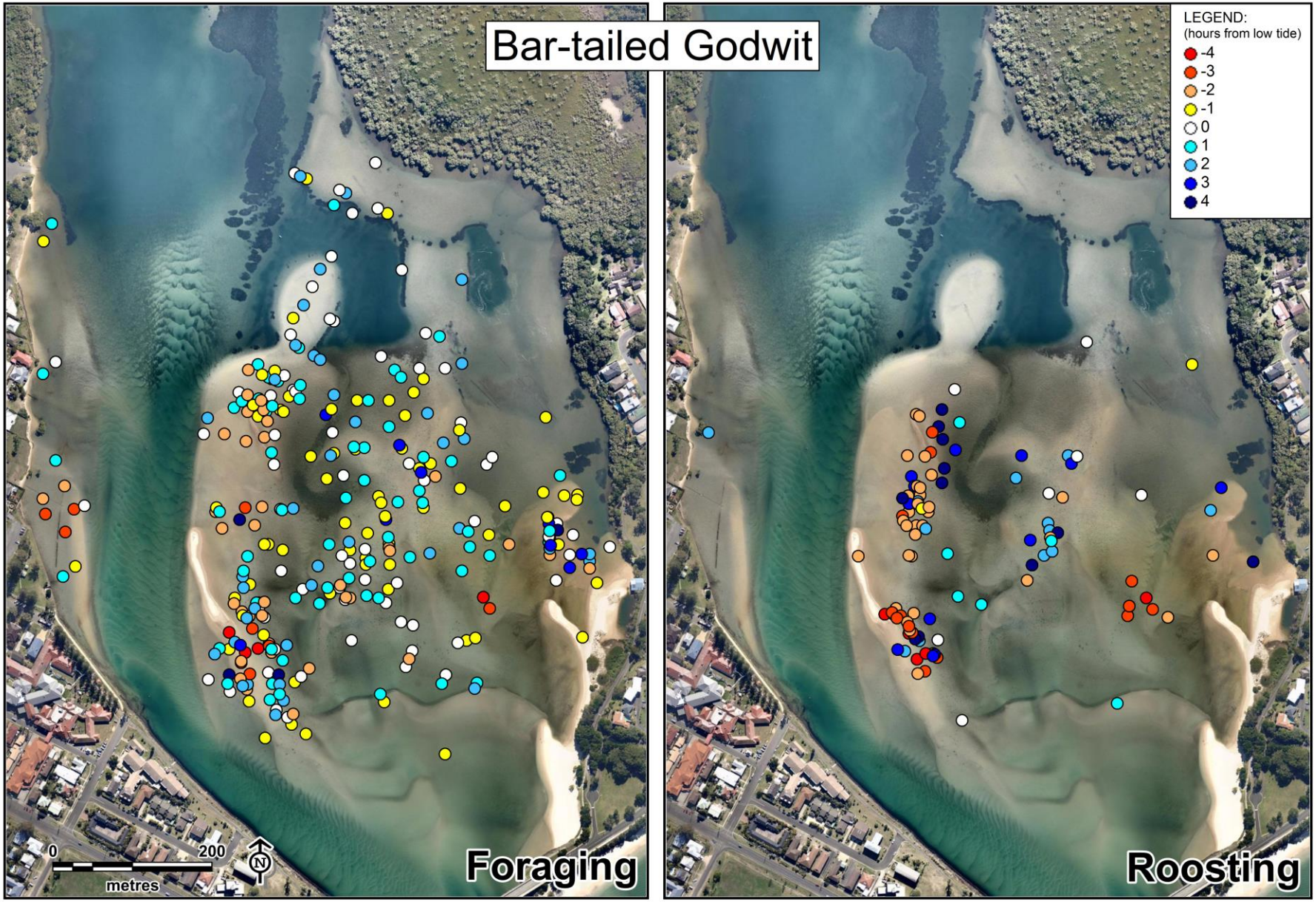

Figure 25: Habitat use by bar-tailed godwit at the Serpentine.

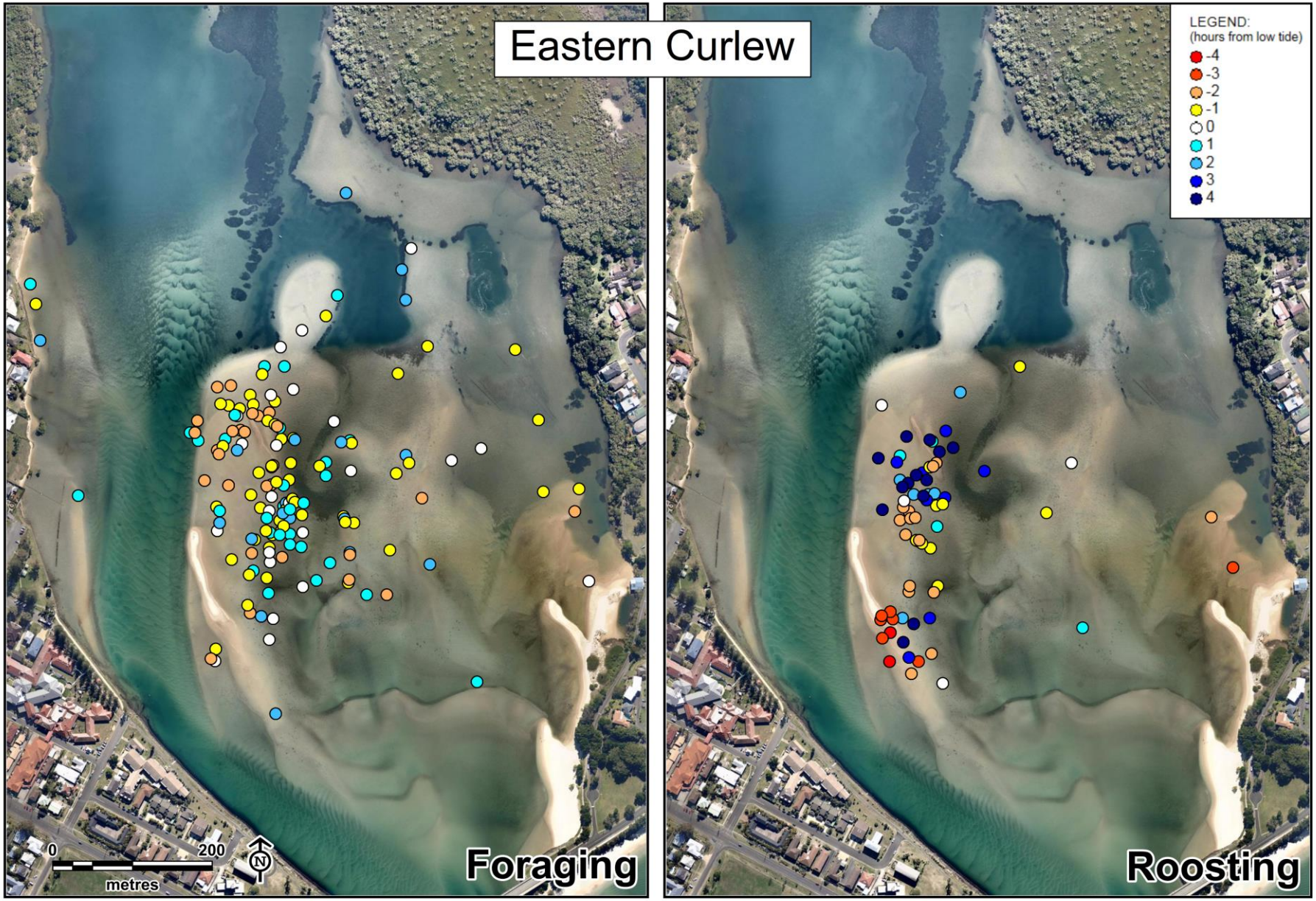

Figure 26: Habitat use by eastern curlew at the Serpentine.

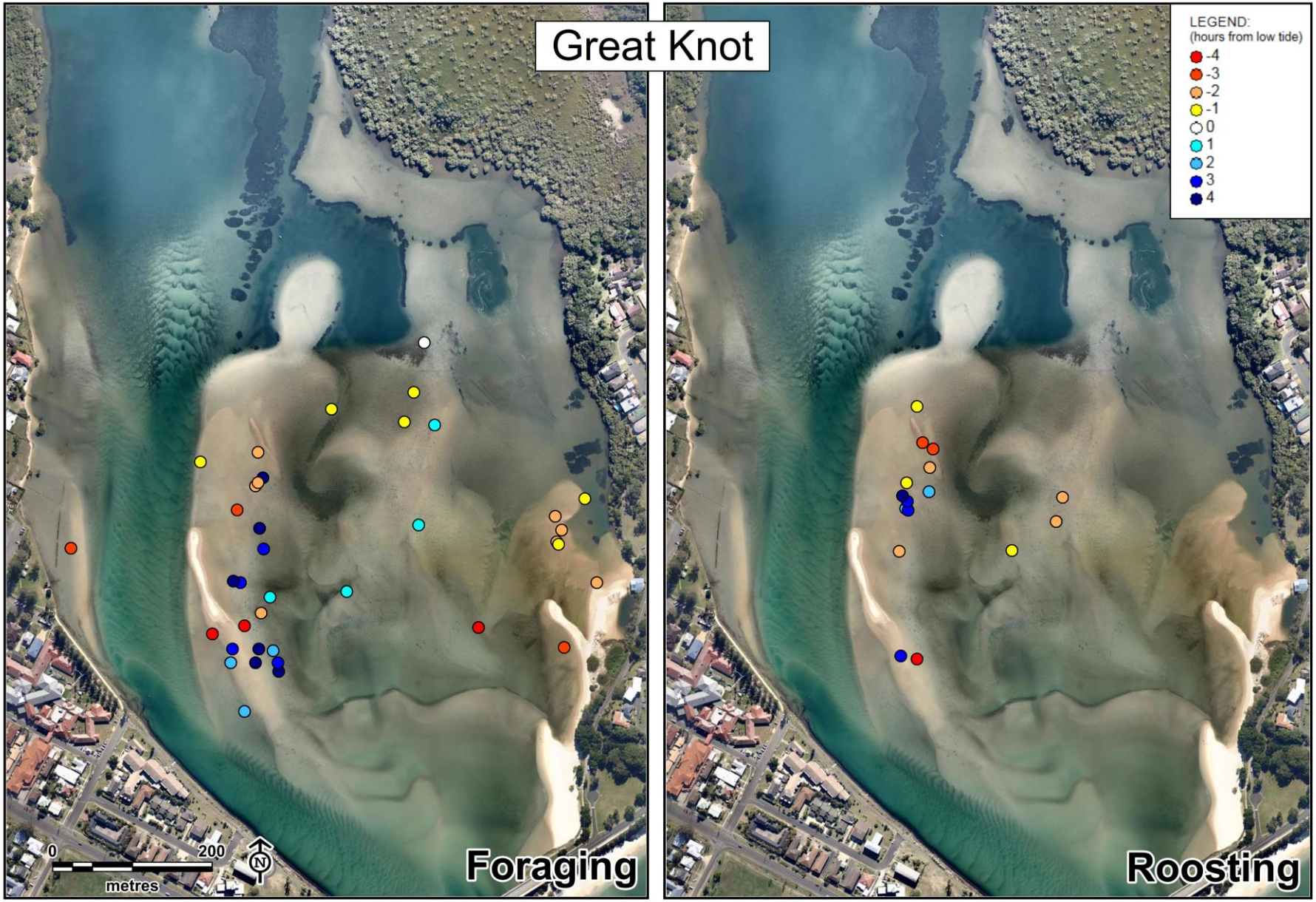

Figure 27: Habitat use by great knot at the Serpentine.

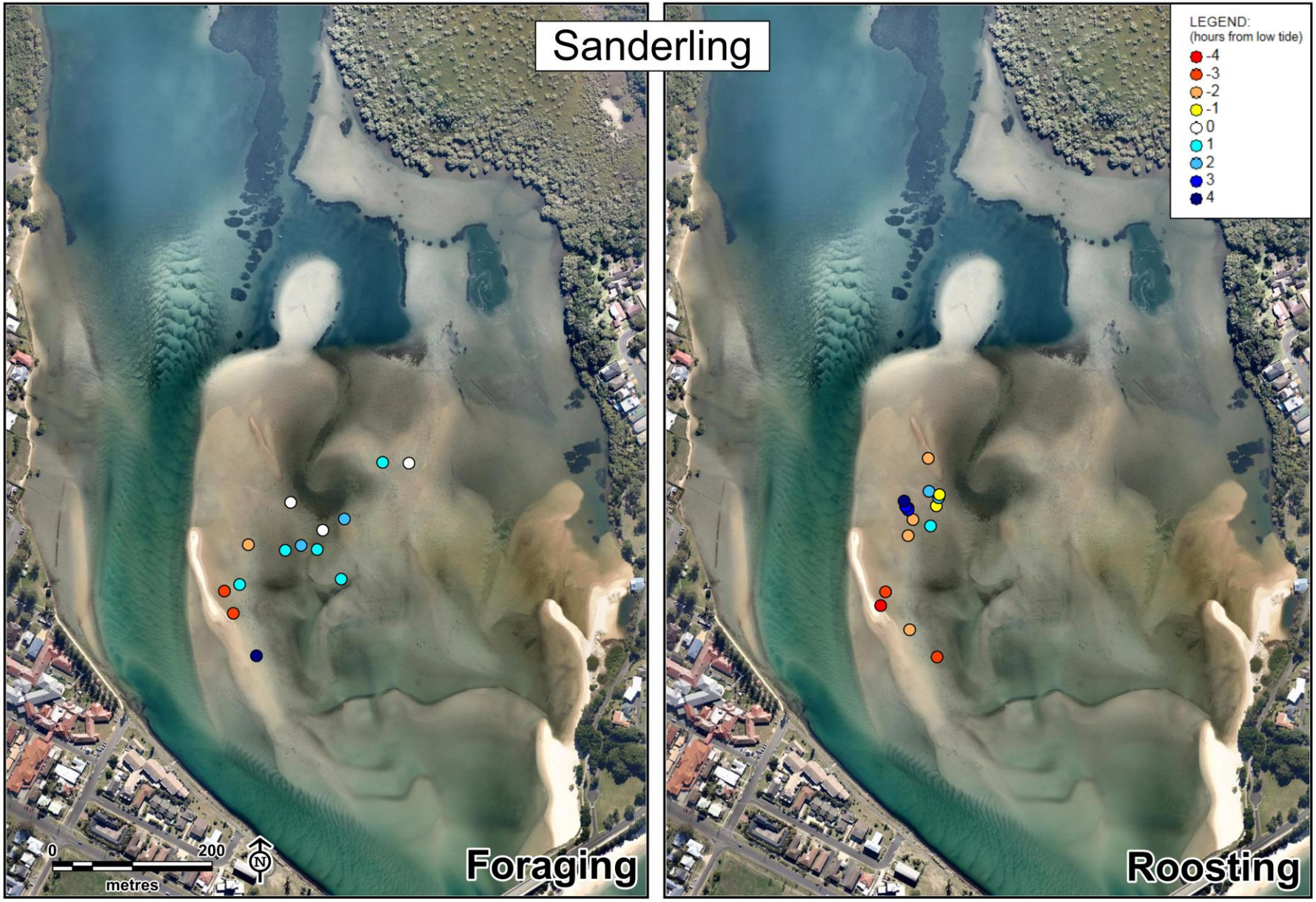

Figure 28: Habitat use by sanderling at the Serpentine.

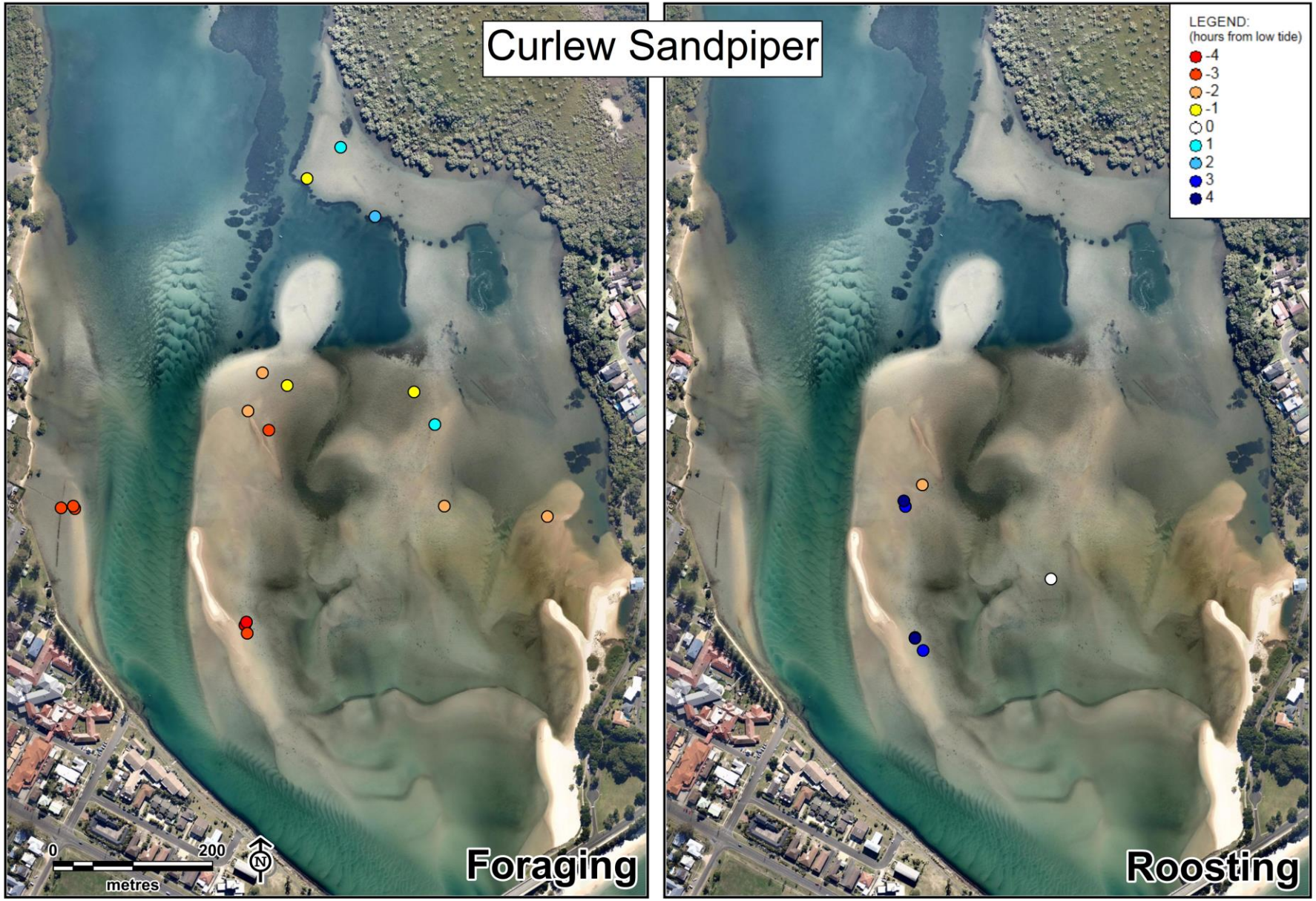

Figure 29: Habitat use by curlew sandpiper at the Serpentine.

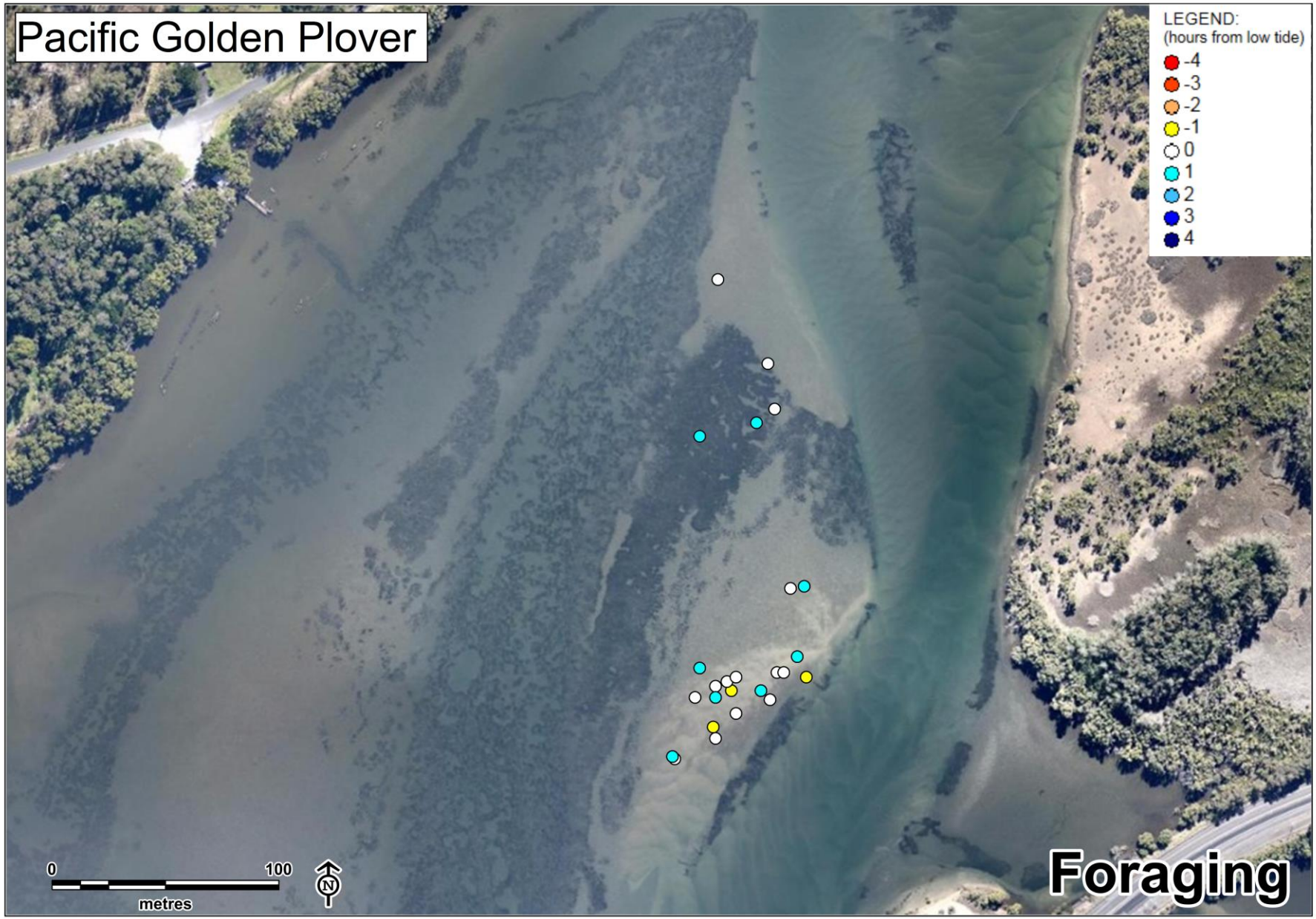

Figure 30: Habitat use by Pacific golden plover at Prospect.

Figure 31: Habitat use by bar-tailed godwit at Prospect.

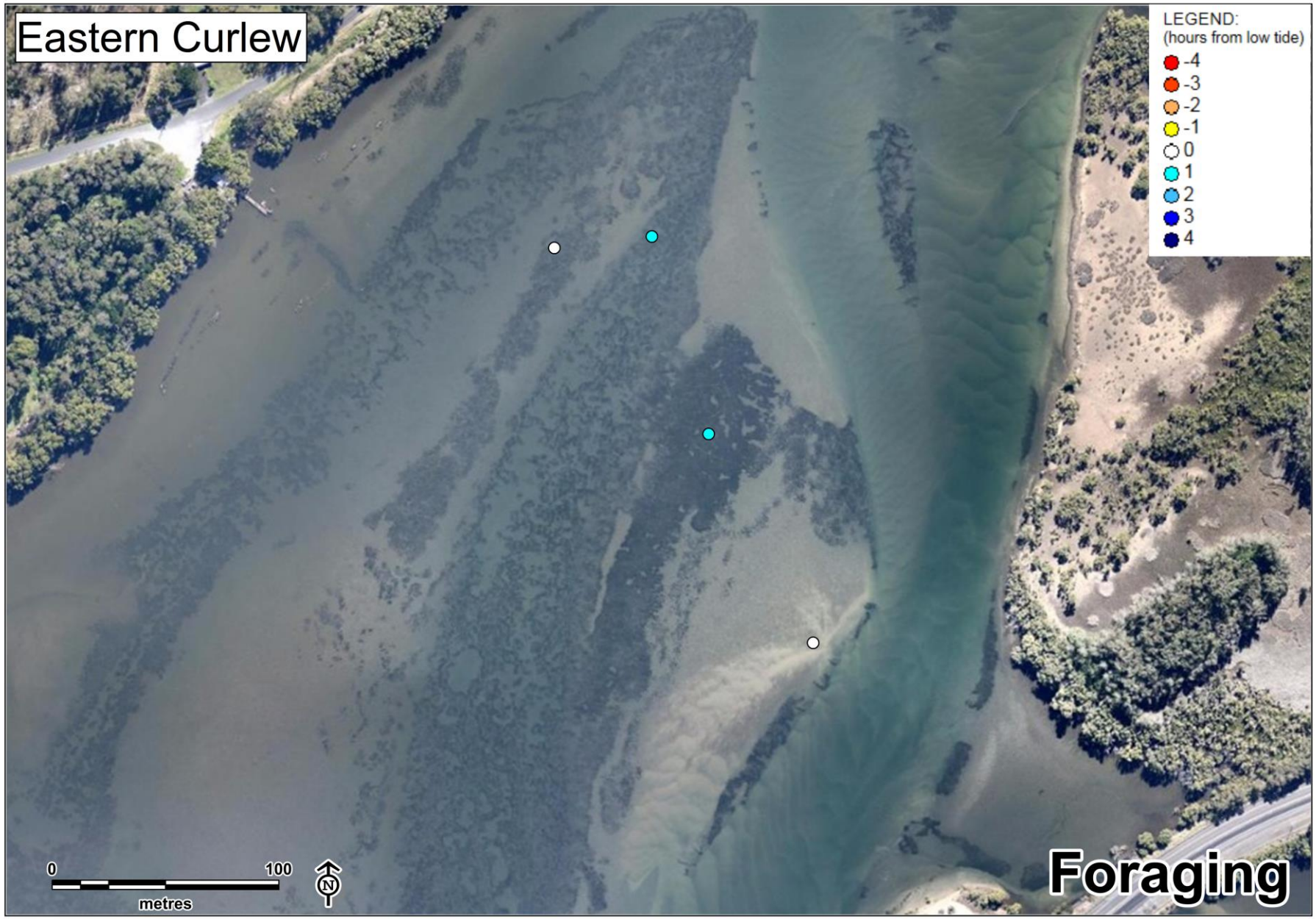

Figure 32: Habitat use by eastern curlew at Prospect.

5. Discussion

5.1 Importance of North Creek for shorebirds

5.1.1 Local, regional and state importance

Sandpiper Ecological (2010) concluded that the Richmond and Clarence estuaries were the most important sites for shorebirds in the Northern Rivers Catchment Management Authority (NRCMA) area. Analysis of available count data showed that the Richmond Estuary was the most important site for greater sand plover, terek sandpiper and sanderling and the second most important site for lesser sand plover and great knot (Sandpiper Ecological 2010). That assessment did not include eastern curlew or curlew sandpiper as they were not listed at the time, however, the Richmond estuary would have rated highly for both species. The conclusion is consistent with earlier assessments of conservation value conducted by Smith (1991) and Straw (2006). Lisson (2015) analysed 34 years of count data for the Richmond Estuary and concluded that the site has supported Nationally significant populations of eight species in the past five years (i.e. 2011-2015).

A substantial proportion of the Richmond Estuary's shorebird population utilise habitat in North Creek for roosting and foraging. During this study between 23% and 36% of the estuary's shorebird population was recorded foraging in North Creek and up to 24% of shorebirds were roosting in North Creek. These proportions are based on the maximum population estimate of 1162 individuals during the sample period. The proportion of birds roosting in North Creek during a single high tide survey ranged from 6% to 38%.

Clemens *et al.* (2008a & b) established criteria for assessing the conservation value of shorebird sites at various spatial scales. These criteria either followed or have been added to by DEWHA (2009a), Bamford *et al.* (2008) and Ramsar (2005). DEWHA (2009a) added one additional criteria "Supports 15 shorebird species". That criterion relates to migratory species only. "Support" is defined as: *migratory shorebirds are recorded during surveys and/or known to have occurred within the area during the previous five years*.

Data collected at North Creek during the baseline surveys was assessed against International, National, State and Regional criteria (Table 10). The assessment indicates that North Creek is of State and Regional significance as it supports threatened shorebird species and is situated in an area where the shorebird population is known to be declining (Table 12; Lisson 2015). Fourteen species of migratory shorebird (including double-banded plover) were recorded in North Creek in February 2016. Using these data the site does not satisfy the DEWHA (2009a) criteria, of 15 (migratory) species, for National significance. However, other migratory species, including terek sandpiper, ruddy turnstone, red knot and marsh sandpiper, have previously been recorded in North Creek (D. Rohweder pers obs). Lisson (2015) also recorded 14 migratory species in North Creek, including red knot, which was not recorded in this study. A review of count data over the previous five years is required to confirm if North Creek satisfies the threshold for National significance. Irrespective, North Creek is a critical component of the Nationally significant Richmond Estuary.

Table 12: Criteria used to determine the significance of shorebird sites at four spatial scales.

Geographic Scale	Source	Accepted Criteria	North Creek
International	Ramsar (2005)	Criterion 5 - The wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds Criterion 6 - The wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.	North Creek does not support more than 20,000 waterbirds, 1% of the population of a species or 0.25% of the population during a migration period. **North Creek is not of international importance for shorebirds.**
	East Asian-Australasian Shorebird Action Plan	Adopted criterion 6 as described above (Ramsar 2005).	
	Bamford *et al.* (2009)	Adopted criterion 6 as described above (Ramsar 2005) and identified a new criterion for identifying staging areas of international importance: 0.25% of a population as the staging criterion. This criterion could apply only during the migration period and the site must be along the migration route of the species.	
National	Clemens *et al* (2008)	Regularly supports greater than 2,000 shorebirds; and Regularly supports greater than 0.1% of the flyway population estimate for at least one migratory shorebird species or sub-species.	North Creek does not regularly support more than 2000 shorebirds or 0.1% of the flyway population of any migratory shorebird species.
	DEWHA (2009)	Adopted the same criteria as above and added one additional criterion: Supports 15 shorebird species	**In February 2016 North Creek & Serpentine supported 14 migratory species.**
State	Clemens *et al.* (2008)	A shorebird area is of state significance if it: Is significant at the National level; Exhibits significant decline in: a) the total number of shorebirds; or b) populations of any species, not known to be experiencing declines more broadly; or Supports threatened or endangered shorebird species; or Supports greater than 1% of the population of any resident Australian shorebird species.	No quantitative evidence of population declines; declines in abundance of individual species consistent with broader trends. **North Creek supports critically endangered eastern curlew, curlew sandpiper, and great knot; endangered lesser sand plover; and vulnerable greater sand plover and bar-tailed godwit. Therefore, North Creek and Serpentine are of state significance for migratory shorebirds.**
Regional	Clemens *et al.* (2008)	A shorebird area is of regional significance if it: Has associated records of 15 or more species of migratory shorebird; Has associated records of 20 or more migratory and resident shorebirds; or Forms one of three most abundant shorebird areas, within each Natural Resource Management boundary, for any of the following species: Latham's Snipe, Little curlew, Oriental Plover, Oriental Pratincole and Australian Pratincole; Areas that support threatened species or endangered shorebirds; or Areas that support greater than 1% of the Australian population of any resident shorebird species.	North Creek has records of >20 species of migratory and resident shorebird; & supports 2 Federally listed and 5 state listed threatened species. Serpentine supports 2 Federally listed and 5 state listed threatened species **North Creek and Serpentine are of regional significance.**

There is no published comparison of temporal trends in the Richmond Estuary's shorebird population, although general comparison suggests that the summer population has decreased from about 1400 in the mid 1990's to about 1200 in February 2016. Count data for individual species shows that some have increased, whilst others have declined. Comparison of count data from February 2016 with data collected in February 1993, 1994, 1995 and 1996 provides a broad indication of population trends and indicates that the abundance of some species has declined over the past 20 years. Comparable methods were used to collect all data (see Rohweder 2000), although greater effort was expended in 2016.

The comparison shows that the number of eastern curlew has decreased by 62%, curlew sandpiper by 63%, sanderling by 85%, lesser sand plover by 86%, greater sand plover by 93%, terek sandpiper by 57% and great knot by 14%. The scale of these declines is consistent with the 73% decline reported by Nebel *et al.* (2008) for migratory shorebirds across Australia and the 43-79% declines of up to 11 species in Moreton Bay (Wilson *et al.* 2011). The result is not consistent with Lisson (2015) who recorded a significant decline in summer abundance of two migratory species, lesser sand plover and sharp-tailed sandpiper and a significant increase in summer abundance of great knot and Pacific golden plover.

According to DotE (2015) the population of lesser sand plover in Australia has declined by 74.8% over the 24 years to 2014. The decline is primarily attributed to the loss of migration staging habitat in the Yellow Sea but local factors such as coastal development, human disturbance and habitat degradation also contribute to declines (DotE 2015). No evidence of population declines by sharp-tailed sandpiper could be obtained.

Lisson (2015) also compared species population trends between the Richmond, Tweed, Clarence and Hastings estuary's. The analysis showed that populations of several species were stable in the Richmond but declining elsewhere. Whilst this analysis appears robust the manner in which differences in effort and sample methods between estuaries was accounted for requires further scrutiny. Furthermore, the influence of zero values for some species in the early 1980's on analysis results should be clarified. Based on the analysis of Lisson (2015) there is quantifiable evidence that some species have decreased in abundance, although overall the Richmond populations have performed better than other nearby estuaries.

5.1.2 Importance of individual sites in North Creek

The small size of North Creek and proximity of roost and foraging areas limits the merit of individual site assessments. Assessing sites separately assumes that each site individually provides a function to the local shorebird community and ignores the interrelationships between sites. For example, the movement of shorebirds upstream from Serpentine to upper North Creek, as the tide recedes, shows the interrelationship between sites. Intertidal foraging areas in North Creek should be viewed as a matrix of interconnected habitats that are used to varying degrees over a lunar cycle rather than individual units. It is the matrix of habitats available that contribute to the areas conservation value for the local shorebird community

Likewise, some roosts may not be used during all high tides but may provide an important function during bad weather or times of high human disturbance. Removal of one roost or foraging site

would have broader impacts on the local shorebird community than suggested by data collected at a single time period. For the purpose of this report and to enable further assessment of the value of individual sites potentially affected by dredging some discussion of individual site importance has been included.

In February 2016 the Serpentine roosts and foraging area supported 14 migratory and four resident shorebird species, including seven threatened species. Based on DEWHA (2009a) and Clemens (2008a & b) the Serpentine satisfies State and Regional conservation criteria. Furthermore, the Serpentine provides roosting and foraging habitat for three nationally listed critically endangered species, eastern curlew, curlew sandpiper and great knot, one endangered species, lesser sand plover, and one vulnerable species bar-tailed godwit. These species have experienced severe population declines in the East-Asian Australasian Flyway (Reid & Park 2003; Gosbell & Clemens 2006). North Creek south, Prospect and upper North Creek intertidal areas also satisfy State and Regional conservation criteria due to the presence of threatened species. Inclusion of a longer-term dataset is likely to show that Serpentine and Prospect support >15 migratory shorebird species and would therefore satisfy National conservation criteria.

Data collected during this study shows that, at low tide, the Serpentine sand flat rates equal first in number of migratory species, equal first in number of shorebird species and second in number of threatened species in the Richmond Estuary. These findings are consistent with Lisson (2015) who ranked the Serpentine sand flat second in terms of habitat value in the Richmond Estuary behind Mobbs Bay outer. Lisson (2015) found that Serpentine had the highest species richness and 3rd highest mean number of individuals in the Richmond Estuary.

The Serpentine is one of two major foraging areas available during neap low tides and is proximal to spring and neap high tide roosts at Serpentine east and west. At high tide, the Serpentine roosts supported the second highest species richness of migratory shorebirds and richness of threatened species and, at times, support >30% of the local populations of eight species, including 100% of the sanderling, great knot and lesser sand plover populations, and 41% and 45% of the curlew sandpiper and eastern curlew populations in the Richmond estuary.

The combined intertidal foraging area and roosts, at the Serpentine, are critically important to the Richmond Estuary's shorebird population. Neap tide foraging areas provide a food resource at a time of resource shortage and proximity of roosts to foraging areas reduces energy expenditure. Although the Serpentine west roost is available during neap high tides only it likely provides a valuable function to the annual energy budget of local shorebirds by reducing energy expenditure during 25-50% of days.

Another important feature of the Serpentine intertidal area is its use as a mid-tide staging area by several species. During spring low tides, eastern curlew, curlew sandpiper, great knot and bar-tailed godwit initially congregate at Serpentine before moving to upstream sites such as North Creek south, Prospect and North creek upper as they become exposed. The upstream movement of shorebirds at low tide means that low tide counts at a single time period do not capture the full importance of a site. Systematic surveys throughout the low tide period are required to gain a thorough understanding of a sites importance.

North Creek rocks was the only other important roost in North Creek during this study. Other roosts that have been used previously include Prospect bridge groyne and Prospect saltmarsh. The latter site supported small numbers of eastern curlew and whimbrel during spring tides in the mid 2000's (D. Rohweder pers obs).

North Creek south, Prospect and North Creek upper are also important foraging areas and represent key components of shorebird habitat in North Creek. Lisson (2015) rated the Prospect intertidal area as the fourth most important low tide site in the estuary. In the context of North Creek, the Prospect intertidal area is regarded as an essential foraging area.

5.1.3 Nocturnal behaviour

Shorebirds forage irrespective of whether it is day or night (McNeil *et al.* 1992), although there are subtle differences in selection of roost and feeding areas between the two periods (Rohweder & Baverstock 1996; Rohweder 2001). Nocturnal behaviour was not investigated during this study, however, previous surveys have shown that both Serpentine and Prospect intertidal areas are used at night (Rohweder 2000). For the purpose of this assessment it is assumed that habitat use and species distribution in North Creek is equivalent between day and night.

Consideration of nocturnal habitat use is important as human disturbance tends to be less at night and sites such as Serpentine, that experience high levels of disturbance during the day, are likely to provide an important function as nocturnal roost and foraging habitat. This function may be critical to the overall energy budget and contribute to a species local viability. One of the key values of the Serpentine is the proximity of roost and foraging areas, which means that birds need to fly only short distances to roost or forage.

5.1.4 Human disturbance

Human disturbance has a substantial negative impact on roosting and foraging shorebirds (Pfister *et al.* 1992), although interactions are complex (see Peters & Otis 2007; Yasue 2005). The primary effect of disturbance is that it increases energy expenditure and therefore influences the ability of shorebirds to successfully migrate. Most shorebird habitats in the lower Richmond Estuary are subject to human disturbance. Disturbance peaks at ocean beach and sandy estuarine habitats, such as Serpentine (east & west), mid-Richmond and Mobbs Bay. Roosts in the upper estuary and feeding areas with muddy substrates tend to be least disturbed. The highest value roost and foraging areas in the Richmond estuary experience high levels of disturbance. Although human disturbance detracts from the value of these sites for shorebirds the presence of disturbance does not detract from conservation value as all sites are equally disturbed.

In the case of Serpentine, which probably experiences greater disturbance than other roost and foraging habitat in the estuary, human disturbance causes birds to abandon the site. The effect of disturbance is most pronounced at roosts, as birds have no option but to abandon the site. At low tide birds can move around tidal flats, although repeated disturbance is likely to disrupt foraging and have a detrimental effect on food intake.

Lisson (2015) applied a habitat/disturbance matrix to foraging habitat in the Richmond estuary. The matrix enabled sites to be ranked in order of conservation significance by using a combination of

habitat value and disturbance risk. The highest ranked site was Serpentine with Serpentine west ranked 3rd and Prospect 4th. Dredging has the potential to isolate foraging habitat and therefore reduce disturbance by making some habitat inaccessible to pedestrians and dogs. Isolated areas would still be accessible to boats and other craft and the smaller area of habitat means that areas accessible to pedestrians may experience higher levels of disturbance.

5.2 Habitat use

The primary factor influencing a shorebirds choice of feeding site is the need to maximise energy intake and minimise energy expenditure (McNeil *et al.* 1992 & Piersma *et al.* 1993). Shorebirds try to achieve this by foraging at sites where they can optimise their energy consumption. There are a number of factors that influence energy consumption, including prey density, competition, disturbance and proximity of roosts to foraging areas.

Observation of shorebird movement across the Serpentine sand flat during the low tide period showed that most of the intertidal area was used for foraging. Whilst there is likely to be micro-scale variation in habitat use associated with prey density and distribution the study was sufficient to conclude that the entire Serpentine sand flat is used by shorebirds. A detailed analysis of prey distribution would be required to identify fine scale patterns of habitat use. Such a study is beyond the scope of this assessment and probably unnecessary to assess the impact of proposed dredging.

The Serpentine sand flat contains a mix of foraging substrates, ranging from soft muddy sand along the northern shoreline to more compacted sand in the south. The southern end of the flat is subject to stronger tidal and wind currents and may consist of coarser grained sediment typical of higher energy estuarine environments (Underwood and Chapman 1995). Yates *et al.* (1993) found that sediment particle size distribution influenced invertebrate prey density and was a good predictor of shorebird density. Such a pattern may also occur at Serpentine, where general observation suggests that a higher density of shorebirds forage on finer sediments. At Serpentine, north-south aligned, sand bars become exposed in the southern section during the latter stages of ebb spring tides. Areas of shallow water separate these sand bars. During this study, small numbers of bar-tailed godwit and occasional Pacific golden plover and eastern curlew were recorded foraging on the sand bars, along the waters edge and in shallow water, but feeding density was lower than elsewhere. The southern section of tidal flat is predicted to contain a lower density of prey and therefore may be less important than the central and northern sections of flat.

Although the Serpentine supports birds throughout the low tide period, its importance peaks during neap low tides, when it is one of only two major foraging areas in the Richmond estuary, and during the ebb tide, prior to exposure of upstream sites. Serpentine may also be an important nocturnal foraging area for sight feeding species, such as greater and lesser sand plovers, eastern curlew and Pacific golden plover. These species may achieve higher feeding rates at Serpentine due to elevated light levels from surrounding urban areas (Rohweder 2000). The southern section of tidal flat tends to be inundated during neap low tides and only becomes exposed during the latter stage of ebb spring tides.

Other key observations from the habitat use study were the presence of several staging areas and movement of shorebirds from the Serpentine to upstream tidal flats as the tide recedes. Staging

areas provide important resting points during the ebb and flood tides when foraging habitat is unavailable. These mid-tide roosts alleviate the competition for space that occurs at high tide roosts and provide alternate resting points during periods of disturbance. In the context of the Richmond estuary, where human disturbance is high, staging roosts provide an important function.

The Serpentine intertidal area represents the starting point for most shorebirds foraging in North Creek. Movement of shorebirds onto recently exposed habitat is a response to maximise energy intake. This is related to two factors, firstly, dispersal over tidal flats reduces competition and, secondly, prey can be more abundant during the early ebb tide and in different habitats. In North Creek shorebirds capitalise on this by moving to sites as soon as they are exposed and using seagrass and muddy substrates.

The Prospect intertidal area also provides an important function as it is the second largest foraging area in North Creek. Its location upstream enables birds to firstly exploit the Serpentine and North Creek south areas before moving to invertebrate rich seagrass and muddy sand habitats at Prospect.

5.3 Key risks and impacts associated with dredging

5.3.1 Key features of shorebird habitat

Key features of shorebird habitat in North Creek that represent a risk to the dredging proposal include:

- Use of roost and foraging habitat in North Creek by a substantial proportion of the estuary population of several federally listed threatened species: eastern curlew, curlew sandpiper, great knot (all critically endangered), lesser sand plover (endangered), greater sand plover and bar-tailed godwit (vulnerable).
- Use of roost and foraging habitat in North Creek by a substantial proportion of the estuary population of several state listed threatened species: Australian pied oystercatcher, and curlew sandpiper (endangered), greater sand plover, lesser sand plover, great knot, and sanderling (vulnerable).
- Proximity of neap (Serpentine west) and spring tide (Serpentine east) roosts to foraging habitat (Serpentine sand flat).
- Predicted importance of Serpentine east and west as nocturnal roosts.
- Presence of neap low tide foraging habitat (Serpentine).
- Presence of early ebb, and low tide foraging habitat (i.e. Serpentine sand flat) situated in the lower estuary.

Specific information on how shorebirds utilise the matrix of roost and foraging areas in the estuary and how diurnal and tidal variations influence habitat use and the daily and annual energy budget of migratory shorebirds in the Richmond Estuary is unknown. Human disturbance acts as a confounding variable due to its unpredictable nature. Neap tide roosts have typically been regarded as less important than spring tide roosts as they are available when space is less restricted. In contrast, spring tide roosts are used when space is limited and the effect of disturbance greatest. In the case of the Richmond estuary, all major roosts are disturbed by humans and are therefore valuable. Neap roosts, such as Serpentine west, provide a critical function by allowing birds to roost close to foraging areas during 25-50% of high tides.

Quantifying the effect of removing a neap tide roost or a section of foraging habitat is difficult without understanding the energetics of habitat use. For example, daytime observations indicate that Serpentine west is functional during neap high tides only and Serpentine east during spring high tides, and both roosts are negatively affected by human recreation. The true value of these sites can only be determined by studying the benefit provided on days of low disturbance, at night, and as staging roosts. Even though the Serpentine roosts may be disturbed on 90% of daytime high tides in summer, their value to the annual energy budget of shorebirds may be in the 10% of undisturbed days. In summary, partial availability of a site and human disturbance is not justification for concluding low importance.

5.3.2 Impact of dredging on shorebirds

Shorebirds display complex patterns of habitat use and quantifying impacts by dividing the shorebird population by the proportion of habitat impacted ignores this complexity. As noted above the Serpentine sand flat provides a variety of functions for the local shorebird community. A comprehensive assessment of impacts is beyond the scope of this report and would be premature given the preliminary nature of existing hydrodynamic and sediment modelling. Nonetheless, a basic overview of potential impacts is warranted to refine the proposal and guide future assessment. The current dredging proposal could have direct and indirect impacts on shorebird habitat. Potential impacts can be divided into three components:

1. *Roosting habitat* - Impacts on the Serpentine west roost. These may be direct, that is, removal of part or all of the roost, or indirect, that is, increased erosion of the roost that results in a lowered elevation or reduces space during neap high tides.
2. *Removal of foraging habitat* - Removal of 7.21ha of intertidal foraging habitat from the Serpentine tidal flat. Based on the dredging proposal at 19 May 2016 the proposal would remove mid-tide staging roosts and a large area of foraging habitat used during the ebb tide, prior to upstream sites becoming available, and throughout the low tide period. A substantial proportion of the local population of several threatened and migratory species use the affected foraging habitat and removal of this habitat would cause local population declines.
3. *Altered hydrology* – Potential hydrological changes could affect shorebird habitat in two ways. Firstly, removing 7.21ha of intertidal habitat and deepening the navigation channel may change tidal flows over the Serpentine sand flat, which may in-turn effect sediment distribution and shorebird prey (i.e. benthic macro-invertebrates). Secondly, increased tidal amplitude in North Creek, potentially resulting in higher highs and lower lows, may have implications for habitat exposure (e.g. seagrass) with resulting effects on shorebird prey. Increased exposure of intertidal habitat would affect species that prefer to forage on moist sand and seagrass, such as great knot, eastern curlew, curlew sandpiper and bar-tailed godwit but could benefit species that prefer to forage on drier substrates such as Pacific golden plover.

These assumed impacts could affect shorebirds in several ways, including:

1. Cause shorebirds foraging at Serpentine to fly greater distances to roost during all high tides thereby increasing energy expenditure.

2. Reduce the number of birds that can forage at Serpentine. The proposal would remove approximately 22% of intertidal habitat at Serpentine during a spring low tide. Quantifying the exact number of individuals affected is difficult due to the complex manner in which birds use the tidal flat throughout low tide, although population level impacts on several threatened species are likely.
3. Reduce the area of neap tide foraging habitat in the Richmond Estuary. No quantitative data are available on the area of foraging habitat available during neap low tides but a conservative estimate is that the proposal may remove between 15 and 25% of available neap tide habitat. During this study mid-Richmond and Serpentine were the major foraging areas during neap low tides. Although the entire Serpentine sand flat was not exposed during neap low tides most of the proposed dredge area (Area B) was exposed. The proposal would remove approximately 7ha of foraging habitat available during neap low tide when the foraging resource is limited.
4. Remove mid-tide staging habitat at Serpentine, which means birds would need to stay longer at other roosts, where they cannot forage and are subject to disturbance, thereby increasing the likelihood of competitive interactions.
5. Remove foraging habitat used during the early ebb tide. The early ebb tide is an important foraging time as birds need to replenish energy after roosting. The Serpentine sand flat provides a large area of foraging habitat available during that period, before other intertidal areas become exposed. As the tide recedes some birds leave Serpentine for upstream foraging areas at North Creek south, Prospect and Upper North Creek. A reduction in the area of foraging habitat during the ebb tide would increase competition for space and affect energy budgets.
6. Reduce the space available for species that defend temporary feeding territories, such as eastern curlew, increasing the likelihood of population level impacts. Quantifying potential territorial effects would require further observation to determine if such behaviour occurs at Serpentine and the size of territories.
7. Changes in tidal flows would effect sediment distribution, which will have a flow-on effect on benthic macro-invertebrate distribution and abundance. The feeding distribution of shorebirds is closely linked to distribution of preferred prey and shorebird abundance is, amongst other things, associated with prey abundance. For example, in North Creek, sanderling, greater sand plover and lesser sand plover predominantly forage at the Serpentine, which is attributed to the distribution of preferred prey. Changes in prey distribution would affect the type and number of shorebirds foraging at a site.
8. Increased exposure of seagrass beds due to increased tidal amplitude may cause an adjustment to the existing seagrass boundary. Any reduction in the area of high elevation seagrass, that is seagrass that becomes exposed during spring low tides, would have a negative effect on shorebirds. Such an impact is regarded as short-term as seagrass beds adjust to the new tidal range.

5.4 Impact mitigation

Mitigating the impact of dredging on shorebirds will depend on the scale of impact. At this stage of the project quantifying exact impacts is difficult. Nonetheless, some mitigation measures should be considered, including:

1. Minimise impacts on roost and foraging habitat wherever possible and conduct a thorough assessment of impacts in accordance with State and Commonwealth legislation.
2. If modeling indicates that the proposal would remove more than 20% of the Serpentine west roost or otherwise reduce the roosts viability then a compensatory roost is required. To offset impacts on the existing neap tide roost (Serpentine west) an artificial spring tide roost could be constructed in the northern third of the Serpentine sand flat, between the existing dredge hole and tidal lagoon. Further evaluation is required to confirm this areas suitability. Such a roost would be less accessible to humans than existing roosts. Constructing a roost from dredge spoil is viable, however, the roost must be designed to ensure it is above spring high water, is available in the long-term (i.e. 15-20 years) and is self-sustaining (i.e. is not high enough above spring high water to support woody vegetation). The proponent would need to commit to replacing the roost if it became unviable as a spring tide roost within 5 years and for ongoing maintenance. Creation of a spring tide roost would result in a net benefit to shorebirds, as the existing Serpentine west roost is available during neap tides only.
3. To manage increased disturbance potential associated with a reduced area of foraging habitat signage should be erected at the Serpentine carpark/recreation area and Martin Street boat ramp to inform visitors that North Creek is important for migratory and resident shorebirds at high and low tide.
4. To manage increased disturbance potential associated with a reduced area of foraging habitat ban domestic dogs from the Serpentine sand flat and ensure that council rangers regularly patrol the site between October and March each year.
5. Alternative sites for Area B should be considered. One such site is the southern end of the Serpentine sand flat. A bathymetric profile, further observation of shorebird habitat use and modeling of sand and water movement, in that area, is required to fully evaluate the sites suitability. Based on present knowledge removal of sand from a smaller area at the south end of the Serpentine sand flat would have less impact on shorebirds.
6. Obtain additional fill by deepening dredge site A.
7. Avoid removing intertidal foraging habitat from Prospect and North creek south intertidal foraging areas.
8. Undertake hydrological and sediment transport modeling to confirm the impact of dredging the tidal channel on existing intertidal areas. This information is essential to assess the impact of dredging on shorebirds and specifically to determine if the proposal would cause changes in shorebird prey.
9. Undertake bank stabilisation work to protect the saltmarsh northeast of the Prospect tidal flat and enhance its value as a spring tide roost.
10. Impacts on other threatened and migratory estuarine birds must be considered.

6 Conclusion

In summary, key features of North Creek shorebird habitat include:

1. North Creek supports a State and Regionally significant shorebird community, including eight threatened species and several species that have undergone substantial population declines in the East Asian/Australasian Flyway.
2. Habitat in North Creek is of critical importance to the Richmond Estuaries shorebird community.
3. Roost and foraging habitat at Serpentine supports >30% of the local shorebird population.
4. Intertidal areas in North Creek form a matrix of inter-related habitats used at different stages of the tidal cycle.

To assess the impact of the proposal on shorebirds further information on the dredging footprint and resultant sand and water movement is required. The proposal must then be assessed in accordance with Section 5A of the *Environmental Planning and Assessment Act 1979* and an assessment of significance completed in accordance with the *Environment Protection and Biodiversity Conservation Act 1999*. These assessments will then enable conclusions to be drawn on the need for a Species Impact Statement and/or referral to the federal Minister for the Environment.

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Appendix A

Table A1: Number of individuals recorded during each low tide survey.

Species/Count	2.2.16	3.2.16	4.2.16	8.2.16	14.2.16	22.2.16	Maximum	Mean	SDEVA
Aust. Pied Oystercatcher	2	13	6	11	9	18	18	11.0	5.6
Sooty Oystercatcher					1		1	0.3	0.4
Black-winged Stilt					3		3	0.9	1.2
Pacific Golden Plover	222	257	233	291	207	288	291	255.6	34.9
Red-capped Plover	1						1	0.3	0.4
Double-banded Plover						1	1	0.3	0.4
Lesser Sand Plover					2		2	0.6	0.8
Greater Sand Plover		4	1	2		1	4	1.7	1.5
Masked Lapwing	3	1		7	44	25	44	17.7	17.6
Bar-tailed Godwit	139	131	103	130	123	138	139	129.0	13.3
Whimbrel	26	30	25	40	25	72	72	41.4	18.4
Eastern Curlew	17	27	22	20	20	24	27	22.4	3.5
Terek Sandpiper	27	29	24	23	18	25	29	25.0	3.8
Grey-tailed Tattler	3	43	66	38	69	49	66	47.7	23.9
Common Greenshank	5	6	6		6	4	6	4.7	2.3
Great Knot	37	36	32	43	33	25	37	34.7	6.0
Sanderling	9	8		8	7	3	9	6.3	3.5
Red-necked Stint	80	98	38	91	66	64	98	76.4	21.7
Sharp-tailed Sandpiper	31	5	21	97	28	25	97	43.4	31.9
Curlew Sandpiper	27	34	28	46	36	16	46	33.3	10.1
Sand plover spp.	4	1			1		4	1.4	1.5
Sandpiper spp.		4					4	1.3	1.8
Tattler/Terek		2					2	0.7	0.9
No Individuals	633	730	605	847	698	778		715.2	90.3
No. Species	15	16	13	14	17	16		15.2	1.5

Table A2: Maximum, mean, standard deviation and proportion of the estuaries shorebird population recorded at each low tide foraging area in February 2016.

Species/Count	Serpentine				North creek south				North Creek central				North Creek north			
	Max	Mean	SD	%PE	Max	Mean	SD	%PE	Max	Mean	SD	%PE	Max	Mean	SD	%PE
Aust. Pied Oystercatcher	11.0	4.7	4.1	42.3	1.0	0.3	0.5	3.8					6.0	3.4	3.1	23.1
Sooty Oystercatcher																
Black-winged Stilt																
Pacific Golden Plover	101.0	63.8	19.9	36.3	5.0	3.5	1.3	1.8	3.0	2.0	0.8	1.1	6.0	1.6	2.6	2.2
Red-capped Plover	1.0	0.2	0.4	100.0												
Double-banded Plover	1.0	0.2	0.4	100.0												
Lesser Sand Plover	2.0	0.3	0.8	50.0												
Greater Sand Plover	1.0	0.2	0.4	25.0												
Masked Lapwing	36.0	8.2	14.0	102.9									3.0	0.6	1.3	8.6
Bar-tailed Godwit	58.0	41.3	9.2	35.4	16.0	13.0	3.5	9.8	3.0	1.0	1.4	1.8				
Whimbrel	16.0	10.0	4.0	29.6	3.0	1.5	1.3	5.6	4.0	2.5	1.3	7.4	1.0	0.4	0.5	1.9
Eastern Curlew	14.0	8.5	2.8	37.8	1.0	1.0	0.0	2.7								
Terek Sandpiper																
Grey-tailed Tattler	24.0	8.8	8.3	38.1	8.0	4.0	3.4	12.7	1.0	0.3	0.5	1.6	11.0	3.2	4.5	17.5
Common Greenshank	3.0	0.5	1.2	50.0												
Great Knot	37.0	14.5	17.3	105.7	20.0	5.0	10.0	57.1								
Sanderling	8.0	4.3	3.8	80.0												
Red-necked Stint	59.0	31.8	16.3	29.1	9.0	3.0	4.2	4.4								
Sharp-tailed Sandpiper					2.0	0.5	1.0	3.2					8.0	1.6	3.6	12.9
Curlew Sandpiper	22.0	7.5	8.9	53.7	10.0	7.0	2.9	24.4	4.0	1.0	2.0	9.8				
Sand plover spp.	4.0	1.0	1.5													
Sandpiper spp.	4.0	0.7	1.6													
Tattler/Terek	2.0	0.3	0.8													
No Individuals	404.0	206.8	45.2	34.8	75.0	38.8	16.2	6.5	15.0	6.8	2.1	1.3	35.0	10.8	6.4	3.0
No. Species	16.0	10.3	1.5	76.2	10.0	6.8	1.9	47.6	5.0	3.0	0.8	23.8	6.0	2.4	1.3	28.6

Table A2 cont.

Species/Count	Prospect				North Creek upper				Mid-Richmond				Mobbs Bay outer			
	Max	Mean	SD	%PE	Max	Mean	SD	%PE	Max	Mean	SD	%PE	Max	Mean	SD	%PE
Aust. Pied Oystercatcher									3.0	1.3	1.2	11.5	2.0	0.3	0.8	7.7
Sooty Oystercatcher									1.0	0.2	0.4	9.1				
Black-winged Stilt	1.0	0.2	0.4	1.4					2.0	0.3	0.8	2.9				
Pacific Golden Plover	31.0	15.0	12.8	11.2	35.0	26.2	12.2	12.6	130.0	95.8	20.8	46.8	72.0	38.5	28.9	25.9
Red-capped Plover																
Double-banded Plover																
Lesser Sand Plover																
Greater Sand Plover									2.0	1.2	1.2	50.0				
Masked Lapwing	1.0	0.2	0.4	2.9	1.0	0.2	0.4	2.9	16.0	3.5	6.4	45.7	2.0	0.3	0.8	5.7
Bar-tailed Godwit	8.0	3.3	3.4	4.9					81.0	45.8	19.4	49.4	43.0	20.0	14.3	26.2
Whimbrel	3.0	1.8	1.0	5.6	4.0	2.0	1.7	7.4	20.0	11.7	5.1	37.0	29.0	7.8	10.7	53.7
Eastern Curlew	2.0	0.7	0.8	5.4	1.0	0.2	0.4	2.7	10.0	8.0	1.4	27.0	6.0	3.5	1.4	16.2
Terek Sandpiper									29.0	21.2	6.2	85.3	11.0	3.2	4.4	32.4
Grey-tailed Tattler	10.0	3.3	3.9	15.9	6.0	2.2	2.6	9.5	27.0	10.0	10.7	42.9	33.0	15.7	12.5	52.4
Common Greenshank	6.0	4.6	1.5	100.0	1.0	0.2	0.4	16.7								
Great Knot	25.0	4.8	10.0	71.4	33.0	13.4	13.9	94.3	3.0	0.5	1.2	8.6				
Sanderling									4.0	3.0	1.0	40.0				
Red-necked Stint									55.0	32.0	18.9	27.1	15.0	7.0	6.7	7.4
Sharp-tailed Sandpiper	22.0	9.8	9.2	35.5	30.0	11.7	10.8	48.4	62.0	10.7	25.2	100.0	4.0	0.7	1.6	6.5
Curlew Sandpiper	1.0	0.3	0.5	2.4	15.0	5.5	5.5	36.6	13.0	8.3	4.8	31.7	10.0	3.5	3.8	24.4
Sand plover spp.																
Sandpiper spp.																
Tattler/Terek																
No Individuals	110.0	45.7	33.3	9.5	126.0	59.2	32.2	10.8	458.0	252.0	50.7	39.4	227.0	100.5	65.1	19.5
No. Species	11.0	6.0	3.3	52.4	9.0	4.8	2.0	42.9	16.0	11.0	1.3	76.2	11.0	7.8	1.1	52.4

Appendix B

Table B1: Habitat, distribution and threatening processes of threatened shorebirds recorded in North creek.

Common name	Habitat Preferences	Known Distribution	Threatening Processes
Lesser Sand Plover	Forages on sand and mudflats in estuaries, ocean beaches and rocky shores. Roosts in similar habitats. Forages primarily on crabs but also eats bivalves, worms and insects.	Northern Hemisphere migrant. Breeds in central Asia and spends non-breeding period (August – March) in Australia. Distribution around entire Australian coast, most common in the Gulf of Carpentaria and east coast of Qld. Recorded in all states. Highly gregarious, recorded in flocks exceeding 100 individuals. Less common South of Shoalhaven estuary in NSW.	Human disturbance of roost and foraging habitat; loss of migrant staging areas; land reclamation leading to removal of high-tide roosts; climate change and associated sea level rise; pollution of habitat.
Greater Sand Plover	At low tide forages on exposed sand and mudflats and occasionally rocky shores. At high tide roosts in mixed species flocks on ocean beaches, sand bars and rocky shores. Forages on a variety of crustaceans and polychaetes.	Northern Hemisphere migrant. Breeds in the vicinity of water from Turkey through to Mongolia and spends non-breeding period (August – March/May) in Australia. Migrates through southeast Asia through New Guinea to Australia. Total population between 200000 and 275000 birds. Predominantly coastal distribution in Australia. Scarce on the east and south coasts. Usually found in parties of 10-20 individuals.	Disturbance at roost and foraging sites; degradation of high tide roosts; removal or degradation of migration staging sites; climate change and associated sea level rise; pollution and land reclamation; introduced plants changing nature of wetlands.
Terek Sandpiper	Sand flats and mudflats in estuaries, occasionally ocean beaches. Forages predominantly on crabs on open sandy habitats, although will forage around mangrove fringe depending on tide stage. Roosts on sandbars, rock groins, and mangrove trees.	Northern Hemisphere migrant. Breeds in Nth Asia and spends non-breeding period (August – March) in Australia. Predominantly coastal distribution in Australia.	Human disturbance of high tide roosts and foraging areas, which affects the ability of birds to migrate; removal of staging habitat within the flyway, especially East Asia; climate change and incidental sea level rise; hunting in China.
Great Knot	Prefers to forage on areas with soft muddy substrates such as mudflats and seagrass beds in estuaries. Forages predominantly on gastropod molluscs. Occasionally recorded foraging on ocean beaches. Roosts on ocean beaches and sandbars.	Northern Hemisphere migrant. Breeds in arctic tundra and spends non-breeding period (August – March) in Australia. Predominantly coastal distribution, with highest numbers in NW Australia.	Land reclamation and development - staging areas in the East Asia flyway have been reclaimed. More vulnerable to land reclamation than other waders due to the very specific species of shellfish they feed on. Oil exploration. Climate change. Human activities, Pollution – heavy metals discharged into the sea.
Sanderling	Occasionally seen in inlets and on tidal mudflats but preferring low beaches of firm sand, often near reefs. Non- breeding period almost always on open sandy beaches exposed to open sea- swell, exposed sandbars and spits. Forage in the wave wash zone and amongst rotting seaweed.	Artic non-breeding migrants to the Australian coastline, occasionally over-wintering here. Breeds in scattered localities from north America, north Russia and islands in the Arctic Ocean. Scattered around coastal fringe of Australia. Arrive in Australia from September and depart from March.	Disturbance of feeding and roosting sites; pollution of estuaries and coastal areas; removal of habitat from hydrological changes to estuaries and water bodies; reduction of habitat from tourism and agricultural developments.
Curlew Sandpiper	Sheltered coastal Intertidal mudflats such as estuaries, bays, inlets and lagoons. Also non-tidal swamps, lakes and lagoons close to the coast. Less often found inland round bodies of water hmeaning bare edges of mud and sand. On high tide will feed among low sparse emergent vegetation i.e.,	Breeding restricted mainly to high Arctic (Siberia). Non-breeding migrate to Aust. Few records in Gulf of Carpentaria, wide spread along coast south of Cairns. NSW widespread east of the Great Divide particularly in coastal regions, occasionally in Tablelands. Widespread and common in coastal bays and inlets of Vic. Also recorded in Tas, SA, WA and NT. Arrive in Aust. August – Nov, depart between March and	Development pressure and human disturbance in coastal foraging sites; human recreational use of beaches, shorelines and estuaries; reduced flow of Murray-Darling Basin shrinking habitat area size; climate change effects to Artic breeding grounds.

	saltmarsh. Roosting on bare dry shingle, shell or sand beaches, sand spits and inlets associated with coastal lagoons.	April.	
Beach Stone-Curlew	Prefers sand islands with adjoining sand flats in the lower reaches of estuaries. Also uses ocean beaches. Most records on beaches are outside the breeding season. Lays eggs in a simple scrape just above high water.	Northern Australia & down the east coast to Old Bar. Vagrants recorded further south – regular records in the Shoalhaven estuary. Population in NSW may be increasing.	Human disturbance around nest sites; vegetation growth on nest and foraging areas; nest predation by foxes, dogs, pigs and cats; Urban and industrial coastal development encroaching on habitat; dredging and pollution of estuaries.
Australian Pied Oystercatcher	Ocean beaches and estuaries. Recorded using both sandy and muddy substrates in estuaries. Forages predominantly on bivalve molluscs, but will also consume crabs and worms. Roosts on sandbars, ocean beaches, rock groins and saltmarsh. Lays egg on sand often just above high tide line or on fore-dune. In estuaries will nest on grass near or beneath vegetation.	Coastal Australia. In NSW the largest population occurs on ocean beaches on the north coast. The national population is estimated to be about 10 000 individuals, whilst the NSW population is estimated to be about 250 individual thinly scattered along the entire coast.	Human disturbance of roost, foraging and nest sites; destruction of eggs and chicks by trampling and 4WD vehicles; predation of eggs and chicks by foxes, cats, ravens, raptors, gulls and dogs; tidal inundation of nest sites; associated effects of climate change; a primary food source, the pipi has undergone long term decline from over harvesting by humans.
Sooty Oystercatcher	Prefers to forage, roost and nest on rocky shores, headlands, although will occasionally forage and roost on ocean beaches and sand flats in estuaries. Lays eggs on rock platform on off-shore islands. Nest site decorated with beach caste materials (e.g. seaweed).	Coastal Australia. Largest populations in NSW occur on the North Coast (Coffs Harbour area) and South Coast (Wollongong area). NSW population of approx. 400. National population approx. 4000 birds.	Human disturbance at nest, foraging and roost sites; predation by gulls, foxes, dogs, cats, rats and raptors; habitat destruction as a result of residential, agricultural and tourism developments. Hydrological changes to estuaries and similar water bodies.

T = tractor; BP = bird of prey; F = fisher; J = jogger; IN = Incoming; P =people; D = dog; B = boat; MC = Mid channel; M Is = Mobbs bay island; MM = Mobbs bay mangroves; Mobbs bay rocks; NCR = North Creek rocks; PR = Prospect rocks; PBR = Prospect bridge rocks; PS Is = Prospect sand island; Serp W = Serpentine west; Serp E = Serpentine east; AP = Airport; EW = Emigrant wetland; SBB = South Ballina beach; CL = Chickiba lake; FR = Flat Rock; E Ck = Emigrant creek; RSL= RSL club; CT = Cumulative Total; * = need to check data.

Serp = Serpentine; NCS = North creek south; NCC = North creek central; NCN = North creek north; Prosp. = Prospect; NCUx3 = Upper north creek x 3 sites; MR = Mid Richmond river; MBO = Mobbs bay outer; BPt = Burns point.