NSW GOVERNMENT
Environment, Climate Change & Water

SHORE BIRDS
of Northern New South Wales

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Northern Rivers CMA CATCHMENT MANAGEMENT AUTHORITY

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This report is an edited version of a report by Sandpiper Ecological Surveys (Dr David Rohweder 2010) 'Shorebird Data Audit – Northern New South Wales', an unpublished report to the Department of Environment Climate Change and Water NSW, funded by the Northern Rivers Catchment Management Authority.

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SUMMARY

Background

This report is an edited version of a report by Sandpiper Ecological Surveys (Dr David Rohweder) 'Shorebirds Data Audit – Northern New South Wales' which was prepared for the Department of Environment, Climate Change and Water NSW and funded by the Northern Rivers Catchment Management Authority.

Shorebird (suborder Charadrii) data for the Northern Rivers Catchment Management Authority (CMA) region was collated with a view to establishing a baseline dataset that can be used for planning and management.

The Northern Rivers CMA region was divided into three primary habitat types: major estuaries (12 locations), minor estuaries and ICOLLs (13 locations) and coastline sections (14 locations). Each major estuary was divided into roost and foraging sites.

Shorebird data collation

Forty-nine data sources were identified and data were collated from 41 sources. The majority of systematic survey data available within the region was collated. Several additional data sources are identified. These include both systematic and point locality data.

Data were collected for all major and minor estuaries and coastline sections, but the amount and quality of data varied substantially across the Study Area. Robust datasets were collated for the Tweed, Richmond and Clarence estuaries. These included surveys at high and low tide.

Long-term datasets were collated for the Brunswick (28 years), Hastings (27 years) Clarence (26 years), Nambucca (24 years), Richmond (23 years) and Tweed (23 years) estuaries. There was a notable deficiency in sampling effort in the Macleay Estuary and generally along the coastline south of Bonville Creek. Further surveys are recommended for these areas.

There is substantial variability in data quality between locations and studies, and it is strongly recommended that data be vetted before use on any future projects.

The collated dataset would be complemented by undertaking a nest site data audit, by auditing other known datasets, and by undertaking targeted surveys in the Macleay Estuary.

Data summary and baseline analysis

Collated data were used to undertake a baseline comparison of shorebird population estimates and species diversity between locations in each of the three major habitats, and to identify important habitats for threatened shorebirds.

The baseline assessment highlighted the importance of the Clarence and Richmond estuaries, but also emphasised the contribution of numerous locations to the overall abundance and diversity of shorebirds in the Northern Rivers CMA region.

A similar trend was recorded for populations of 12 locally 'abundant' species. While many species were most abundant in the Richmond and Clarence estuaries, other major estuaries provide important habitat for some species. The Hastings, Macleay and Tweed provide important habitat for Common Greenshank, Whimbrel and Eastern Curlew. Smaller estuaries, such as Corindi, Wooli, Nambucca and Sandon, provide important habitat for Red-capped Plovers.

Important locations for threatened species were determined by averaging population estimates during the 'summer' period (i.e. Oct–Apr). The Clarence and Richmond estuaries and intervening coastline were the priority areas for Pied Oystercatcher, Greater and Lesser Sand Plovers, Terek Sandpiper, Great Knot and Sanderling.

Priority habitats for Sooty Oystercatcher and Beach Stone-curlew were more widespread. Populations and breeding pairs of Sooty Oystercatchers peaked in the vicinity of Coffs Harbour, while Beach Stone-curlew priority habitat was distributed between several long-term breeding sites and a small number of recent breeding sites.

The outcomes of the baseline population and threatened species assessment emphasise the importance of the Clarence and Richmond estuaries and intervening section of coastline to the shorebird population in the Northern Rivers CMA region. The value of many smaller estuaries, such as Sandon, Corindi, Wooli, Nambucca and Bonville — particularly for resident shorebirds and Little Terns — and the more natural state of these estuaries contributes to the environmental values of the Study Area.

Pilot roost site prioritisation, Clarence Estuary

A preliminary threat assessment was undertaken to assess the level of threat experienced at shorebird roosts in the Clarence Estuary. Thirty-six potential threats from five threat categories were used to predict the level of threat experienced at 24 roosts in the lower estuary.

The threat assessment was combined with an assessment of roost values to obtain an overall threat ranking. The overall threat status of each roost was ranked as very high, high, medium and low. One roost, Dart/Hickey Island was classified as having a very high threat level, and two roosts (Peninsula and Prawn Farm) had a high threat level. Numerous roosts had a medium threat level including several within Bundjalung National Park. These roosts are regarded as priorities for management in the Clarence Estuary.

Pilot shorebird habitat mapping, Clarence and Sandon estuaries

Geographic information systems were used to map shorebird roost and foraging habitat within the Clarence and Sandon estuaries. Roost mapping in the Clarence was supported by summary data on each roost, enabling roost values and management priorities to be viewed using GIS.

The preliminary mapping program emphasised the value of combining summary data on shorebird populations with GIS mapping to assist with local and regional scale planning and management.

Conclusions and recommendations

Shorebirds of Northern New South Wales has summarised a substantial amount of data on shorebirds in the Northern Rivers CMA region. Nonetheless, there are a small number of additional data sources that should be explored, and a nest site audit would complement the collated data.

Focusing management and conservation initiatives on the Clarence and Richmond estuaries and intervening section of coastline would protect the majority of shorebird values in the Northern Rivers CMA region.

A state and national perspective should be considered when assessing management priorities.

Recommendations have been prioritised.

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Departmental staff who contributed to the report by way of report review, layout and design, and map production, were Katrina McKay, Mick Andren, Andrew Steed and Andrew McIntyre.

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PART 1: BACKGROUND INFORMATION

1.1 Introduction

Shorebirds[1] (suborder Charadrii) are an important component of coastal ecosystems, and they are often the most visible proportion of vertebrate fauna within estuarine, ocean beach and rocky shore environments. Habitats relied upon by shorebirds are also used intensively for recreation and occur within estuarine systems that are affected by industry, urban development and agriculture. In recognition of their conservation value and vulnerability to threatening processes, there has been a substantial amount of information gathered on the diversity, abundance and distribution of shorebirds in coastal habitats. Non-government organisations, such as the Australasian Wader Studies Group (WSG) and affiliated state groups, focus solely on gathering information on the population dynamics and movements of shorebirds in Australia.

Shorebirds are protected by several international migratory bird agreements, the Bonn Convention, and NSW State and Commonwealth threatened species legislation. Numerous habitats have been protected under the Convention on Wetlands of International Importance (the Ramsar Convention) and within the national parks and wildlife estate. Compared to many terrestrial vertebrates, shorebirds continue to experience a disproportionately high level of threat — particularly habitat disturbance. This is despite the large amount of information on population dynamics and habitat, and the various statutes and agreements that afford shorebirds protection. This situation is indicative of many estuarine and marine species.

Protecting and managing shorebirds and their habitat requires sound baseline data on species diversity, distribution, abundance and habitat use. This information can be used to identify important sites, provide baseline statistics for population monitoring, and to identify threatening processes. There has been a substantial amount of data gathered on shorebird populations in northern NSW since the late 1980s. In theory, these data should provide a robust dataset to identify conservation priorities and assess population trends. Unfortunately, the data varies in spatial and temporal coverage and quality, and occurs in a variety of disparate sources.

1.2 Scope of the report

Shorebirds of Northern New South Wales (NSW) was a joint project of the Department of Environment, Climate Change and Water NSW (DECCW) and the Northern Rivers Catchment Management Authority (CMA).

The four main components of the project report are:

1. data collation: identification and collation of available shorebird data including survey data, literature and spatial data
2. baseline analysis of the data: generation of baseline statistics on shorebird diversity and abundance, assessment of the quality and utility of the collated data for identification of priority sites, and identification of data gaps
3. pilot threat and habitat prioritisation: matrix-based approach to threat and habitat value prioritisation of high tide roost sites in the Clarence Estuary
4. pilot habitat mapping: mapping of foraging and roosting habitats in the Clarence and Sandon rivers.

Each of these components is presented in separate sections of the report. The final section lists recommendations for further research, analyses, management, planning and mapping.

The ability to satisfy the scope of work varied between components due to the time available and the scale of the various tasks. The collation of shorebird data was the primary focus as all other components relied upon the completion of a satisfactory data audit. That most data were available in

[1] Shorebirds are also called waders.

hard copy format only (as opposed to digital), was an issue that increased the time taken to complete the primary task.

1.3 Study Area

The Study Area includes coastal and estuarine habitats within the Northern Rivers CMA region, including the NSW coastline from the Queensland–NSW border south to the Camden Haven River (**Figure 1**). The eastern boundary of the Study Area is the lowest astronomical tide, and the western boundary is the extent of marine tidal influence (limit of mangroves).

Defining the western boundary is difficult as the distance that shorebirds occur upstream from a river mouth varies depending on estuary morphology and, more particularly, the size of the estuary. Nonetheless, limiting the Study Area to the area affected by marine tidal influence ensures that virtually all estuarine habitat is included. Offshore islands have not been included. Floodplains adjoining estuaries and in the upper reaches of coastal catchments also represent important shorebird habitat (see Gosper 1981). However, survey coverage of these areas has generally been patchy and they have been excluded from the Study Area to limit the survey coverage to a manageable area.

The Study Area includes a range of coastal and estuarine habitats including rivers, creeks, lakes, lagoons and beaches. For the purposes of the project, three main habitats were defined as follows:

- 'major estuaries' — the estuaries of 12 major rivers which were further classified by size (large, medium)
- 'minor estuaries and ICOLLs' — including nine creeks and 16 intermittently closed and open coastal lakes and lagoons
- 'coastline sections' — including headlands, rock platforms and ocean beaches.

These broad habitat types include a variety of habiats that are used by shorebirds. To enable data to be summarised and compared, 'locations' were identified and grouped under one of these three habitat types. There are 12 major estuary locations, 13 minor estuary locations, and 14 coastline locations (see **Table 1**). The boundaries of the coastline locations were based on prominent landscape features such as river mouths, headlands and harbours.

Table 1 Northern NSW shorebird locations

Major estuaries	
Tweed Estuary (large)*	Wooli Estuary (medium)
Brunswick Estuary	Corindi Estuary (medium)
Richmond Estuary (large)	Bellinger Estuary (medium)
Evans Estuary	Nambucca Estuary (medium)
Clarence Estuary (large)	Macleay Estuary (large)
Sandon Estuary (medium)	Hastings Estuary (large)
Minor estuaries and ICOLLs	
Cudgen Creek	Arrawarra Creek
Cudgera Creek	Station Creek
Mooball Creek	Flat Top Point
Belongil Creek	Moonee Creek
Salty Lagoon	Boambee Creek
Jerusalem Creek	Bonville Creek
Cakora Lagoon	
Coastline sections	
Tweed River to Mooball Creek	Wooli River to Arrawarra Headland
Mooball Creek to Cape Byron	Arrawarra Headland to Coffs Harbour

Cape Byron to Richmond River	Coffs Harbour to Bellinger River
Richmond River to Goanna Headland	Bellinger River to Nambucca River
Goanna Headland to Clarence River	Nambucca River to Laggers Point
Clarence River to Sandon River	Laggers Point to Crescent Head
Sandon River to Wooli River	Crescent Head to Tacking Point

Note: * relates to relative size of major estuaries

Size, hydrology, geology and geomorphology varies substantially between the various rivers and creeks, which influences the area, type and productivity of shorebird habitat and subsequently species richness and abundance. There are substantial differences in species composition and abundance between the various estuaries. These differences have not been explored in this report as they represent a major avenue of research beyond the scope of this project.

Each location can be divided into numerous ‘sites’ that are used to satisfy different components of a shorebird’s autecological requirements. Sites include roosting, foraging and nesting areas. In some cases sites are discrete areas isolated from one another, but in many instances they overlap. Delineating sample sites is a critical component of local shorebird habitat management. The ability to identify sites depends on the level of information available on a sample location, such as site-specific data and site descriptions. Such information is not available for all sample locations. The number of sites per location is often dependent on the size of the location, particularly the size of the estuarine system.

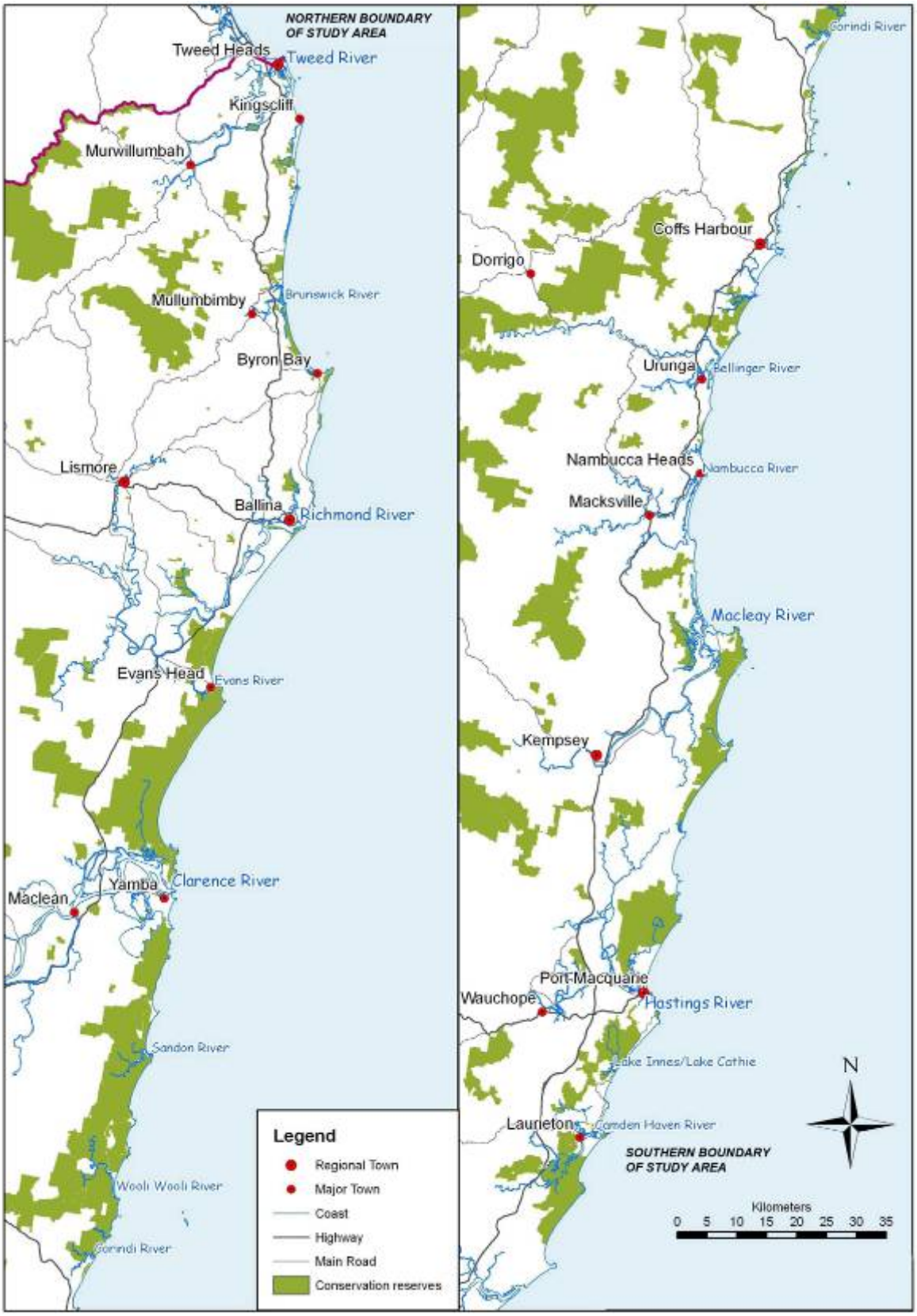


Figure 1 The Study Area

1.4 Target species and habitats

All species of shorebirds listed in **Table 2** were targeted during the project. Nomenclature in the report generally follows Christidis and Boles (2008). Not all species recorded in the Study Area are evenly distributed. Due to the distances travelled and variety of migration routes, migratory species can sometimes be recorded outside their normal range. These species are generally regarded as vagrants (Christidis & Boles 2008) and may only occur in the Study Area occasionally and in small numbers (e.g. Lesser Yellow Legs and Long-toed Stint). Other species have specific habitat requirements that are not met in the Study Area (e.g. Comb-crested Jacana), or the Study Area is outside the species known range (e.g. Hooded Plover). Some species may be more common in the Study Area than the data suggest, but they are only occasionally recorded due to difficulties in identification (e.g. Broad-billed Sandpiper).

Shorebirds belong to the suborder Charadrii within the order Charadriiformes. **Table 2** lists the nine shorebird families occurring in Australia, of which six have been recorded in the Study Area. Of the 77 species recorded in Australia, 42 are known from the Study Area (**Table 2**).

Shorebirds can be divided into two groups: migrants and residents. 'Migrants' breed mainly in the northern hemisphere and spend the non-breeding season in Australia. These shorebirds come to Australia via the East-Asian Australiasian Flyway (the Flyway). 'Residents' permanently live and breed in Australia and may undertake regular movements between coastal and inland wetlands along the coast.

Table 2 Species of migratory and resident shorebird recorded in Australia and the Study Area

(after Christidis & Boles 2008)

FAMILY / Species name	Common name	Status TSC Act	Status EPBC	Recorded in Study Area
BURHINIDAE				
Esacus magnirostris	Beach Stone-curlew	CE		✓
Burhinus grallarius	Bush Stone-curlew	E		
HAEMATOPODIDAE				
Haematopus finschi	South Island Pied Oystercatcher			✓*
Haematopus longirostris	Pied Oystercatcher	E		✓
Haematopus fuliginosus	Sooty Oystercatcher	V		✓
RECURVIROSTRIDAE				
Himantopus himantopus	Black-winged Stilt			✓
Recurvirostra novaehollandiae	Red-necked Avocet			✓
Cladorhynchus leucocephalus	Banded Stilt			
CHARADRIIDAE				
Pluvialis fulva	Pacific Golden Plover		M	✓
Pluvialis dominicus	American Golden Plover[V]		M	✓*
Pluvialis squatarola	Grey Plover		M	✓*
Charadrius hiaticula	Ringed Plover[V]		M	
Charadrius dubius	Little Ringed Plover[V]		M	
Charadrius alexandrinus	Kentish Plover[V]			
Charadrius ruficapillus	Red-capped Plover			✓
Charadrius bicinctus	Double-banded Plover		M	✓
Charadrius mongolus	Lesser Sand-plover	V	M	✓
Charadrius leschenaulti	Greater Sand-plover	V	M	✓

FAMILY / Species name	Common name	Status TSC Act	Status EPBC	Recorded in Study Area
Charadrius asiaticus	Caspian Plover[V]		M	
Charadrius veredus	Oriental Plover		M	✓*
Charadrius australis	Inland Dotterel			
Elseyornis melanops	Black-fronted Dotterel			✓
Thinornis rubricollis	Hooded Plover	CE		
Erythrogonys cinctus	Red-kneed Dotterel			✓
Vanellus tricolor	Banded Lapwing			✓*
Vanellus miles	Masked Lapwing			✓
Vanellus cinereus	Grey-headed Lapwing[V]			
PEDIONOMIDAE				
Pedionomus torquatus	Plains-wanderer	E	V	
JACANIDAE				
Irediparra gallinacea	Comb-crested Jacana	V		
Hydrophasianus chirurgus	Pheasant-tailed Jacana[V]		M	
ROSTRATULIDAE				
Rostratula australis	Australian Painted Snipe	E	M, V	
SCOLOPACIDAE				
Gallinago hardwickii	Latham's Snipe		M	✓
Gallinago stenura	Pin-tailed Snipe[V]		M	
Gallinago megala	Swinhoe's Snipe		M	
Limosa limosa	Black-tailed Godwit	V	M	✓
Limosa haemastica	Hudsonian Godwit[V]			
Limosa lapponica	Bar-tailed Godwit		M	✓
Numenius minutus	Little Curlew		M	✓*
Numenius phaeopus	Whimbrel		M	✓
Numenius madagascariensis	Eastern Curlew		M	✓
Bartramia longicauda	Upland Sandpiper[V]			
Xenus cinereus	Terek Sandpiper	V	M	✓
Actitis hypoleucos	Common Sandpiper		M	✓
Tringa ochropus	Green Sandpiper[V]			
Tringa brevipes	Grey-tailed Tattler		M	✓
Tringa incana	Wandering Tattler		M	✓
Tringa erythropus	Spotted Redshank[V]			
Tringa gittifer	Nordman's Greenshank[V]		M	
Tringa nebularia	Common Greenshank		M	✓
Tringa flavipes	Lesser Yellowlegs[V]			
Tringa stagnatilus	Marsh Sandpiper		M	✓
Tringa totanus	Common Redshank		M	
Tringa glareola	Wood Sandpiper		M	
Arenaria interpres	Ruddy Turnstone		M	✓
Limnodromus semipalmatus	Asian Dowitcher		M	
Limnodromus griseus	Short-billed Dowitcher[V]			
Calidris tenuirostris	Great Knot	V	M	✓

FAMILY / Species name	Common name	Status TSC Act	Status EPBC	Recorded in Study Area
Calidris canutus	Red Knot		M	✓
Calidris alba	Sanderling	V	M	✓
Calidris minuta	Little Stint		M	
Calidris ruficollis	Red-necked Stint		M	✓
Calidris subminuta	Long-toed Stint		M	✓*
Calidris fuscicollis	White-rumped Sandpiper[V]			
Calidris bairdii	Baird's Sandpiper		M	
Calidris melanotus	Pectoral Sandpiper		M	✓*
Calidris acuminata	Sharp-tailed Sandpiper		M	✓
Calidris alpina	Dunlin[V]		M	
Calidris ferrugenea	Curlew Sandpiper		M	✓
Calidris himantopus	Stilt Sandpiper[V]			
Tryngites subruficollis	Buff-breasted Sandpiper[V]		M	
Limicola falcinellus	Broad-billed Sandpiper	V	M	✓*
Philomachus pugnax	Ruff		M	✓
Steganopus tricolor	Wilson's Phalarope[V]			
Phalaropus lobatus	Red-necked Phalarope		M	
Phalaropus fulicarius	Grey Phalarope		M	
GLAREOLIDAE				
Glareola maldivarum	Oriental Pratincole		M	✓*
Stiltia isabella	Australian Pratincole			

Notes: M = Listed as a migratory species on the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
V = Listed as a vulnerable species on the NSW *Threatened Species Conservation Act 1995* (TSC Act)
E = Listed as an endangered species on the TSC Act
CE = Listed as a critically endanagered species on the TSC Act
[V] = vagrant
* rare in the Northern Rivers CMA area

In Australia, shorebirds have three basic habitat requirements:

- roosting areas — where they can rest at high tide when foraging habitats are unavailable
- foraging areas — where they can forage in a manner that enables them to satisfy their daily energy requirements
- nesting areas — where resident shorebirds can nest and raise chicks.

The use of foraging and roosting areas is governed by the tidal cycle — shorebirds forage irrespective of whether it is day or night (McNeil et al. 1992). There is evidence that some species use different roost and foraging areas during the night from those used during the day (Rohweder & Baverstock 1996). The reasons for changes in habitat use are complex but often relate to food availability and a requirement to increase energy intake (Rohweder 1999).

At high tide, shorebirds gather at roosting area which are typically located just above the high water mark, have an open field of view, have access to the water, and are located 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 prior to high tide before moving to spring tide roosts. Shorebirds use 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.

Other roosting site characteristics include:

- areas free from human disturbance
- mangroves with exposed upper branches or an open midstorey with exposed branches
- areas adjoining the shoreline or open expanses of low vegetation where birds have a clear line of sight
- areas situated close to intertidal foraging habitat where there are a variety of suitable prey species and where birds can forage immediately prior to and after high tide
- areas where there is a mix of nocturnal and diurnal sites.

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 use 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 levels 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.

Foraging sites are also characterised by areas where there are:

- expansive areas of intertidal habitat situated close to high tide roosts
- abundant supplies of benthic invertebrate prey
- low levels of human disturbance
- a mix of diurnal and nocturnal sites.

Nesting areas are relevant for resident shorebirds only. These species nest in a variety of different habitats. One feature of nest sites is that they are often situated just above the high tide line. In northern NSW, shorebirds often breed on ocean beaches, sand islands and bars in estuaries, offshore islands and in saltmarsh (i.e. areas of Saltmarsh *Puccinellia stricta*). In coastal habitats, shorebirds nest in pairs and often defend small territories (Geering et al*.* 2006).

Other nesting site characteristics include:

- areas of sand, shingle, or saltmarsh above spring high water and storm surge
- areas were canopy vegetation is sparse or absent
- adjoining intertidal habitat where adults can forage close to nest sites
- areas where there are abundant prey for adults and chicks that will enable birds to satisfy their daily energy requirements while staying close to nest sites
- areas free from predators, particularly foxes — small sand islands are ideal in this regard
- areas with nil or low levels of human disturbance such as pedestrians, 4WD vehicles and dogs.

1.5 Previous studies

Morris (1981 and 1983 in Martindale 1984) provides the earliest population estimates for shorebirds in NSW. According to Martindale (1987) these estimates ranged from 29,000 to 33,000 individuals.

A decade later, Smith (1991) summarised count data from various sources including the Wader Studies Program (1981-1985), the early stages of the Shorebird Population Monitoring Program (1986-1990), published papers, unpublished reports and personal communication with local ornithologists. The extent to which the data were vetted is unclear, although the population estimates appear to be cumulative totals of maximum counts derived from various sites throughout the State and at various times. Watkins (1993) relied on Smith's (1991) data to identify important sites and derive species population estimates for NSW. Smith's population estimates provide a benchmark for maximum populations prior to 1990.

Since 1990 there has been a plethora of surveys and research conducted on shorebirds. Most work has been undertaken as part of the national Shorebird Population Monitoring Program which ran from 1986 to 1990, and its successor, Shorebirds 2020 (1986-2009). Regular monitoring (including monthly at some sites) by state-based wader studies groups also contributed substantial amounts of data. Counts of shorebirds have also been undertaken during research on various species of shorebird (e.g. Harrison 2009; Owner 1997; Rohweder 1999). Lawler (1994) undertook systematic surveys of shorebirds in selected north coast estuaries, and all estuaries between Tweed Heads and Woolgoolga were sampled during the Natural Resource Audit Council (NRAC) surveys in 1994. Beach-nesting birds were sampled during state-wide biennial surveys between 1996 and 2004 (NSW WSG unpublished data). Targeted surveys have also been conducted for rare species (Rohweder 2003) and long-term monitoring has been undertaken at some sites, for example, Tweed Estuary (Sandpiper Ecological Surveys 2003) and Clarence Estuary (Clancy 1992). Recently, Whetham and Scanlon (2007) mapped threatened shorebird habitat and identified priority sites in the Northern Rivers CMA region and Sandpiper Environmental (2004) identified issues associated with the management of shorebirds in the Clarence Estuary.

More recently, Bamford et al. (2008) summarised population estimates for shorebirds that use the East Asian-Australasian Flyway and identified internationally important sites[2]. They estimated the shorebird population in coastal NSW to be 23,200, and identified four coastal sites of international importance: Cedar Hill and Hexham Swamp (both Port Stephens), Hunter Estuary and Tuggerah Lakes — all of which occur on the NSW Central Coast. Watkins (1993) identified twice as many internationally important sites in the early 1990s, however, this reduction in sites is due to improved Flyway population estimates. These estimates have increased the numerical thresholds required to satisfy the 1% criterion[2].

Recent studies have seen greater focus on the use of geographic information systems (GIS) to map important sites and habitats. Examples include Whetham and Scanlon (2007), Avifauna Studies and Research (2006) and Sandpiper Ecological Surveys (2006). The greater emphasis on spatial data is a positive move as it builds on existing datasets to delineate focal points for conservation and management.

While most of the abovementioned studies have provided useful information on shorebirds and satisfied the individual project aims, greater benefits could be derived by collating and summarising the available data to identify conservation and management priorities and identify areas where management is required.

1.6 Conservation and management

Many species of shorebird are of high conservation status due to their migratory habits, small population size, susceptibility to threatening processes, declining population size and/or inability to recover from population declines. Conservation of migratory shorebird populations and their habitat is focussed primarily at the national and international levels, which is appropriate given their movement patterns. Conservation of resident shorebirds is focussed at the national and State level.

At an international level, migratory shorebirds are protected by agreements such as the Japan – Australia Migratory Bird Agreement (JAMBA), the China – Australia Migratory Bird Agreement (CAMBA) and the Republic of Korea – Australia Migratory Bird Agreement.

At a national level, all migratory species are listed on the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). There are 48 migratory shorebirds in Australia and 31 of these have been recorded in the Study Area (see **Table 3**).

In terms of threatened species, two shorebirds in Australia are listed on the *Threatened Species Conservation Act 1995* (TSC Act) as critically endangered, including the Beach Stone-curlew (which is known from the Study Area) and Hooded Plover. Four shorebirds that occur in Australia are listed

[2] For a site to be classified as 'internationally important' it must contain at least 1% of the known East Asian-Australiasian Flyway population of a particular species. This is referred to as the '1% criterion'.

on the TSC Act as endangered; one of these occurring in the Study Area. Ten shorebirds are listed as vulnerable, nine of which have been recorded in the Study Area (see **Table 3**).

Table 3 Numbers of threatened shorebirds in Australia and in the Study Area

	Australia		Study Area	
Status	EPBC Act	TSC Act	EPBC Act	TSC Act
Critically endangered	0	2	0	1
Endangered	0	4	0	1
Vulnerable	2	10	0	9
Migratory	48	na	31	na

Notes:

EPBC Act = Environment Protection and Biodiversity Conservation Act 1999

TSC Act = *Threatened Species Conservation Act 1995*

Some shorebird habitats are protected within marine and terrestrial conservation reserves and Ramsar sites. Other areas are afforded protection via local planning instruments, for example, by appropriate environmental zoning and/or restrictions on 4WD and dog access. The majority of habitats, however, occur outside of conservation areas and are often used for human recreation.

Threats to shorebirds and their habitat are increasing as the human population increases along the coast. Common threats include predation and disturbance at sites within conservation reserves. In many instances the reservation and gazettal of land alone is not sufficient to manage threats or ensure the long-term occupancy of habitat. Despite the national and international focus of much shorebird conservation effort, local and regional efforts play an important part in protecting migration 'stopover' sites and breeding habitat.

PART 2: SHOREBIRD DATA COLLATION

2.1 Introduction

Whetham and Scanlon (2007) summarised point locality records from accessible databases. To build on that work, this project focuses on gathering systematic survey data. Systematic survey data is defined as data gathered from a site or group of sites (location), using standardised and repeatable methods, to determine the number of species and individuals at that site/s. Systematic surveys may occur over single or multiple sample periods. Interrogation of systematic data is the best method to compare population trends and identify important sites within locations — two essential components for determining conservation and management priorities.

2.2 Methods

The data collation component of the project involved the following:

- an audit of existing relevant datasets
- the entry of all available data into a spreadsheet
- a preliminary analysis of the collated data.

These processes are described below.

2.2.1 Data audit

A rapid data audit was undertaken to determine the amount, type, format and accessibility of shorebird data relevant to the Study Area. This involved gathering information on shorebird data from readily available sources, including shorebird surveys in the Study Area (e.g. Shorebirds 2020), unpublished reports ('grey' literature), published reports and journal articles (e.g. *The Stilt*). Contact was also made with special interest groups, such as the NSW Wader Studies Group and Birds Australia. In general, pursuing local ornithologists for data was beyond the scope of this audit. The short project timeframes did not allow all available information to be acquired.

Information gathered on each data source included: reference details, a description of the survey, the availability of the data, format (digital or hard copy), the attribute/s sampled (roosts, foraging areas etc.), spatial coverage (number of sites sampled), temporal coverage (duration of study), basic survey method used, and the type of data available. The three main types of data included 'count data' (i.e. maximum counts for each species at a location and/or site over a specified period), hard copy maps of roost and foraging sites, and digital spatial data.

2.2.2 Data entry

Data were entered into an Excel spreadsheet in a site-by-species matrix. For major estuaries, data were divided into roost surveys (high tide), foraging surveys (low tide) and population estimates. Population estimates were derived from a combination of roost and foraging surveys (conducted during the same period) or roost surveys only. Data obtained from Birds Australia, *The Stilt* and some reports did not include any site-specific information, and is therefore presented as population estimates only.

A clear distinction has been made to differentiate between surveys that covered the whole spatial extent of a location ('entire' surveys), and those that covered only part of the location ('partial' surveys).

2.3 Results

2.3.1 Data sources

Forty-seven count data sources and five spatial data sources were identified in the rapid shorebird data audit (**Appendix 1**). Data were collated from 41 count data sources. All spatial data sources

were collated and reviewed. Due to the various licence agreements, approvals and contracts attached to these datasets, only summary results are presented in this report. Access to the collated dataset (i.e. the site-by-species matrix) and spatial data should be arranged through DECCW Biodiversity Assessment and Conservation Section, Coffs Harbour. A substantial amount of the data is from unpublished sources and permission must be obtained from the appropriate person/organisation before such data are used for other purposes.

2.3.2 Temporal and spatial coverage of shorebird data

Major estuaries

Data were gathered for the period 1981–2009, although temporal coverage of individual studies varies substantially between locations. While the data audit is not complete, the majority of known systematic data for major estuaries were collated, including most of the Australasian WSG Shorebird Population Monitoring Project summer and winter count data for 1986–2006; and Shorebirds 2020 count data for 2008–2009. Digital count data for 1981–2009 were obtained from Birds Australia for the Brunswick, Nambucca and Hastings estuaries. Some counts for 1981–1985 were collated for the Richmond and Clarence estuaries but the data were presented as combined values and were not included. Additional data for 1981–1985 may be available from Birds Australia.

Shorebird Population Monitoring Program data collated from *The Stilt* related to the Tweed, Richmond and Clarence estuaries only. The majority of Population Monitoring Program counts for these sites were obtained directly from the observers and, as such, are presented in the data summary under the observer's name. The majority of data relates to the Tweed, Richmond and Clarence estuaries (**Table 4**). This reflects the focus of survey effort at these sites as opposed to bias in the data audit process.

Data series were also collated for the Hastings (33 surveys), Brunswick (18 surveys) and Nambucca (15 surveys) estuaries, although spatial coverage of these locations appears restricted to a small number of sites. Limited data were collated for other major estuaries. The Sandon, Wooli, Corindi and Bellinger estuaries have each been sampled on five to eight occasions, while the Macleay and Evans estuaries have been sampled on two and three occasions respectively. Natural Resource Audit Council (NRAC) surveys and Lawler (1994) were the main sources of data for these sites.

It is difficult to draw conclusions on spatial coverage for all surveys, particularly as the Population Monitoring Program data included no site-specific information. Nonetheless, the information available indicates that the proportion of surveys that sampled an entire estuary varied substantially between locations. More than 90% of surveys in the Tweed, Richmond, Bellinger and Macleay estuaries sampled the majority of important roosts. In contrast, less than 20% of surveys in the Brunswick, Clarence, Nambucca and Hastings estuaries covered the entire location. Although the Clarence Estuary has been sampled in a systematic and regular manner over a 26-year period, the majority of surveys have sampled the southern half of the estuary only. Six major estuaries have been sampled over a time period greater than 20 years (**Table 4**). The Evans and Macleay estuaries have been sampled for one and two years respectively.

The majority of surveys at major estuaries have been conducted at high tide, although only three of the major estuaries have no low tide data. The Tweed, Richmond and Clarence estuaries have been sampled most frequently at low tide — with 55, 18 and 6 surveys collated for each site respectively (**Table 4**). Most of the low tide surveys at other major estuaries were conducted by NRAC.

Table 4 Summary of shorebird datasets in the Study Area

Location	No. of population estimates	% entire surveys	Time period (years)	Time of survey (Tide) *	
				High	Low
Major estuaries					
Tweed Estuary (L)	89	90%	23	74	55
Brunswick Estuary	18	11%	28	3	2
Richmond Estuary (L)	127	94%	23	103	18
Evans Estuary	3	100%	1	1	2
Clarence Estuary (L)	55	18%	26	46	6
Sandon Estuary (M)	6	50%	16	6	2
Wooli Estuary (M)	5	80%	8	6	2
Corindi Estuary (M)	6	50%	9	6	2
Bellinger Estuary (M)	8	100%	10	8	1
Nambucca Estuary (M)	15	nil	24	15**	0
Macleay Estuary (L)	2	100%	2	2	0
Hastings Estuary (L)	33	9%	27	33**	0
Minor estuaries and ICOLLs					
Cudgen Creek	2	100%	1		2
Cudgera Creek	2	100%	1		2
Mooball Creek	3	100%	3		3
Belongil Creek	5	40%	12	3	2
Salty Lagoon	6	100%	16		6
Jerusalem Creek	1	100%	1	uk	uk
Cakora Lagoon	2	100%	10		1
Arrawarra Creek	3	100%	3		3
Station Creek	1	100%	1		1
Flat Top Point	1	100%	1		1
Moonee Creek	29	100%	4		2
Boambee Creek	1	nil	1	uk	uk
Bonville Creek	5	100%	7	1	uk
Coastline sections					
Tweed River to Mooball Creek	8	63%	7	n/a	n/a
Mooball Creek to Cape Byron	8	63%	7	n/a	n/a
Cape Byron to Richmond River	102	8%	19	n/a	n/a
Richmond River to Goanna Headland	112	4%	19	n/a	n/a
Goanna Headland to Clarence River	32	13%	13	n/a	n/a
Clarence River to Sandon River	6	83%	10	n/a	n/a
Sandon River to Wooli River	5	100%	7	n/a	n/a
Wooli River to Arrawarra Headland	5	100%	7	n/a	n/a
Arrawarra Headland to Coffs Harbour	5	60%	7	n/a	n/a
Coffs Harbour to Bellinger River	4	100%	5	n/a	n/a
Bellinger River to Nambucca River	3	100%	5	n/a	n/a
Nambucca River to Laggers Point	3	100%	5	n/a	n/a

Location	No. of population estimates	% entire surveys	Time period (years)	Time of survey (Tide) *	
				High	Low
Laggers Point to Crescent Head	3	100%	5	n/a	n/a
Crescent Head to Tacking Point	3	100%	5	n/a	n/a

Notes: * includes only surveys that sampled two or more sites.

** assumes that Shorebird Population Monitoring Program surveys conducted at high tide.

uk = unknown.

(L/M) = in this report major estuaries are further classified into large (L) estuary or medium (M) estuary

Minor estuaries and ICOLLs

Data were gathered for 13 minor estuaries and ICOLLs, all of which occur between Tweed Heads and Sawtell (**Table 4**). Data for these locations were obtained predominantly from NRAC and the biennial Beach Nesting Bird Surveys in 1996, 1998 and 2000. Although there are several small estuaries and ICOLLs in the southern half of the Study Area, no site-specific records were collated for those locations. Many southern sites were sampled during the Beach Nesting Bird Surveys but data are presented for sections of coastline and have consequently been included with the coastline dataset. Most minor estuaries and ICOLLs have been sampled on six or less occasions (**Table 4**). The exception is Moonee Creek which was sampled 27 times during a 12-month period by Murphy (2008).

Data were gathered for one or two samples only at Cudgera Creek, Cudgen Creek, Jerusalem Creek, Cakora Lagoon, Station Creek, Flat Top Point and Boambee Creek. Most surveys of minor estuaries and ICOLLs have included the entire location. The longest data period was 16 years at Salty Lagoon. Most surveys at minor estuaries have been conducted at low tide (**Table 4**). Exceptions include Belongil Creek and possibly Bonville Creek.

Coastline sections

Distinguishing coastal surveys from estuary surveys was problematic as many estuary surveys also include adjoining coastal habitats. Prominent examples include Flat Rock and South Ballina Beach near the Richmond Estuary; and Shark Bay, Woody Head, Back Beach, Frasers Reef and Iluka Bluff near the Clarence Estuary. Surveys at these sites are duplicated in the coastline and estuary datasets and contribute to the high proportion of partial surveys for the relevant sections of coastline. Other locations where overlap is known to exist between coastal and estuary surveys, but where site-specific data could not be distinguished, include Belongil Creek, Salty Lagoon, Corindi River, Bonville Creek, Bellinger River and Nambucca River. Many coastline surveys are likely to include counts from estuary mouths and caution must be exercised in attributing counts to a section of coastline.

The number of coastline surveys and period of sampling decreases from north to south. There is a distinct peak in survey frequency and period of sampling near the Richmond and Clarence estuaries (**Table 4**). Most coastline surveys have been done at low tide, except where there are roosts that have been sampled repeatedly at high tide.

2.3.3 Spatial data

Four of the spatial data sources include mapped habitat attributes for various sites throughout the entire Study Area (EPA 1999; Avifauna Studies & Research 2006; Whetham & Scanlon 2007; and Shorebirds 2020). The fifth study covers only the Clarence Estuary (Sandpiper Ecological Surveys 2006). The spatial datasets are listed in **Appendix 2**). Each of the spatial data sources provides an example of how shorebird data can be linked with GIS to enable important habitats and areas to be identified.

The detail included in the spatial datasets varies depending on the aims and scale of the project. For example, Shorebirds 2020 used broad scale (1:100,000) mapping to delineate estuaries (sample

locations) that are part of the Shorebird Population Monitoring Program. This mapping is supported by summary statistics on species richness and abundance that has been derived from the Program (see **Appendix 3** for examples). The broadscale mapping undertaken for the Shorebirds 2020 project may not always be accurate at the location scale, but it does provide good summary data for comparison between major estuaries in the Study Area. Shorebirds 2020 also includes some more localised mapping of sample sites within estuaries. This mapping includes information on each site sampled as part of the project.

The Environment Protection Agency (1999) mapped various attributes within estuaries, including some intertidal habitat/roost sites used by threatened and migratory shorebirds, and point locality records for shorebirds. This data source is largely redundant because the mapping of roosts is not particularly accurate and the point locality records are out of date.

Avifauna Studies and Research (2006) mapped important roost and foraging sites for threatened migratory shorebirds in major NSW estuaries and prioritised estuaries in order of importance for each threatened migratory species and all threatened migratory species combined. The value of the maps could have been improved by combining data on threatened shorebirds with each mapped polygon to enable the relative value of sites to be compared. Some inaccuracies have also been identified with the mapping.

Sandpiper Ecological Surveys (2006) used GIS to map roosts and a subset of foraging areas in the Clarence Estuary. Summary data on the use of each roost by shorebirds was combined with spatial data to enable GIS users to assess the distribution and extent of roosts and their relative importance. That study provides a useful example of how site-specific data can be combined with GIS. Similar methods were used by Shorebirds 2020 and Sandpiper Ecological Surveys (2006) to combine spatial and site count data.

2.3.4 Shorebird research in the Study Area

A small number of shorebird research projects and species-specific surveys have been undertaken in the Study Area, including:

- research on the ecology and population dynamics of Pied and Sooty Oystercatchers in northern NSW (Harrison 2009)
- research on the distribution and foraging behaviour of Pied Oystercatchers between Kingscliff and the Clarence Estuary (Owner 1997)
- research on the use of nocturnal habitat by migratory shorebirds, the densities of foraging birds during the day and night, and the distribution of shorebirds and their prey (Rohweder 1999)
- a census of Beach Stone-curlew in northern NSW (Sandpiper Ecological Surveys 2000).

There are also a number of third-year university projects related to protection of Pied Oystercatchers inhabiting ocean beaches south of the Richmond River.

2.3.5 Additional data sources

While this project attempted to gather as much systematic data as possible, there are several additional datasets relevant to the Study Area that were not collated and entered. These datasets are known to contain information that would complement data collated during this project. Specific examples include:

- the 2002 and 2004 Beach Nesting Bird Surveys for NSW
- all shorebird count data from the 2000 Beach Nesting Bird Surveys — only data for resident shorebirds was available for this project
- Pied Oystercatcher Protection Program — including information on Australian Pied Oystercatcher nest sites, breeding success and population estimates between the Richmond River and Black Rocks and selected sites between the Clarence and Corindi estuaries
- additional surveys in the Nambucca Estuary during the 1990s — hard copy count data for the Nambucca Estuary has recently been sent to Birds Australia for inclusion in the shorebird population database (P. Straw pers comm.)
- additional Shorebird Population Monitoring Program data between 1981 and 1985 may exist for some major estuaries

- data for Belongil Creek gathered by the Belongil Bird Buddies
- nesting and population data for Pied and Sooty Oystercatchers from Harrison (2009)
- long-term surveys of shorebirds in the Evans Estuary by Bt Abus Consulting.

A substantial amount of additional data for smaller estuaries, coastline sections, and specific high tide roosts are likely to be contained within private databases. Examples of locations for which additional systematic data may exist include Flat Rock, Sandon, Wooli and Corindi estuaries; Bonville Creek mouth; Station and Korogoro creeks; Cakora Lagoon; and the Woody Head area.

2.3.6 Data type and quality

The data consists of counts of shorebirds at high and/or low tide at specific roost and foraging sites within locations or, in the case of creeks and ICOLLs, entire locations. The data include information on species diversity and abundance at most sites and locations. Site-specific (i.e. roost and foraging areas) data are not available for the Brunswick, Nambucca or Hastings estuaries as the Shorebird Population Monitoring Program does not include such information. The level of detail varies substantially between surveys and locations, and the data have been collated using a variety of methods. The collated datasets include variations in survey effort, timing and spatial coverage.

Examples of variability identified in the collated datasets and how it influences the data, include:

- Variability in the number and skills of observers: The number of observers varies from one for many of the major estuary surveys, to dozens for the Beach Nesting Bird Surveys. Larger estuaries such as the Clarence are sampled by multiple observers working in a coordinated manner.
- Population estimates derived from repeated systematic surveys over several months: These surveys are generally incomparable to other surveys in any assessment of temporal trends. Some of the recent count data presented by Shorebirds 2020 includes maximum counts over the summer period, not just counts on a single sample date.
- Variations in survey duration: Survey duration varies from single-day surveys to surveys over several days, and repeated systematic surveys over several days. Repeated systematic surveys of a location over several days are ideal as they enable comparison of survey results between successive days and derivation of accurate population estimates. In contrast, counts derived by conducting a single survey over several days increases the risk of duplication.
- Spatial coverage: The collated datasets include both entire and partial location surveys and single-site surveys. Comparing entire and partial population surveys to identify temporal trends is inappropriate. Single-site surveys can provide useful information on the importance of a site if conducted over a long duration.
- High and low tide surveys: The inclusion of both high and low tide can improve population estimates and enable important foraging habitat to be identified.
- Temporal variation: Surveys have been conducted at a variety of times. Due to the migration and breeding cycles of shorebirds it is important to consider survey timing. Comparison of temporal trends should focus on samples collected at similar times in the migration and breeding cycle.

Variability in methods influences both the accuracy of data and the ability to make comparisons between surveys. Shorebird datasets need to be carefully scrutinised to ensure that comparisons between counts are appropriate. Rohweder (2007) provided some indication of the variability that exists within shorebird datasets and how it affected the ability to analyse temporal population trends in the Tweed Estuary.

2.4 Discussion

The data collation component of the project has been successful in collecting and collating a substantial amount of count data on shorebirds within the Study Area. The process emphasised the vast amount of datasets that are available on shorebirds in northern NSW. Although there are additional data sources that were not accessed, it is likely that the majority of systematic survey data has been collated. Additional data are likely to exist for several smaller estuaries and specific sites. These data would undoubtedly add to our knowledge of these sites. A large number of additional

point locality data are likely to be housed in local ornithologists' private databases. These data are known to include records of individual species and repeated surveys of specific sites. It is unlikely that private databases include systematic survey data that has not already been submitted to either the NSW WSG or Australasian WSG.

Despite some limitations, the collated data could be used for a variety of means including quantitative analysis of population trends and species distribution, assessment of population trends over time, site prioritisation for management, and linkage with GIS mapping for regional planning. The Shorebird Population Monitoring Program and subsequent Shorebirds 2020 programs have been the impetus for much of the data collection at major estuaries. The NRAC Coastal and Estuarine Bird Surveys in 1994 and surveys by Lawler (1994) between 1992 and 1994 provide baseline data for many of the smaller estuaries.

One notable feature of the data is the large variation in samples between major estuaries. The spatial pattern of data collation seems to have varied during the life of the Shorebird Population Monitoring Program and Shorebird 2020 projects. During initial surveys from 1981–1985, many of the major estuaries were sampled although site coverage appears incomplete for most sites. Between 1986 and 2006 survey effort was concentrated in the Tweed, Richmond and Clarence estuaries. More recently the Shorebirds 2020 project has sought to expand survey coverage to include the estuaries sampled in the early 1980s.

Although the low survey effort at some smaller estuaries is expected, sample effort at the Macleay Estuary is particularly surprising. The Macleay is one of the larger estuaries in the Study Area yet it has received a fraction of the survey effort of other estuaries. Further data collation or survey in the Nambucca River Estuary is also warranted to fully determine its importance. Lawler (1994) recorded substantial numbers of Whimbrel and Common Greenshank in the Macleay indicating that it may include important shorebird habitat. Smith (1991) identified the Macleay Estuary as warranting further survey effort. Other prominent data gaps include the absence of site-specific data for small estuaries and ICOLLs between Bonville Creek and Port Macquarie, and the absence of nest records. Nest site data are essential to ensure a thorough evaluation of shorebird habitats and the identification of management priorities.

While the collated dataset is a useful resource, its value will diminish over time as more surveys are undertaken. This would require that new data be added, say on an annual basis, to ensure that the dataset remains valid. Further work may be warranted to investigate such things as a data transfer agreement with the Shorebirds 2020 project to obtain digital data, or whether uploading hard copy Shorebirds 2020 data from annual reports and *The Stilt* may be useful to updating the data. Collating the 2002 and 2004 Beach Nesting Bird Surveys data would add to the coastline dataset. These Surveys have been particularly useful in gathering data on areas that are typically not surveyed, and the inclusion of the 2002 and 2004 data would provide a more robust dataset.

Although the dataset collated for some locations includes numerous samples over a prolonged period, caution must be exercised if the data are used to assess population trends or compare populations between sites. Specific issues that must be considered when comparing population trends include: survey timing, survey coverage, and whether the estimates were derived from surveys during a brief period or are maximum values collected over a longer duration. A review of data in the Tweed Estuary highlights the influence of changes in survey coverage. Recent surveys in the Tweed Estuary conducted as part of the Shorebird Population Monitoring Program and Shorebirds 2020 have recorded very few shorebirds. This result is not due to a rapid population decline but rather a change in observers and reduced survey effort. The decision by Shorebirds 2020 to present maximum summer counts as opposed to the more standardised single-survey population estimates presented in previous years will also confound comparisons with future surveys (Kearney et al. 2008).

PART 3: DATA SUMMARY AND BASELINE ANALYSIS

3.1 Introduction

Shorebird data could be used in a variety of ways to obtain information on shorebirds in the Study Area. Examples include:

- identification of locations and sites (roosts and foraging areas) used by shorebirds
- prioritisation of locations (i.e. estuaries, ICOLLs and coastline sections) based on species diversity and abundance
- prioritisation of sites (roost, foraging and nesting areas) both within and between locations — this approach is most feasible for major estuaries due to the availability of data for those sites
- investigation of temporal trends in shorebird populations and species populations
- identification of priority sites for threatened species
- assessments of shorebird species status in the Northern Rivers CMA region
- research on population ecology and habitat use.

In general, the collated data represent a valuable resource to assist in identifying management priorities, to assist in development regulation, and to prioritise future survey effort. Linking the data with GIS mapping would enhance its utility. Before any of the above tasks are undertaken, particularly those that require the use of statistical methods, it would be necessary to vet the data to reduce variability and ensure that standardised procedures were applied.

Previous studies that compared and/or prioritised estuarine sites on the NSW north coast include Smith (1991), Lawler (1994) and Chafer (1995). Smith (1991) provides the only prioritisation of estuarine sites for all species in the entire Study Area, and indeed the entire NSW coast. Smith (1991) assigned estuaries to four priority levels using maximum counts for 1970–1990 and the 1% criterion. No estuaries in the Study Area were ranked as priority 1. The Richmond and Clarence estuaries were ranked as priority 2 sites, the Tweed and Hastings estuaries as priority 3 sites, and the Corindi and Nambucca estuaries as priority 4 sites. The latter two sites were seemingly included in priority 4 as they were deemed to be the only known regular breeding sites in NSW for Beach Stone-curlew.

Lawler (1994) surveyed shorebirds at seven major estuaries in the Study Area between 1992 and 1994. Although Lawler (1994) did not undertake a rigorous comparison between sites, he did include a summary of four criteria that were used to determine conservation value. The Tweed, Richmond, Clarence and Macleay estuaries satisfied all four criteria, while the Wooli, Bellinger and Hastings satisfied only two criteria. Chafer (1995) summarised NRAC Coast and Estuarine Bird Survey data and emphasised the importance of the Clarence Estuary. Avifauna Research and Services (2006) ranked NSW estuaries in order of importance for threatened migratory shorebirds. That study ranked the Clarence as the most important site for threatened migratory shorebirds followed by the Richmond and Hunter estuaries.

Apart from the above studies, the majority of other published reports have focused on single sites. Sandpiper Ecological Surveys (2003, 2009) suggested that the Tweed Estuary was one of the top five estuaries for estuarine birds in NSW, and one of the top ten sites for shorebirds in NSW.

The aim of the following section is to present a general overview of the collated data by comparing shorebird and target species populations between locations, and identifying priority areas for threatened species.

3.2 Methods

As discussed in the previous section, there are limitations associated with using the shorebird data to assess population trends and make comparisons between locations. To undertake rigorous data analysis, a considerable amount of vetting would be required. The data have not been vetted for this baseline analysis.

For the purpose of this report ‘summer’ extends from 1 October to 5 April. This period covers the ‘summer’ migration cycle for migratory species and most of the breeding season for resident species. A broad time period was adopted to simplify the process of identifying maximum and average populations, and to nullify the effect of differences in movement patterns — particularly by migratory species. A broad time period was used to account for all movement variability. Using a broad time period reduces average values but provides a better idea of maximum values, and hence provides an upper limit of population estimates.

As explained previously, 'entire' surveys refer to those that cover the entire spatial extent of a location, and 'partial' surveys refer to those that cover only part of a location.

As well, in this report, the term 'population' refers to the total shorebird population at a particular location, that is, *all* individuals of *all* species of shorebird.

3.2.1 Comparison of shorebird populations between locations

Two data derivation processes were undertaken to compare the shorebird populations between various locations in the Study Area.

1) For each location in each of the three habitats (i.e. major estuaries, minor estuaries and ICOLLs, and coastline sections) basic population statistics were derived.

This included the following:

- number of migratory, resident and threatened species
- breeding records (D. Rohweder pers. obs.)
- maximum summer population estimate = the maximum number of all shorebirds recorded during a single 'summer' survey
- average summer population estimate = the average number of individual shorebirds recorded during 'summer' surveys (either both partial and entire surveys, or just entire surveys)
- maximum species diversity (richness) = the maximum number of shorebird species recorded during a single 'summer' survey
- average species diversity (richness) = the average number of species recorded during 'summer' surveys (either both partial and entire surveys, or just entire surveys)
- total species diversity (richness) = the sum total of all migratory and resident species recorded at a location during all collated surveys.

Averages were derived by dividing the sum total of summer period population estimates by the number of estimates. Standard deviations or standard errors have not been calculated due to the baseline nature of the analysis. Although data variability reduces the likelihood of identifying trends in average population estimates, in many cases the variability is standardised across sample locations. Cases where variability has affected the results are noted in the text.

Partial surveys were removed from the datasets of the Tweed and Richmond estuaries as both sites include a substantial number of population estimates and the removal of some replicates did not affect the results. The influence of partial surveys on data is shown by including the averages for all surveys (partial & entire) and entire surveys only in the Clarence Estuary. These are listed as 'Clarence (all)' surveys and 'Clarence (full only)' in the tables and figures. The cumulative maximums summarised by Smith (1991) for 1970–1990 have not been included in the maximum or average population estimates.

The results of these calculations are presented in Results Section 4.3.1.

2) Maximum and average populations of 12 selected species at major estuaries were derived and compared.

The 12 species selected for the comparison are either common or otherwise important within the Study Area:

Bar-tailed Godwit	Pacific Golden Plover
Common Greenshank	Pied Oystercatcher
Curlew Sandpiper	Red-capped Plover
Eastern Curlew	Red-necked Stint
Grey-tailed Tattler	Sharp-tailed Sandpiper
Less Sand Plover	Whimbrel

The results of these calculations are presented in Results Section 4.3.2.

3.2.2 Identifying priority sites for threatened shorebirds

For each migratory and resident threatened shorebird, average population estimates were calculated for each location across the three habitats (i.e. major estuaries, minor estuaries and ICOLLs, and coastline sections).

The three sites/locations with the highest average population for a species were deemed to be 'priority sites' for that species. These sites were ranked in order of abundance. Priority sites were plotted onto small-scale maps of the Study Area using ArcView. See Results Section 4.3.3 for migratory threatened shorebird priority sites, and Section 4.3.4 for resident threatened shorebird priority sites.

Priority site rankings were verified by comparing average population estimates to maximum population estimates and the frequency that a species was present at a site. Average populations less than one were not included in the comparison. This meant that not all threatened shorebirds had three priority sites identified. In some instances (i.e. Sanderling) the same ranking was given to two sites because they were known to be used by the same population.

Two threatened species were not included in the analysis: Beach Stone-curlew owing to its scarcity (see below), and Broad-billed Sandpiper because it only occurs sporadically in the Study Area.

Due to the small population size but high conservation status of Beach Stone-curlew, priority sites for that species were identified using the following criteria:

- priority 1: presence of a long-term breeding pair
- priority 2: presence of a long-term pair or recent (last two years) breeding record
- priority 3: recorded at the site for a continuous period greater than 12 months.

In addition to the prioritisation method described above, a breeding site prioritisation was also undertaken for Pied and Sooty Oystercatchers. The criteria used were:

- priority 1: greater than five breeding pairs in a location
- priority 2: three to five breeding pairs in a location
- priority 3: two breeding pairs in a location.

The above criteria resulted in the identification of more than three priority sites for Beach Stone-curlew. The prioritisation for Beach Stone-curlew and Pied Oystercatcher is based on a combination of data gathered during the audit and expert knowledge (D. Rohweder, Sandpiper Ecological Surveys and associates). Nest site prioritisation for Sooty Oystercatchers is based on limited point locality data gathered during NRAC, Beach Nesting Bird Surveys and Harrison (2009).

3.3 Results

3.3.1 Population estimates and species diversity

All Sites

The audited surveys included records for 42 shorebird species, including 10 resident species and 32 migratory species (**Table 2**). Ten species are considered rare visitors, six of which could be classified as vagrants. Eleven threatened species have been recorded in the Study Area (**Tables 2 & 3**).

Major estuaries

Comparison of average and maximum summer populations and species diversity between major estuaries reveals some clear trends (**Table 5; Figures 2 & 3**). The highest maximum population estimate has been recorded in the Clarence Estuary followed by the Richmond and Tweed estuaries. The highest summer population estimate recorded in the Clarence Estuary (including Clarence Broadwater) was 3747 individuals, recorded in November 1994. This estimate is 2.5 times greater than the maximum summer population of 1461 individuals recorded in the Richmond Estuary in January 1994 (**Table 5**). Total species diversity is greater in the Richmond (38 species) than the Clarence (36 species), although nine threatened shorebirds have been recorded at both locations (**Table 5**).

The maximum summer population estimate for the Hastings Estuary (863 individuals) is similar to the Tweed (996) (**Table 5**) but the average summer population estimate is substantially less in the Hastings (251) than the Tweed (605) (**Table 5**). There is also substantial difference in average and maximum species diversity between the two estuaries. In the Tweed Estuary 23 migratory and 10 resident species have been recorded, compared to 15 migratory and 5 resident species in the Hastings (**Table 5**). In the Tweed, 9 threatened species have been recorded, compared to 7 in the Hastings. Differences in total species diversity and average summer population estimates may be due to survey effort as most surveys in the Hastings are partial surveys while virtually all surveys in the Tweed are entire surveys. The effect of partial and entire surveys on averages is shown for the Clarence where average diversity and abundance was less for partial surveys than entire surveys (**Table 5**).

Due to the small number of samples in the Macleay Estuary, there is some doubt regarding the accuracy of population estimates and species diversity in this location, and therefore some caution is required in interpreting these figures where low sample sizes occur (**Table 5**). Furthermore, maximum species diversity in the Macleay, one of the larger estuaries in the Study Area, is similar to many smaller estuaries (**Table 5**).

There is some similarity in maximum summer population estimates and species diversity between the smaller or medium sized major estuaries, however, population size and diversity in these estuaries is substantially less than in the Clarence, Richmond and Tweed. Based on population size and species diversity, the remaining estuaries can be divided into three groups: 1) Sandon and Nambucca; 2) Wooli, Bellinger and Brunswick; and 3) Evans and Corindi (**Table 5**).

The Sandon and Nambucca estuaries have similar maximum and average population estimates. The Nambucca has a higher total species diversity (26 species) than the Sandon (17 species). Both estuaries contain breeding pairs of Beach Stone-curlew, Pied Oystercatcher and Red-capped Plover (**Table 5**). The lower average summer population in the Sandon and Nambucca estuaries is due to a greater proportion of partial surveys which affect averages.

The total number of species is similar between most of the smaller major estuaries, ranging from 15 to 19 (**Table 5**). The exception is the Evans Estuary which has a total species diversity of 10. The number of threatened species is also similar between most of the smaller estuaries, ranging from 2 at Evans to 6 at Bellinger estuaries (**Table 5**). Maximum population estimates and species diversity at most sites were obtained from surveys in the early 1980s and 1990s. Exceptions include the Bellinger, where maximums were recorded in 2002/2003, and Hastings, where maximum species diversity was recorded in 2005 (**Table 5**).

Table 5 Summary of shorebird data for the major estuaries and minor estuaries and ICOLLs

Location	No. mig spp	No. res spp	Tot spp div	No. th spp	Breeding records	Smp size	Max pop est (year)	Ave pop est	Max spp div (year)	Ave spp div
Major estuaries										
Tweed	23	10	33	9	PO	45	996 (1994)	604.94	23 (1994)	15
Brunswick	10	5	15	3*	PO	12	108 (1994)	37.4	12 (1994)	5.41
Richmond	29	9	38	9	PO, RCP, BWS	67	1461 (1994)	983.19	25 (1995)	20.58
Evans	6	4	10	2	PO	3	139 (1994)	110.33	10 (1994)	7.33
Clarence (all)	27	9	36	9	PO, BSC, RCP, BWS	29	3747 (1994)	1459.55	28 (1994)	18.27
Clarence (entire)						(10)	3747 (1994)	1818.3	28 (1994)	21.8
Sandon	11	6	17	4	PO, BSC, RCP	5	275 (1994)	153.8	12 (1994)	9.8
Wooli	11	5	16	4	PO, BSC	4	194 (1994)	171.25	12 (1994)	11.25
Corindi	14	6	20	5	PO, RCP, BSC	3	103 (1994)	85.67	13 (1994)	9
Bellinger	14	6	20	6	PO	6	189 (2003)	165.67	11 (2002)	9.67
Nambucca	18	8	26	5	BSC, PO, RCP	7	276 (1982)	148.29	13 (1982)	9
Macleay	17	5	22	4		2	492 (1993)	433.5	9 (1993)	8.5
Hastings	15	5	20	7	PO	18	863 (1983)	295.61	12 (2005)	7.83
Minor estuaries and ICOLLs										
Cudgen Creek	5	3	8	1		2	15	14	7	6.5
Cudgera Creek	4	2	6	0		2	28	26.5	7	6.5
Mooball Creek	6	2	8	1		3	28	17	5	4
Belongil Creek	10	5	15	4*	PO, BSC	4	114	63.75	12	6.75
Salty Lagoon	7	5	12	3	PO, BSC, RCP	5	96	54.8	10	7
Jerusalem Creek	2	2	4	1	PO					
Cakora Lagoon	5	4	9	1	PO, RCP	2	72	50	8	6
Arrawarra Creek	5	2	7	1		3	13	8.67	5	3.67
Station Creek	0	3	3	1	PO, RCP					
Flat Top Point	2	1	3	0						
Moonee Creek	3	4	7	3		2	4	4	1	1
Boambee Creek	3	0	3	0						
Bonville Creek	6	5	11	3	PO, RCP	5	110	69.8	10	7.6

Notes:

No. mig spp = number of migratory species.

No. res spp = number of resident species.

Tot spp div = total species diversity (migratory + resident).

No. th spp = number of threatened species.

Smp size = sample size.

Max pop est = maximum population estimate.

Ave pop est = average population estimate.

Max spp div = maximum species diversity.

Ave spp div = average species diversity.

* includes record of Beach Stone-curlew from a survey that was not audited.

BSC = Beach Stone-curlew.

BWS = Black-winged Stilt.

PO = Australian Pied Oystercatcher.

RCP= Red-capped Plover.

Data summarised by Smith (1991) for 1970–1990 substantially increases the total species diversity and number of threatened species recorded in the Corindi, Bellinger, Nambucca, Macleay and Hastings estuaries. In many instances the maximum counts of most additional species included in Smith (1991) are less than five.

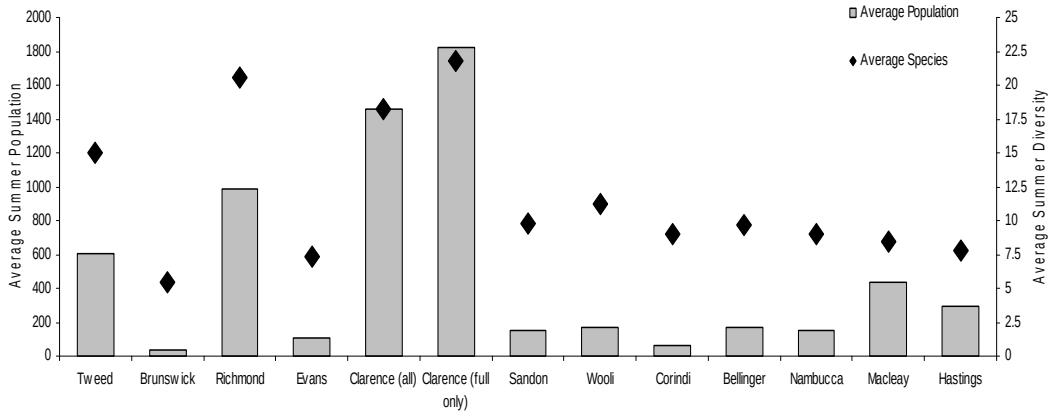


Figure 2 Average 'summer' diversity and population estimates for shorebirds at major estuaries in northern NSW.

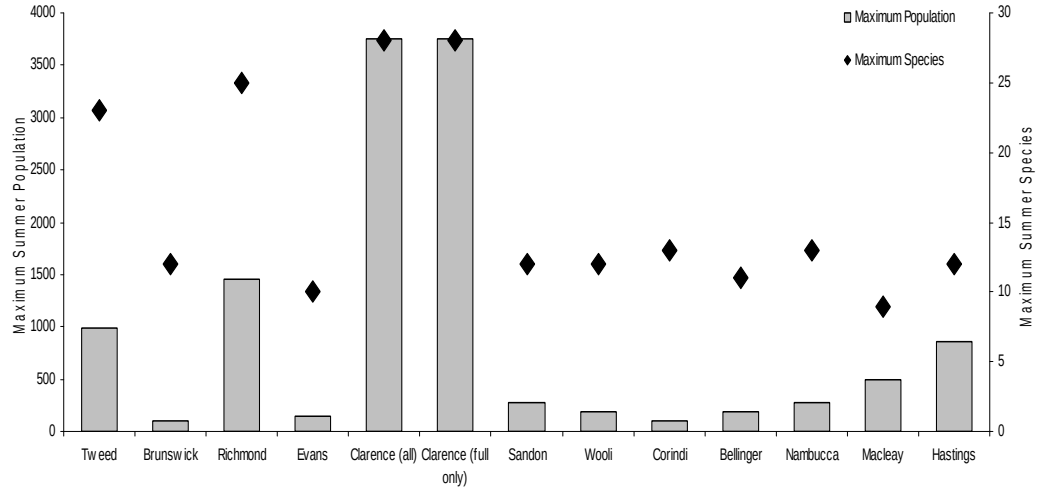


Figure 3 Maximum 'summer' diversity and population estimates for shorebirds at major estuaries in northern NSW.

Minor estuaries and ICOLLs

Substantial variation occurs between minor estuaries and ICOLLs in maximum and average summer population estimates (**Table 5**; **Figures 4 & 5**). Belongil Creek, Salty Lagoon, Cakora Lagoon and Bonville Creek have substantially greater maximum and average population estimates than other minor estuaries and ICOLLs. Maximum species diversity was also greatest at those sites. However, average species diversity at Cudgen Creek and Cudgera Creek were similar to sites with larger shorebird populations (**Table 5**).

Total species diversity was greatest at Belongil Creek (15 species) followed by Salty Lagoon (12 species) and Bonville Creek (11 species). The number of threatened species was also greatest at Belongil Creek followed by Salty Lagoon, Moonee Creek and Bonville Creek (**Table 5**).

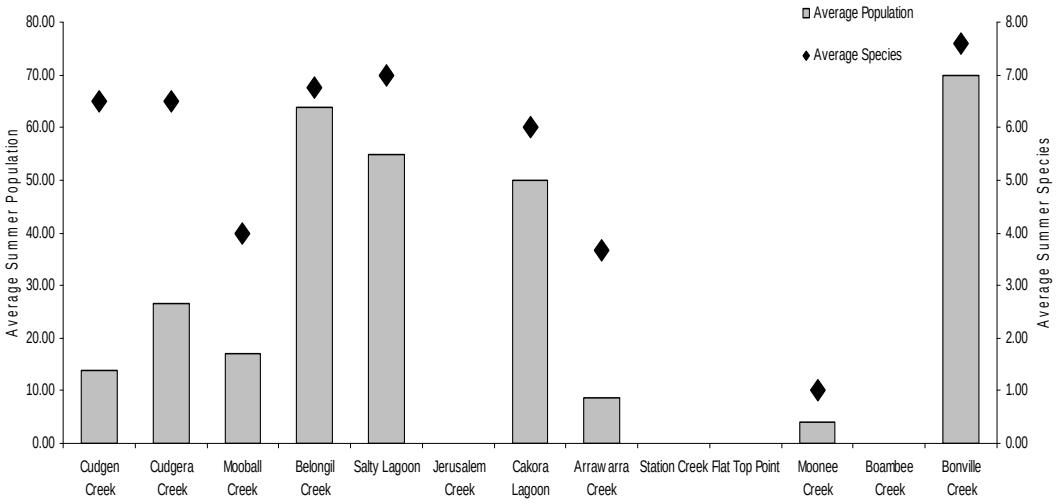
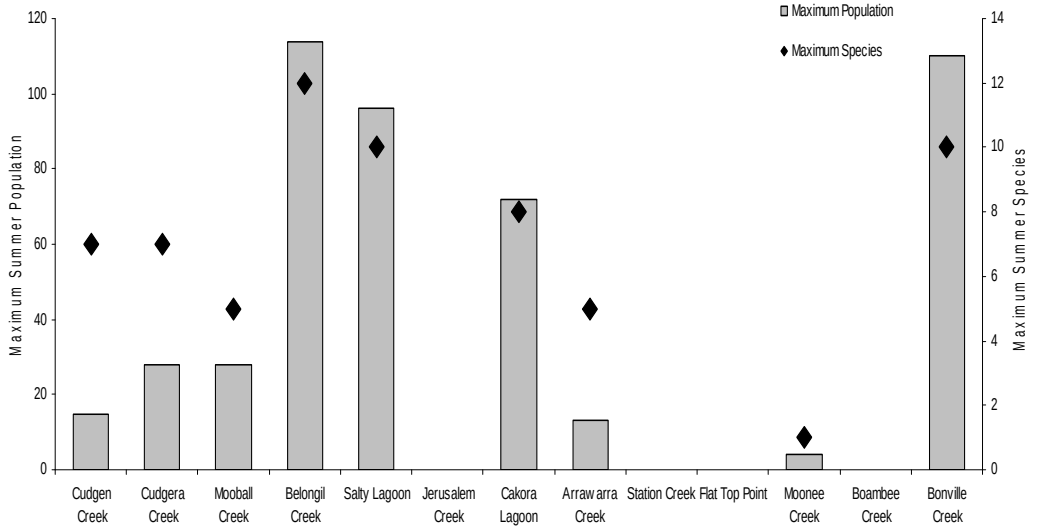


Figure 4 Average 'summer' diversity and population estimates for shorebirds at minor estuaries and ICOLLs in northern NSW.

Figure 5 Maximum 'summer' diversity and population estimates for shorebirds at minor



estuaries and ICOLLs in northern NSW.

Coastline sections

The highest maximum and average summer population estimates at coastal sites were recorded along the Richmond River to Goanna Headland coastline, followed by Goanna Headland to Clarence River and Laggers Point to Crescent Head (**Table 6; Figures 6 & 7**). Similar average summer population estimates of between 60 and 70 individuals have been recorded along the Cape Byron to Richmond River, Clarence to Sandon Rivers, Arrawarra Headland to Coffs Harbour and Coffs Harbour to Bellinger River coastlines (**Table 6**). Each of these areas includes rocky shores that are favoured foraging habitat for migratory shorebirds and/or ICOLLs that may have been included in the various samples.

The highest maximum species diversity was recorded along the Richmond River to Goanna Head and Clarence River to Sandon River coastlines (each with 13 species), followed by Goanna Headland to Clarence River coastline with 11 species (**Table 6**). Average species diversity peaked at 8.3 species per sample between the Clarence and Sandon rivers. Most sites had a maximum diversity of 7–8, with the lowest diversity recorded between the Bellinger and Nambucca rivers. The total number of species was greatest between the Richmond River and Goanna Headland (22 species), followed by Cape Byron to Richmond River (20 species) and Goanna Headland to Clarence River (18 species). The number of threatened species followed a similar trend, although five threatened species have also been recorded between the Clarence and Sandon Rivers and Laggers Point and Crescent Head (**Table 6**).

Table 6 Summary of shorebird data for coastline sections

Coastline section	No. mig spp	No. res spp	Tot spp div	No. th spp	Breeding records	Smp size	Max pop est	Ave pop est	Max spp div	Ave spp div
Tweed River to Mooball Creek	7	5	12	4	PO	5	18	9	8	4.6
Mooball Creek to Cape Byron	7	5	12	4	PO, BSC, RCP	5	47	23	7	4.4
Cape Byron to Richmond River	16	4	20	5	RCP	66	83	62	8	4
Richmond River to Goanna Headland	16	6	20	6	PO, RCP, BSC	74	512	174	13	5.86
Goanna Headland to Clarence River	13	5	18	5	PO, RCP	25	244	101	11	6
Clarence River to Sandon River	9	6	15	5		6	144	68.83	13	8.3
Sandon River to Wooli River	5	5	10	3	PO	5	41	19	7	4.2
Wooli River to Arrawarra Headland	7	6	13	4	PO, RCP	5	64	33.4	7	5
Arrawarra Headland to Coffs Harbour	6	4	10	3	SO, RCP	5	96	60	8	3.6
Coffs Harbour to Bellinger River	6	4	10	2	PO, RCP	4	112	59.25	7	5.5
Bellinger River to Nambucca River	0	3	3	2		3	16	11.67	3	2.33
Nambucca River to Laggers Point	5	2	7	2		3	55	23	7	3.33
Laggers Point to Crescent Head	9	3	12	5		3	213	95.67	8	5.67
Crescent Head to Tacking Point	3	3	6	2		3	68	32.67	5	4

Notes:

No. mig spp = number of migratory species.

No. res spp = number of resident species.

Tot spp div = total species diversity (migrant + resident).

No. th spp = number of threatened species.

Smp size = sample size.

Max pop est = maximum population estimate.

Ave pop est = average population estimate.

Max spp div = maximum species diversity.

Ave spp div = average species diversity.

* includes record of Beach Stone-curlew from a survey that was not audited.

BSC = Beach Stone-curlew.

BWS = Black-winged Stilt.

PO = Australian Pied Oystercatcher.

RCP= Red-capped Plover.

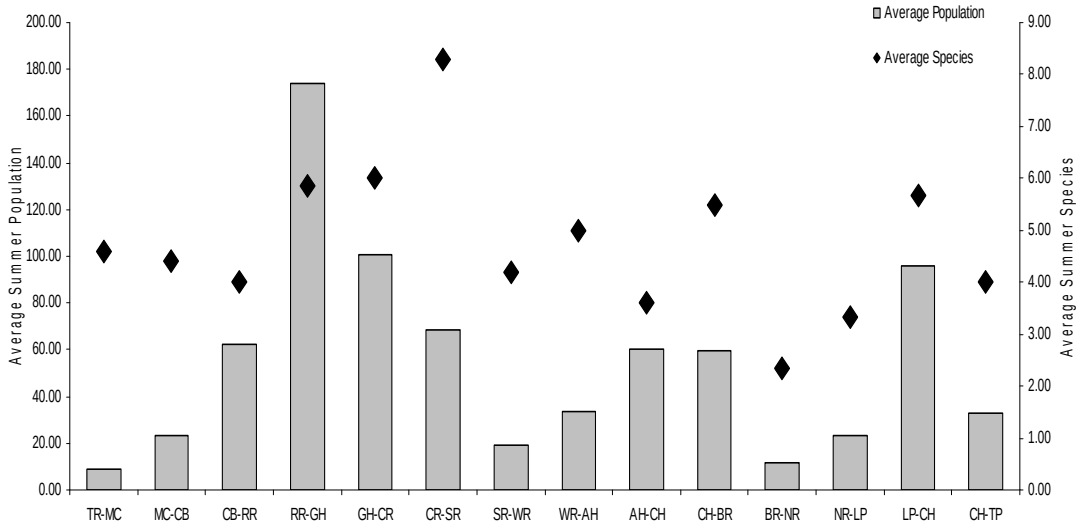


Figure 6 Average 'summer' diversity and population estimates for shorebirds within coastline sections

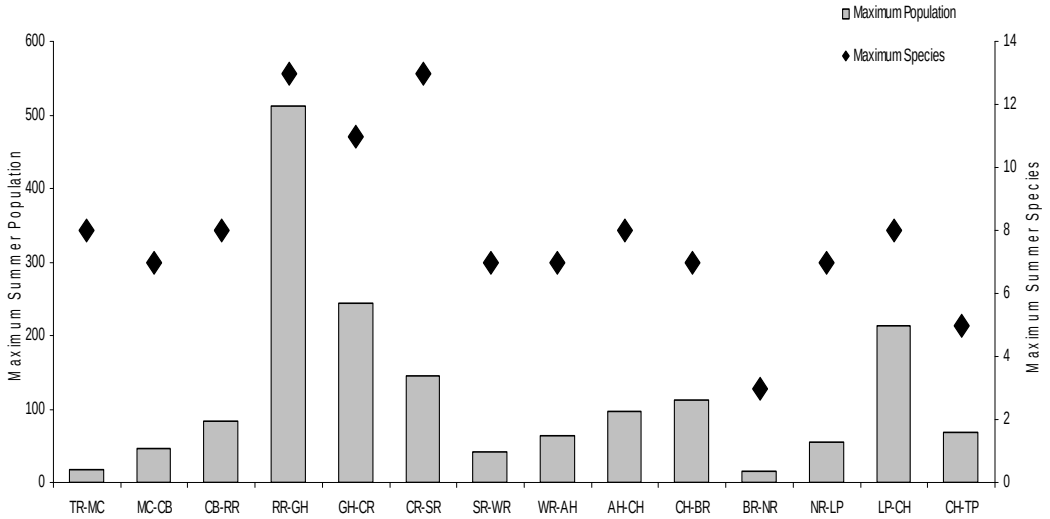


Figure 7 Maximum 'summer' diversity and population estimates for shorebirds within coastline sections

Abbreviations used in Figures 6 and 7:

TR - MC Tweed River to Mooball Creek
MC - CB Mooball Creek to Cape Byron
CB - RR Cape Byron to Richmond River
RR - GH Richmond River to Goanna Headland
GH - CR Goanna Headland to Clarence River
CR - SR Clarence River to Sandon River
SR - WR Sandon River to Wooli River
WR - AH Wooli River to Arrawarra Headland
AH - CH Arrawarra Headland to Coffs Harbour
CH - BR Coffs Harbour to Bellinger River
BR - NR Bellinger River to Nambucca River
NR - LP Nambucca River to Laggers Point
LP - CH Laggers Point to Crescent Head
CH - TP Crescent Head to Tacking Point

3.3.2 Major estuary selected species accounts

Summary data for the 12 selected shorebird species are presented in charts in **Figures 8 to 19** below. The raw data on which these charts are based is presented in **Table 7**.

The highest maximum and average population estimates for 9 of the 12 selected species (Pied Oystercatcher, Pacific Golden Plover, Lesser Sand Plover, Bar-tailed Godwit, Eastern Curlew, Grey-tailed Tattler, Red-necked Stint, Sharp-tailed Sandpiper and Curlew Sandpiper) occurred at either the Clarence or Richmond estuaries (**Figures 8 to 19**). The Tweed Estuary had high average and maximum population estimates of Eastern Curlew and Grey-tailed Tattler and similar average and maximum population estimates to the Clarence Estuary for Whimbrel (**Figure 13**). The highest average and maximum population estimates of Whimbrel and the highest average population estimate of Common Greenshank were recorded in the Macleay Estuary (**Figures 13 and 16**). High average summer population estimates of Common Greenshank were also recorded in the Richmond and Tweed, and maximum population estimates were similar between these estuaries and the Clarence and Macleay (**Figure 16**).

Average summer population estimates of between five and seven Pied Oystercatchers were recorded in the Tweed, Richmond, Wooli and Nambucca estuaries, with a maximum of 13 individuals recorded in the Clarence. The maximum population estimate of Pied Oystercatchers was 59 recorded in the Richmond Estuary (**Figure 8**). Average population estimates of Red-capped Plovers peaked at 23 individuals at the Sandon and Wooli estuaries, with averages of between 15 and 20 individuals recorded at Corindi and Nambucca (**Figure 10**). The highest maximum summer population estimate of Red-capped Plovers (74 individuals) was recorded at the Clarence Estuary (**Table 7**).

As was the case for the total population comparisons, smaller estuaries tended to have small populations of the 12 selected species. Exceptions include those mentioned above for Red-capped Plover and Pacific Golden Plover in the Bellinger (**Figure 9**) and Whimbrel in the Sandon (**Figure 13**). Very few Sharp-tailed Sandpiper, Red-necked Stint and Curlew Sandpiper have been recorded in the smaller estuaries.

The Hastings Estuary had maximum population estimates for Eastern Curlew, Whimbrel, Red-necked Stint and Bar-tailed Godwit that were comparable to other large estuaries. However, average population estimates were substantially lower, possibly because few surveys have sampled the entire estuary.

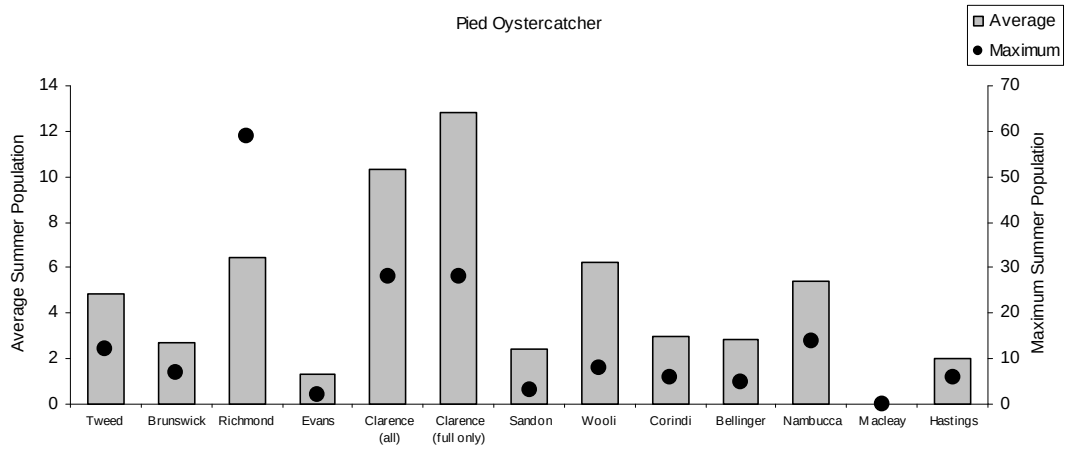


Figure 8 Maximum and average 'summer' populations of Pied Oystercatcher at major estuaries in northern NSW.

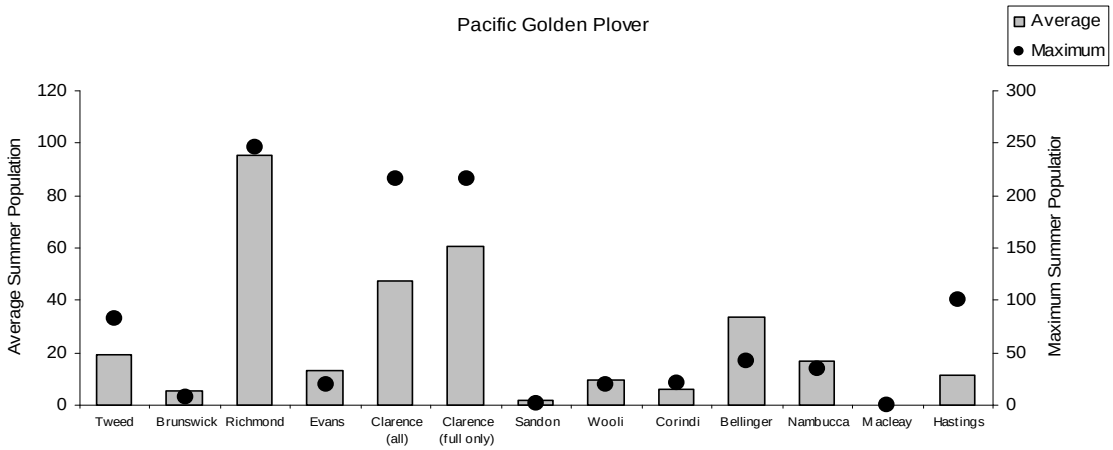


Figure 9 Maximum and average 'summer populations of Pacific Golden Plover at major estuaries in northern NSW.

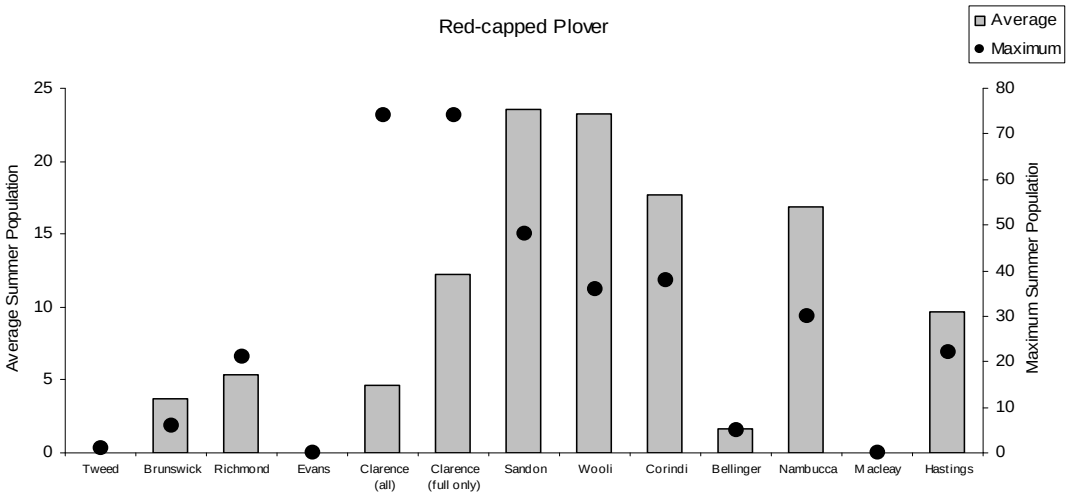


Figure 10 Maximum and average 'summer' populations of Red-capped Plover at major estuaries in northern NSW.

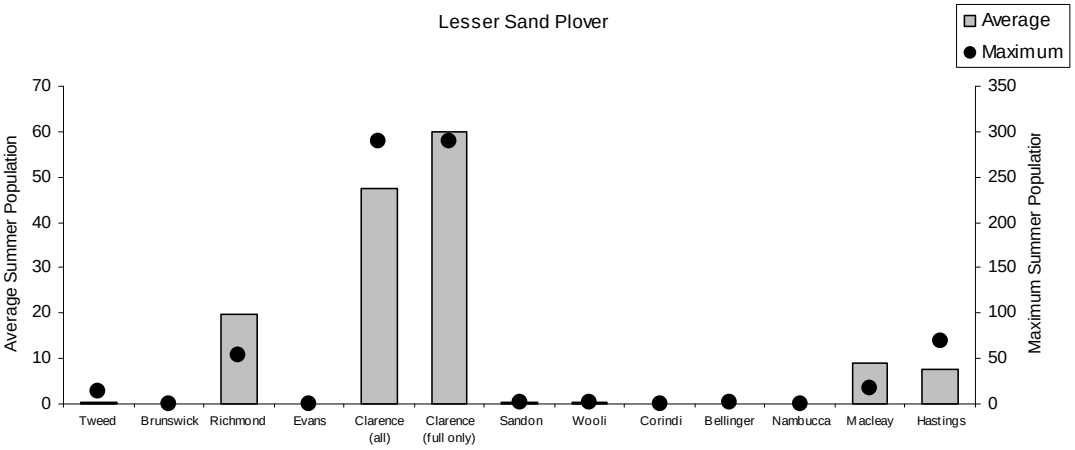


Figure 11 Maximum and average 'summer' populations of Lesser Sand Plover at major estuaries in northern NSW.

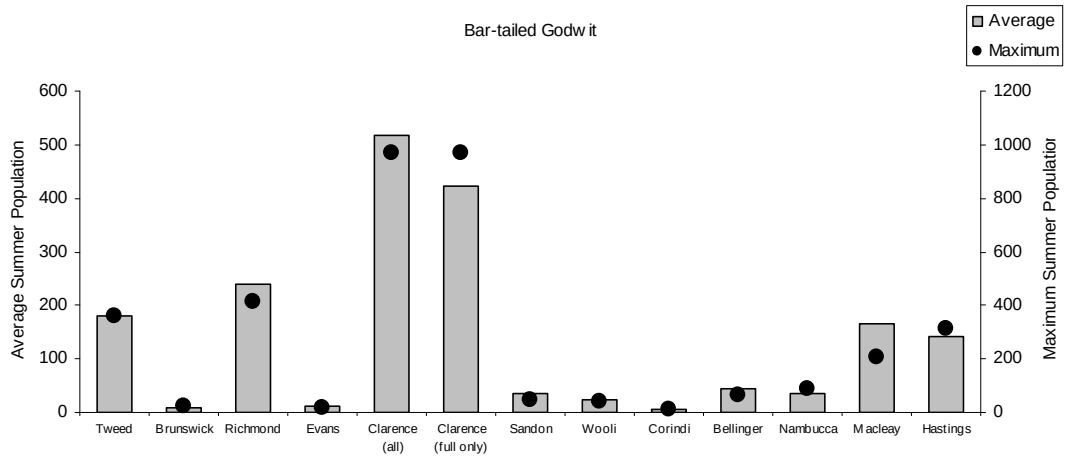


Figure 12 Maximum and average 'summer' populations of Bar-tailed Godwit at major estuaries in northern NSW.

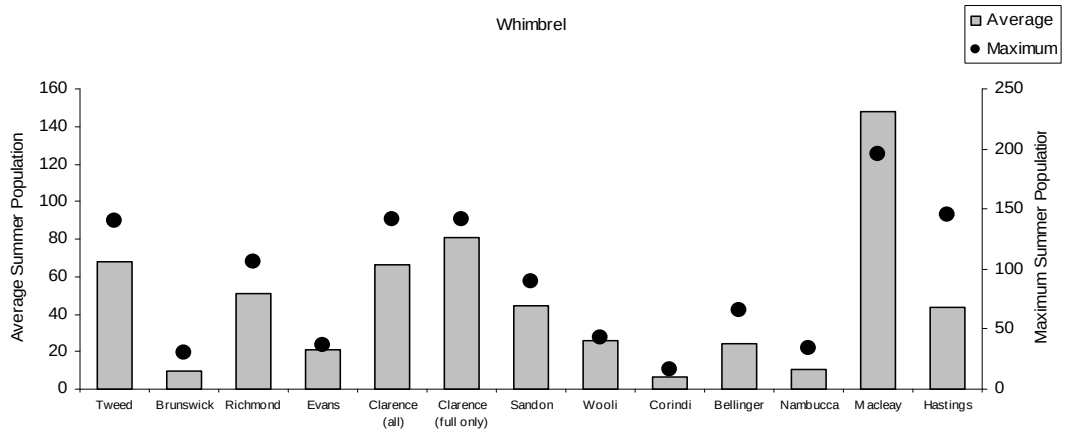


Figure 13 Maximum and average 'summer' populations of Whimbrel at major estuaries in northern NSW.

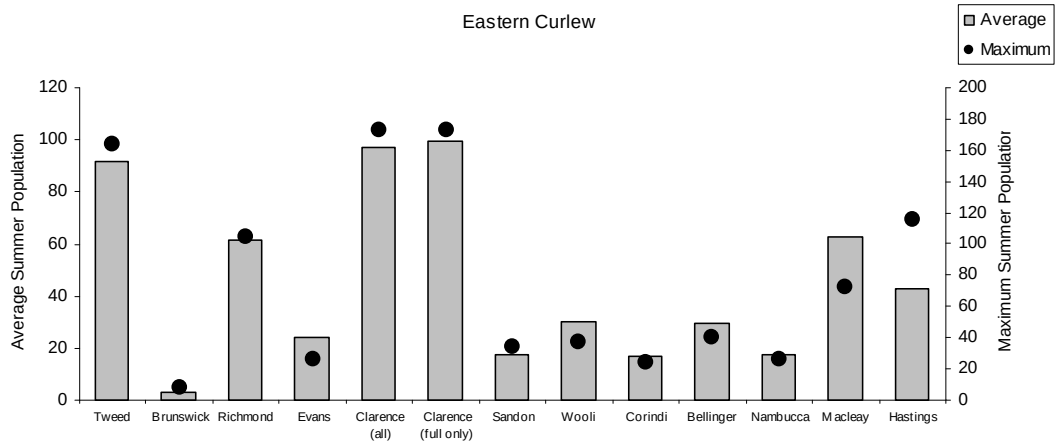


Figure 14 Maximum and average 'summer' populations of Eastern Curlew at major estuaries in northern NSW.

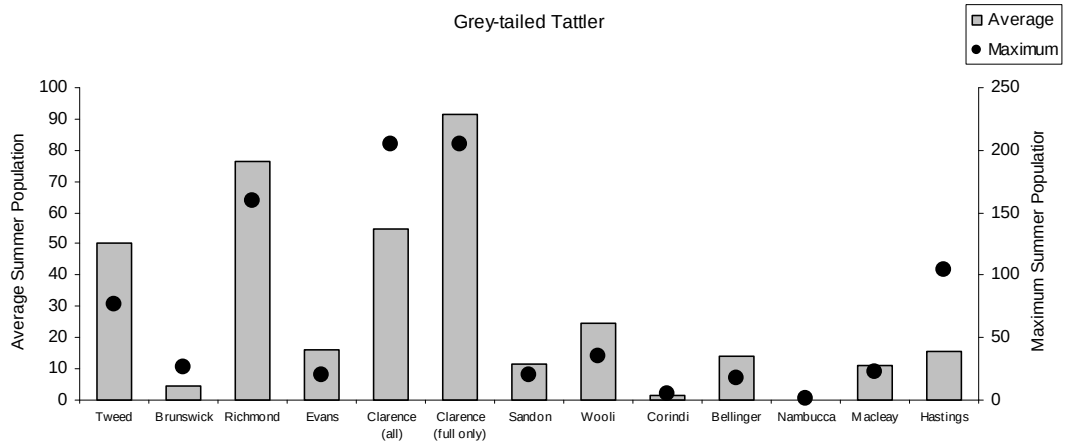


Figure 15 Maximum and average 'summer' populations of Grey-tailed Tattler at major estuaries in northern NSW.

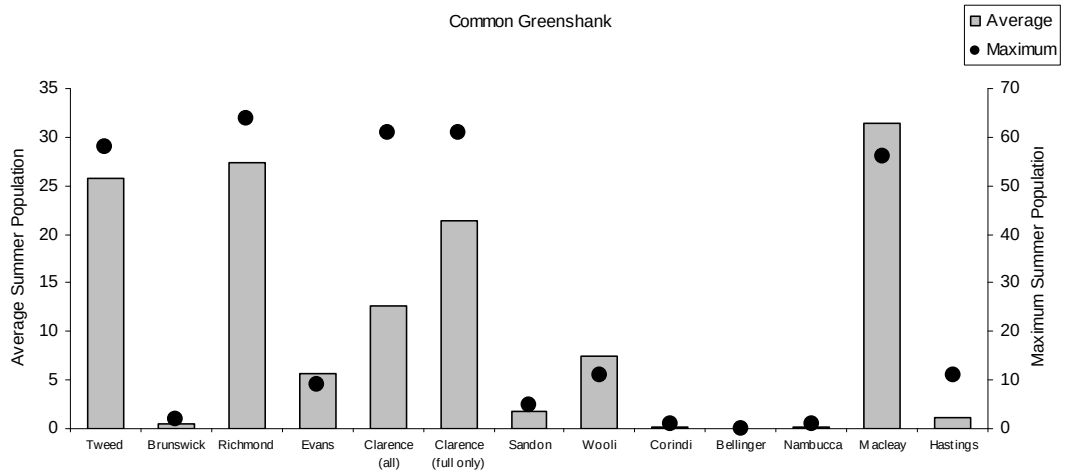


Figure 16 Maximum and average 'summer' populations of Common Greenshank at major estuaries in northern NSW.

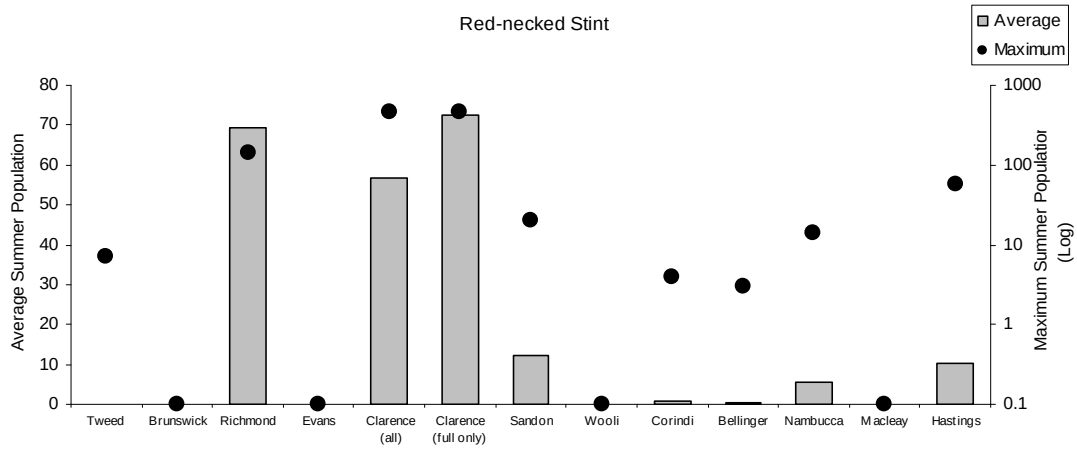


Figure 17 Maximum and average 'summer' populations of Red-necked Stint at major estuaries in northern NSW.

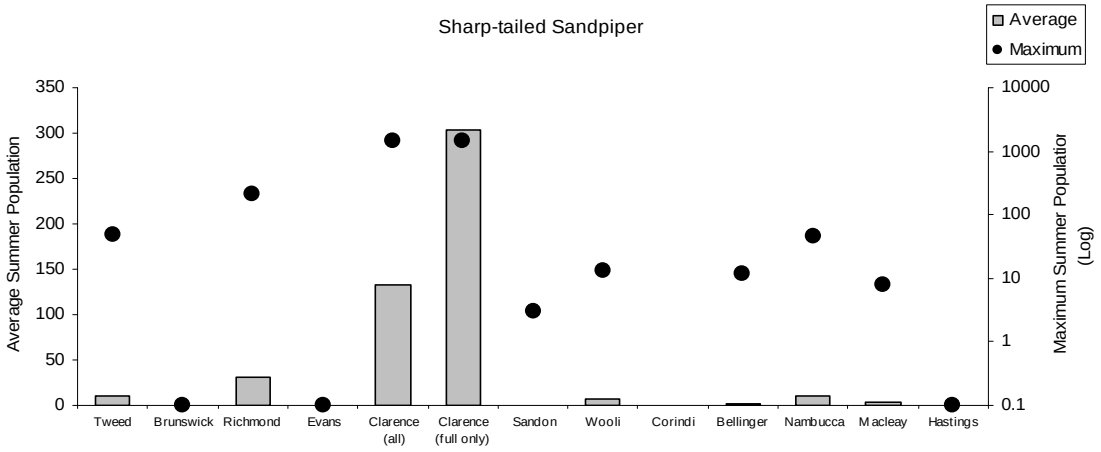


Figure 18 Maximum and average 'summer' populations of Sharp-tailed Sandpiper at major estuaries in northern NSW.

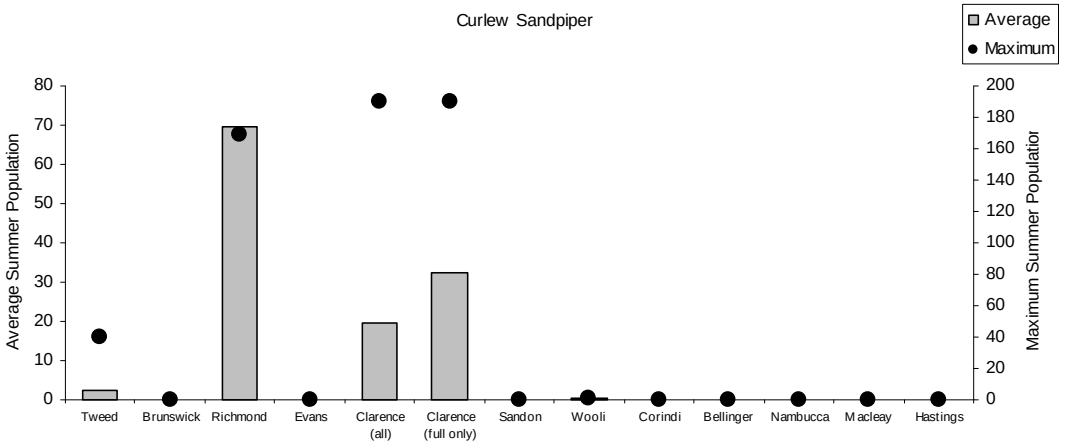


Figure 19 Maximum and average 'summer' populations of Curlew Sandpiper at major estuaries in northern NSW.

Table 7 Maximum and average 'summer' population estimates for 12 selected shorebird species at major estuaries

	Tweed	Brunswick	Richmond	Evans	Clarence (all)	Clarence (full only)	Sandon	Wooli	Nambucca	Bellinger	Macleay	Hastings
Sample size	45	12	67	3	29	10	5	4	7	6	2	18
Australian Pied Oystercatcher												
Maximum	12	7	59	2	28		3	8	14	5	-	6
(Year of maximum)	2000	2008	1996	1994	1987		1994	1992	2000	2003		2008
Average	4.86	2.67	6.45	1.33	10.34	12.8	2.4	6.25	5.43	2.83	-	2
Pacific Golden Plover												
Maximum	83	8	246	20	216		1	20	34	42	-	100
(Year of maximum)	1991	1994	2008	1994	1997		1994	1994	2003	2003		2005
Average	19.41	5.5	95.6	13.33	47.55	60.4	2	9.5	17	33.33	-	11.61
Red-capped Plover												
Maximum	1	6	21	-	74		48	36	30	5	-	22
(Year of maximum)	1997	1982	1998		1984		1994	1994	1985	2002		2008
Average	0.02	3.67	5.31	-	4.61	12.2	23.6	23.25	16.86	1.67	-	9.67
Lesser Sand Plover												
Maximum	13	-	54	-	290		2	1	-	1	18	70
(Year of maximum)	1987		1987		1987		1994	1992		1994	1993	1983
Average	0.48	-	19.64	-	47.55	60.1	0.4	0.25	-	0.17	9	7.56
Bar-tailed Godwit												
Maximum	363	26	414	19	972		47	41	86	65	206	316
(Year of maximum)	1991	2008	1993	1994	1995		1994	1994	2003	2002	1994	1983
Average	180.48	9.92	239.02	12	517.76		34.2	23.5	36.71	43.33	165.5	141.44
Whimbrel												
Maximum	140	30	106	36	141		90	43	34	66	196	145
(Year of maximum)	1987	1994	1995	1994	1994		1994	1994	2001	1994	1993	1985
Average	67.98	9.5	50.87	21	66.07	80.7	44.2	26	10.14	24	147.5	44
Eastern Curlew												
Maximum	164	8	105	26	173		34	37	26	40	72	116
(Year of maximum)	1991	1994	1994	1994	1994		1994	1992	2001	2002	1993	1983
Average	91.5	3	61.66	24.3	97.14	99.6	17.2	30.25	17.71	29.5	63	42.83

	Tweed	Brunswick	Richmond	Evans	Clarence (all)	Clarence (full only)	Sandon	Wooli	Nambucca	Bellinger	Macleay	Hastings
Grey-tailed Tatler												
Maximum	77	26	160	20	205		20	35	1	17	22	104
(Year of maximum)	1996	1994	1988	1994	1984		1994	1994	2003	2003	1993	1983
Average	50.46	4.67	76.38	16.33	54.61	91.6	11.4	24.5	0.14	13.83	11	15.78
Common Greenshank												
Maximum	58	2	64	9	61		5	11	1	-	56	11
(Year of maximum)	1998	1981	1997	1994	1984		1994	1994	1982		1993	2005
Average	25.8	0.42	27.32	5.67	12.59	21.4	1.8	7.5	0.14	-	31.5	1.17
Red-necked Stint												
Maximum	7	-	144	-	470		20	-	14	3	-	58
(Year of maximum)	1994		2008		1987		2003		1985	1994		1983
Average	0.06	-	69.25	-	56.69	72.4	12.2	-	5.71	0.5	-	10.17
Sharp-tailed Sandpiper												
Maximum	48	-	215	-	1433		3	13	45	12	8	-
(Year of maximum)	1996		1989		1994		1994	1994	1982	2002	1994	
Average	10.58	-	31.5	-	132.07	302.6	0.6	6.75	9.57	2.33	4	-
Curlew Sandpiper												
Maximum	40	-	169	-	190		-	1	-	-	-	-
(Year of maximum)	1987		1994		1987			1994				
Average	2.47	-	69.52	-	19.48	32.5	-	0.25	-	-	-	-

3.3.3 Priority sites for threatened migratory shorebirds

All but one of the priority sites for threatened migratory shorebirds occurred in the Richmond and Clarence estuaries and the intervening section of coastline (**Figure 20**). The Richmond Estuary and/or adjoining South Ballina Beach are priority 1 sites for Greater Sand Plover, Sanderling and Terek Sandpiper. The Richmond Estuary is also a priority 2 site for Great Knot and Lesser Sand Plover. The Clarence Estuary is a priority 1 site for Black-tailed Godwit, Lesser Sand Plover and Great Knot and a priority 2 site for Terek Sandpiper and Greater Sand Plover. The coastline north of the Clarence Estuary, specifically the area around Woody Head, is a priority 2 site for Greater Sand Plover and a priority 3 site for Lesser Sand Plover. The Tweed Estuary is a priority 3 site for Terek Sandpiper.

Only priority 1 sites were identified for Sanderling and Black-tailed Godwit — emphasising the restricted distributions of these species in the Study Area. Priority 1 and 2 sites were identified for Great Knot and Greater Sand Plover, while priority 1, 2 and 3 sites were identified for Lesser Sand Plover and Terek Sandpiper (**Figure 20**). Although Sanderling, Black-tailed Godwit, Greater Sand

Plover and Great Knot have been recorded at numerous other locations in the Study Area, they occur in very low numbers and sporadically at these locations.

3.3.4 Priority sites for threatened resident shorebirds

Priority sites for threatened resident shorebirds are more broadly distributed (**Figures 21 and 22**).

Priority 1, 2 and 3 population sites and nesting sites for Pied Oystercatchers occur in the northern half of the Study Area, particularly between the Richmond and Clarence estuaries. Priority 1 nesting areas for Pied Oystercatchers occur between Richmond Estuary and Clarence Estuary, with priority 2 nesting sites in the Clarence and Wooli estuaries and priority 3 sites at the Tweed, Corindi, Bonville and Nambucca estuaries. Pairs of Pied Oystercatchers also breed regularly at Belongil Creek, Richmond, Evans, and Sandon estuaries, Station Creek, Moonee Creek and Bellinger Estuary.

Priority 1 sites for Beach Stone-curlew include the Clarence, Wooli, Corindi and Nambucca estuaries. Priority 2 sites include the Sandon Estuary and coastline between the Richmond River (including the Richmond Estuary) and Clarence Estuary where there have been recent successful and unsuccessful breeding attempts (B. Moffatt pers comm.). Numerous priority 3 sites were identified for Beach Stone-curlew including Tweed, Richmond, Evans, Bonville, Bellinger and Hastings estuaries (**Figures 21 and 22**).

Priority population sites for Sooty Oystercatcher include, in order of priority, the Arrawarra Headland to Coffs Harbour coastline, Clarence Estuary (including Woody Head), and the Crescent Head to Tacking Point coastline (**Figure 21 and 22**). Priority nest sites for Sooty Oystercatchers were recorded in the following areas: Arrawarra to Coffs Harbour coastline (priority 1); Coffs Harbour to Bellinger River and Clarence River to Sandon River coastlines (priority 3).

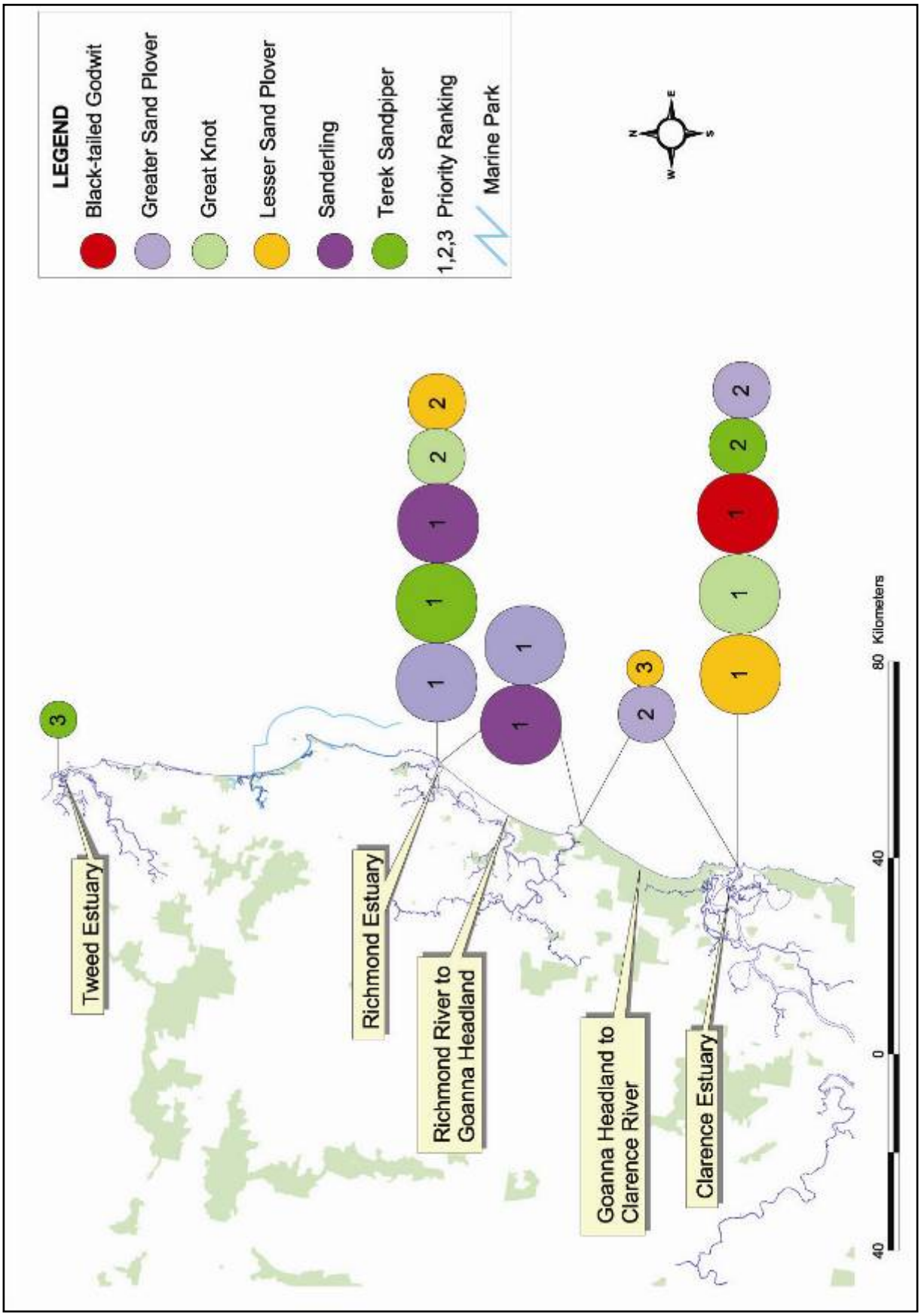


Figure 20 Priority locations for threatened migratory shorebirds

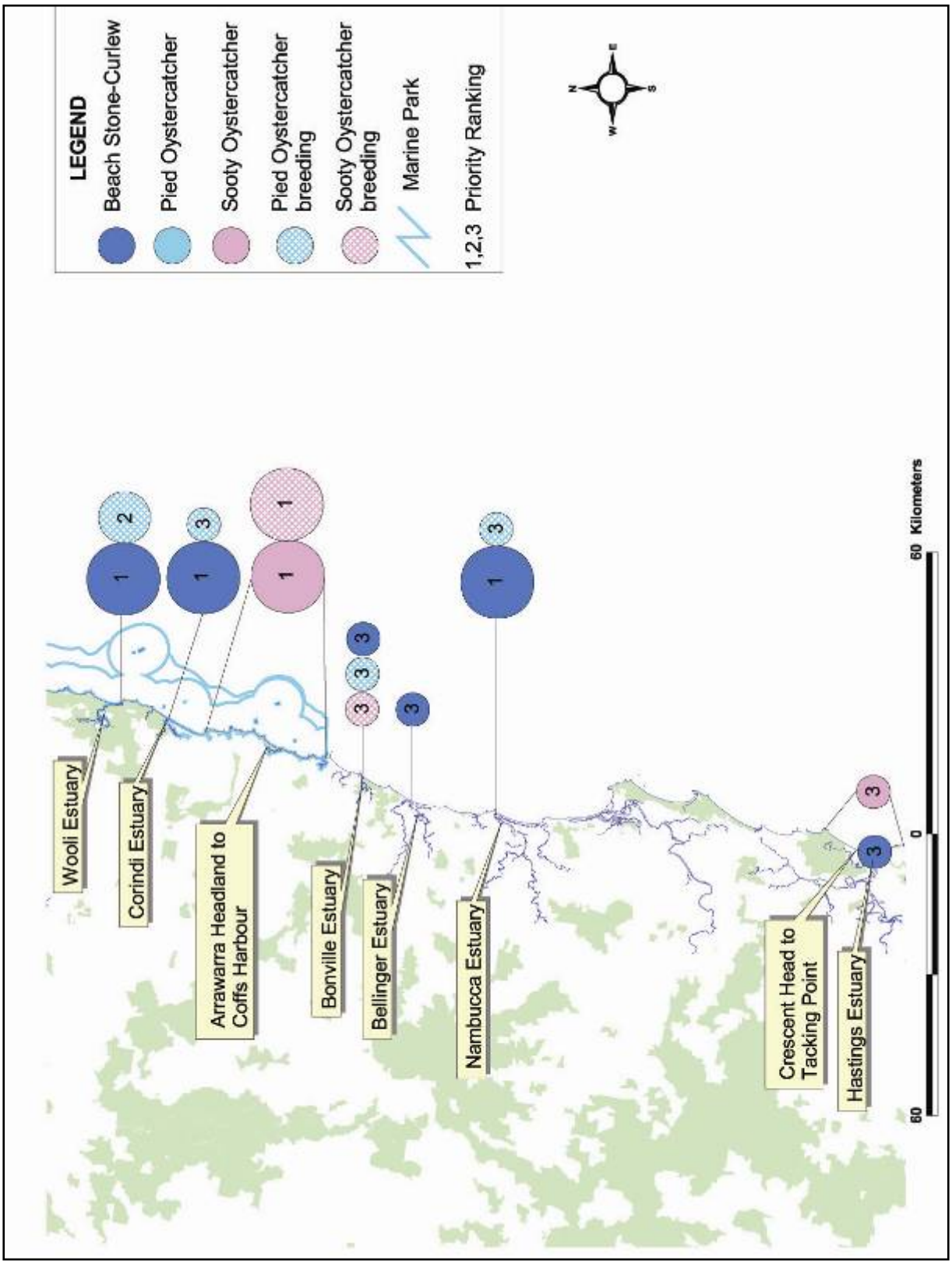


Figure 21 Priority locations for threatened resident shorebirds (northern Study Area)

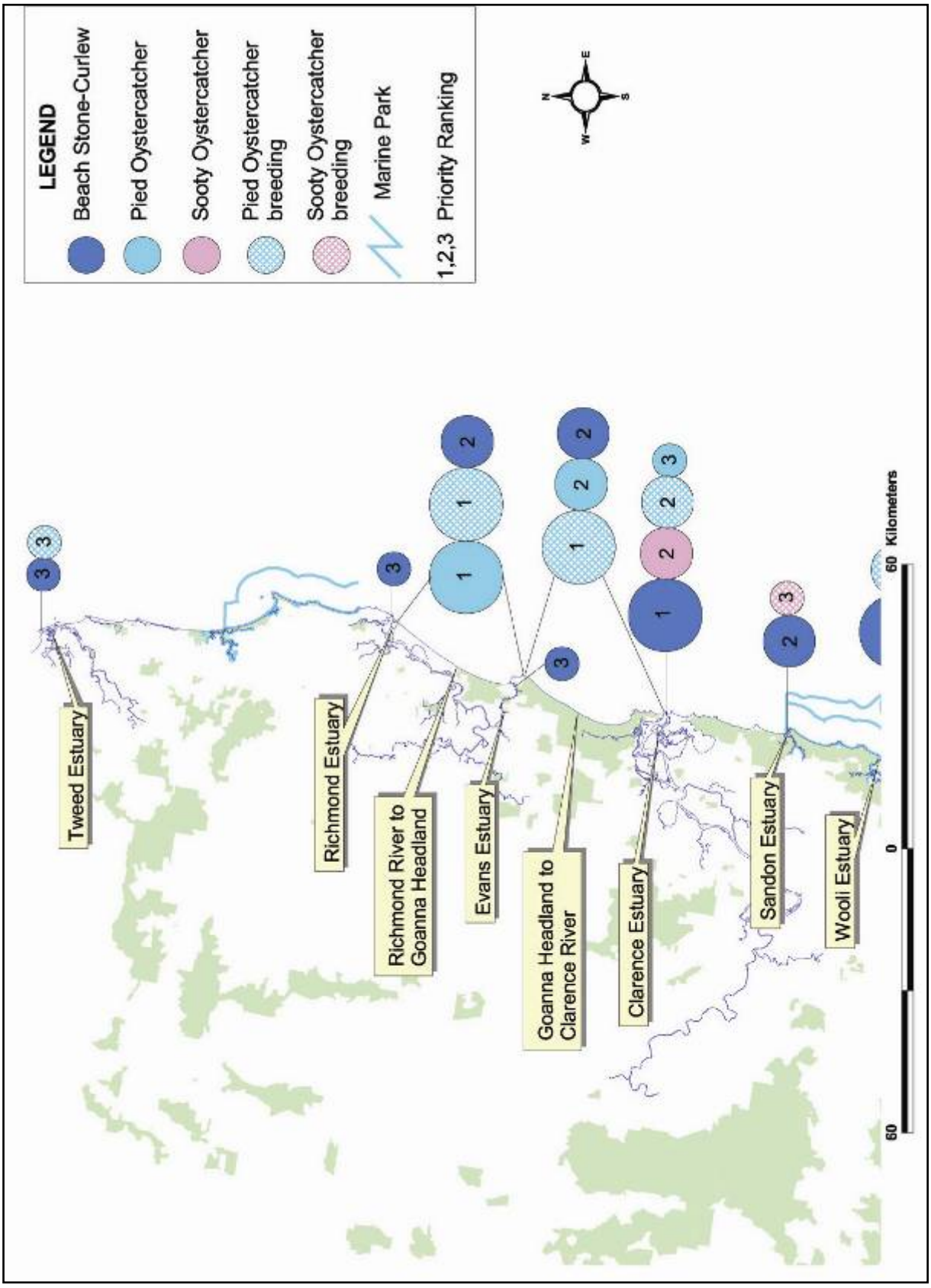


Figure 22 Priority locations for threatened resident shorebirds (southern Study Area)

3.4 Discussion

3.4.1 Distribution of important shorebird locations

The baseline data assessment comparing shorebird populations and species diversity between locations supports previous suggestions that the Clarence and Richmond estuaries are the priority shorebird locations in northern NSW (Smith 1991; Avifauna Research and Services 2006). The section of coastline between these two estuaries also has the highest average and maximum shorebird population estimates for coastal sites in the Northern Rivers CMA region. Priority sites for threatened shorebirds, with the exception of Beach Stone-curlew and Sooty Oystercatcher, are also clustered in the Richmond and Clarence estuaries and intervening section of coastline, further emphasising the regional importance of this area to shorebirds.

The maximum population estimate of 3747 individuals in the Clarence Estuary, including The Broadwater, indicates that the estuary is one of the top two coastal shorebird locations in NSW — second only to the Hunter Estuary (Smith 1991). When considering maximum population estimates it is important to realise that shorebird populations have declined at many sites and, as such, maximums derived by this project may not reflect present values. An analysis of changes over time in shorebird populations at priority sites would be a worthwhile exercise. Such an analysis in the Tweed Estuary identified a significant decline over time in the abundance of migratory shorebirds (Rohweder 2007).

Despite the greater size of the shorebird population in the Clarence Estuary, it has comparable total species diversity (richness) to the Richmond and Tweed, although there are subtle differences in species composition. The similarity in total species diversity is attributed to the large size of the estuaries, the diversity of habitats present at each estuary, and the number of surveys conducted by experienced observers. The high total species diversity recorded in the Tweed is attributed to intensive survey effort. Many species common in the Richmond and/or Clarence occur only occasionally in the Tweed. Several vagrant or rare species — such as Ruff, Long-toed Stint, Oriental Pratincole, Oriental Plover, Broad-billed Sandpiper, Grey Plover and American Golden Plover – have only been recorded in the Tweed, Richmond and Clarence estuaries. Records of rare species are strongly influenced by survey effort and observer experience.

Differences in species composition between the estuaries are attributed to the habitat types present and the proximity of habitats at different tidal and diurnal stages. For example, the Richmond Estuary is the only location in the Study Area that regularly supports a population of Sanderling, while the Clarence is the only location that regularly supports a population of Black-tailed Godwit. These estuaries provide the combination of habitats required by the respective species. In many cases, adjoining sections of coastline contribute substantially to the value of estuaries as certain species move between estuarine and ocean beach/rocky shore habitats on a tidal and diurnal cycle. South Ballina Beach and Flat Rock provide such a function for the Richmond Estuary, and Woody Head, Back Beach and Shark Bay do the same for the Clarence Estuary.

Comparisons of maximum and average summer population estimates emphasise the importance of the major estuaries to the abundance and diversity of shorebirds in northern NSW. The five large major estuaries in the study area — Tweed, Richmond, Clarence, Macleay and Hastings — provide habitat for the majority of the shorebird population. Medium sized major estuaries — Nambucca, Sandon, Bellinger, Corindi and Wooli — are used by substantial numbers of individuals and species, and provide important breeding habitat for resident shorebirds. Medium estuaries are also priority sites for Red-capped Plover, a species whose coastal population and distribution may be contracting (D. Rohweder pers. comm.). Despite their size, the Evans and Brunswick estuaries appear to be used by small numbers of shorebirds and these estuaries are comparable in diversity and abundance to the much smaller Belongil and Bonville creeks and Salty Lagoon. Other small coastal creeks in the south of the Study Area such as Korogoro Creek may also be used by similar numbers of shorebirds, although further surveys are required to confirm their importance.

More detailed investigation of foraging and roosting habitat is required to determine why shorebird abundance and diversity varies between locations. Estuary size and area of habitat alone may be poor predictors of shorebird population size and diversity. This is particularly the case at present when some estuaries are effected by numerous threatening processes. Nutrient cycles, catchment

geology, estuary and coastal geomorphology, estuarine hydrology, habitat diversity and proximity of roosts to foraging habitats are likely to contribute strongly to the abundance and diversity of shorebirds within an estuary. The collection of data on food resources and characteristics of foraging areas in a sub-set of estuaries would complement population data and assist in determining why some estuaries are more important than others. Such information would also be useful for management.

Murphy (2008) notes that while small estuaries such as Moonee Creek contain small areas of estuarine habitat, they may be important as stopover sites during migration, and their collective area of habitat may be significant. It is unclear how Murphy (2008) defined 'small', although the geographic area he refers to when quoting habitat area values includes the Sandon, Wooli and Corindi estuaries. These estuaries undoubtedly provide important habitat for shorebirds and are substantially more important than many small coastal creeks, such as Moonee Creek. Although Murphy (2008) makes a valid point about the value of 'smaller' estuaries it is essential to compare similar sized systems and not combine 'intermediate' sized estuaries such as the Sandon with minor estuaries like Moonee Creek, although all have important individual habitat values.

A quick comparison of average population estimates at the five large major estuaries with all smaller estuaries and ICOLLs shows clearly that the major estuaries support more than three times the number of individuals. Priority sites for threatened shorebirds are also clustered around the large major estuaries. Nonetheless, smaller estuaries (i.e. Sandon, Wooli, Corindi, Bellinger and Nambucca) are still important as they provide important roosting and foraging habitat for migratory shorebirds, important breeding habitat for resident shorebirds, and may be used as staging areas during migration.

One notable feature of the maximum population estimate data is that the majority of maximum counts were made in the early 1990s or in the early 1980s, as is the case for the Nambucca and Hastings. The exception is the Bellinger which was only sampled intensively in the early 2000s (Rohweder 2004). The age of maximum counts may indicate that populations have declined since the early 1990s or that sampling intensity has declined. The collation of additional data for the Nambucca and Macleay estuaries is likely to provide a better indication of maximum population size at those locations. If population trends observed in the Tweed Estuary are any indication, declines may have also occurred at other north coast estuaries (Rohweder 2007).

3.4.2 Distribution of priority sites for threatened shorebirds

The majority of priority sites for threatened migratory shorebirds occur within and between the Richmond and Clarence estuaries. Both estuaries provide critical, regional habitat for Sanderling, Greater and Lesser Sand Plover, Terek Sandpiper and Black-tailed Godwit.

Some species move regularly between coastal and estuarine habitats depending on the tidal stage and time of day. Such movement influenced the identification of priority sites. For example, South Ballina Beach and the Richmond Estuary are used by the same population of Sanderlings and Greater Sand Plovers and both sites were classified as priority 1 areas for both species. A similar situation occurs between the Clarence Estuary and coastal habitats near Woody Head. The critical links between coastal and estuarine habitats emphasise the need to take a landscape approach to managing shorebird populations. Our present understanding of the nocturnal behaviour of shorebirds is poorly understood and it is possible that many species change their behaviour between day and night.

Despite the noted importance of the Richmond and Clarence estuaries, the prioritisation also highlights the value of smaller estuaries for resident threatened species, particularly as breeding habitat. The Sandon, Wooli, Corindi, Bonville and Nambucca estuaries were identified as priority sites for resident threatened species. The presence of Little Tern *Sterna albifrons* nest areas at the Corindi, Bonville and Nambucca estuaries further increases the conservation value of these sites. The importance of these estuaries for nesting shorebirds is attributed to their reasonably natural state. Four of these five smaller estuaries do not have training walls on both sides of the river mouth. This enables large sandspits and sandbars to form which provide suitable nesting habitat in close proximity to productive estuarine foraging habitat.

3.4.3 Validity of the baseline data summary

The broad comparison of shorebird populations across the Study Area has provided a general idea of how important locations are distributed. Despite the use of basic methods and the variability in survey effort and methods, the results are indicative of the distribution and abundance patterns of shorebirds in the Study Area. Nonetheless, vetting of the dataset is recommended if a more rigorous assessment is undertaken. Further data on nesting sites of resident shorebirds and updated population estimates at some sites would improve the identification of priority areas and the overall reliability of the results.

3.4.4 Priority habitats – land tenure and threats

Two notable features of the site prioritisation and baseline data summary are:

- almost none of the highest priority shorebird habitat in the Northern Rivers CMA region occurs within conservation reserves
- the highest priority habitat occurs over a reasonably small geographic area encompassing the Richmond and Clarence estuaries and the coastline in between.

Although more than half the coastline between Richmond and Clarence rivers is in the national parks and wildlife estate, in some cases park boundaries along beaches only extend to the high water mark. As such, areas of the coastline within priority habitat are often subject to use by 4WD vehicles. Additionally, the Richmond and Clarence estuaries are popular for aquatic-based recreation. These activities can impact on shorebirds using these areas. While there is some active management of shorebird habitats between the Richmond and Clarence estuaries, such as the annual Pied Oystercatcher Protection Program, present management is concentrated on controlling European Red Fox *Vulpes vulpes* predation at Pied Oystercatcher nest sites. Although foxes represent a substantial threat to eggs and chicks of breeding shorebirds, they do not threaten adults or the suitability of habitat for breeding.

While predation is a major threat to breeding success, threats to adult mortality and habitat suitability are also significant. In the context of Pied Oystercatchers it is essential that management also addresses threats to habitat quality and mortality such as 4WD vehicles, recreational disturbance, and commercial and recreational fishing. Furthermore, present management is strongly focused on threatened resident shorebirds with minimal emphasis on migratory species. There is some overlap in management, such as at South Ballina Beach, but in other areas, such as Woody Head, there are obvious deficiencies.

PART 4: PILOT ROOST SITE PRIORITISATION, CLARENCE ESTUARY

4.1 Introduction

Shorebirds experience a range of threatening processes. The impact of some activities — such as 4WD vehicles, pedestrians and introduced predators — on beach nesting birds is well researched and publicised (Buick & Paton 1989; Priest et al. 2002; Weston 2003; DoL 2007). However, the effect of other threats — such as mangrove encroachment, sea-level rise and human disturbance — on migratory shorebirds are either poorly understood, conflict with other conservation measures, or are contrary to habitat management objectives (Pfister et al. 1992; Priest et al. 2002). Managing threatening processes, particularly recreation, poses many challenges as a substantial number of roost and foraging sites occur in areas that are promoted for aquatic or outdoor recreation. There are many instances in the Study Area where important shorebird habitat occurs within or adjacent to conservation reserves yet is still threatened by recreational activity.

Due to the challenges associated with managing shorebird habitat, it is essential that management actions are based on sound data and robust methods. The procedure used to develop management actions is critical. The shorebird data collated as part of this project provides a sound base to:

- identify the need for management at a location by showing that the location is critical for a threatened species, or by showing that a species or population is declining
- rank locations in order of conservation priority
- rank sites within locations in order of priority.

Once a priority location is identified there are at least two different methods that can be applied to identify and prioritise management actions. The first method involves the development of a species-by-threat matrix. A species-by-threat matrix would enable species with high levels of threat to be identified. To apply the threat assessment it would be necessary to also rank sites used by the target (or priority) species.

The second approach involves the development of a site-by-threat matrix to identify sites (i.e. roost, nest or foraging sites) with high levels of threat. To ensure the efficient application of threat mitigation to sites, it is necessary to also prioritise sites in order of importance to shorebirds. The site and threat prioritisation can then be combined to develop an overall priority ranking that considers each site's biological value and level of threat.

There are merits with both methods. Method one is most suitable for resident breeding species that roost, nest and forage in pairs, while method two is most suited to non-breeding residents and migratory species that roost and forage in large mixed-species flocks. In either method it is necessary to combine species, site and threat attributes to develop an overall ranking. Method two has greater appeal as it focuses on sites as the unit of management and considers the shorebird population in ranking sites. In addition, threats often occur at the site level and vary between sites. This means that a species-by-threat matrix would need to consider how each species is threatened at different sites, which is likely to be a complicated process. The species-by-threat matrix would have some application identifying broad priorities at a large scale. An example is the identification of priority threats and sites for Beach Stone-curlew or Pied Oystercatchers.

This project, therefore, trials a two-tiered approach to the site-by-threat matrix approach to prioritise high tide roosts in the Clarence Estuary:

- the first tier involves the prioritisation of roosts in order of habitat importance to shorebirds
- the second tier involves prioritising roosts in order of threat.

The habitat and threat priority scores for each roost are then combined to obtain an overall site priority. This approach was initially applied in the Clarence Estuary by Sandpiper Environmental (2004), although that study did not combine the two priority scores.

The threat matrix developed by Sandpiper Environmental (2004) has been revised for this Study by: including a specific category on sea-level rise; updating information on the magnitude of threats; and reviewing and modifying threat types. Shoreline stabilisation work, training walls/groins and canal estates were removed as potential sources of habitat modification. While these attributes are known

to affect estuary hydrology and geomorphology, their impact on shorebird habitat is difficult to predict.

While there is ongoing debate about the magnitude of sea-level rise and its likely effects on coastal habitats, a 40 cm rise by 2050 has been accepted by the NSW Government (DECCW 2009). The inclusion of sea-level rise in this and any future assessments of shorebird habitat is warranted.

4.2 Methods

4.2.1 Site habitat prioritisation

The site habitat prioritisation undertaken by Sandpiper Environmental (2004) has been adopted. The prioritisation method has not been amended, although it is recommended that this method be carefully scrutinised. Sandpiper Environmental (2004) prioritised 34 roosts and 13 foraging areas, but only data for the 24 high tide roosts are presented here.

Criteria used in the roost prioritisation included the following, which were calculated for each site: maximum spring/summer counts, species diversity, number of threatened species, number of migratory species and average number of shorebirds (total/no. surveys) ± standard deviation^{-1}. To ensure that the assessment was easy to interpret, it was necessary to combine sites with similar names that occurred within close proximity. The prioritisation was problematic due to the small number of criteria included in the assessment and the variability in temporal and spatial coverage between surveys. The criteria were scored as follows:

- 0.5 points were awarded for every 100 individuals recorded at a site under the category of maximum spring/summer count
- 1 point was awarded for every 100 individuals recorded at a site under the category of mean no. birds
- 0.5 points were awarded for each species recorded at a site
- 1 point was awarded for each migratory species recorded at a site
- 1 point was awarded for each threatened species recorded at a site
- 10 points were awarded if a site is used as a spring tide roost.

The high weighting given to sites available during spring high tides recognises the critical importance of these sites for shorebirds.

Scores for each criterion were added together and the cumulative total was used to assess the relative importance of each roost as follows:

- high priority = sites with a cumulative score of 45 or higher
- medium priority = sites scoring between 20 and 45
- low priority = sites that scored less than 19.

4.2.2 Threat prioritisation

Numerous factors are known to threaten shorebirds and their habitat (Priest et al. 2002; Sandpiper Environmental 2004; Oldland et al. 2009). However, there is minimal published information on specific threatening processes in northern NSW estuaries and there have been few quantitative studies to determine how threats affect shorebird populations. This absence of published information was overcome by using general knowledge of threats and applying a broad approach to threat identification. Seven threat categories were identified:

1. habitat loss: removal of habitat through reclamation, habitat destruction, severe erosion and sea-level rise
2. sea-level rise: changes in habitat (potential gains and losses), possible invasion by mangroves, potential for erosion
3. habitat modification: changes in the characteristics of habitat (i.e. level of exposure at high tide, visibility, size) that reduce its utility for shorebirds

4. habitat disturbance (proximity): activities that result in disturbance to roosting and foraging shorebirds
5. mortality and kleptoparasitism: mortality and egg loss from introduced predators and recreation
6. habitat disturbance (sources): activities that result in disturbance to roosting and foraging shorebirds
7. pollution sources: accumulation of pollutants in body fat that reduces life span and potentially reproductive ability and the abundance of prey.

A list of potential threatening factors specific to the Clarence Estuary was derived using the above categories. Sources of information included published papers, unpublished reports on the Clarence Estuary, experience observing shorebirds in the Clarence Estuary and other estuaries in northern NSW and general observations (D. Rohweder pers. obs.).

A total of 36 potential threats were identified and grouped into the above seven threat categories (see **Table 8**). A site-by-threat matrix was developed that assessed the level of each specific threat at 24 roosts. The assessment has focused on high tide roosts only, although the same technique could be applied to foraging and nest sites or in a location by location comparison. Threats were scored as follows for each specific threat within the seven categories:

1. Habitat loss, habitat modification and sea-level rise category threats:

   20 points = loss/modification of entire site

   10 points = severely reduced habitat quality of site

   5 points = partial reduction in roost quality

   1 point = minor effect.

2. Disturbance and pollution category threats:

   10 points = threat occurs on-site

   5 points = threat occurs within 100 m of site

   1 point = threat occurs within 1 km of site.

3. Predation category threats:

   10 points = predators and/or kleptoparasites present at known nest site

   5 points = predators or kleptoparasites present at a site.

The output from the threat analysis is a cumulative score per roost site and threat: the higher the score the greater the level of threat.

Table 8 Potential threats, specific to the Clarence Estuary, and the manner in which the level of threat was assessed

(reviews, direct observations and discussions were conducted by Sandpiper Ecological Surveys)

Threat category	Specific threats	Methods of assessing level of threat
Habitat loss	Erosion	Presence/absence of erosion & the extent: severe >75%; moderate 25-75%; minor <25%
	Areas being developed – foreshore or adjacent	Identified areas from direct observation and discussions with Clarence Valley Council
	Areas proposed for development	Discussions with Clarence Valley Council planning staff
	Development permissible within zone	Reviewed zoning maps and Local Environment Plan
	Aquaculture	Direct observation & 1:25,000 topographic maps
Sea-level rise	Reduced habitat area and duration of exposure or increased inundation	Whilst many types of roosts would be affected by sea-level rise it is predicted that sandbars and spits may remain viable due to sediment accretion. Saltmarsh and

Threat category	Specific threats	Methods of assessing level of threat
		rocky shores are regarded as being under direct threat from sea-level rise as these habitats have limited or no ability to expand into higher elevations. Maximum sea-level rise would increase the frequency and duration that saltmarsh and rock platforms are inundated. Saltmarsh would also be subject to increased colonisation by mangroves, which in the long-term may render these roosts unsuitable.
	Enhanced conditions for mangroves	Sea-level rise is likely to improve conditions for mangroves in areas where tidal inundation is presently insufficient to enable plants to mature. The assessment focussed on sites where seedling mangroves already occur as there is tangible evidence that mangroves could expand at these sites.
	Erosion	Predicted likelihood of erosion caused by boat-wash at high tide level. Erosion may affect nest sites used by Beach Stone-curlew and Pied Oystercatcher such as Dart Island and Rabbit Island. Some increase in roosting habitat may occur through erosion.
Habitat modification	Mangrove encroachment	Assessed in the field: present or absent on roost/feeding; if absent estimate (with reference to a 1: 25,000 topographic map) distance to the nearest stand of mangroves; estimate of the area (m^2) covered by mangroves; height or height range (m) of mangroves; record the species of mangrove; estimate % cover of mangroves <1m tall; estimate total area (m^2) covered by mangroves <1m tall; assess if mangroves will affect roost quality.
	Grazing	Direct observation
	Artificial lighting	Direct observation and inferred from proximity of site to urban areas
	Altered drainage/Drains	Direct observation of drains & 1: 25,000 topographic map; Discussions with Clarence Valley County Council
Habitat disturbance (proximity)	4WD vehicles	Direct observation & Clarence Valley Council
	Walking/swimming	Direct observation
	Commercial fishing site	Discussions with NSW Department of Industry and Investement (previously Primary Industries) and the Clarence River Professional Fishermen's Association
	Recreational fishing site	Direct observation & discussions with Clarence River Fishing Clubs Association
	Bait collecting site	Direct observation & discussions with Clarence River Fishing Clubs Association
	Dog exercise Area (formal & informal)	Discussions with Clarence Valley Council and direct observation
	Sailing boat route	Discussions with local sailing clubs to identify main sailing routes
	Jetski/waterski/kite surf area	Discussions with NSW Waterways Authority
	Main boating channel	Discussions with NSW Waterways Authority
Mortality and kleptoparasitism	Introduced predators	NSW Department of Environment, Climate Change and Water and D. Rowheder (pers. comm.)
	Scavengers & kleptoparasites	Large flocks of roosting Silver Gulls *Larus novaehollandiae* can disturb roosting and foraging birds

Threat category	Specific threats	Methods of assessing level of threat
	4WD vehicles	4WD vehicles represent a known source of mortality to adult and juvenile birds and eggs
Habitat disturbance (sources)	Formal boat ramp	Direct observation and review of topographic maps
	Formal picnic site	Direct observation and review of topographic maps
	Informal picnic site	Direct observation
	Boat hire	Direct observation, tourist pamphlets, yellow pages
	Camp/Caravan park	Direct observation, tourist pamphlets, yellow pages, 1: 25,000 topographic map
	Tourist facility (hotel/motel/restaurant)	Direct observation
	Marina/mooring site	Direct observation and review of topographic maps
	Major road	Direct observation, topographic maps
	4WD access point	Direct observation
	Developed areas (urban) foreshore	Direct observation
Pollution sources	High risk acid sulphate soils	Maps contained in the Clarence Estuary Management Plan
	Sugar Cane	1:25,000 topographic maps, Umwelt (2002)

4.2.3 Overall roost site priority ranking

An overall site priority ranking was developed by multiplying the habitat priority score by the threat score to give an overall site priority ranking. Sites were ranked as follows:

- very high priority = sites with scores more than 5000
- high priority = sites with scores between 3000 and 4999
- medium priority = sites with scores between 1500 and 2999
- low priority score = sites with scores less than 1499.

In cases where nearby sites were combined due to variation in habitat or threat coverage, the highest score was used to determine overall priority. Combined sites include Esk Mouth, Woody Head–Back Beach and Bolorobo Island.

4.3 Results

4.3.1 Habitat prioritisation

Dart/Hickey Island, Wooloweyah Entrance and Prawn Farm were ranked as high priority roosts. These roosts regularly support large numbers of birds, including several threatened and migratory species, and are available during spring high tides. Goodwood south, Iluka Breakwall, The Peninsula, Freeburn Island, Rabbit Island sandbar, Yamba Quays, Micalo Island north, Shark Bay and Woody Head-Back Beach were ranked as medium priority sites (**Table 9**). High standard deviations were recorded for several sites indicating that shorebirds use of these sites is variable. Variability in roost use can be caused by several factors including differences in site availability between spring and neap tides, changes in the quality of habitat over time, and disturbance which forces birds to move between sites.

Table 9 Habitat scores for 24 roosts in the Clarence Estuary

Sites	Priority Ranking	Maximum count (spr/sum)	Mean No. spr/sum	Tot Spp	No. Thr spp	No. Mig spp	Cum. Score	Neap or spring
Eureka Island	Low	115 (11/94)	63 (sd 73.5, n 2)	5	1	5	9.5	neap
Narrabarribi Island	Low	93 (3/84)	65 (sd 40.8, n 4)	11	2	10	17.5	neap
Woram Channel	Low	24(3/84)	24 (N/A, n 1)	3	0	3	14.5	spring
Bolorobo Island	Low	50 (3/84)	41 (sd 12, n 2)	6	1	6	10	neap
Goodwood South	Medium	128 (10/94)	49 (sd 68.2, n 3)	7	1	7	22.5	spring
Iluka Breakwater	Medium	127(2/02)	42 (sd 45.12, n 7)	10	2	7	25	spring
Dart/Hickey	High	1050 (1/87)	347 (sd 248.3, n 32)	27	9	19	64.5	spring
Hickey Saltmarsh	No data							
The Peninsula	Medium	247 (3/96)	52 (sd 62.1, n 19)	13	4	9	32.5	spring
Freeburn Island	Medium	215(3/84)	32 (sd 66, n 17)	11	2	7	26.5	spring
Reedy Creek	Low	114 (11/95)	75 (sd 37.1, n 3)	3	0	3	15.5	spring
Rabbit Island-sandbar	Medium	367 (12/91)	110 (sd 173.4, n 4)	11	5	8	22.5	neap
Sleeper Island	Low	46 (2/04)	33 (sd 19.1, n 3)	6	0	5	8	neap
Crystal Waters	Low	194 (2/84)	75 (sd 102.6, n 3)	10	2	9	17	neap
Yamba Quays/Thorny Is	Medium	301(11/95)	127 (sd 91.7, n 10)	14	3	8	32	spring
Micalo Is Nth	Medium	82 (10/94)	32 (sd 27.1, n 8)	13	1	9	26.5	spring
Wooloweyah Entrance	High	1460 (2/97)	636 (sd 449.6, n 11)	30	6	22	73	spring
Palmers Is SE	Low	118 (2/03)	53 (sd 58.4, n 3)	5	1	3	17.5	spring
Prawn Farm	High	1277(10/94)	857 (sd 312.9, n 3)	13	0	9	46.5	spring
Fraser's Reef	Low	25	12 (sd 10.8, n 5)	5	1	4	7.5	Neap
Shark Bay	Medium	115	69 (sd 51, n 4)	13	4	10	31	Spring
Iluka Bluff	Low	13	6 (sd 5.2, n 5)	5	2	3	17.5	Spring
Woody Head-Back Beach	Medium	196	121 (sd 40, n 7)	13	4	9	31	Spring

Notes:

Spr = spring. High = 45 or greater.

Sum = summer.
Tot. spp = total species
No. Thr spp = number of threatened species.
No. Mig spp = number of migratory species.
Cum. Score = cumulative score.

Medium = 20 to 44.
Low = 1 to 19.
sd = standard deviation-1.
n = number of samples.

4.3.2 Threat prioritisation

Potential threats were assessed for 24 roosts. The complete threat-by-roost matrix is included in **Appendix 4**. Dart/Hickey Island received the highest threat ranking, followed by Goodwood Island, Micalo north, The Peninsula, Prawn Farm, Yamba Quays, Shark Bay, Woody Head and Freeburn Island (**Table 10**). The table shows, for each roost site, the score of all specific threats within the seven threat categories and the total of all categories.

Both Dart/Hickey and Goodwood Islands received threat scores over 100 and have been classified as having a very high threat level. Other sites that scored between 75 and 100 were classified as having a high threat level.

The most significant threat type affecting Dart/Hickey Island is disturbance, while sea-level rise is the most significant threat facing Goodwood Island. The most significant threat at The Peninsula, Freeburn Island, Shark Bay and Woody Head was disturbance, and habitat modification and sea-level rise contributed most weight to Micalo north. The Prawn Farm is threatened by habitat loss. Sea-level rise also contributed to the threat score at Shark Bay, while Yamba Quays is threatened by a combination of habitat loss and disturbance.

Moderate levels of threat (scores between 45 and 75) were recorded at Iluka Breakwall, Hickey Saltmarsh, Rabbit Island, Reedy Creek, Sleeper Island, Palmers Island SE, Back Beach, Frasers Reef and Iluka Bluff. Low threat scores (scores below 45) were recorded at Esk Mouth, Bolorobo Island north, Bolorobo Island, Woram Channel, Crystal Waters and Wooloweyah Entrance.

Table 11 shows, for each specific threat, the sum of all 24 roost site scores. It also shows the total score for each threat category. Comparison of threat categories indicates that disturbance is the most substantial threat in the Clarence Estuary, followed by sea-level rise, mortality (risk), habitat modification and habitat loss (**Table 11**). The most prominent individual threats within threat categories (see **Table 11**) were changes in roost quality caused by sea-level rise (with a score of 174), followed by recreational fishing (127), high risk acid sulphate soils (94), walking/swimming (92), enhanced conditions for mangroves caused by sea-level rise (91) and introduced pests (90).

Table 10 Threat scores for each roost assessed in the Clarence Estuary as part of the threat analysis pilot study

Roost site	Hab loss	Sea rise	Hab mod	Dist prox	Mort	Dist src	Polln	Total Score	Threat Level
Esk Mouth	1	20	5	7	0	0	10	43	Low
Woram Channel	0	0	0	6	0	0	5	11	Low
Bolorobo Nth	0	10	11	13	0	3	5	42	Low
Bolorobo Is	0	0	0	6	0	0	5	11	Low
Goodwood Is	15	35	10	19	10	3	10	102	Very High
Iluka Breakwall	0	5	1	22	10	11	1	50	Medium
Freeburn Nth	10	15	10	23	0	16	1	75	High
Dart/Hickey Island	1	12	2	62	25	17	1	120	Very High
Hickey Saltmarsh	0	15	1	20	5	8	1	50	Medium
The Peninsula	1	11	6	50	10	17	1	96	High
Rabbit Is	1	11	1	31	5	13	1	63	Medium
Reedy Ck sm	5	30	1	4	5	7	10	62	Medium

Roost site	Hab loss	Sea rise	Hab mod	Dist prox	Mort	Dist src	Polln	Total Score	Threat Level
Sleeper Is	5	20	6	16	5	2	10	64	Medium
Crystal Waters	0	1	1	23	0	16	1	42	Low
Yamba Quays	20	10	15	23	5	12	1	86	High
Micalo North	6	30	25	15	5	6	10	97	High
Prawn Farm	40	10	20	3	5	0	10	88	High
Wooloweyah Entrance	0	5	10	16	5	0	1	37	Low
Palmers Is SE	5	25	5	7	5	0	11	58	Medium
Shark Bay	5	25	0	35	11	7	0	83	High
Back Beach	0	15	0	26	10	8	0	59	Medium
Woody Head	0	10	0	31	10	25	0	76	High
Fraser's Reef	0	15	0	21	10	1	0	47	Medium
Iluka Bluff	0	20	0	26	10	10	0	66	Medium

Notes:

Hab loss = habitat loss.

Sea rise = sea-level rise.

Hab mod = habitat modification.

Dist prox = habitat disturbance (proximity).

Mort = mortality.

Dist src = habitat disturbance (sources).

Polln = pollution sources.

Table 11 Scores for each threat and threat category included in the threat matrix for shorebird roosts in the Clarence Estuary

Threat category	Specific threat	Score
Habitat loss	Erosion (existing)	35
	Areas being developed - foreshore	20
	Areas proposed for development	25
	Development permissible within zone	15
	Aquaculture	20
	Sub-Total	115
Sea-level rise	Reduced habitat & altered duration of exposure	174
	Enhanced conditions for mangroves	91
	Erosion (predicted)	80
	Sub-Total	345
Habitat modification	Mangrove Encroachment (existing)	57
	Grazing	16
	Artificial lighting	12
	Altered drainage/drains	31
	Sub-Total	116
Habitat disturbance (proximity)	Commercial fishing site	83
	Popular recreactional fishing site	127
	Bait collecting site	73
	Dog exercise area	37
	Walking/swimming area	92
	Sailing boat route	3

Threat category	Specific threat	Score
	Jetski/waterski/Kite surf	2
	Main boating channel	69
	4WD vehicles	15
	Major road	4
	Sub-Total	505
Mortality	Introduced pests (predicted)	90
	Kleptoparasites	50
	4WD vehicles	11
	Sub-Total	151
Habitat disturbance (sources)	Formal boat ramp	23
	Marina/Mooring site	17
	Formal picnic site	23
	Informal picnic site	72
	Boat hire	4
	Camp/caravan park	12
	Tourist facility (hotel/motel/restaurant)	7
	4WD beach entrance	1
	Developed areas (urban) foreshore	23
	Sub-Total	182
Pollution sources	High risk acid sulphate soils	94
	Sugar Cane	1
	Sub-Total	95

4.3.3 Overall roost site priority ranking

The combination of threat and habitat priority scores identified Dart/Hickey Island as the only very high priority site and Prawn Farm and Peninsula as high priority sites (**Table 12**).

Table 12 Overall roost site priorities in the Clarence Estuary

Sites	Threat priority score	Habitat priority score	Total score	Priority ranking
Esk Mouth**	43	17.5	753	Low
Woram Channel	11	14.5	160	Low
Bolorobo Island**	42	10	420	Low
Goodwood Is	102	22.5	2295	Medium
Iluka B'Wall	50	25	1250	Low
Dart/Hickey Island	120	64.5	7740	Very High
Hickey Saltmarsh	50	No data		Na
The Peninsula	96	32.5	3120	High
Freeburn Island	75	26.5	1988	Medium
Reedy Ck sm	62	15.5	961	Low
Rabbit Island	63	22.5	1418	Low
Sleeper Is	64	8	512	Low
Crystal Waters	42	17	714	Low

Sites	Threat priority score	Habitat priority score	Total score	Priority ranking
Yamba Quays	86	32	2752	Medium
Micalo North	97	26.5	2571	Medium
Wooloweyah Entrance	37	73	2701	Medium
Palmers Is SE	58	17.5	1015	Low
Prawn Farm	88	46.5	4092	High
Fraser's Reef	47	7.5	353	Low
Shark Bay	83	31	2573	Medium
Iluka Bluff	66	17.5	1155	Low
Woody Head – Back Beach**	76	31	2356	Medium

Note: ** includes multiple nearby sites

4.4 Discussion

Shorebirds have been recorded roosting at 34 sites in the Clarence Estuary. Some of these roosts are used only occasionally or are no longer used. Changes in roosting sites seem to be a typical occurrence in north coast estuaries. The reasons for changes are thought to be caused by the complex interplay between estuarine hydrology (and the effects of rock walls, bridges etc.), historical habitat disturbance, vegetation regrowth, mangrove expansion, human recreation patterns and urban development. Conditions during a survey, such as recreational disturbance and tide height, can also affect site use. Shorebirds tend to be fairly opportunistic in their selection of roosts, although they prefer sites with a good field of view that are close to foraging areas (Zharikov & Milton 2009). Temporal changes in roost use must be considered when undertaking roost prioritisation.

Sandpiper Environmental (2004) found that many roosts in the Clarence Estuary were small in size and were declining in quality due to repeated disturbance or habitat modification. A variety of roost types and sizes in different parts of an estuary is critical to maintaining a shorebird population. The decreasing number and quality of roosts in the Tweed Estuary was identified as one reason for the declining shorebird population at that site (Rohweder 2007). Many estuaries in the Study Area have limited roosting habitat (i.e. limited in area, type and distribution), and many of the available roosts are threatened.

The present assessment has ranked roosts in order of habitat value and threat. Whilst this approach is adequate, the assessment has not considered whether roosts are of sufficient size to satisfy roosting requirements in the long-term, particularly given the possible affect of sea-level rise. As some sites become less suitable, the demand for space will increase at other sites. The habitat and threat prioritisation is regarded as the first step in managing roosts and it should be followed by specific measures to reduce threats at high priority sites.

The threat prioritisation shows that threats are not concentrated within a particular part of the estuary. Although the majority of roosts with a high or very high threat rating occur near the estuary mouth or along the coast, they also occur in more protected areas of the estuary, such as within Oyster Channel and near the entrance to Wooloweyah Lagoon. The high intensity of recreational activity in the lower estuary and along the coast contributes to threats in these areas, while the potential effect of sea-level rise on saltmarsh and rocky shore roosts contributes to threats both along the coast and in the more sheltered parts of the estuary. Rocky shore, saltmarsh and sandbar roosts in the lower estuary and along the coast are the most threatened habitat types in the Clarence Estuary.

By understanding the distribution of threatened roosts and the factors that contribute to threats, it is possible to determine the type of management measures that may be required. Management of threats in the Clarence can be approached in two ways: management of sites that are deemed viable in the long-term, and/or creation of artificial habitat to compensate for the loss of unviable sites. Sea-level rise is likely to render some roosts unviable due to increased inundation. Conversely sea-level rise may cause erosion of small vegetated islands thereby creating roosting habitat. The

effect of sea-level rise on shorebird habitat in estuarine systems is likely to be complex and it requires further investigation. The two shorebird habitats that may be most affected by sea-level rise (rock platforms and saltmarsh) may have limited ability to expand landwards.

4.4.1 Managing specific sites in the Clarence Estuary

The method used to combine threat and habitat prioritisation scores appears to be effective in ranking sites for conservation and management. The Dart/Hickey Island roost was identified as a clear priority for management, followed by The Peninsula and Prawn Farm. These sites are threatened by a range of factors. Dart/Hickey Island are situated in the lower estuary and experience high levels of recreational activity. The islands provide known breeding habitat for Pied Oystercatcher and Beach Stone-curlew, and important roosting habitat for migratory shorebirds. Management of recreational disturbance is critical to the future viability of the roost (Sandpiper Environmental 2004).

The Prawn Farm has a valid approval for the reinstatement of farming activity, which has increased the threat score for that site. The Prawn Farm is somewhat unique in that it is a highly modified (almost artificial) habitat that is used for foraging and roosting. Use of the Prawn Farm by shorebirds may have decreased since the early 1990s. To improve shorebird management, the farm ponds could be manipulated to allow some tidal exchange, exclude mangrove seeds and provide artificial foraging and roosting habitat for shorebirds.

The coastal roosts of Shark Bay, Woody Head and Back Beach were ranked as medium priority sites (**Figure 23**). Despite this, they should be regarded as 'flagship' sites for management. These sites are regularly used by four threatened species of shorebird, occur within a priority 2 site for Greater Sand Plover and priority 3 site for Lesser Sand Plover (refer to Part 3), and are situated within or adjacent to Bundjalung National Park. Despite their conservation significance, both Shark Bay and Woody Head ranked as high in the threat prioritisation due to high levels of recreational disturbance and threat from sea-level rise. The presence of highly threatened sites (as identified by this analysis) within a conservation reserve illustrates that human activities still operate within these areas. Education of visitors within these areas by way of signage or brochures may help ameliorate these threats.

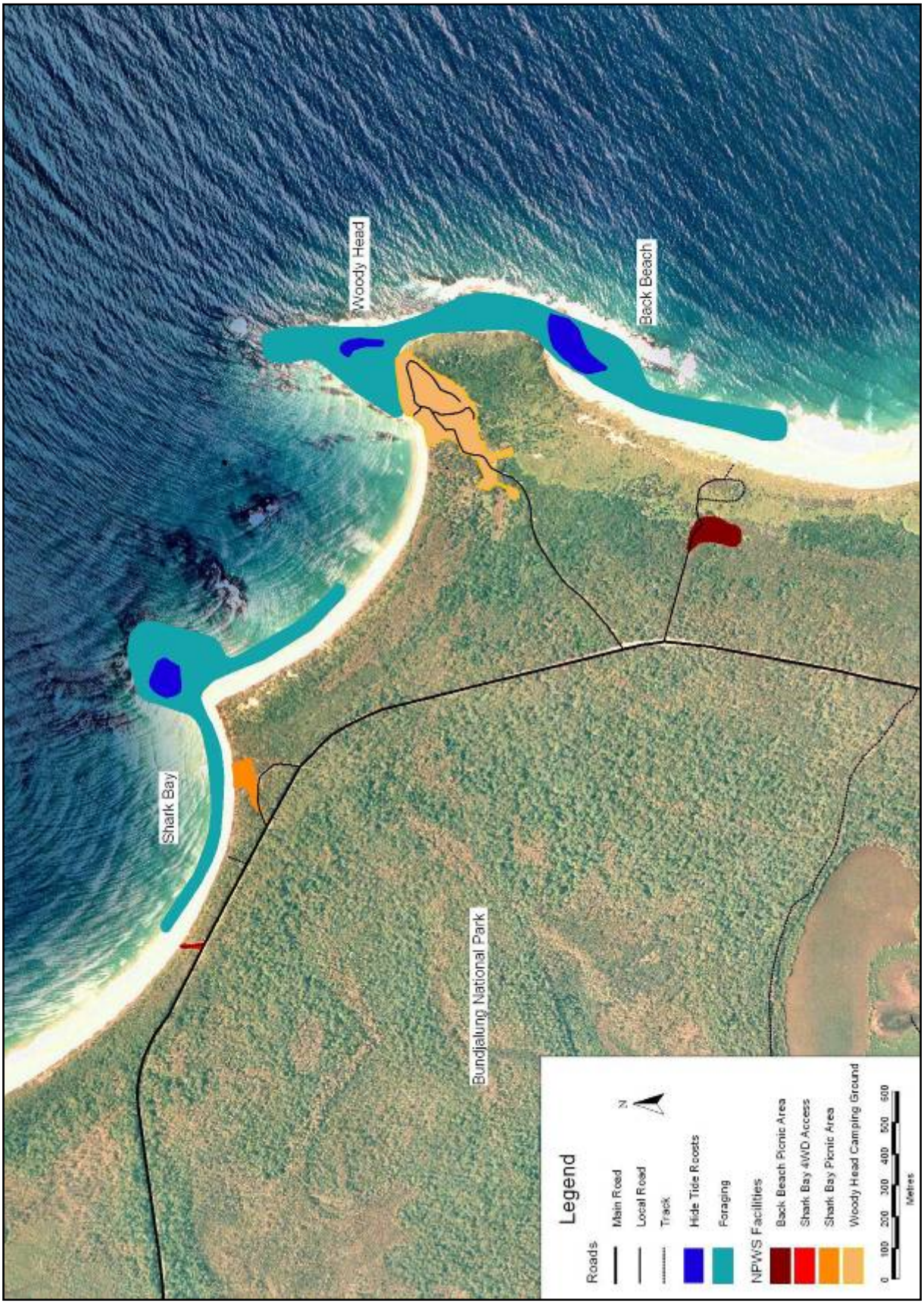


Figure 23 Distribution of shorebird foraging and roosting habitat at Woody Head

Colonisation of shorebird roosts by mangroves is another difficult management issue as it creates a conflict between the management of shorebirds and estuarine habitat. The expansion of mangroves into saltmarsh is occurring in several north coast estuaries (Saintilan 2003; Saintilan & Williams 1999). The negative impact of this on shorebird roosting habitat has been suggested by Straw (1999), Rohweder (2007) and Sandpiper Environmental (2004), and the quality of many roosts in the Clarence Estuary (and other north coast estuaries) is being reduced by mangroves. Although some approvals have been obtained to remove mangrove seedlings from roosts, these typically apply to artificial sites such as Stockton sand spit (Hunter Estuary) and Chickiba Lake (Richmond Estuary).

Generally, the NSW Department of Industry and Investment is not supportive of mangrove removal from 'natural' sites; possibly because mangrove expansion is deemed part of 'natural' estuarine processes, mangroves provide fisheries habitat, and their removal would be required on a regular basis. More recently, mangrove control has been approved for several 'natural' sites on Ash Island in the Hunter Estuary (pers. comm. C. Herbert). While the importance of mangroves in estuarine systems is not questioned, the need for a more proactive approach to their control at shorebird roosts is required. An audit of shorebird roosts in priority north coast estuaries is required to identify which sites are threatened by mangroves. The audit should recommend appropriate mangrove management actions in key sites.

4.4.2 Applying the threat prioritisation method elsewhere

The types of threats identified in the Clarence Estuary are not unique to that location but rather affect shorebirds in most north coast estuaries. The pilot assessment in the Clarence provides a useful insight into the type of threats that could be expected in other estuaries. Although differences will occur in the magnitude of threats between locations and habitats, the major threat types of disturbance, modification and loss are widespread. Notable threats that were not prevalent in the Clarence assessment include impacts from 4WD vehicles and predation of eggs and chicks by foxes and dogs. These threats are known to be prevalent at some important shorebird breeding sites, such as the beaches south of the Richmond Estuary.

The broadscale application of the threat prioritisation to all locations in the Northern Rivers CMA region is unfeasible due to the time and costs involved. Nonetheless, it would be feasible to apply the method to priority locations, such as the Richmond Estuary and the coastline between the Richmond and Clarence Estuaries. Improved delineation of threats and application of the threat prioritisation can be achieved by integrating threat and habitat prioritisations with GIS mapping.

In some instances there are existing management plans and strategies that include actions to protect shorebird habitat. Rather than doing further assessment, improved protection could be achieved by ensuring that management actions proposed in an approved plan or strategy are applied. In the case of the South Ballina beaches a *Threatened Species (Pied Oystercatcher) Management Strategy* already exists (DoL 2007) and the *Richmond River Nature Reserve Plan of Management* (NPWS 2005) addresses issues pertaining to shorebird habitat in that reserve. The Pied Oystercatcher Strategy includes several appropriate management actions that should be implemented to protect nesting birds, including improved management of 4WD vehicles. This could include investigating the introduction of a 'restricted' permit system and ongoing rationalisation of beach access tracks to manage Pied Oystercatchers between the Richmond and Evans Rivers.

PART 5: PILOT SHOREBIRD HABITAT MAPPING

5.1 Background

Mapping of shorebird roost, foraging and nesting sites should be an integral component of any site and threat prioritisation as it enables the location of priority sites to be viewed and manipulated using GIS. Combining information on shorebird habitats with GIS is an effective means of synthesising large amounts of data into a format that can be readily used for planning and conservation projects. Mapping of priority habitats for threatened migratory shorebirds is an example of how shorebird count data can be combined with GIS mapping (Avifauna Studies and Research 2006). Other examples include Whetham and Scanlon (2007) for the Northern Rivers CMA region and Sandpiper Environmental (2006) for the Clarence Estuary.

The potential value of GIS as a tool for planning and management of shorebird habitat is substantial (Clemens et al. 2008). Because shorebirds consistently use well-defined habitats it is relatively easy to map habitats and integrate mapping into zoning and/or management plans. To date there has been no targeted approach to map shorebird habitat in coastal northern NSW, despite the potential utility of GIS. Such a project would be valuable to determine the area of different habitats available to shorebirds and in tracking temporal changes in habitat extent and quality. The Department of Industry and Investment has mapped seagrass, saltmarsh and mangroves in many north coast estuaries but not intertidal sand and mudflats or supra-tidal sandspits and bars, which are the preferred habitats of most shorebirds. Historical comparisons of the distribution and extent of habitat can be made using GIS, and the Department of Industry and Investment estuarine habitat mapping includes such comparisons.

Mapping shorebird habitat in all north coast estuaries is a large task that would require considerable funding. Estuarine habitats and shorebird roost sites also change, which means that maps can become out-dated in a short period. It is probably only feasible to focus on the highest priority shorebird sites, beginning with the Clarence and Richmond estuaries.

The following section discusses the mapping of shorebird foraging and roosting areas in the Clarence and Sandon estuaries that was trialled as part of this project.

5.2 Methods

A combination of orthorectified aerial photographs and satellite imagery (Google Earth ©) was used to broadly map intertidal habitat in both the Clarence and Sandon rivers. Mapping of shorebird roosts in the lower Clarence Estuary was undertaken by Sandpiper Ecological Surveys (2006) and that information has been used in this project. Each mapped roost polygon is supported by summary data on shorebird abundance and diversity. For this project the mapping was reviewed, some polygons were modified (enlarged) slightly, and the summary data was expanded to include the site and threat prioritisation scores.

The broad habitat maps were reviewed by Sandpiper Ecological Surveys (David Rohweder) and foraging and roosting habitat in the Sandon Estuary was ground-truthed on 22 August 2009. Maps were subsequently revised. Mapping of foraging habitat in the Clarence Estuary was not ground-truthed, although the mapping was carefully checked by David Rohweder who has a detailed knowledge of the estuary. Delineating the boundary of some intertidal mudflats in the Clarence Estuary was difficult due to a lack of contrast between the habitat and water. This problem was particularly noticeable in Wooloweyah Lagoon. Mapping for the Clarence Estuary requires field verification.

5.3 Results

Maps of shorebird foraging and roosting habitat in the Clarence and Sandon estuaries are shown in **Figures 24 and 25**. These maps provide an example of the habitat mapping and show the distribution of foraging and roosting habitat in the Clarence and Sandon estuaries. Fine-scale map

layers may be available through DECCW subject to relevant licences. Integration of priority rankings with roost mapping enables management priorities to be viewed graphically (**Figure 26**). By querying a roost polygon in ArcView, information can be obtained on the following: habitat type, threat and habitat priority ranking, site name, substrate type, roost type, number of shorebird surveys, maximum count for each species, total number of species, number of threatened and migratory species recorded at that site, shorebird species and number of individuals recorded at that site.

Figure 24 Clarence Estuary pilot mapping — Shorebird habitats

Figure 25 Sandon Estuary pilot mapping — Shorebird habitats

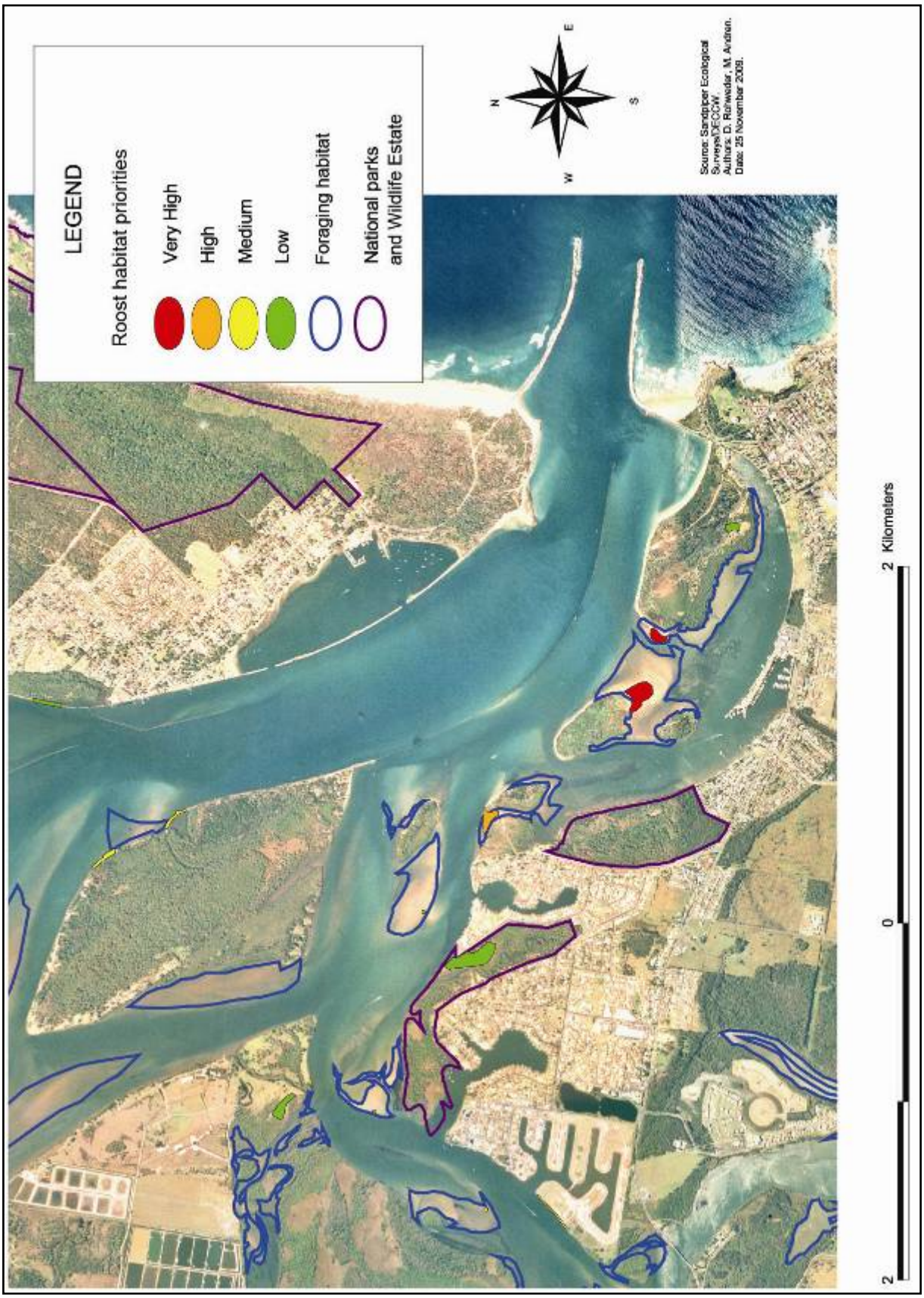


Figure 26 Distribution of shorebird roosting and foraging habitat, and roost management priorities near Yamba

5.4 Discussion

Shorebird habitat mapping provides a useful indication of potential sources of disturbance and of how roost and foraging areas are distributed in relation to each other. Integration of habitat and threat priority rankings enables planners and managers to visualise which parts of the estuary require protection. The inclusion of nesting habitat would further add to the utility of the maps and should be a high priority.

In the Clarence Estuary, the mapping highlights the presence of one very high priority roost site (Dart/Hickey Island) and one high priority site close to the town of Yamba, with another high priority site (Prawn Farm) situated close to several medium priority roosts at Wooloweyah Entrance and in Oyster Channel. From a management perspective, the very high and high priority management sites situated close to the town of Yamba reflect the threats associated with the town's proximity to these sites.

In the Sandon Estuary, the major roosts occur near the estuary mouth, although there are numerous potential saltmarsh roosts further upstream. One noticeable feature of the Sandon Estuary is that several roosts are situated close to the camping ground, boat ramp and Sandon Village — focal areas for human activity. Despite the fact that the Sandon Estuary is situated within a marine park and surrounded by national park, it is predicted that shorebirds using roosts and foraging areas in the lower estuary would experience similar levels of recreational disturbance to those using Dart/Hickey Island in the Clarence Estuary.

Another feature of the Sandon Estuary is the expansion of mangroves over roosting habitat in the lower estuary and the possible expansion into saltmarsh habitats further upstream (David Rohweder pers. obs.). An historical analysis of the extent of sand flats, mangrove forest and saltmarsh in the Sandon Estuary would be worthwhile to determine how different habitats are responding in an estuary that is protected by conservation reserves and that has not been affected by breakwalls or trainwalls.

Mapping of shorebird habitat in other north coast estuaries would provide a useful resource for managers, planners and researchers. It is unlikely that all estuaries could be mapped and effort should be concentrated on the highest priority sites, commencing with inclusion of nest sites and verification of the Clarence Estuary mapping followed by mapping of roost, nest and foraging habitat in the Richmond Estuary. An alternative to detailed mapping of each estuary would be to map the more-easily defined, but critically important, roost and nest sites throughout the Northern Rivers CMA region. Such broadscale mapping would be beneficial for region-wide planning and conservation purposes. Estuarine and coastal habitat mapping prepared by the Department of Industry and Investment could also be integrated with shorebird habitat maps to provide a more complete coverage of estuarine habitat.

PART 6: RECOMMENDATIONS

Recommendations have been divided into the following five categories:

- data and research
- threat identification and analysis
- management
- mapping
- planning.

Each recommendation has been prioritised as high, medium or low (**Table 13**). Three primary criteria were used to assign priorities based on the level to which the recommendation would either:

a) complement data presented in this report or link with existing programs

b) be of value to the future viability of a species in the Northern Rivers CMA region

c) be cost effective.

The implementation of public awareness and education campaigns as a means of reducing the impacts of recreational disturbance on shorebirds is also important and is reflected in some of the recommendations.

Table 13 Recommendations

Category / Number	Aspect	Recommendation	Priority
Data & Research			
1	Survey	Undertake shorebird surveys in the Macleay Estuary to gather up-to-date information on population size, species richness and the distribution of roost and foraging areas.	High
2	Audit	Undertake an audit of shorebird nesting records to include with the audit of roost and foraging data.	High
3	Research	In association with the Department of Industry and Investment (Fisheries) and the Marine Parks Authority NSW, investigate as part of a long-term program to monitor primary prey species of Pied Oystercatcher at major nesting beaches, the decline and availability of pipis, and if appropriate, revise bag limits and/or introduce seasonal closures.	High
4	Survey	Audit shorebird roosts in the Northern Rivers CMA region to describe major roosting habitat features and assess threats.	Medium
5	Maintenance	Include grid references for all roost and foraging areas listed in the shorebird dataset and modify the dataset so it can be utilised with GIS spatial data.	High
6	Audit	Update the shorebird dataset on an annual basis by arranging a data transfer agreement with the Shorebirds 2020 project or by uploading data from annual Shorebirds 2020 reports and *The Stilt*.	Medium
7	Audit	Collate additional historical survey data for the Nambucca Estuary or undertake shorebird surveys to gather up-to-date information.	Medium
8	Survey	Undertake shorebird surveys in the Nambucca Estuary to gather up-to-date information on population size, species richness and the distribution of roost and foraging areas.	Medium
9	Survey	Undertake targeted surveys of small estuaries and ICOLLs between Bonville Creek and Port Macquarie to gather up-to-date information on population size, species richness and the distribution of roost and foraging areas to improve the	Medium

Category / Number	Aspect	Recommendation	Priority
		assessment of habitat values for that area.	
10	Analysis	Utilise existing datasets to assess temporal changes in shorebird populations in the Richmond and Clarence estuaries.	Medium
11	Survey	Undertake a population census of Beach Stone-curlew in northern NSW to provide an update to the 2000 survey data.	Medium
12	Assessment	Use the collated data and other readily available sources to assess temporal trends in the distribution and abundance of Red-capped Plover in the Northern Rivers CMA region as a basis for assessing the status of the species and upgrading conservation status if necessary.	Medium
13	Survey	In association with the Department of Industry and Investment (Fisheries) and the Marine Parks Authority NSW, undertake baseline surveys to describe and quantify the food resources at important shorebird foraging areas, including beaches between the Richmond and Evans rivers.	Low
14	Audit	Liaise with the NSW WSG to obtain count data for the 2002 and 2004 Beach Nesting Bird Surveys.	Medium
Threat Identification and Analysis			
15	Site Prioritisation	Extend the Clarence habitat and threat prioritisation to include the Richmond Estuary and the intervening section of coastline. The results should be used to identify at-risk sites and develop management actions for those sites.	High
16	Research	Undertake research to describe the types of human activities that affect nesting, roosting and foraging shorebirds and quantify the effect of these activities on the bird's daily energetic requirements and/or breeding success.	Medium
Management			
17	Action	Work with the appropriate land managers to develop and implement a management strategy for shorebird roosting habitat at Shark Bay, Woody Head and Back Beach.	High
18	Action	Encourage the appropriate land managers (eg Department of Lands) to initiate management actions proposed in the Threatened Species (Pied Oystercatcher) Management Strategy, particularly actions pertaining to the management of 4WD vehicles on ocean beaches.	High
19	Planning	Where possible, ensure that shorebird habitat mapping, site prioritisation data and information on threats are included in estuary management plans.	High
20	Planning	Work with the appropriate land managers to develop actions to reduce threats at very high and high priority sites in the Clarence Estuary.	High
21	Conservation	In consultation with key stakeholders, investigate conservation options for the long-term protection and management of the Micalo Island Prawn Farm.	High
22	Shorebird status assessment	Assess the status of all shorebirds and major shorebird habitat in the Northern Rivers CMA region to identify threatened species that require a change in status; i.e. species whose status should be increased to vulnerable or endangered; endangered populations; and key threatening processes.	Medium
Mapping			

Category / Number	Aspect	Recommendation	Priority
23		Expand roost and foraging area mapping already completed for the Clarence and Sandon estuaries to include the Richmond Estuary and intervening section of coastline. Nest sites should be included as a third attribute. Prepare maps that show shorebird values (nest, roost and foraging habitat) with threats (e.g. dog exercise areas, 4WD beaches, camping grounds, car parks, high use surfing and swimming areas, hiking trails, fishing areas etc.).	High
24	Climate change	Use Lidar data to map how incremental sea-level rise will affect the area of saltmarsh and rocky shore roosts and identify areas where saltmarsh may be able to expand into adjoining habitat.	Medium
25	Review	Review and update the mapping of threatened shorebird habitat (Avifauna Research and Surveys 2006) for the Northern Rivers CMA region to correct errors and build on the existing dataset.	Medium
26		Use GIS to map the extent of all shorebird roosts in the Northern Rivers CMA region and include bird survey data from the roost audit. Distribute mapping to all coastal councils for inclusion in local planning instruments.	Medium
27	Coordination	Liaise with other government agencies to exchange GIS mapping data for estuarine and coastal habitats.	Medium
28	Habitat change	Assess temporal changes in the extent of saltmarsh and supra-tidal sandbar habitat in the Sandon Estuary.	Low
Planning			
29		Provide shorebird habitat mapping to Clarence Valley, Richmond Valley and Ballina Shire Councils for inclusion in their GIS systems.	High
30		Liaise with local councils in the Northern Rivers CMA region to prepare educational information for identified priority areas to improve management of shorebird habitat.	High
Climate change			
31		Investigate the potential impact of sea-level rise on the distribution and extent of shorebird nest, roost and foraging habitat in the Northern Rivers CMA region.	High
Information			
32		Prepare local government area–specific guidelines to assist local government planners ensure that shorebirds are considered in local planning programs.	High
33		Consider state and national research, planning and management priorities before prioritising or implementing actions at the regional scale.	High

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ACRONYMS

CMA	Catchment Management Authority
DECCW	Department of Environment, Climate Change and Water NSW
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GIS	geographic information system
ICOLLs	intermittently closed and open lakes and lagoons
NRAC	Natural Resources Audit Council
NSW	New South Wales
TSC Act	*Threatened Species Conservation Act 1995*
WSG	wader studies group