Review of known shorebird habitats, distribution and threats in Gold Coast waterways (SRMP-013)

Gold Coast Waterways Authority

Scientific Research and Management Program

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Glossary of terms used

Acronym, abbreviation or term	Definition
GCWA	Gold Coast Waterways Authority
DEHP	Department of Environment and Heritage Protection (QLD)
DNPSR	Department of National Parks, Sport and Racing (QLD)
CoGC	City of Gold Coast (formerly Gold Coast City Council)
MBMP	Moreton Bay Marine Park
SEQ	Southeast Queensland
EAAF	East Asian-Australasian Flyway (see www.eaaflyway.net)
IUCN	International Union for Conservation of Nature
Cwlth	Commonwealth (i.e. Australian Government)
NSW	New South Wales
QLD	Queensland
GCWA Act	*Gold Coast Waterways Authority Act 2012* (QLD)
NCA or NC Act	*Nature Conservation Act 1992* (QLD)
TSCA or TSC Act	*Threatened Species Conservation Act 1995* (NSW)
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999* (Cwlth)
CR	Critically Endangered Species (as defined under the EPBC Act)
EN	Endangered Species (as defined under the EPBC Act)
VU	Vulnerable Species (as defined under the EPBC Act)
FID	Flight Initiation Distance – the distance at which a disturbance prompts a flight response in a bird
SLR	Sea Level Rise
SST	Sea Surface Temperature
LGA	Local Government Area
QWSG	Queensland Wader Study Group
Ramsar	The Convention on Wetlands, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources (see http://www.ramsar.org/ for details).
Shorebird	A general term used to describe birds from the taxonomic order Charadriiformes, often termed 'waders' or 'waterbirds'. Australian shorebirds include resident and migratory species
PWC	Personal Watercraft (*e.g.* jet skis, wave runners, wave riders)

For additional explanations of terminology used in this report please refer to Appendix H

1. Executive Summary

Gold Coast Waterways Authority (GCWA) has a responsibility to strategically plan for, promote and manage the sustainable use of Gold Coast waterways under the *Gold Coast Waterways Authority Act 2012* (GCWA Act). These waterways contain a variety of ecosystems of environmental importance, including mangroves, seagrass meadows, inland waters and tidal flats. These ecosystems provide important habitat for many species, including populations of resident and migratory shorebirds.

This project reviewed existing information (i.e. literature and available data) on known shorebird habitats, distributions and threats in Gold Coast waterways under the following broad objectives:

- Identify the important shorebird populations, communities and habitats in Gold Coast waterways.
- Assess the relative importance of shorebird populations, communities and habitats in Gold Coast waterways on a local, regional, national and global scale.
- Assess the important shorebird populations, communities and habitats in Gold Coast waterways for their resilience and sensitivity to current and future threats.

This project is part of GCWA's broader Scientific Research and Management Strategy (SRMS) and accompanying Scientific Research and Management Program (SRMP).

In Australia, migratory shorebirds are recognised as a matter of national environmental significance under the *Environmental Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act, Australian Government 2016a). Consequently, for migratory species currently listed in the Wildlife Conservation Plan for Migratory Shorebirds, Australia has a strategy in place to protect, conserve and manage these species. A small number of species specifically listed as threatened do not fall under the Wildlife Conservation Plan but have their own provisions under the EPBC Act. Nationally, therefore, shorebirds require ongoing conservation and management, for example through habitat protection. Shorebirds may also act as indicators of ecosystem health, and monitoring long-term population trends is important.

Existing data on shorebird populations, habitats and threatening processes were collated and synthesised to document the current understanding of shorebirds in Gold Coast waterways. These data sources included:

- Queensland Wader Study Group (*provision of shorebird records from monitoring sites*)
- City of Gold Coast (*shorebird records collected from City of Gold Coast monitoring surveys*)
- ebird.org (*global citizen science database searched for records of shorebirds from sites within the Gold Coast waterways*)

- peer-reviewed literature (*science pertaining to shorebirds, their habitats and threats facing these birds nationally and internationally*)
- documents published by the Queensland and Australian Government (*various reports e.g. Wildlife Conservation Plan for Migratory Shorebirds, EPBC Act*)
- other literature (*e.g. consulting reports pertaining to shorebirds*)
- communications with various experts in the field of shorebird research and management (*identification of shorebird sites, evaluation of threats*)
- other online sources (*data repositories for shorebirds, wetlands, trend analyses*).

Shorebirds utilise a variety of coastal and inland habitats that are typically associated with aquatic environments. As such, coastal areas with extensive intertidal sand and mudflats as well as mangroves provide a diverse range of habitats used by shorebirds. These habitats are used at different times of the year (e.g. when birds are either arriving or departing on annual migrations) and for different purposes (e.g. foraging, roosting, nesting). Shorebird persistence is therefore reliant on the conservation and protection of a full range of habitats available to them.

The review identified areas within Gold Coast waterways that are nationally important for both migratory and resident populations of certain shorebird species (*e.g.* Eastern Curlew, Double-banded Plover, Bar-tailed Godwit, Greater Sand Plover and Whimbrel).

Considerable areas of shorebird habitat within Gold Coast waterways are located within protection zones provided by the Moreton Bay Marine Park (MBMP) and Ramsar wetland areas to the north of the Gold Coast seaway. However, this project identified additional areas of national significance within the Gold Coast waterways that are located outside of these protection zones. The Southport Wavebreak area (i.e. Kurringle Flats, Curlew Banks, Curlew Island, see Figure 6 and Appendix F for details) in particular meets these requirements for three of the aforementioned species, namely Eastern Curlew, Bar-tailed Godwit and Whimbrel. It was not possible to differentiate between key foraging, roosting and nesting sites based on the available data.

Globally, shorebirds are threatened by various natural and anthropogenic pressures throughout their range. Such threats include stochastic natural extreme events (e.g. cyclones) and those with a more gradual effect (e.g. climate change, changes in sedimentation rates [accretion/erosion]). Numerous threats are associated with anthropogenic pressures and include habitat modification (positive and negative), pollution, changes to predator-prey relationships, hunting, invasive species and physical disturbance. There may also be future threats facing shorebirds that are currently poorly understood, such as the effects of microplastics (i.e. plastic particles under 5 mm in length), new forms of recreation (e.g. kite boarding), changes in primary productivity at key migratory staging areas and pharmaceutical contamination of waterways.

Shorebird populations in Australia face a slightly narrower range of threats to those globally. Documented declines in Australian migratory shorebird populations have been linked to factors outside Australia (e.g. habitat loss and modification in Asia). However, local threats to shorebirds and their habitats in Australia remain, and include reductions in roosting and foraging habitats, physical disturbance, declining water quality and coastal development. In Moreton Bay, key threats include habitat loss and degradation, anthropogenic disturbance and a lack of awareness surrounding shorebird conservation issues.

In Gold Coast waterways, shorebird populations and habitats potentially face similar threats to those elsewhere in Queensland and Australia, however, there is a distinct lack of empirical data of this nature and this should be addressed. Threatening processes on the Gold Coast, including coastal development, recreational disturbance, climate change, pollution, dredging and nourishment, may affect shorebirds within and outside the protection zones provided by the Moreton Bay Marine Park and the Ramsar wetland areas. Nonetheless, shorebirds and their habitats require appropriate management, regardless of the protection status afforded to these areas. Gold Coast waterways are also relatively confined compared to the greater Moreton Bay region and are particularly heavily utilised by both commercial and recreational users. This potentially places increased pressure on shorebirds and their habitats and may therefore increase the risk associated with anthropogenically-derived threats, particularly disturbance, in Gold Coast waterways. Greater public education and awareness around shorebirds and their habitats, particularly during periods of high shorebird activity, may be required to ensure long-term species viability in the region.

This review provides a baseline of known shorebird habitats, distribution and threats in Gold Coast waterways that could inform management decision-making. However, current information is somewhat limited by data availability for shorebirds locally (i.e. an emphasis on known and well-monitored suite of sites within the Gold Coast waterways), and may not capture all areas of value to shorebirds. For example, the approach to shorebird monitoring has not been comprehensive throughout the waterways and there was no existing shorebird habitat assessment that permitted the differentiation of habitat use by shorebirds. Furthermore, threats were not quantified empirically, nor was it possible to determine their likelihood of occurrence. Additional research effort would provide a more comprehensive understanding of shorebird habitats, distribution and threats in Gold Coast waterways.

Key preliminary research recommendations include:

- Undertake further surveys of shorebirds to ground-truth current data and enable accurate ranking of shorebird habitats in Gold Coast waterways in terms of their relative importance as foraging, roosting or nesting sites at a local, regional, national and global scale.
- Evaluate the nature and extent of potential threats to shorebirds in and around important habitats during important lifecycle stages (e.g. breeding).

Disclaimer

This report presents the findings of an independent review undertaken by Griffith University. The information presented herein summarises existing literature and data on shorebirds, their habitats and threats. It should be noted that while this report was commissioned by Gold Coast Waterways Authority (GWCA) under the Scientific Research and Management Program (SRMP), it does not explicitly bind GCWA to implement any of the specific recommendations as there are complex multi-jurisdictional responsibilities throughout Gold Coast waterways. As such, the purpose of this report is to provide the relevant background information to aid in the overall decision-making process.

2. Introduction

The Gold Coast Waterways Authority (GCWA) was established in December 2012 by the *Gold Coast Waterways Authority Act 2012* (GCWA Act). It is a Queensland Government Statutory Body with responsibility under the provisions of the GCWA Act to strategically plan for, promote and manage the sustainable use of the Gold Coast waterways. As defined by the GCWA Act the purpose of the GWCA is to:

- deliver the best possible management of the Gold Coast waterways at reasonable cost to the community and government, while keeping government regulation to a minimum
- plan for and facilitate the development of the Gold Coast waterways over the long term in a way that is sustainable and considers the impact of development on the environment
- improve and maintain navigational access to the Gold Coast waterways
- develop and improve public marine facilities relating to the Gold Coast waterways
- promote and manage the sustainable use of the Gold Coast waterways for marine industries, tourism and recreation.

In accordance with the GCWA Act, a 10-year Waterways Management Strategy and 4-year (rolling 1+3) Program providing a range of navigational access and waterways management works have been prepared. As part of the Waterways Management Program 2015-2019 GCWA has identified a number of actions aimed at sustaining, enhancing and promoting the sustainable use of Gold Coast waterways.

These actions include the protection of environmental values (Strategy 1.6) in collaboration with environmental authorities, and the promotion and communication of the waterways (Strategy 3.1-3.4). Improvement of the understanding of Gold Coast waterways issues and management options is facilitated through the Scientific Research and Management Strategy (SRMS) and its associated Program (SRMP) of works, as implemented by the Scientific Advisory Committee (SAC). This framework provides the context for this review of shorebird habitats, distribution and threats, which is included in the current SRMP.

2.1 Aims and objectives

This project aimed to review existing information on known shorebird habitats, distribution and threats in Gold Coast waterways. The following broad objectives and key tasks contribute to achieving the aim:

- Identify the important resident and migratory shorebird populations, communities and habitats (feeding, roosting and nesting sites) in Gold Coast waterways.
- Assess the relative importance of Gold Coast waterways important shorebird populations, communities and habitats on a local, regional, national and global scale.

- Assess the important shorebird populations, communities and habitats in Gold Coast waterways for their resilience and sensitivity to current and future threats.
- Collate a summary of shorebird management measures currently available/in use.
- Identify key areas where information is inadequate and/or non-existent and suggest potential measures that may suitably address these data gaps.
- Based on the available information, identify—
    - practices and/or measures that may help mitigate or avoid adverse effects
    - studies that may help address the information gaps identified from the above.

2.2 Background

The Gold Coast waterways contain a wide variety of ecosystems of environmental importance, including mangroves, seagrass meadows, inland waters and tidal flats, providing important habitat for many species, including populations of both resident and migratory shorebirds. Some recent studies report on changes in the distribution, sensitivity and resilience of seagrass meadows throughout the Gold Coast waterways (see Cuttriss et al. 2013; Connolly et al. 2015). Furthermore, many of these ecosystems are affected by coastal processes (e.g. tidal influence in mangroves, see Knight et al. 2008). Climate change is also likely to alter these ecosystems further, and securing the conservation of important habitats within protected areas or reserves has been identified as a priority (Shoo et al. 2014).

Globally, shorebirds have received considerable attention, given their wide ranging distribution and migratory patterns (Bamford et al. 2008, Wetlands International 2010, Sutherland et al. 2012, Clemens et al. 2016). Shorebirds populations are threatened by habitat loss and degradation (often through urbanisation and development), reduction in feeding resources in key habitats from harvesting and collection (Goss-Custard et al. 2004; van Gils et al. 2006; Verhulst et al. 2004) and dredging (Brereton and Taylor-Wood 2010). Anthropogenic disturbance at foraging and roosting sites (Liley and Sutherland 2007), agricultural intensification, water regulation, pollution, eutrophication, invasive species, hunting and predation, changes in habitat quality as well as climate change also impact on shorebird populations (Oldland et al. 2009; Wetlands International 2010; Sutherland et al. 2012; Clemens et al. 2016).

Many global populations (44%) are in decline as a result of the aforementioned threats (Zöckler et al. 2003; Wetlands International 2010), but the loss and degradation of habitats features prominently. Furthermore, some of the greatest and most widespread declines are reported from the East Asian-Australasian Flyway (EAAF)[1] (Amano et al. 2010). Recent evidence from Australia suggests that population trends are worse than global averages (Nebel et al. 2008; Clemens et al. 2016). For example, in eastern Australia between 1983

[1] Refer Appendix I, Figure I38–Figure I43, for information on the East Asian-Australasian Flyway.

and 2006, migratory shorebird populations declined by 73% while resident species declined by 81% (Nebel et al. 2008). In a more recent analysis, Clemens et al. (2016) showed continental decreases in the abundance in 12 of 19 migratory species, while this increased to 17 of 19 species in southern regions of Australia. Rates of change in migratory shorebird populations in Australia are not homogeneous, with populations declining more rapidly in eastern and southern Australia than elsewhere in Australia (Clemens et al. 2016). Rates of change in populations of migratory shorebirds at a local level are not associated with local threats (Clemens et al. 2016) and appear to be related more to habitat loss in other areas of the migratory EAAF outside Australia (Wilson et al. 2011; Clemens et al. 2016). Resident shorebird species typically show significant declines for inland species associated with non-tidal wetlands, whereas coastal species are generally increasing (Clemens et al. 2016).

Shorebirds have been used by Butchart et al. (2010) as global biodiversity indicators, where the Waterbird Population Status Index (one of 24 global biodiversity indicators) reveals that global populations have declined by 33% since 1970. However, patterns and trends in shorebird populations are not consistent in all regions. For example, in the Oceania region, the majority of populations with known trend data are either declining (38%) or fluctuating (20%) (Wetlands International 2012). Consequently, there are a number of provisions in place for the conservation and management of shorebirds at global, national and regional levels as outlined below, with particular reference to Australia.

Australia is a signatory to several agreements concerning migratory species, including shorebirds (e.g. Bonn Convention, Ramsar Convention, JAMBA, CAMBA, ROKAMBA) (refer to Table 1, Appendix A). The combination of these international and bilateral agreements provides for the protection and conservation of migratory birds and their important habitats given that their distribution is not confined to any single nation. A fundamental principle underpinning these agreements is the acknowledgement of the importance of conserving migratory species, with signatory range states agreeing to take actions to achieve this end when possible and appropriate. Specific provisions outlined in the articles of these agreements include measures such as the establishment of protected areas for the management and protection of shorebirds, preventing damage to migratory shorebirds and their environments and to reduce, prevent or control threats to shorebird species (refer to Appendix A).

These agreements also strengthen international relationships and collaboration by encouraging the exchange of data and publications, formulating collaborative research programs and the conservation of migratory species more generally. The East Asian-Australasian Flyway Partnership, established in 2006, is a demonstration of these efforts where 22 countries have endorsed the recognition and conservation of migratory shorebirds and their habitats within the flyway (Szabo et al. 2016).

Table 1: International and bilateral agreements relevant to migratory shorebirds in Australia, ordered by the year in which these agreements were signed.

Agreement	Number of sites/species	Year established
JAMBA – Japan-Australia Migratory Bird Agreement	66 species	1974
Ramsar – Ramsar Convention on Wetlands	65 sites#	1975
CAMBA – China-Australia Migratory Bird Agreement	81 species	1986
CMS / Bonn Convention – Convention on the Conservation of Migratory Species of Wild Animals	76 species	1991
ROKAMBA – Republic of Korea-Australia Migratory Bird Agreement	59 species	2007

refer Appendix G, Figure G32, Figure G33 and Figure G34 for detail.

As a signatory to these aforementioned agreements, Australia has an obligation to conserve migratory shorebirds and their habitats. Any of the 37 migratory shorebird species listed under one of the agreements is protected under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) as a 'matter of national environmental significance'. For example, under the EPBC Act, actions[2] that have, or are likely to have, a significant impact[3] on these listed species require approval from the Federal Environment Minister (see Chapter 2, Part 3, Division 1, Subdivision D, Section 20, EPBC Act). Further guidelines to assist stakeholders in avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebirds are available in the recent EPBC Act Policy Statement 3.21 (Australian Government 2015b).

Under the EPBC Act the Wildlife Conservation Plan for Migratory Shorebirds (Australian Government 2015a) provides a framework for the conservation of shorebirds and their habitats within Australia. This plan makes provisions only for those species that are not

[2] ***Action***:
An action is defined broadly in the EPBC Act and includes: a project, a development, an undertaking, an activity or a series of activities, or an alteration of any of these things. A lawful continuation of an existing use is not an action. A decision by a government body to grant an authorisation (for example, a permit or licence) or to provide funding is not an action. Actions include, but are not limited to: construction, expansion, alteration or demolition of buildings, structures, infrastructure or facilities; storage or transport of hazardous materials; waste disposal; earthworks; impoundment, extraction and diversion of water; research activities; vegetation clearance; military exercises and use of military equipment; and sale or lease of land.
(see http://www.environment.gov.au/epbc/about/glossary)

[3] ***Significant impact***:
A significant impact is an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts. You should consider all of these factors when determining whether an action is likely to have a significant impact on the environment.
(see http://www.environment.gov.au/epbc/about/glossary)

specifically listed as threatened species under the EPBC Act. Listing of a number of shorebird species in 2015, and most recently in May 2016, has resulted in several species being captured under the specific threatened species provisions of the EPBC Act that were previously only covered by the Wildlife Conservation Plan, as follows:

- Critically Endangered—
    - Eastern Curlew (*Numenius madagascariensis*)
    - Curlew Sandpiper (*Calidris ferruginea*)
    - Great Knot (*Calidris tenuirostris*)
    - Northern Siberian Bar-tailed Godwit (*Limosa lapponica menzbieri*)
- Endangered—
    - Lesser Sand Plover (*Charadrius mongolus*)
    - Red Knot (*Calidris canutus*)
- Vulnerable—
    - Greater Sand Plover (*Charadrius leschenaultii*)
    - Western Alaskan Bar-tailed Godwit (*Limosa lapponica baueri*).

The *Nature Conservation (Wildlife) Regulation 2006* (QLD) lists two shorebird species as Vulnerable within the state (Beach Stone-curlew [*Esacus magnirostris*] and Eastern Curlew) and specifies provisions for 'special least concern animals', which includes migratory birds covered by the JAMBA, CAMBA and Bonn Convention. Overall, the proposed management intent for least concern wildlife includes:

- to monitor and review the conservation status of wildlife
- to the extent practical, to prepare and put into effect conservation plans or other instruments for least concern wildlife that—
    - is of commercial, recreational, traditional or potential conservation interest
    - considered to be potentially vulnerable
- to encourage scientific research and inventory programs likely to contribute to an understanding of the wildlife or the Australian biota
- to incorporate into educational material and programs provided by the Queensland Government, information about the wildlife's contribution to Queensland's and Australia's biodiversity.

A key concept underpinning the legislative provisions for migratory shorebirds is the identification of 'important habitat'. The '*Matters of National Environmental Significance: Significant Impact Guidelines 1.1*' (Australian Government 2013) states that an area of 'important habitat' for migratory species is:

- habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of the species, and/or
- habitat that is of critical importance to the species at particular life-cycle stages, and/or

- habitat that is utilised by a migratory species which is at the limit of the species range, and/or
- habitat within an area where the species is declining.

There are multiple sites around Australia that are identified as shorebird habitats of international importance (Bamford et al. 2008), being those that meet Criterion 6 of the Ramsar Convention. This states that 'a wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird' and in cases where a species has an estimated population >2 000 000, the 1% threshold is set at 20 000.

Furthermore, under the EPBC Act some habitats can be defined as sites of national importance depending on the species and populations that use the area (Australian Government 2015a; b). These sites support at least 0.1% of the flyway population ***or*** a single species or 2000 migratory shorebirds ***or*** at least 15 migratory species (Clemens et al. 2014; Australian Government 2015a; b).

There are over 230 shorebird areas in Australia that have been identified through monitoring programs (e.g. BirdLife Australia's Shorebirds 2020 Program, BirdLife Australia 2016a) (Clemens et al. 2014). Shorebird areas are broadly defined as those used by the same group of shorebirds over the primary non-breeding season (Clemens et al. 2010). The boundaries of these shorebird areas attempt to link ecologically connected habitats that encompass the home range of local populations, and may include multiple roosting and foraging sites (Clemens et al. 2014). Overall, 118 of these shorebird areas are considered as internationally significant sites (Bamford et al. 2008; Figure 1, Appendix B), including 65 Ramsar Wetland sites (Australian Government 2016b and Appendix G, Figure G32). As shown in Figure 1, there are 15 internationally important sites (including four inland sites) in Queensland, comprising 13% of all Australian sites. Only one of these sites is in southeast Queensland (i.e. Moreton Bay). More recent assessments of the shorebird habitats as part of BirdLife Australia's Shorebirds 2020 program identify seven discrete areas in the greater Moreton Bay region, that together comprise the 'Pumicestone Passage' shorebird area (Figure 1). The Shorebirds 2020 'Pumicestone Passage' area extends from Caloundra in the north to the Nerang River bridge in the southern reaches of the Gold Coast Broadwater, covering almost 82,000 ha (Figure 1). Within this shorebird area are some 236 count areas that define smaller discrete areas that cover the main roosting and foraging sites where counts can be completed. Of these, there are 42 (17.8%) count areas in Gold Coast waterways (Figure 2). An additional Shorebirds 2020 shorebird area is located at Tallebudgera Creek on the southern Gold Coast.

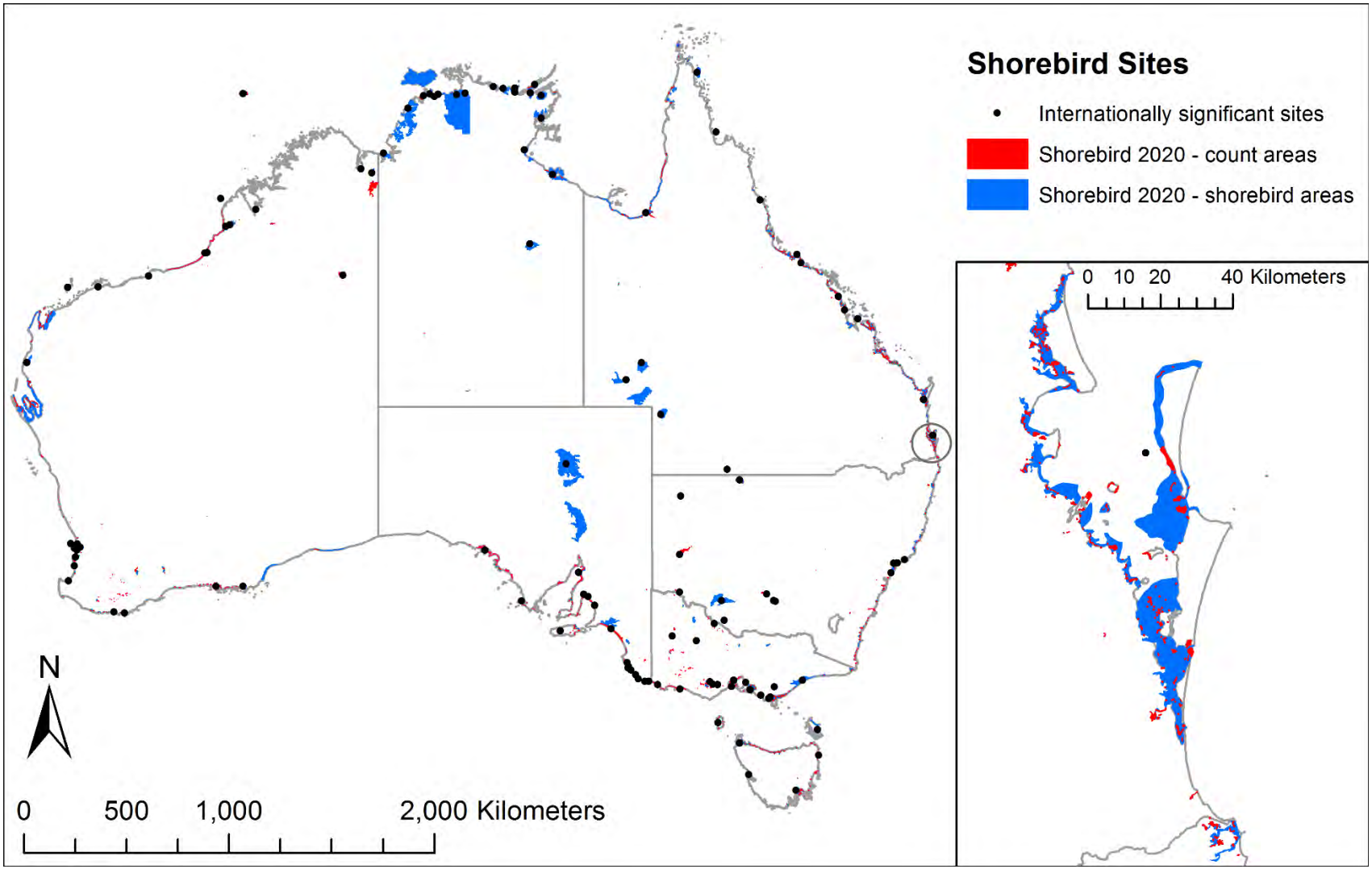

Figure 1: Australian shorebird sites of international significance (black circles, Bamford et al. 2008), as well as the Shorebirds 2020 sites that include 'shorebird areas' as well as 'count areas' (see Birdlife Australia 2016b for definitions). Sites within the southeast Queensland region (Moreton Bay circled) are depicted in the inset, with the shorebird area here identified as the 'Pumicestone Passage'.

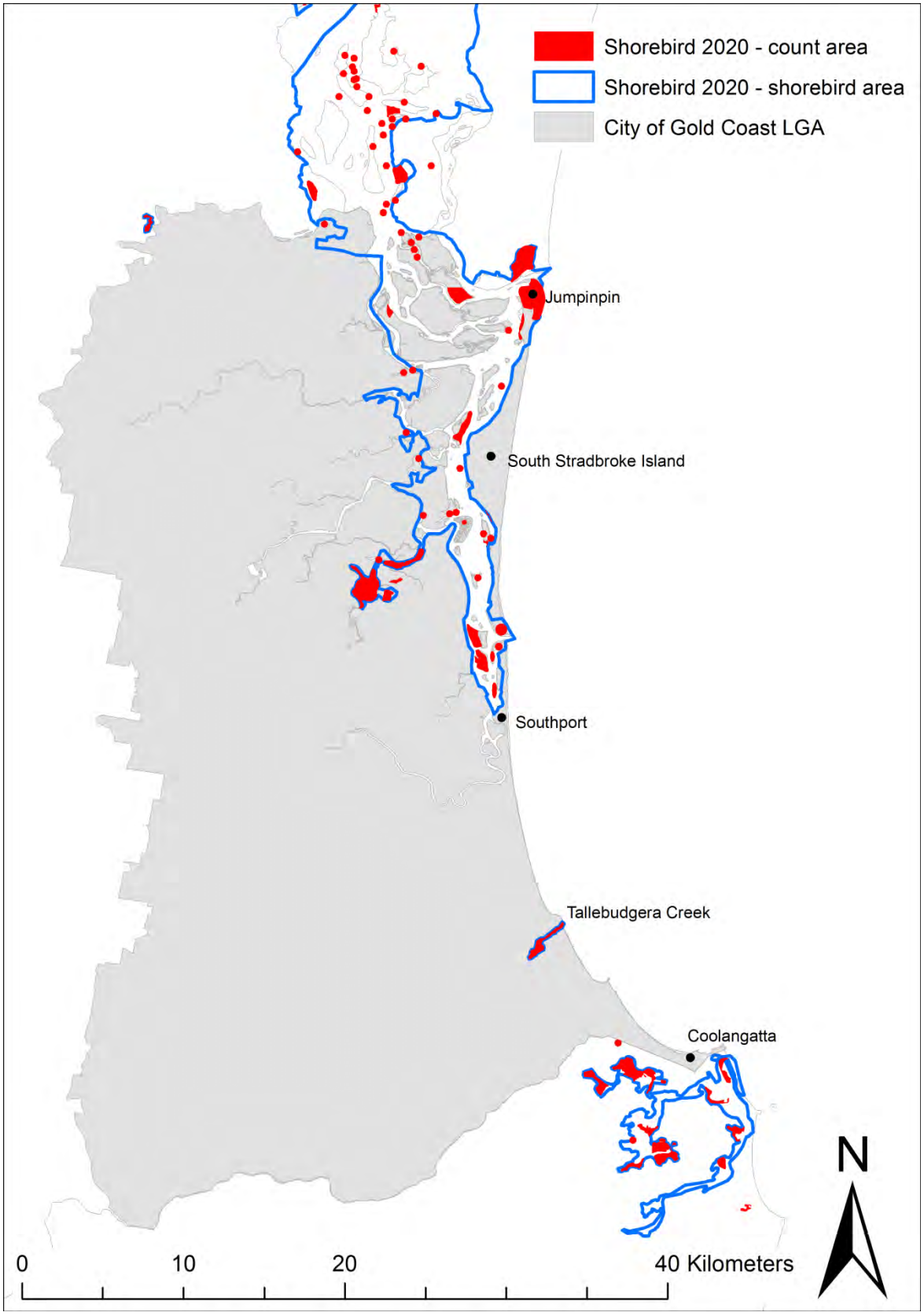

Figure 2: The southernmost section of the 'Pumicestone Passage' shorebird area and count areas in relation to the City of Gold Coast local government area.

Shorebirds use habitats for foraging, resting and breeding but not all habitats provide equivalent opportunities for all such activities at all times (Figure 3). Therefore, adequate representation of all habitat types is critical for species' long-term viability in a given area (Thompson 1998; Zharikov and Milton 2009).

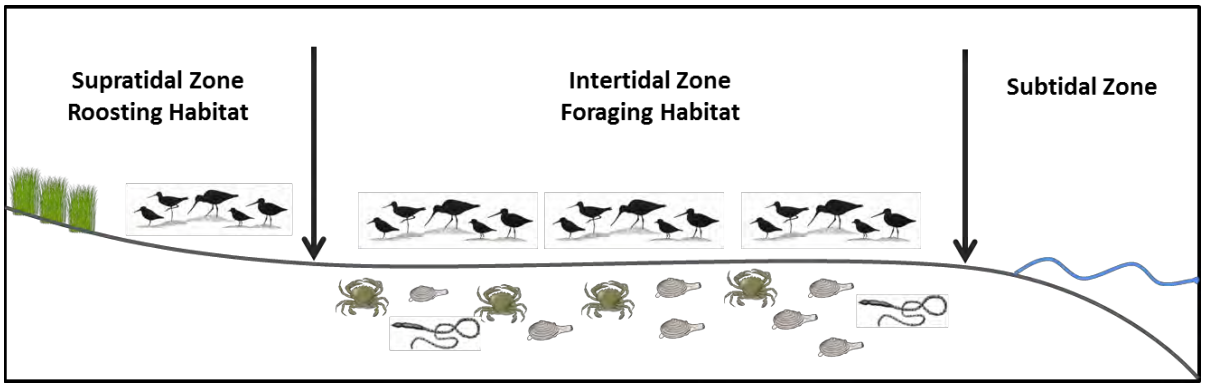

Figure 3: Shorebird habitat use schematic diagram.
Note: Shorebird profile illustration sizes are not to scale; Roosting habitat is not always adjacent foraging habitat (Source: King 2010).

Thirty-seven species of migratory shorebirds spend their non-breeding season in Australia (Clemens et al. 2012), during the Austral summer (i.e. southern hemisphere summer months between November and February). These birds use the EAAF to travel great distances, with some species completing round-trip journeys of 30, 000 km each year (Szabo et al. 2016). Some 2 million shorebirds make this migration to Australia each year (Purnell et al. 2012), with up to 40, 000 birds stopping in Moreton Bay alone (Wilson et al. 2011). There are another 18 resident shorebird species that occur in Australia throughout the year (Geering et al. 2007) and these species account for a further 3,500 individuals in Moreton Bay (Queensland Government 2005). Substantial numbers of migratory shorebirds also over-winter in Moreton Bay where winter counts are about 12% those of summer counts (Scholten et al. 2012). Moreton Bay is an important overwintering site for some threatened species, particularly Eastern Curlew where numbers in winter are approximately 27% those in summer (Finn et al. 2001; 2002).This further highlights the region's importance for these birds year round.

2.3 Scope of the review

This project reviewed existing data and information on shorebirds, their habitats and threats within Gold Coast waterways. The Gold Coast waterways include the rivers, canals, lakes and dams within the City of Gold Coast local government area as well as areas at the mouth of the Nerang River (Gold Coast seaway), Tallebudgera Creek and Currumbin Creek. This area specifically excludes open exposed beaches within the region (refer to Figure 4 for details). For the purposes of this study, the inland waters of the Hinze Dam and Little Nerang Dam were excluded as there are limited shorebird monitoring data from these areas. Furthermore, management activities (e.g. dredging) and recreation are either absent, or at reduced levels, in these areas.

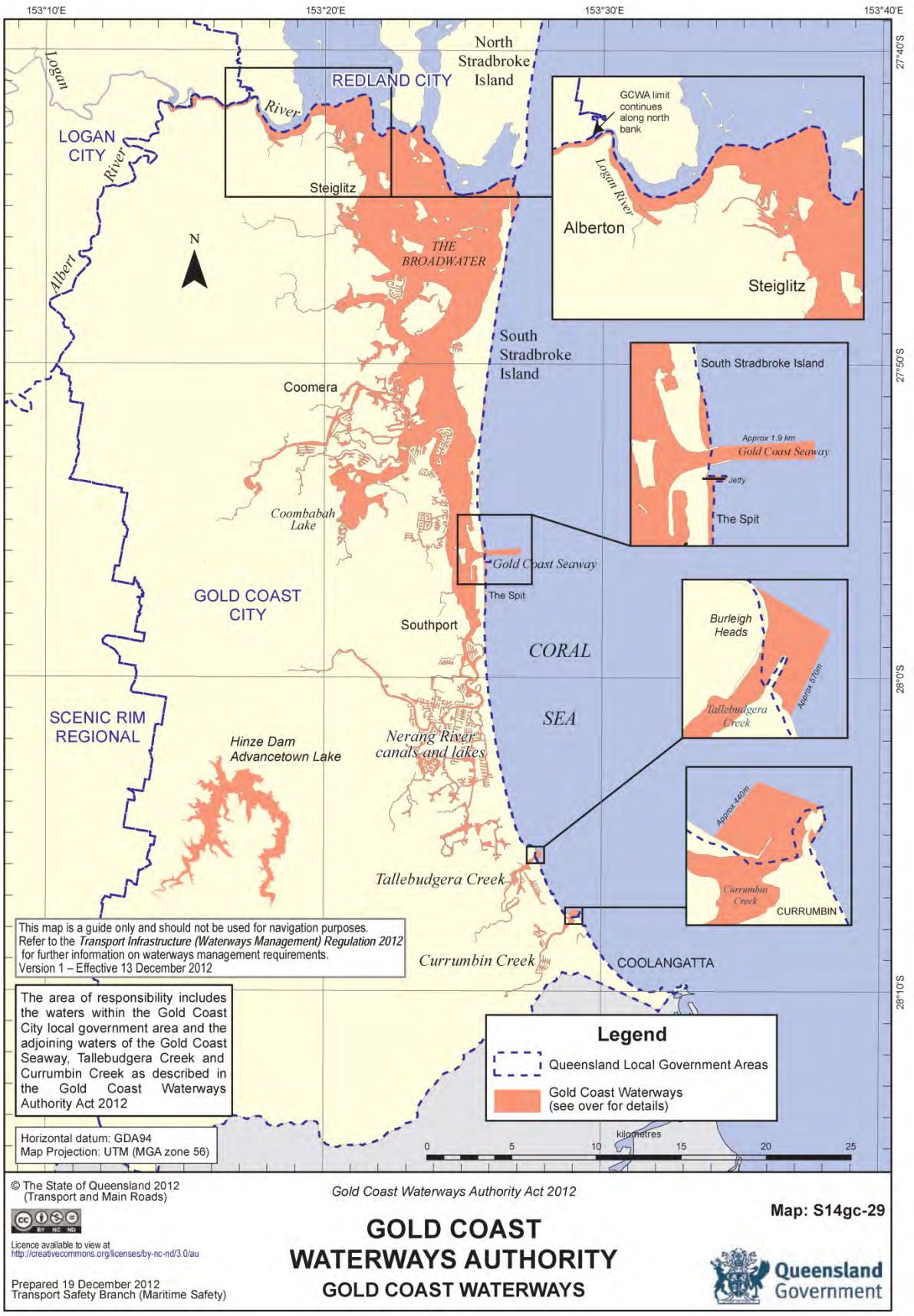

Figure 4: Relative extent of Gold Coast waterways (as described in the *Gold Coast Waterways Authority Act 2012*).

As outlined previously, it is the responsibility of GCWA to give effect to the *Gold Coast Waterways Authority Act 2012.* However, it should be noted that GCWA does not own Gold Coast waterways, nor does it have autonomous control over the various activities that occur in these areas. There are also other local and state government entities with various responsibilities in and around Gold Coast waterways, especially in relation to the management of shorebirds, such as:

- City of Gold Coast (e.g. http://www.goldcoast.qld.gov.au/shorebirds-of-the-broadwater-15625.html)
- Department of Environment and Heritage Protection (e.g. https://www.ehp.qld.gov.au/wildlife/threatened-species/shorebirds/)
- Department of National Parks, Sport and Racing (e.g. http://www.nprsr.qld.gov.au/parks/moreton-bay/zoning/information-sheets/shorebirds.html).

Therefore, this review provides information available to all stakeholders with a responsibility for the ongoing management of Gold Coast waterways, with a specific focus on important shorebirds and their habitats.

2.2 Methodological approach

The review assessed the current known distributions of resident and migratory shorebirds and their habitats in the Gold Coast waterways. Specifically, the review collated literature using online searches (*e.g.* Google Scholar, Web of Science). Literature comprised both academic papers and grey literature such as conservation agency reports, consulting reports, as well as web sites. The literature review was supplemented by collating and analysing shorebird monitoring data for the area (see data sources below). Habitats occupied were identified from known records (e.g. QWSG, Shorebird 2020 sites). A threat matrix was developed in consultation with a shorebird stakeholder focus group consisting of representatives from GCWA, QWSG, City of Gold Coast and Griffith University, as well as individuals engaged in shorebird monitoring and research.

The review also assessed the significance of shorebird populations and habitats in relation to regional, national and international patterns. The importance of shorebird habitat is assessed based on the numbers of individuals present within a species and the number of species that regularly use a given area (Bamford et al. 2008; Australian Government 2015a). Defining the importance of shorebird habitats in Australia at an international or national level was recognised by Watkins (1993), who proposed a combination of the existing Ramsar Convention guidelines for internationally important sites and a modification of these for nationally important sites. Since then, changes to these criteria have been made and the currently accepted definitions use a combination of the Ramsar Convention criteria as well as measures outlined in the *EPBC Act Policy Statement 3.21* (see Clemens et al. 2014;

Australian Government 2015a; b). Accordingly, habitats are considered internationally important for migratory shorebirds if they regularly support:

- **1% of the individuals in a population of one species or subspecies of waterbird or**
- **a total abundance of at least 20,000 waterbirds**

Under the EPBC Act, habitat is recognised as being nationally important habitat for migratory shorebirds when it regularly supports:

- **0.1% of the flyway population of a single species of migratory shorebird, or**
- **2,000 migratory shorebirds, or**
- **15 migratory shorebird species**

The aforementioned approaches and guidelines provided a frame of reference to review the current knowledge and understanding of shorebird populations in Gold Coast waterways. The subsequent detailed review, data analysis and threat assessment provided information that may be beneficial in the management of shorebirds and their habitats in Gold Coast waterways.

This report focuses on shorebirds and it is useful to provide a description of this group here to clarify those species that are included in the review. Shorebird species conventionally include those in the taxonomic order Charadriiformes and the suborder Charadrii (Geering et al. 2007). Shorebirds are characterised by their long legs and associations with wetland habitats and include sandpipers, plovers, dotterels, stints, oystercatchers, godwits, stilts, curlews, greenshanks, snipes etc., but exclude species in the suborder Alcae (auks, puffins) and suborder Lari (terns, gulls, noddies, skuas, skimmers) (Geering et al. 2007; Purnell et al. 2012). The latter species are generally considered to be seabirds, and have very different foraging and roosting patterns to other species in the order. Three species (i.e. Australian Painted Snipe, Masked Lapwing and Bush Stone-curlew) that generally use terrestrial habitats beyond Gold Coast waterways were also excluded from the current analysis, as they are not primarily associated with saline waterways. While terns and gulls were excluded from the main analysis, a small section acknowledging some key sites for Little Terns in Gold Coast waterways was included as this species:

- is a listed migratory species (EPBC Act)
- is Endangered in New South Wales (*Threatened Species Conservation Act 1995* [New South Wales], TSCA 1995)
- has been identified as a priority species in the 'Back on Track' species prioritisation framework in Queensland.

The restriction to wading groups and species outlined above is in line with other studies that have investigated population trends, habitat use and threats to shorebirds (Milton and Driscoll 2006; Glover et al. 2011; Clemens et al. 2012).

Shorebirds have been actively monitored on the Gold Coast using various survey protocols (*e.g.* standardised counts of high tide roosts, Shorebird 2020 seasonal counts, incidental

observations) for approximately 23 years, with records dating back to 1992. The main sources of survey data for shorebirds on the Gold Coast, and included in this study, are:

- QWSG shorebird surveys (and their volunteers) (e.g. monthly counts at various sites throughout Queensland – refer to Figure 1, Figure 2)
- CoGC shorebird surveys and Gold Coast Flora and Fauna Database records, (Environmental Planning and Conservation Section) (restricted counts at certain locations, e.g. Jumpinpin – refer to Figure 2, Figure 5, Figure 6)
- Bird enthusiasts that upload sighting data to the global database 'eBird' which is moderated and managed by the Cornell Lab of Ornithology (e.g. incidental observations – see http://ebird.org/content/australia/).

Available shorebird data from 2010 to 2016 were included in analyses for this report as these were considered the most reliable given land use changes in the region since 1992. Despite this, earlier records are provided for comparison to recent surveys of threatened species to illustrate declines in certain species. Shorebird data (i.e. count records, survey locations, number of surveys, richness, abundance) were summarised for the Gold Coast waterways based on aggregate statistics (e.g. total abundance, total species richness, total effort), but richness and abundance data were also considered in the context of survey effort. As survey effort was variable across the Gold Coast waterways, shorebird data were standardised by dividing aggregated data (e.g. records, abundance) from each survey location by the total effort (total number of surveys completed) for this location. Data are presented and discussed at the following three spatial scales:

- individual sites of shorebird surveys
- 500 m x 500 m grid cells overlayed on Gold Coast waterways (Figure 5)
- broad regional areas throughout the Gold Coast (Figure 6).

Individual sites were identified from available shorebird monitoring surveys and these locations were captured as points to identify the spread of locations across the Gold Coast waterways. As data spanned multiple years, a systematic grid was generated in ArcMap (ESRI) over the Gold Coast waterways with a grid cell size of 500 m x 500 m (Figure 5). This enabled shorebird monitoring data to be aggregated and summarised (e.g. survey effort, species observations), at a relatively fine resolution. Finally, the monitoring sites of the Gold Coast waterways were groups into six broad regional areas based on their spatial proximity (Figure 6).

The focus group described above was consulted to:

- check the validity of data reviewed on the distribution of shorebirds in Gold Coast waterways
- highlight areas that are thought to provide key habitat for shorebirds but are not adequately surveyed, and
- review threatening processes to shorebirds in Gold Coast waterways.

Specifically, the threatening processes identified prior to the focus group workshop were presented to the focus group with an accompanying risk assessment matrix (Appendix C). Participants were asked to complete the risk assessment to the best of their knowledge following an explanation of the process. Information was also circulated via email to key participants that were unable to attend the focus group workshop. Additional commentary obtained in this manner was also used to supplement data gathered during the study.

3. Current distribution of shorebirds and their habitats in Gold Coast waterways

Thirty shorebird species are recorded in Gold Coast waterways at numerous sites, extending from the northern boundary limits (e.g. Jumpinpin) to Currumbin Creek in the south (Table 2). Known shorebird sites in the northern region (e.g. Jumpinpin, Coombabah Lakelands, South Stradbroke Island) also fall within the Moreton Bay Marine Park (Figure 6 and Appendix G, Figure G31), while those south of the Gold Coast seaway do not (e.g. Wavebreak Island, Currumbin Creek). Based on the reporting rates and survey effort there appears to be a bias to particular sites within Gold Coast waterways, particularly the Jumpinpin and Wavebreak Island sites. Populations of at least five species are currently sufficient to have locations within the Gold coast waterways classified as areas of national importance for shorebirds because their numbers exceeded the 0.1% threshold limit on numerous occasions (e.g. Eastern Curlew, Double-banded Plover, Greater Sand Plover, Bar-tailed Godwit and Whimbrel – see Section 4). These data are outlined in further detail below.

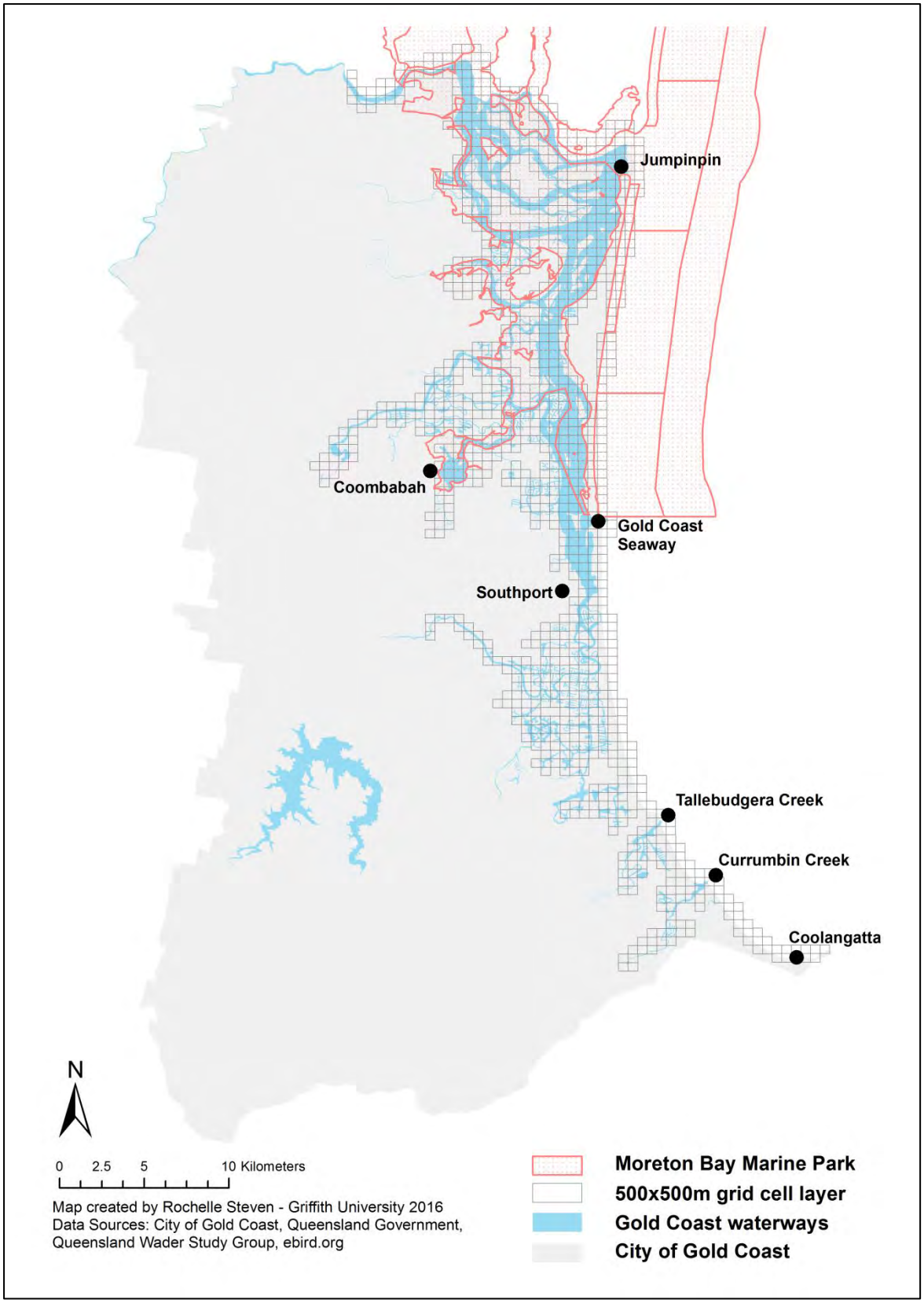

Figure 5: Distribution of 500 m x 500 m grid cells overlayed on Gold Coast waterways.

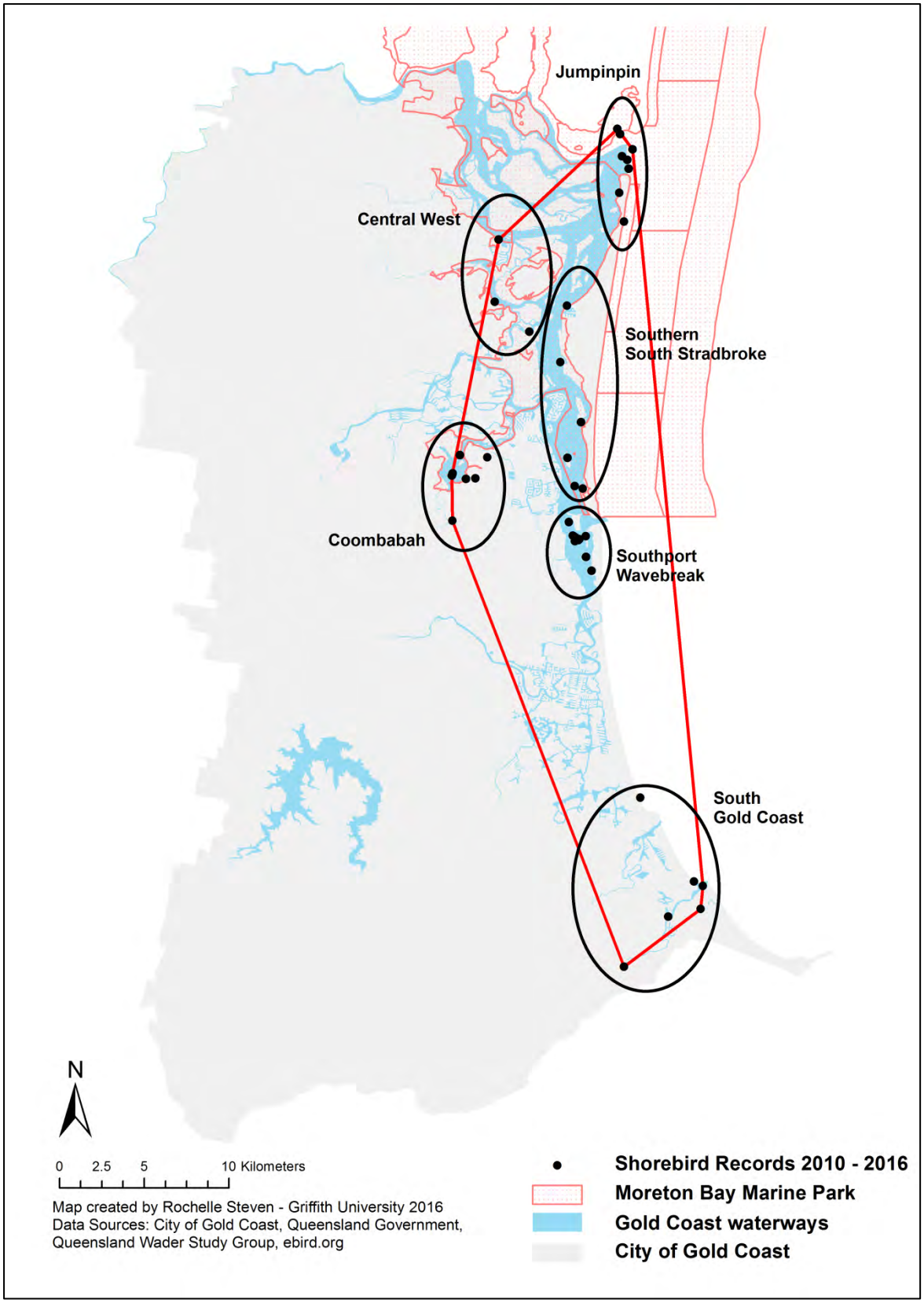

Figure 6: The 40 sites in Gold Coast waterways with records of resident and migratory shorebird presence (2010-2016) nominally grouped into six broad regional areas based on the spatial proximity of survey records. The Minimum Convex Polygon (MCP) depicting the broad extent of occurrence is shown by the bold red line that encompasses all shorebirds records localities.

3.1 General shorebird distribution patterns

Shorebirds records between 2010 and 2016 (n=1347) come from 40 sites (specific individual survey locations from the combined dataset) within the Gold Coast waterways intertidal and supratidal zones, across six broad regional areas (refer to Figure 6 and Appendix D for details), referred to in this report as:

1. Jumpinpin (8 sites)
2. Central West (3 sites)
3. Southern South Stradbroke (5 sites)
4. Coombabah (7 sites)
5. Southport Wavebreak (11 sites)
6. South Gold Coast (6 sites).

Jumpinpin and Southport Wavebreak have the highest absolute number of shorebird records, representing 45% and 35% of all records respectively (Figure 7 and Figure 8) (also refer to section 3.2 and Figure 14 for further clarification). Key sites in the Southport Wavebreak broad regional area include the Kurringle Flats, Curlew Banks and Curlew Island (see Appendix F, Figure F30). Gold Coast waterways in the South Gold Coast (i.e. Tallebudgera and Currumbin Creeks) regional area have few shorebird records (only ~1% of the total number of all records) relative to the northern areas. This is in part due to the lower survey effort in this region but may also be a reflection of relatively lower shorebird abundance in these areas. These sites can quite often be heavily utilised for recreational purposes (G Castley 2017, personal observations, 2010-2017) and this may also affect shorebird richness and abundance (see Martin et al. 2015, Murchison et al. 2016 for example).

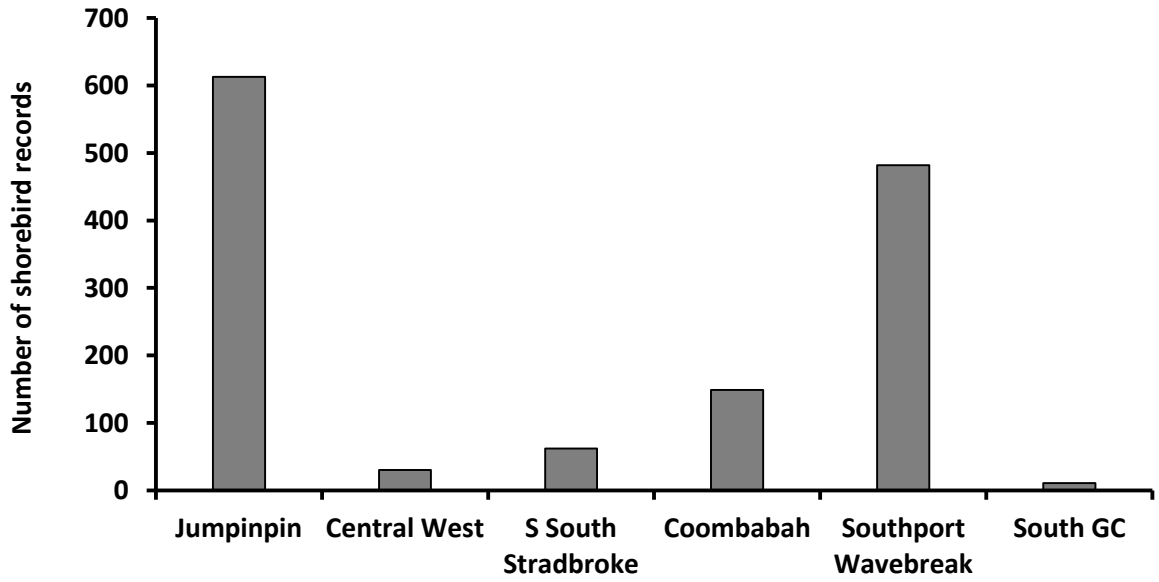

Figure 7: Distribution of all shorebird records (2010-2016) among the six broad regional areas of Gold Coast waterways (refer to Figure 6 for relative locations of these areas). Broad regional areas arranged from North to South on the x-axis.

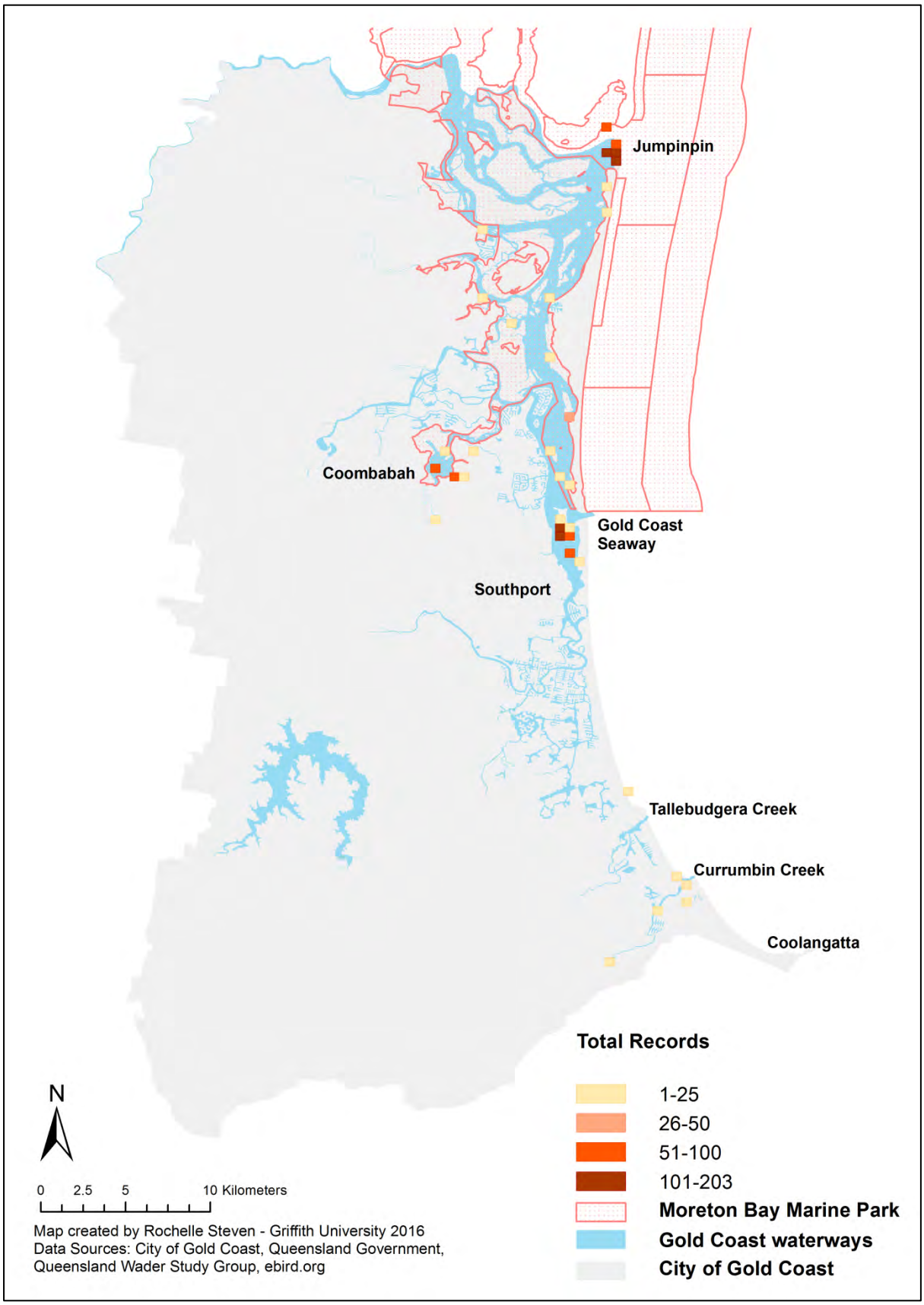

Figure 8: Distribution of shorebird records per 500 m x 500 m grid cell for Gold Coast waterways.

Abundance of shorebirds (within species) is related to an individual species ecology and may be affected by density dependence in habitat and resource-limited landscapes (Folmer et al. 2010; Stillman and Goss-Custard 2010; Bocher et al 2014). For example, Beach Stone-curlews will generally occupy territories as a pair (or more when offspring are present) (Milton 1998), while Bar-tailed Godwits tend to flock together during roosting and at least some of their foraging activities (Geering et al. 2007). Notwithstanding the extent of a shorebird area, these tendencies could result in variation in the expected abundance of species in a given area. Jumpinpin and Southport Wavebreak are the broad regional areas (with corresponding grid cells) that have the highest absolute abundance of shorebirds (Figure 9), with 51.6% and 39.1% respectively, of all birds recorded from these areas. However, these areas also have higher survey effort and species richness, which would also contribute to higher abundance values (refer to Figure 10 and Table 2 and Figure 11 in section 3.2).

Thirty species of shorebird were recorded using Gold Coast waterways between 2010 and 2016, including both resident (n=8 species) and migratory (n=22 species) shorebirds (Table 2). Sites vary in the species richness detected ranging from 1 to 17 (average of 6 species) among survey locations and 8 to 20 across all broad regional areas, with most species in the Jumpinpin (n = 20) and Southport Wavebreak (n = 19) areas (Table 2 and Figure 10) (noting that these two sites received the greatest survey effort during this period with ~75% of all surveys completed at these locations [Jumpinpin ~48%; Southport Wavebreak ~27%], refer to section 3.2 regarding survey effort). Shorebirds use multiple sites that provide roosting, foraging and in the case of resident species, breeding habitats. The rate of occupancy for species across the areas surveyed varies due to seasonality and other ecological factors. For example, for those areas where Australian Pied Oystercatcher were recorded, the species was observed on average in 71% of surveys. Conversely, Bar-tailed Godwit (a species that only occupies Gold Coast waterways in spring/summer) were observed on average 56% of the time in surveys of areas where this species was recorded (Table 2).

The extent of occurrence for shorebirds is relatively large covering the majority of the Gold Coast waterways. For example, a minimum convex polygon (i.e. that area that encloses all records by linking the outermost points) drawn to include all known records would cover all but the northwestern areas of the Gold Coast waterways (e.g. see Figure 6). However, notwithstanding the sporadic survey effort in some broader regions, the species-specific area of occupancy (i.e. area actually occupied by birds) is greatly reduced (e.g. as depicted by grid cell abundance and richness [as shown in Figure 9 and Figure 10 respectively], etc.). Therefore, while habitats may seem to provide similar resources (e.g. foraging and roosting habitat) to meet shorebird requirements throughout Gold Coast waterways, not all locations meet the species-specific habitat requirements for all species. It will be important to consider this when applying management actions for any specific future goals for particular species or suites of species.

Eight shorebird species in Gold Coast waterways are resident in Australia and the remaining 22 are migrants (Table 2). Two additional species were recorded prior to 2010. The Common Sandpiper (*Actitis hypoleucos*) was last recorded in Gold Coast waterways in 1995 while the Sooty Oystercatcher (*Haematopus fuliginosus*) was last recorded in 2009. However, the Sooty Oystercatcher has been an irregular occurrence with records in 1996, 2004 and 2009. This highlights that the absence of any species within a period of a year or two in Gold Coast waterways does not equate to complete abandonment of the area, but also that regular monitoring is required to provide ongoing evaluation of species occurrence and habitat use more broadly. Additionally, based on the these time spans (*i.e.* 8 years and 5 years), it could also be logically argued that a species would need to be absent from recordings for quite a number of years before the conclusion could be reached that it is no longer present in the area.

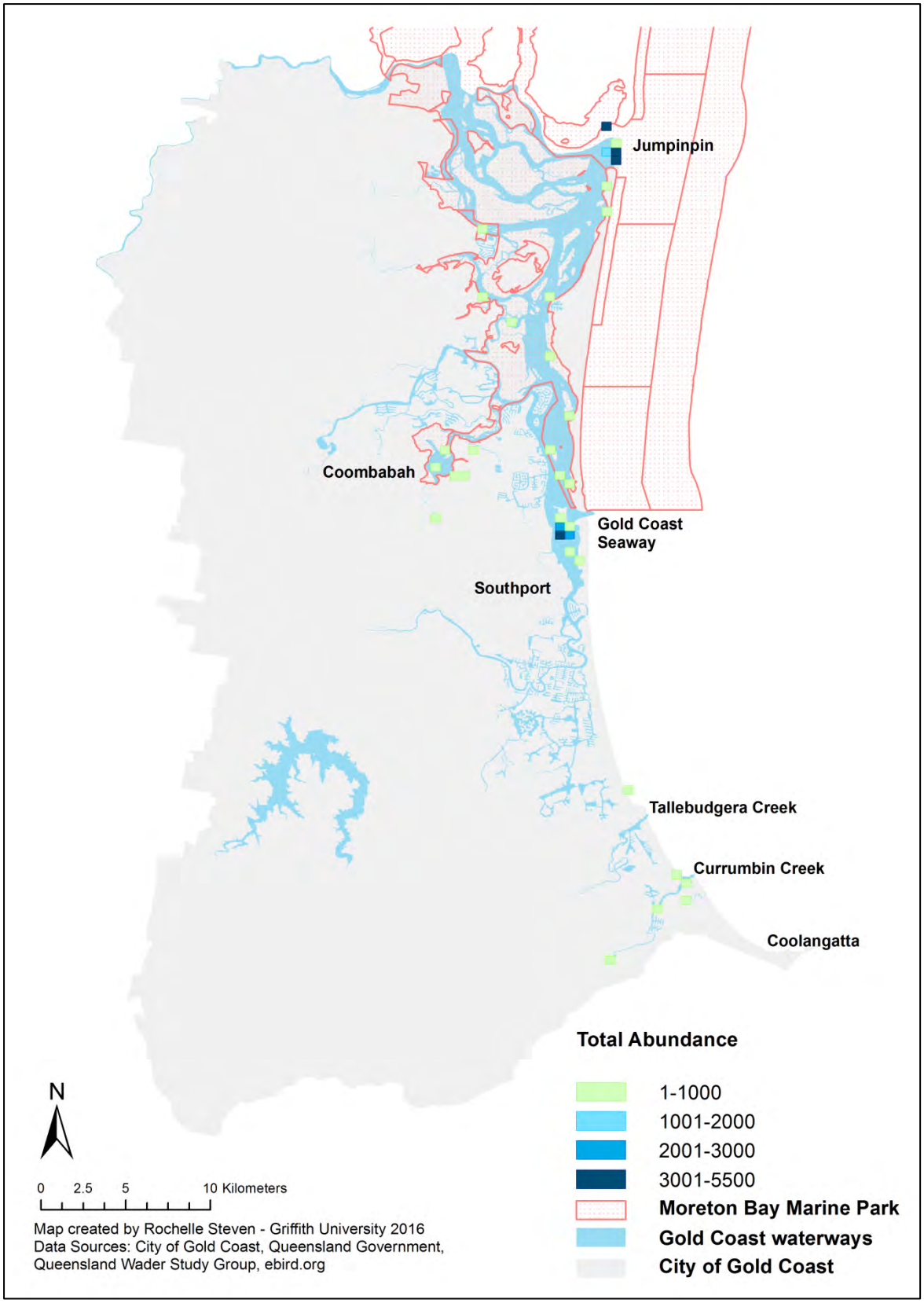

Figure 9: Distribution of shorebird abundance per 500 m x 500 m grid cell for Gold Coast waterways.

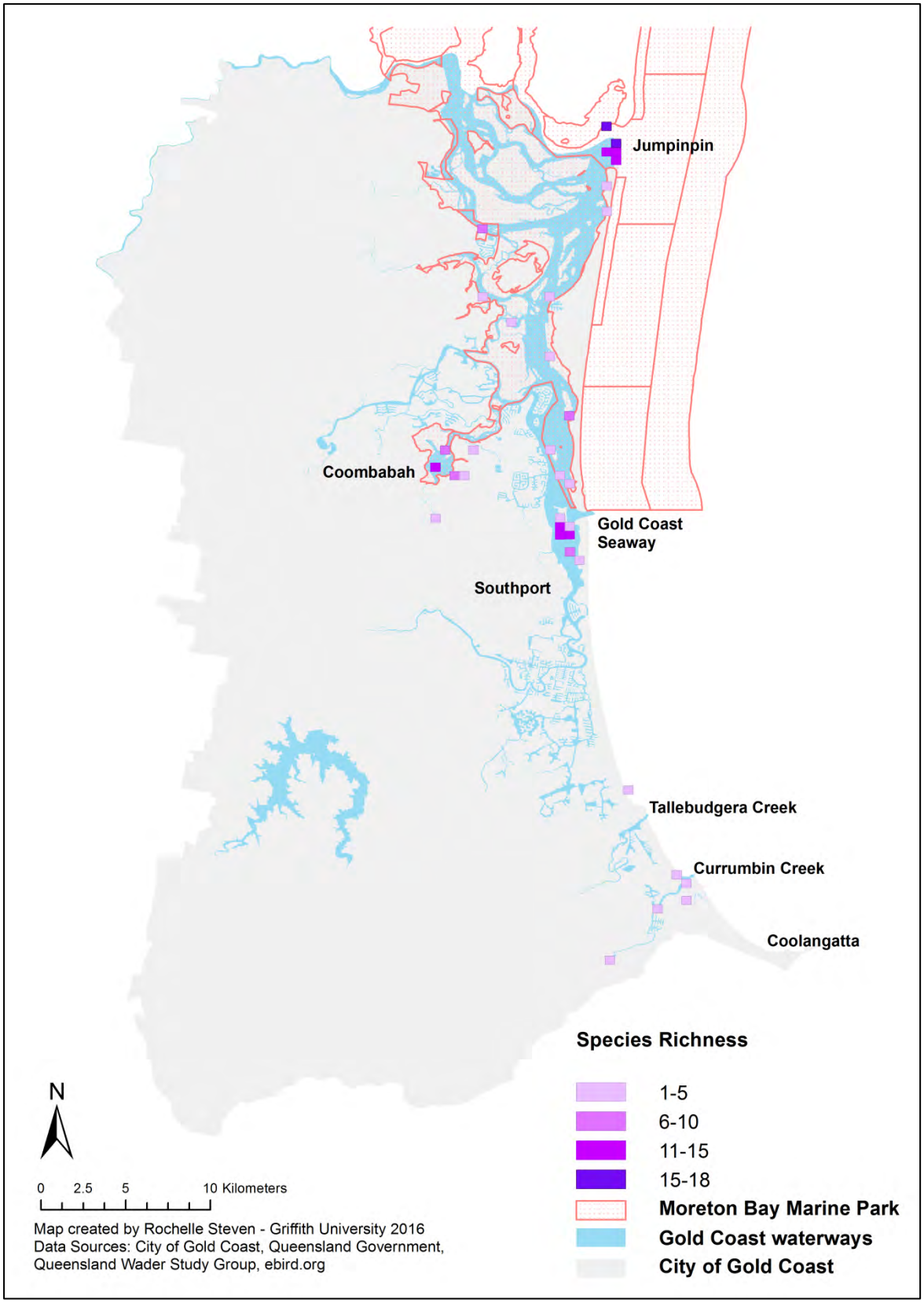

Figure 10: Distribution of species richness per 500 m x 500 m grid cell for Gold Coast waterways.

Table 2: Number of current (2010-2016) records for each of the 30 shorebird species in Gold Coast waterways. Species listed alphabetically. Scientific names provided in Appendix E.

Species (common name)	Total effort per species	Number of times recorded* between 2010-2016 (Number outside MBMP)	Broad regional areas** where species were observed	Average rate of occupancy relative to survey effort per unit area (%)
Australian Pied Oystercatcher[@]	318	275 (102)	CW, JPP, SSS, SGC, SWB	71
Banded Stilt[@]	53	1 (0)	CBB	2
Bar-tailed Godwit[#]	363	193 (76)	CW, CBB, JPP, SSS, SWB	56
Beach Stone-curlew[#@]	311	40 (21)	JPP, SSS, SGC, SWB	19
Black-fronted Dotterel[@]	61	3 (1)	CBB, SGC	13
Black-tailed Godwit	155	3 (1)	CBB, SWB	2
Black-winged Stilt[@]	170	49 (17)	CW, CBB, SGC, SWB	32
Broad-billed Sandpiper	102	1 (1)	SWB	1
Common Greenshank	53	11 (0)	CBB	21
Curlew Sandpiper[#]	356	19 (1)	CBB, JPP, SSS, SWB	5
Double-banded Plover	279	26 (18)	JPP, SWB	11
Eastern Curlew[#]	363	212 (94)	CW, CBB, JPP, SSS, SWB	59
Great Knot[#]	279	4 (2)	JPP, SWB	2
Greater Sand Plover[#]	279	23 (2)	JPP, SWB	7
Grey Plover	279	7 (1)	JPP, SWB	2
Grey-tailed Tattler	318	23 (10)	CW, JPP, SSS, SGC, SWB	12
Latham's Snipe	53	2 (0)	CBB	4
Lesser Sand Plover[#]	177	23 (0)	JPP	13
Marsh Sandpiper	7	1 (0)	CW	14

Species (common name)	Total effort per species	Number of times recorded* between 2010-2016 (Number outside MBMP)	Broad regional areas** where species were observed	Average rate of occupancy relative to survey effort per unit area (%)
Pacific Golden Plover	286	19 (11)	CW, JPP, SWB	19
Red-capped Plover[@]	303	124 (35)	JPP, SSS, SWB	32
Red-kneed Dotterel[@]	53	2 (0)	CBB	4
Red-necked Avocet[@]	230	13 (0)	CBB, JPP	12
Red-necked Stint	279	91 (26)	JPP, SWB	31
Red Knot[#]	177	11 (0)	JPP	6
Ruddy Turnstone	177	12 (0)	JPP	7
Sanderling	177	15 (0)	JPP	8
Sharp-tailed Sandpiper	155	3 (1)	CBB, SWB	2
Terek Sandpiper	339	5 (1)	CW, CBB, JPP, SWB	8
Whimbrel	363	136 (71)	CW, CBB, JPP, SSS, SWB	53

Legend:
* Not number of individuals
MBMP: Moreton Bay Marine Park
** The six broad regional areas of Gold Coast waterways: CW = Central West; CBB = Coombabah; JPP = Jumpinpin; SSS = Southern South Stradbroke; SWB = Southport Wavebreak; SGC = South Gold Coast (refer Figure 6 for relative locations of these areas)
[#] Threatened Species (Listed under the EPBC Act and/or under the *Queensland Nature Conservation Act 1992*)
[@] Resident Species (see Milton 2003).

3.2 Shorebird distribution and abundance in relation to survey effort

All raw data for shorebird records and abundance needs to be considered in the context of actual survey effort across Gold Coast waterways (Figure 11, Figure 12) and in individual locations (Figure 13). When record data were standardised by survey effort, most areas (67%) had up to three records per survey, 20% had between three and five records per survey and 11% had more than 5 records per survey (Figure 14). This removed the impression that the Jumpinpin and Southport Wavebreak areas are the only key habitats for shorebirds by showing that shorebird records are more evenly spread across sites in Gold Coast waterways (Figure 15). This highlights the need for surveys across a greater extent of the Gold Coast waterways. In designing such surveys consideration should be given to the application of a consistent and rigorous survey methodology, stratification of effort to ensure adequate representation of all potential shorebird habitats, as well as the number of surveys required to be able to interpret any patterns in the data. How these surveys might also contribute to national shorebird surveys as part of the BirdLife Shorebirds 2020 program should also be considered as BirdLife has a range of resources available related to gathering shorebird data (see http://birdlife.org.au/projects/shorebirds-2020/counter-resources).

Accessibility is the main challenge to surveying many areas in Gold Coast waterways. There are limited land-based vantage points for many potential habitat areas and limited accessibility by road to many potential mainland, island and coastal zone sites. This would necessitate vessel-based surveys for many of these locations. Data presented here showed that despite apparent availability of potential intertidal and supratidal habitat across large areas in the north of the Gold Coast, shorebirds may be selecting sites that are sub-optimal in terms of threats (i.e. frequently disturbed areas). For example, Wavebreak Island and Jumpinpin are areas with considerable levels of recreational boating activity (City of Gold Coast 2013) with anecdotal evidence suggesting that Curlew Island and Curlew Banks face similar pressures and that all of these areas are also subject to substantial pedestrian access. Furthermore, other factors may be precluding occupancy in areas that might seem suitable superficially. For example, the physico-chemical profile of the sediments may affect prey availability and accessibility through eutrophication (Estrella et al. 2011; Green et al. 2014) as well as sediment type/structure (Finn et al. 2007; Pandiyan and Asokan 2016). This in turn may be leading to changes in the habitat use by shorebirds as their habitat preferences may be affected by prey availability and sediment conditions (Zharikov and Skilleter 2002; Finn et al. 2007; 2008). The nature of these effects in Gold Coast waterways requires further research and monitoring to assess the habitat preferences for a range of species. However, absence of shorebird records in various areas throughout Gold Coast waterways (such as those in the northwest) could also simply be an artefact of a lack of survey effort, again suggesting that additional survey effort, as outlined above, may be required to provide a more representative coverage of the Gold Coast waterways.

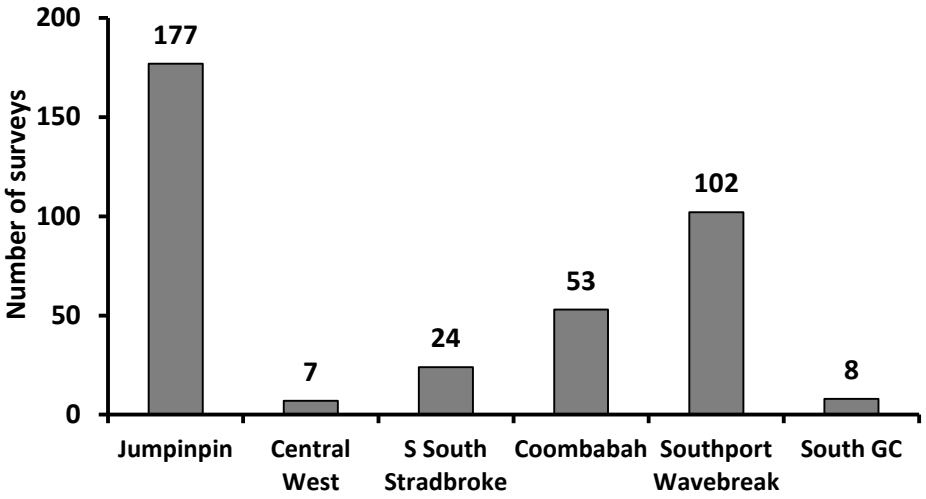

Figure 11: Distribution of shorebird survey effort (2010-2016) across the six broad regional areas of Gold Coast waterways (refer to Figure 6 for relative locations of these areas).
Legend: South GC = South Gold Coast; S South Stradbroke = Southern South Stradbroke.

Viewing the abundance of shorebirds standardised by survey effort among the six broad regional areas (Figure 13) illustrates how important some sites may be for shorebirds as the standardised abundance resulted in a more equitable spread of shorebirds among the broad regional areas. While the Jumpinpin and Southport Wavebreak areas still had the highest standardised abundance there was considerably less variability in these data once standardised (Figure 12). The standardised abundance of shorebirds in the Central West, Coombabah, Southern South Stradbroke and sites in the South Gold Coast area showed an increase (Figure 12, Figure 17) and suggests that additional surveys may be required in these areas to provide a more accurate representation of shorebird communities in these locations.

Variation in the standardised records of shorebirds throughout the Gold Coast waterways was also noted, with certain sites within the six broad regional areas yielding higher average numbers of records than others. However, the variability around these records among sites was not significant (one-way ANOVA; $F = 2.49$; d.f. = 5, 34; $P = 0.46$) (Figure 15). This suggests that when bird observers are in the field they generally make a similar number of records during each survey regardless of the survey location.

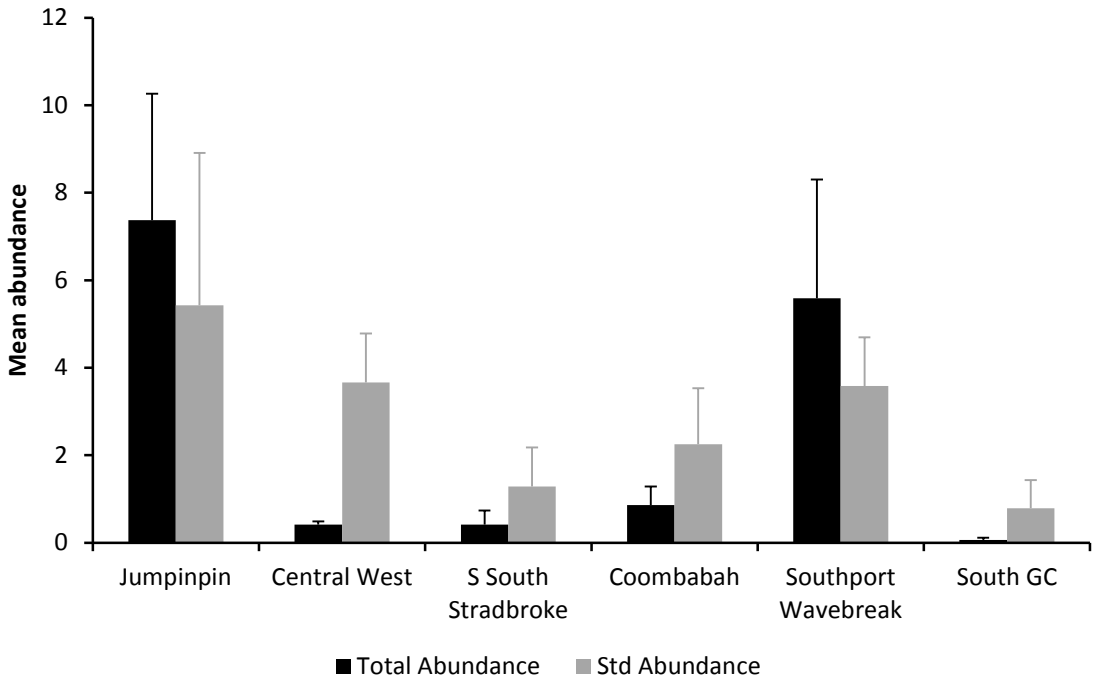

Figure 12: Comparison of the mean + SE for both absolute and standardised abundance across the six broad regional areas of Gold Coast waterways (refer to Figure 6 for relative locations of these areas).

Legend: South GC = South Gold Coast; S South Stradbroke = Southern South Stradbroke.

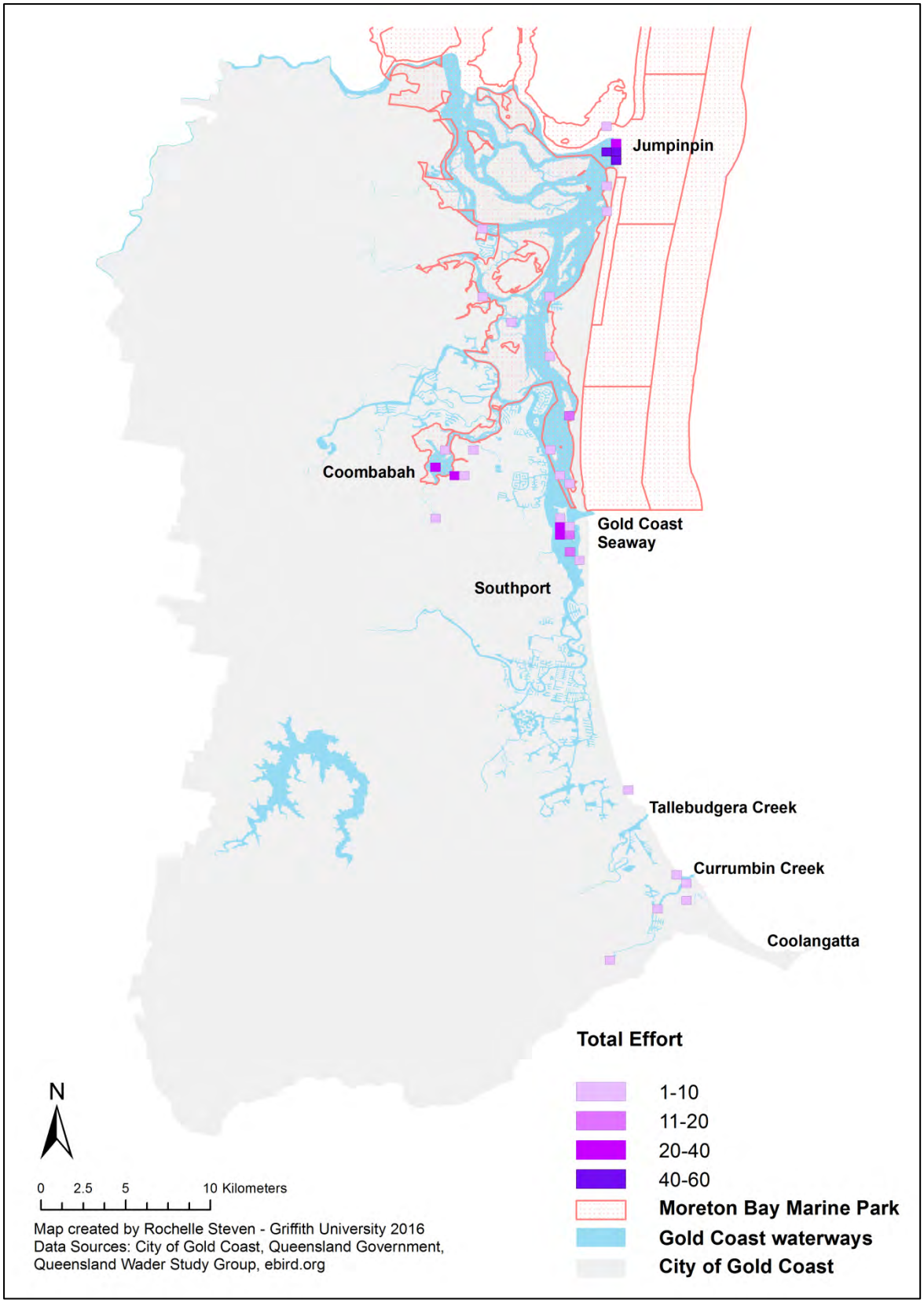

Figure 13: Distribution of total survey effort (i.e. number of surveys) per 500 m x 500 m grid cell for Gold Coast waterways.

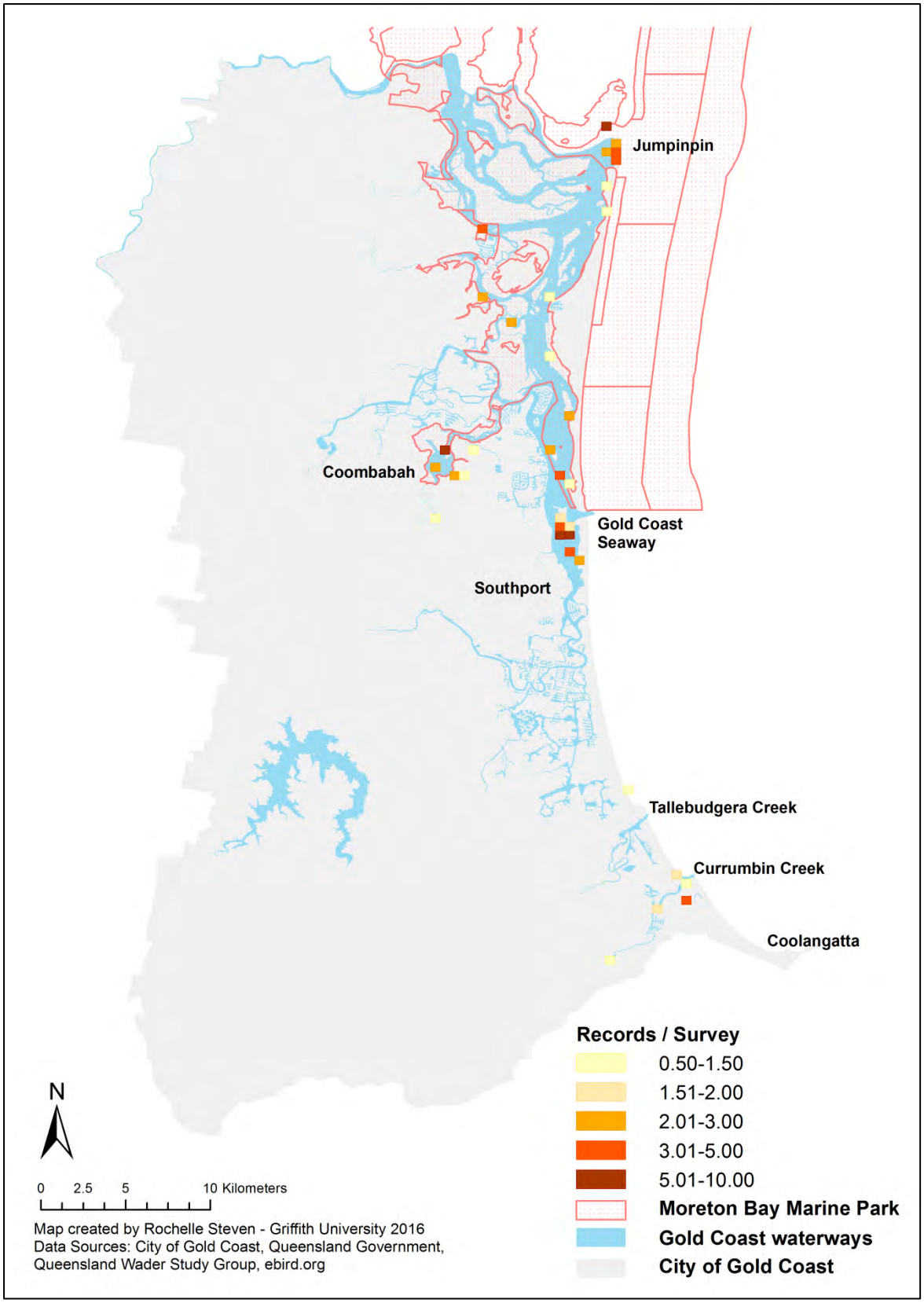

Figure 14: Distribution of shorebird records standardised by total survey effort per 500 m x 500 m grid cell for Gold Coast waterways.

Note: Due to variable survey effort, shorebird data were standardised by dividing aggregated data (e.g. records, abundance) by the total effort (total number of surveys completed) for the survey location.

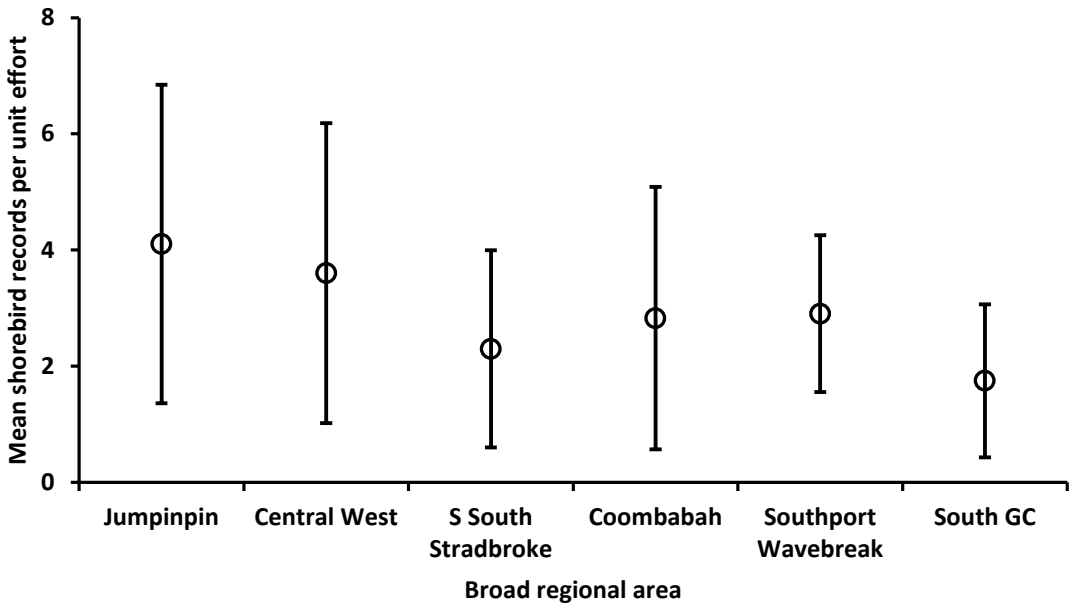

Figure 15: Shorebird records (2010-2016) (Mean ± 95% confidence interval) standardised by survey effort in each of the six broad regional areas of Gold Coast waterways (refer to Figure 6 for relative locations of these areas).
Legend: South GC = South Gold Coast; S South Stradbroke = Southern South Stradbroke.

Species richness in each broader regional area is proportional to the relative survey effort for each area (Figure 16). The point at which few new species are detected appears to be after approximately 100 surveys, however somewhere between 50 and 100 surveys will capture approximately 75% of species richness for an area. Three of the six broader regional areas of Gold Coast waterways have received fewer than 50 surveys (i.e. Central West, Southern South Stradbroke and South Gold Coast) and further survey effort in these areas may detect additional species. This may require consideration as part of a broader survey program based on a scientifically rigorous research methodology.

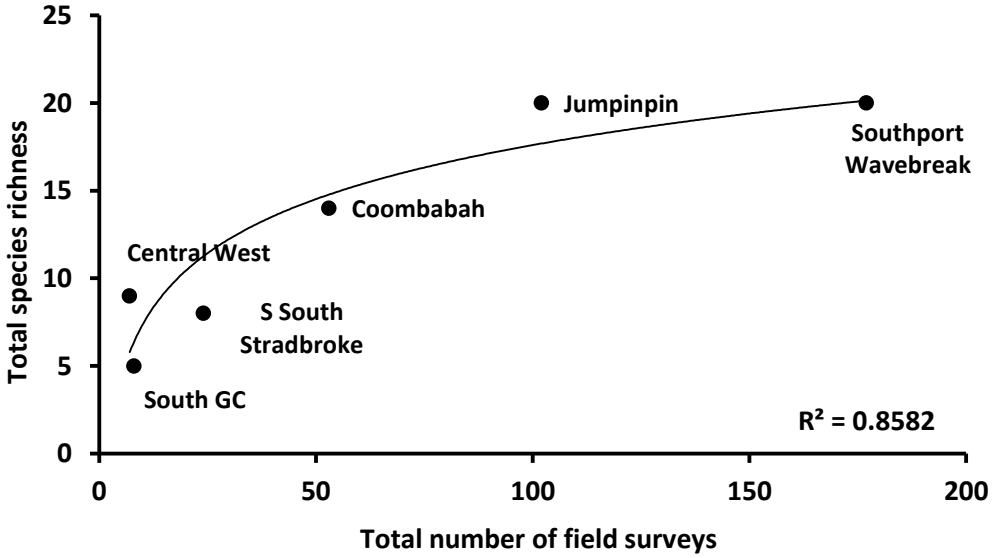

Figure 16: Shorebird species richness relative to survey effort for the six broad regional areas of Gold Coast waterways (refer to Figure 6 for relative locations of these areas).
Legend: South GC = South Gold Coast; S South Stradbroke = Southern South Stradbroke.

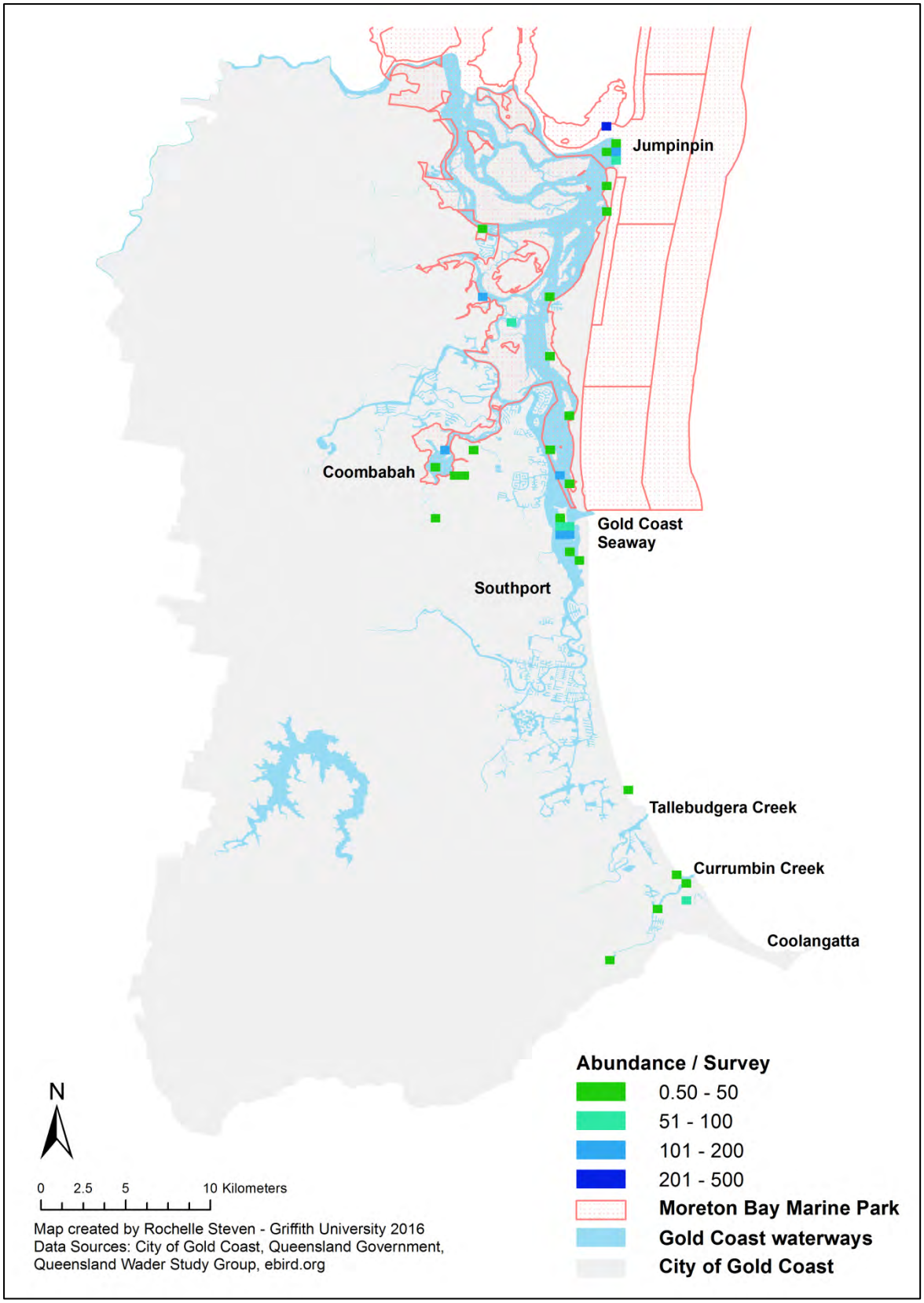

Figure 17: Distribution of shorebird abundance standardised by total survey effort per 500 m x 500 m grid cell for Gold Coast waterways.

Note: Due to variable survey effort, shorebird data were standardised by dividing aggregated data (e.g. records, abundance) by the total effort (total number of surveys completed) for the survey location.

3.3 Tidal variation in shorebird distribution

The selection of roosting and foraging habitats by shorebirds is often spatially linked, with a general preference for these two types of habitat to be relatively close to each other (Zharikov and Milton 2009). There is also significant variation in habitat preferences among species. For example, Eastern Curlews roost together but forage separately and prefer substrates with low resistance (i.e. those where feeding is not hampered by hard material such as rocks, coral, shells, wood etc.) (Finn et al. 2007). Bar-tailed Godwits, on the other hand, roost and forage together and some preference for seagrass habitats over sandy substrates has been observed, particularly amongst male birds (Zharikov and Skilleter 2002). The majority of data reviewed for this study were based on surveys of habitats exposed at high tides, suggesting that this is primarily a reflection of roost sites (due to foraging sites generally being exposed at low tides). After focus group discussions, important foraging habitat for shorebirds was found to be poorly surveyed in Gold Coast waterways with key foraging habitat only known for Horseshoe Bay (in the broad regional area of Jumpinpin, refer Figure F29 in Appendix F for details) and to a lesser extent, the western shore of Wavebreak Island on the Kurringle Flats (in the broad regional area of Southport Wavebreak) (refer Figure F30 in Appendix F for details). Identification of key shorebird foraging sites may benefit from additional low tide surveys.

3.4 Distribution of threatened species of shorebirds

Based on a previous analysis of population trends (Wilson et al. 2011) and recent revisions (i.e. May 2016) and additions to the EPBC Act List of Threatened Fauna (see Australian Government 2016e for details), eight threatened species of shorebird are known to occur within the greater Moreton Bay region (refer to Figure 4 and Appendix G, Figure G31, Figure G34 and Figure G35 for a general understanding of the location and extent of the greater Moreton Bay region relative to Gold Coast waterways). Five species, Curlew Sandpiper, Eastern Curlew, Bar-tailed Godwit (subspecies *Limosa lapponica menzbieri*), Great Knot and Red Knot are listed as Critically Endangered; one species, Lesser Sand Plover is listed as Endangered and the Bar-tailed Godwit (subspecies *Limosa lapponica baueri*), Greater Sand Plover and Beach Stone-curlew are listed as Vulnerable. All but the Beach Stone-curlew are listed under the EPBC Act with the latter being listed under Queensland's Nature Conservation Act (refer Table 3 for detail). Table 3 also shows that all eight of these species have been recorded in Gold Coast waterways. Records for the Curlew Sandpiper and Eastern Curlew over this period revealed that there has been a declining trend in the absolute numbers of individuals recorded. However, restricting the review of shorebird abundance to only absolute numbers observed during any particular period to discern possible trends in populations can be misleading. The data were therefore also standardised to evaluate these temporal patterns. The relative abundance (numbers of individuals per year of observation) of Curlew Sandpiper fell from 67 birds recorded/year for the period 1992-2009 to 36 birds recorded/year for the period 2010-2016. This represents a

decline of approximately 46%. Contrastingly, the relative abundance of Eastern Curlew showed little change between these two periods with 1223 and 1246 birds recorded/year for the two periods respectively. Furthermore, both species are yet to be recorded within one of the broad regional areas of the Gold Coast waterways where they have been recorded previously (Table 3).

Focus group discussions identified that key broad regional areas for threatened shorebirds in Gold Coast waterways, based on local knowledge and ongoing monitoring by groups such as the Queensland Wader Study Group (QWSG) are:

- Jumpinpin—
    - Curlew Sandpiper
    - Eastern Curlew
    - Beach Stone-curlew
- Southport Wavebreak—
    - Eastern Curlew
    - Beach Stone-curlew.

The distribution of threatened shorebirds in Gold Coast waterways was highly variable (as shown in Figures 18 – 25) and may be a reflection of species-specific ecological requirements and associations with particular intertidal habitat types (Thompson 1998). For example, shorebird habitat preferences may be affected by prey availability or sediment conditions (Zharikov and Skilleter 2002; Finn et al. 2007; 2008), but this may also vary depending on the season (Thompson 1998). For example, Beach Stone-curlews have been recorded nesting at the specified sites/area on the western side of South Stradbroke Island (S South Stradbroke in Table 3) as well as Southport Wavebreak (i.e. on Curlew Island). The distribution patterns may also be a reflection of survey effort where QWSG counts are typically confined to monthly high tide roost counts using standardised methods. Some supplementation of these data with opportunistic sightings has also been made and highlights the need for future surveys to consider replication and monitoring of other shorebird habitats (e.g. feeding sites).

Table 3: Threatened species distribution, record and abundance values over two reporting periods (*i.e.* 1992-2009 and 2010-2016).

Area	Total Records 1992-2009	Total Abundance 1992-2009	Total Records 2010-2016	Total Abundance 2010-2016
Curlew Sandpiper (*Calidris ferruginea*) **Critically Endangered [EPBC Act, Cwlth], Endangered [TSCA, NSW]**				
Central West	4	113	–	–
Coombabah	9	423	5	71
Jumpinpin	26	319	12	137
S South Stradbroke	1	64	1	5
Southport Wavebreak	13	218	1	2
Total	**53**	**1137**	**19**	**215**
Eastern Curlew (*Numenius madagascariensis*) **Critically Endangered [EPBC Act, Cwlth], Vulnerable [NCA, QLD]**				
Central West	16	1166	4	32
Coombabah	72	844	29	165
Jumpinpin	147	14,540	76	4391
S South Stradbroke	30	463	8	162
South Gold Coast	11	37	–	–
Southport Wavebreak	80	3746	93	2728
Total	**356**	**20,796**	**210**	**7478**
Bar-tailed Godwit (two subspecies) **Western Alaskan Bar-tailed Godwit (*Limosa lapponica baueri*)** **Vulnerable [EPBC Act, Cwlth]** **Northern Siberian Bar-tailed Godwit (*Limosa lapponica menzbieri*)** **Critically Endangered [EPBC Act, Cwlth]**				
Central West	12	622	6	92
Coombabah	61	1773	20	211
Jumpinpin	140	14,800	81	3713
S South Stradbroke	23	392	9	103
Southport Wavebreak	81	10,894	77	3753
Total	**317**	**28,481**	**193**	**7872**
Great Knot (*Calidris tenuirostris*) **Critically Endangered [EPBC Act, Cwth], Vulnerable [TSCA, NSW]**				
Coombabah	5	11	–	–
Jumpinpin	7	10	2	11
Southport Wavebreak	15	18	2	6
Total	**27**	**39**	**4**	**17**

Area	Total Records 1992-2009	Total Abundance 1992-2009	Total Records 2010-2016	Total Abundance 2010-2016
Red Knot (*Calidris canutus*) Critically Endangered [EPBC Act, Cwlth]				
Jumpinpin	10	41	11	59
Southport Wavebreak	7	19	–	–
Total	**17**	**60**	**11**	**59**
Lesser Sand Plover (*Charadrius mongolus*) Endangered [EPBC Act, Cwlth], Vulnerable [TSCA, NSW]				
Central West	2	3	–	–
Jumpinpin	42	1905	23	482
Southport Wavebreak	13	1889	–	–
Total	**57**	**3797**	**23**	**482**
Greater Sand Plover (*Charadrius leschenaultii*) Vulnerable [EPBC Act, Cwlth], Vulnerable [TSCA, NSW]				
Central West	2	801	–	–
Jumpinpin	36	1597	21	535
Southport Wavebreak	6	91	2	3
Total	**44**	**2489**	**23**	**538**
Beach Stone-curlew (*Esacus magnirostris*) Vulnerable [NCA, QLD], Critically Endangered [TSCA, NSW]				
Jumpinpin	32	56	12	23
S South Stradbroke	8	12	4	8
South Gold Coast	–	–	1	1
Southport Wavebreak	2	3	18	42
Total	**42**	**71**	**35**	**74**

Legend:

Area: The six broad regional areas of Gold Coast waterways, *i.e.*— Central West; Coombabah; Jumpinpin; S South Stradbroke; Southport Wavebreak; South Gold Coast ('S South Stradbroke' = Southern South Stradbroke, refer to Figure 6 for relative locations of these areas).

EPBC Act, Cwlth: The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

TSCA, NSW: The NSW *Threatened Species Conservation Act 1995*

NCA, QLD: The Queensland *Nature Conservation Act 1992*

– : Species not recorded during this period

Note—

(i) Where broad regional areas are not listed for a particular species, this means that the species was not recorded in that broad regional area.

(ii) A map depicting the areas surveyed in the 1992-2009 period is provided in Appendix D, Figure D28.

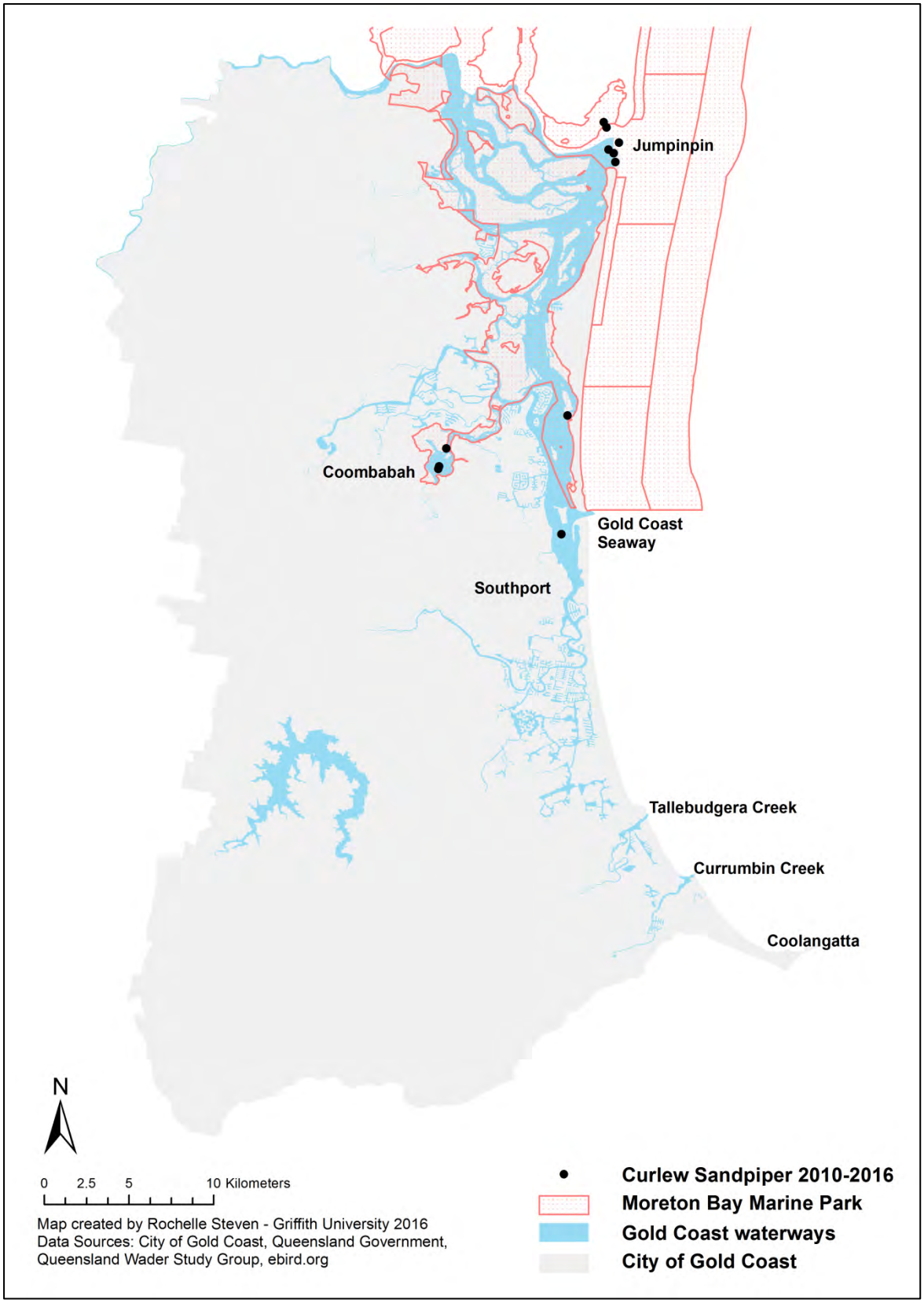

Figure 18: Distribution of current Curlew Sandpiper records for Gold Coast waterways.

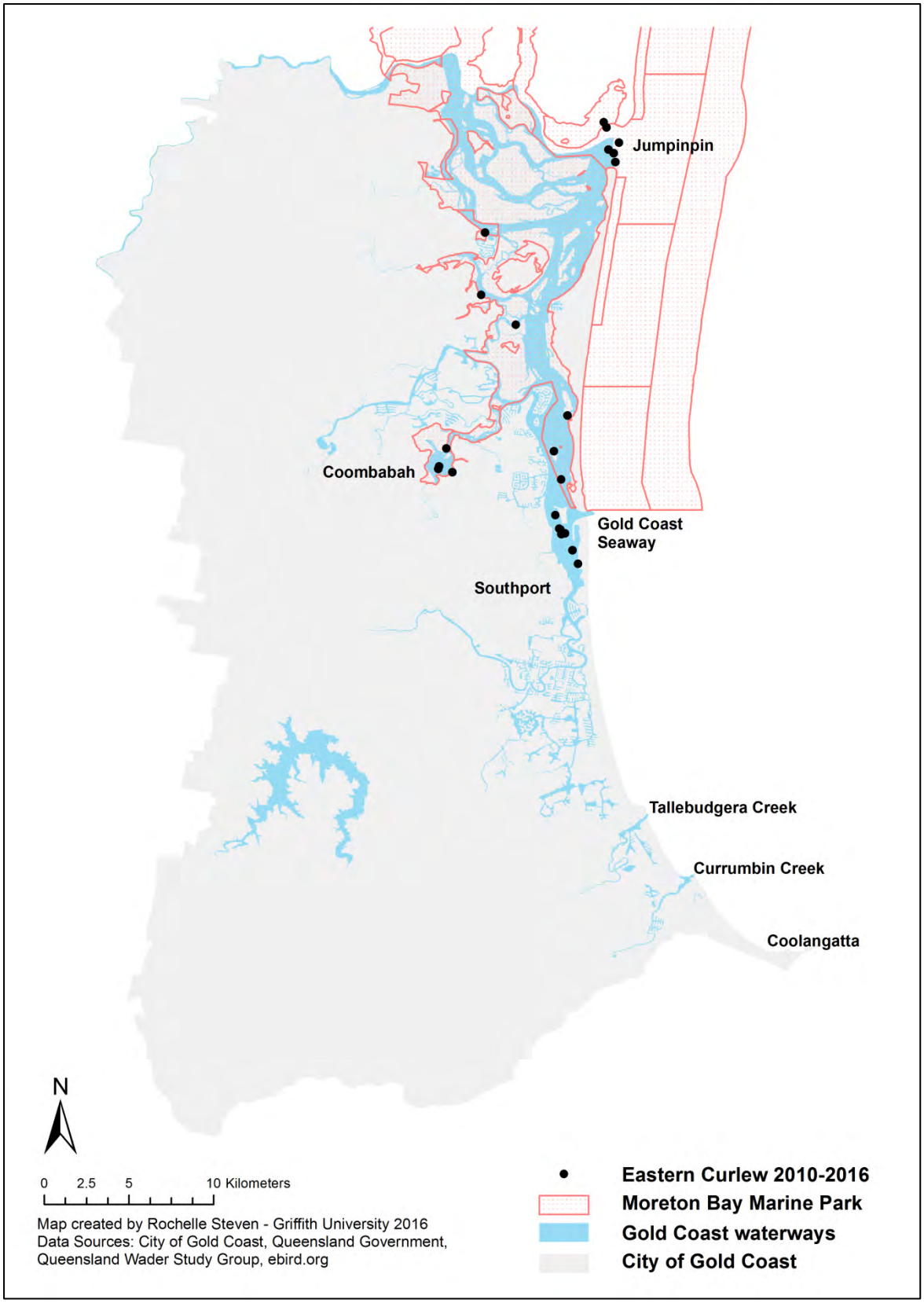

Figure 19: Distribution of current Eastern Curlew records for Gold Coast waterways.

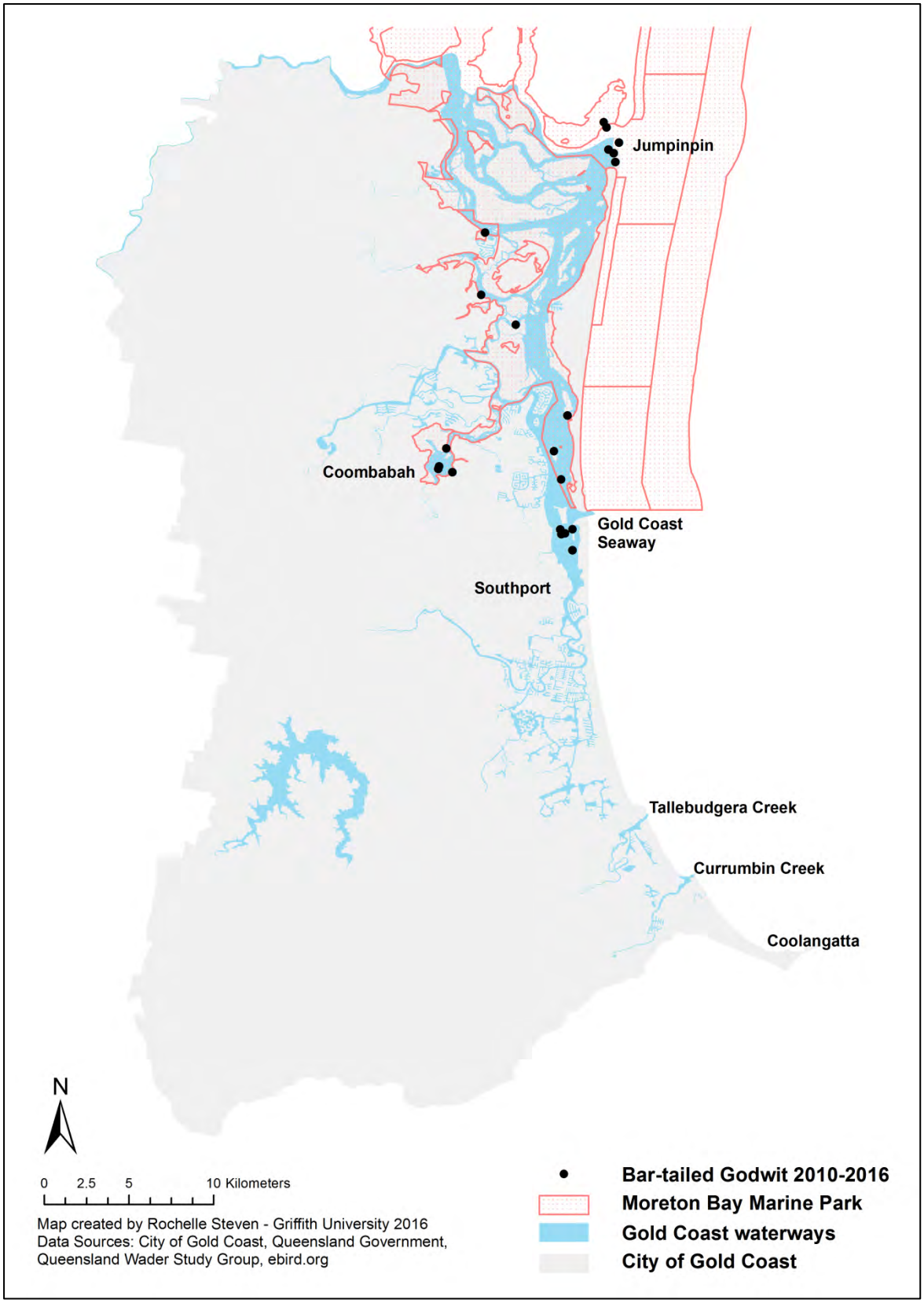

Figure 20: Distribution of current Bar-tailed Godwit records for Gold Coast waterways.

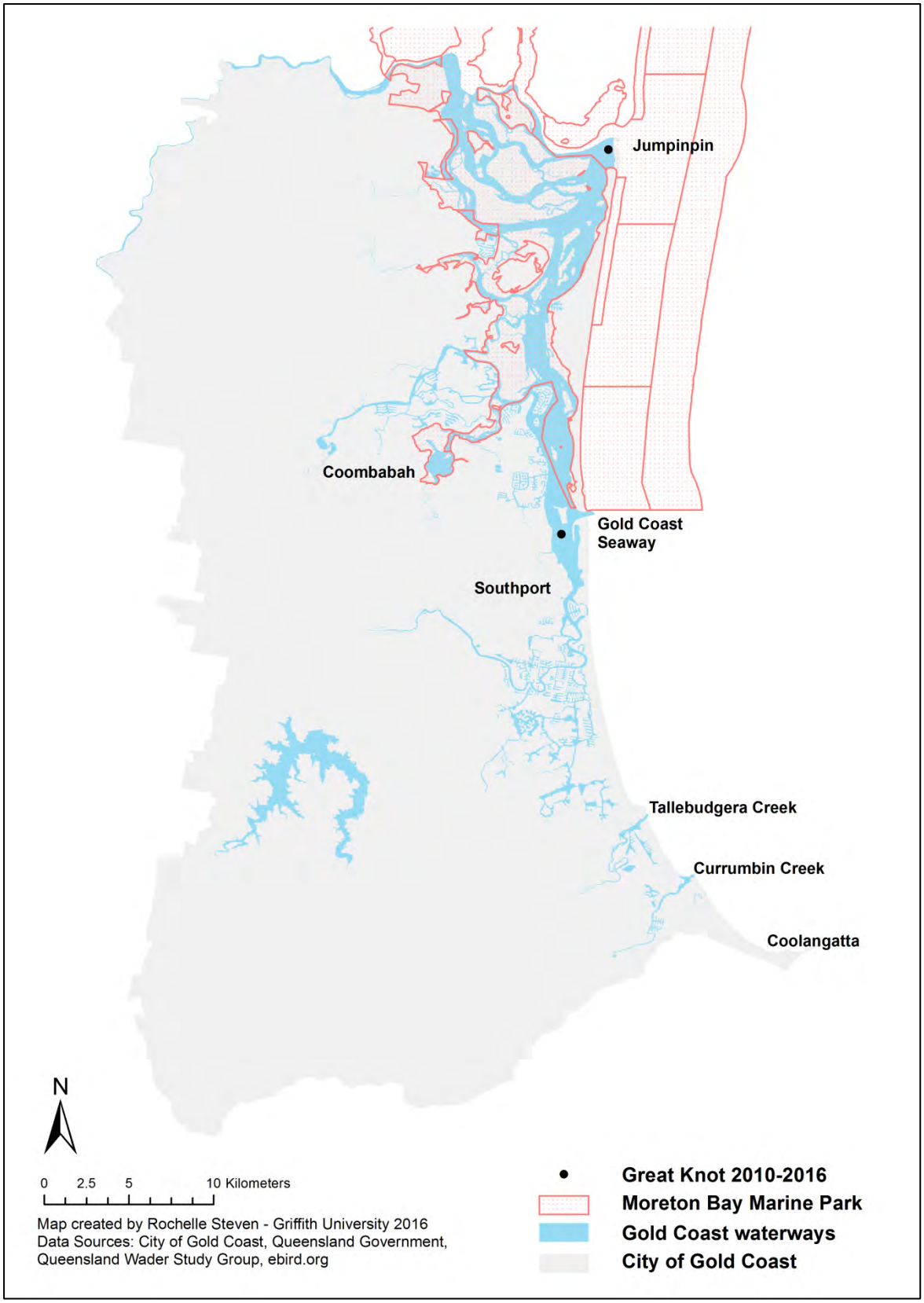

Figure 21: Distribution of current Great Knot records for Gold Coast waterways.

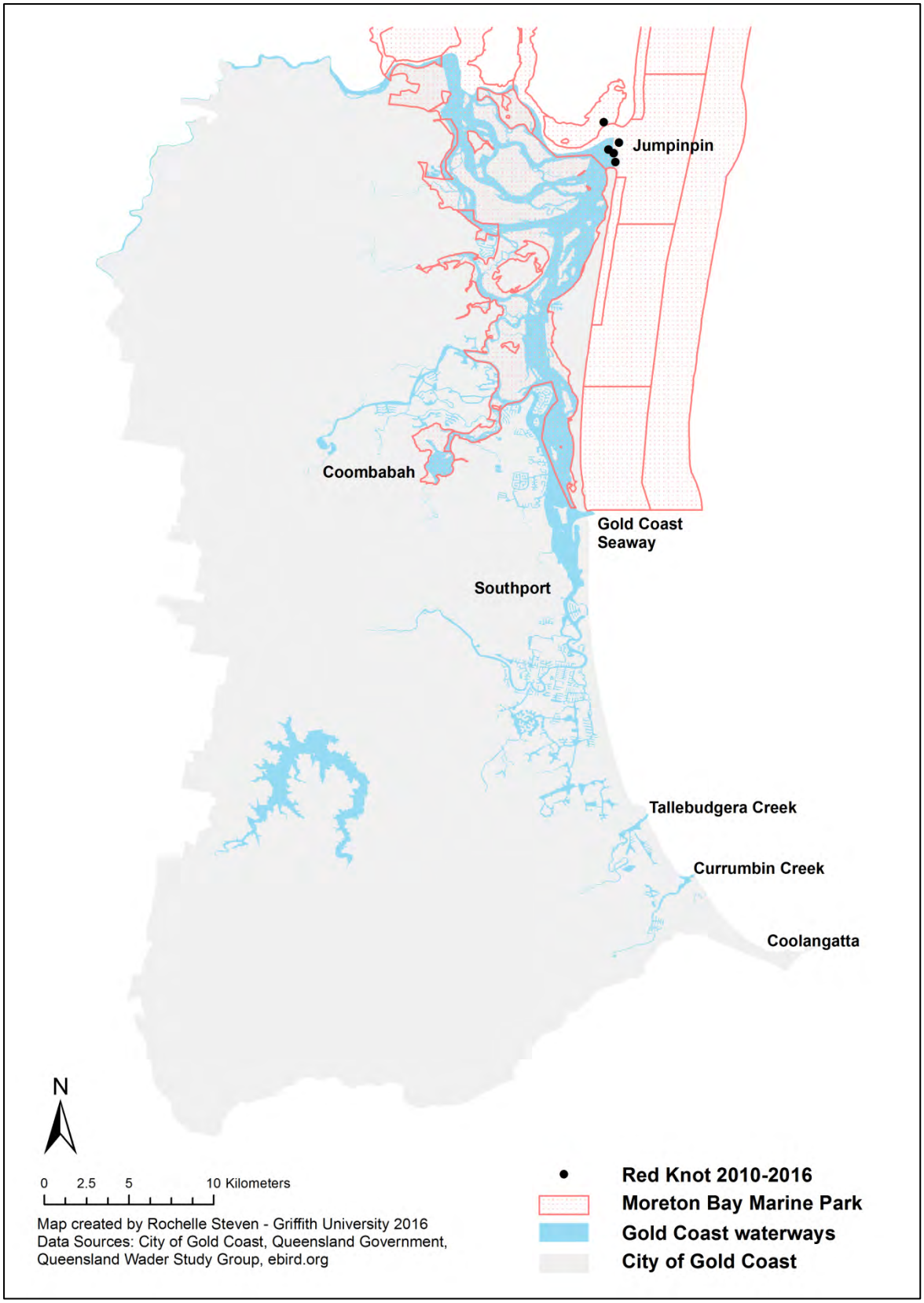

Figure 22: Distribution of current Red Knot records for Gold Coast waterways.

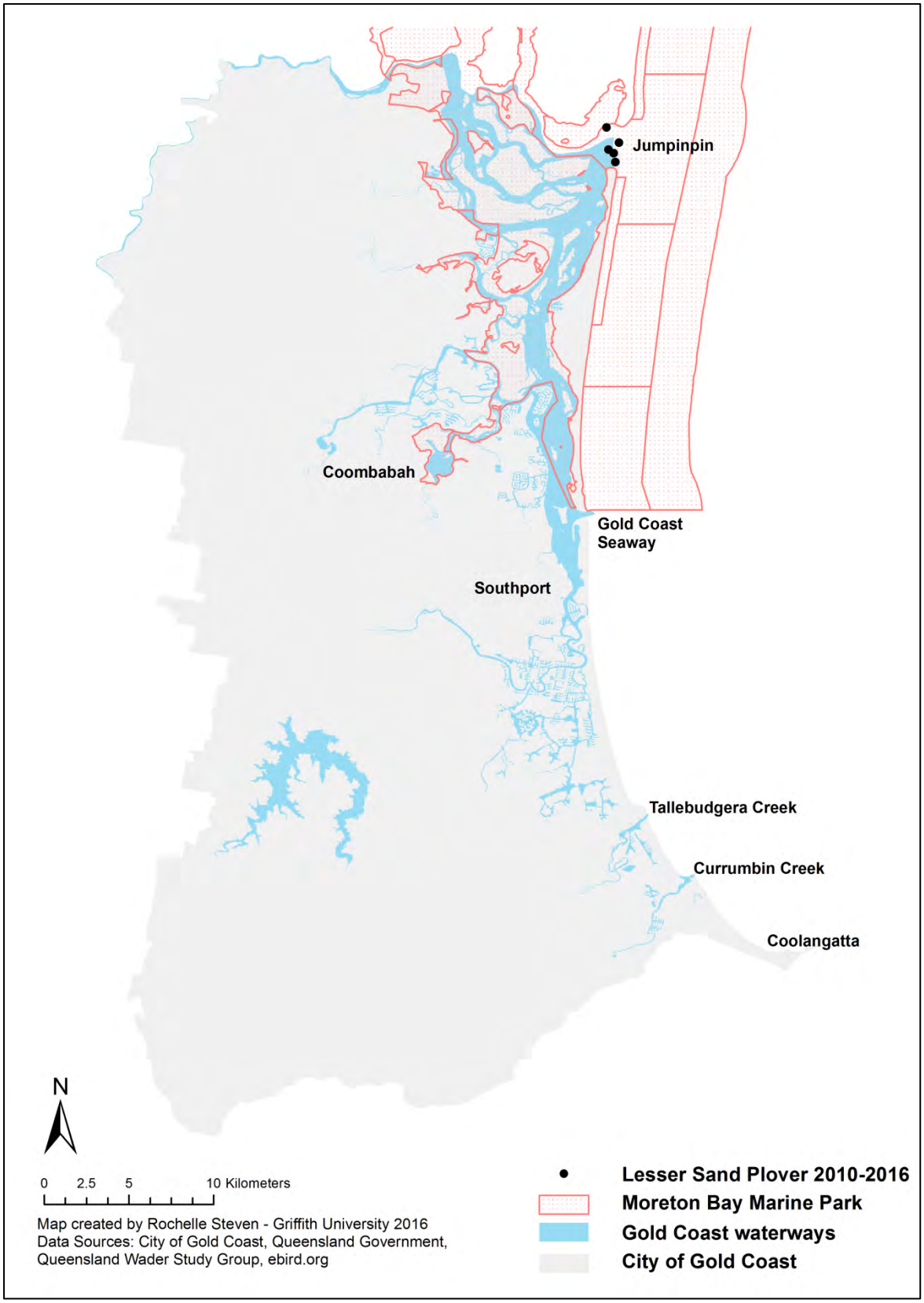

Figure 23: Distribution of current Lesser Sand Plover records for Gold Coast waterways.

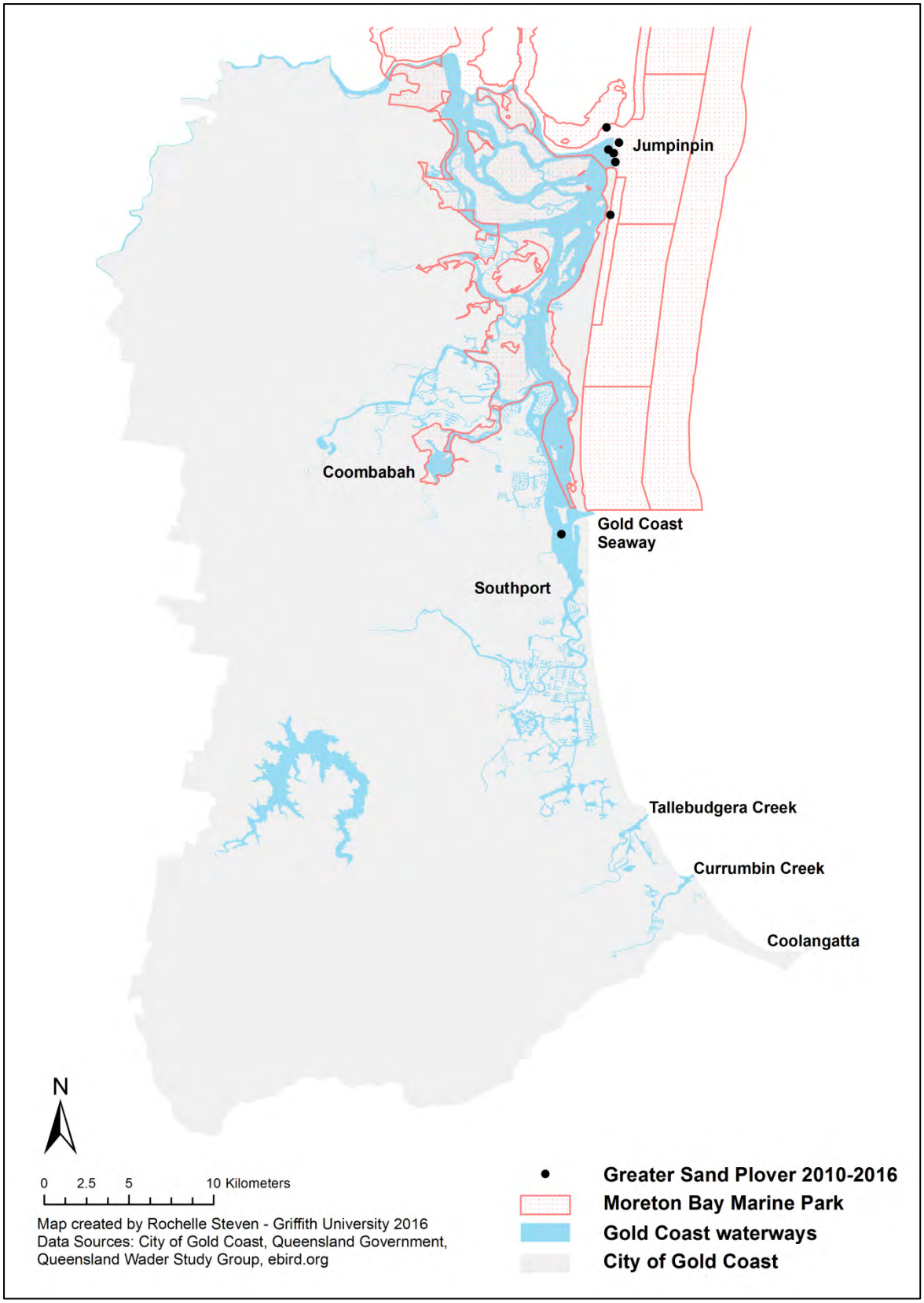

Figure 24: Distribution of current Greater Sand Plover records for Gold Coast waterways.

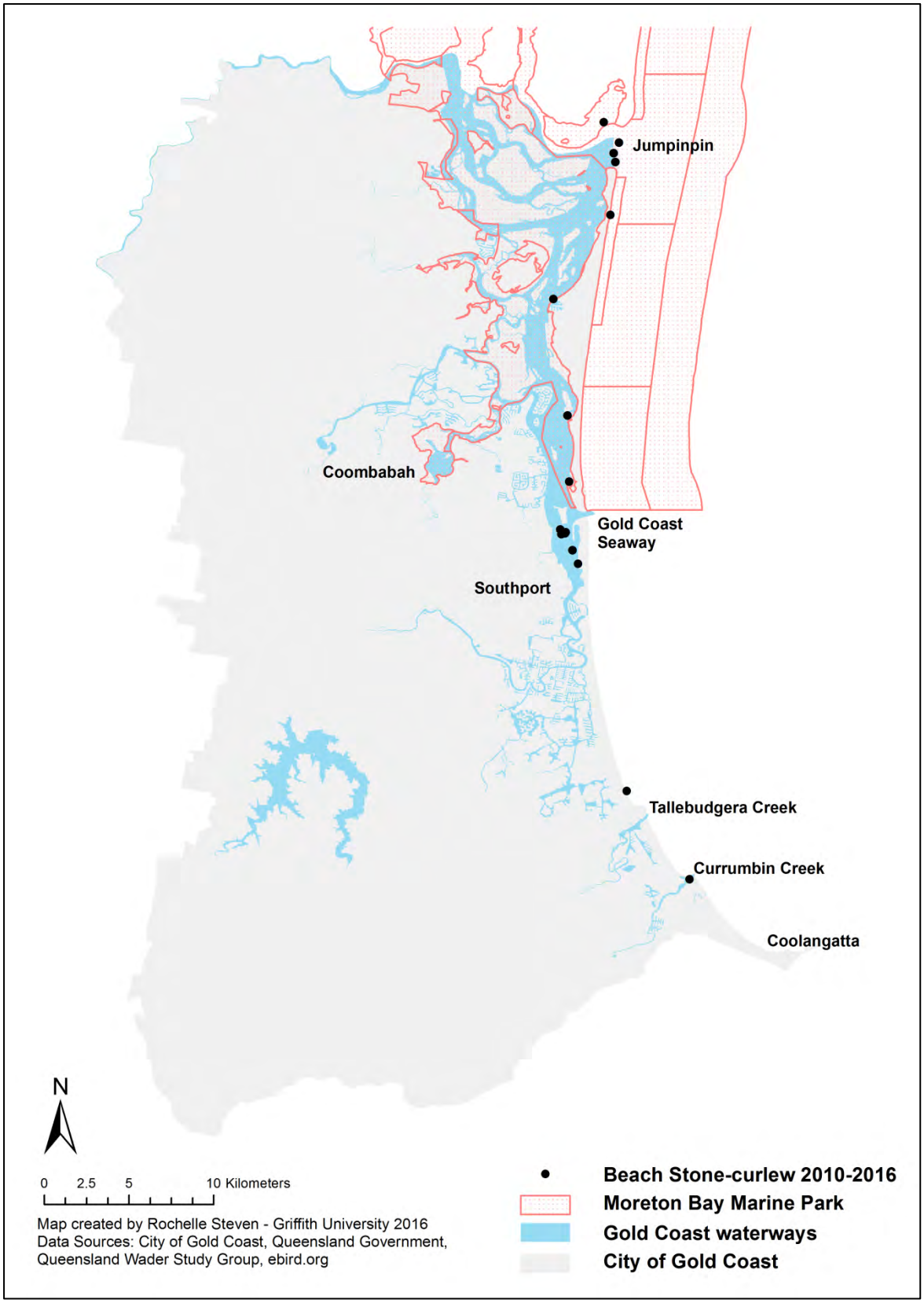

Figure 25: Distribution of current Beach Stone-curlew records for Gold Coast waterways.

Little Terns

Little Terns (*Sterna albifrons*) are listed as Endangered under the *Threatened Species Conservation Act 1995* (TSCA) in New South Wales (NSW). The species is currently listed as Least Concern in Queensland but was previously listed as being endangered. Given the proximity of Gold Coast waterways to NSW and the species presence on the Gold Coast they are given consideration here. Little Terns breed on the eastern side of South Stradbroke Island at the northern tip (in the Jumpinpin broad regional area) between September and January (Searle et al. 2016). This is the only known breeding site for Little Terns in Moreton Bay. The species also uses sand bars as roosting sites when they are not foraging in open waters (Chan and Dening 2007). Little Terns have been the subject of active monitoring and management at their breeding sites on South Stradbroke Island in the past (between 2008-2013), with City of Gold Coast (CoGC) conservation officers and members of the QWSG patrolling the nesting beach twice per week and on alternating weekend days during the breeding season. Management responses put in place by CoGC and the Queensland Parks and Wildlife Service (QPWS) include interpretive signage, the demarcation of a voluntary exclusion zone to minimise disturbance and potential trampling of nests, as well as educational patrols during peak recreational periods over the breeding season (S Britton[4], CoGC, pers. comm.). In addition to these actions, dogs were also specifically prohibited within a Council-administered 'permit to occupy' area above the highest astronomical tide with subsequent enforcement patrols (by officers from CoGC and Qld Police). This management activity has been reduced since 2013 when CoGC surrendered its 'permit to occupy' over the land in the Jumpinpin region to the QPWS (S Britton, CoGC, pers. comm.). Interpretive signage in the area cautioning people about disturbing the birds remains but participants in the focus group questioned the efficacy of these methods/signage. The Little Tern nesting site is also very close to Horseshoe Bay in the Jumpinpin broad regional area where shorebirds roost. As such, a reinstated management presence and/or more engaging educational tools (e.g. bird hides, web cameras) could have multiple benefits for the monitoring and management of birds using the broader area.

[4] Sinclair Britton, Acting Coordinator Environmental Planning, Planning and Environment, City of Gold Coast. Email correspondence from June 2016.

4. Relative importance of shorebird habitats in Gold Coast waterways

Australia currently has 118 sites, supporting 28 migratory shorebird species, that satisfy the criteria for internationally important habitats (Bamford et al. 2008) (Appendix B). Moreton Bay is an internationally important habitat for migratory shorebirds, and portions of the Bay are listed as a Ramsar wetland of international importance (Appendix G; Figure G34). Remaining areas are listed as nationally important in the Australian Wetlands Database (Appendix G; Figure G35). Given the high site fidelity (i.e. birds routinely returning to the same location year after year) seen in migratory shorebirds during the non-breeding season (Minton et al. 2011; Coleman and Milton 2012), non-breeding habitat sites in Gold Coast waterways may be particularly important. For example, Eastern Curlew are recorded from Curlew Island and Curlew Banks to the south of Wavebreak Island in the non-breeding season.

As some species, such as the Eastern Curlew, fly 8,000 km non-stop on their northward migration (Minton et al. 2011), the long-term viability of non-breeding sites for migratory shorebirds may be particularly important (Piersma and Baker 2000). The plight of shorebirds habitats in south-east Asia has been reported (Murray et al. 2014; 2015), and is one of the major factors affecting migratory shorebird populations in Australia (Clemens et al. 2016). However, ongoing efforts to minimise the loss of shorebird populations in non-breeding habitats throughout the EAAF (see Appendix I for details) are still required (Szabo et al. 2016). This has a bearing on the management of shorebirds and their habitats in Gold Coast waterways, particularly listed threatened species, to ensure that there is no net loss or deterioration of potential shorebird habitats and that shorebird populations are monitored to assess population trends. For wetlands of international importance (i.e. Ramsar sites), listed threatened species and communities and well listed migratory species (i.e. matters of national environmental significance), the EPBC Act has provisions that limit actions that have, or are likely to have, a significant impact on such matters of national environmental significance (see Appendix A and also footnotes 2 and 3 on page 16) in that such actions require approval from the federal environment minister (Australian Government 2013).

Using the criteria defined by Clemens et al. (2010) and adopted by the Australian Government (Australian Government 2015a), this study identified areas of Gold Coast waterways, including areas outside of the MBMP, that meet the criteria for recognition as nationally important habitat for migratory shorebirds. Furthermore, these areas are used by species listed as Critically Endangered, Endangered and Vulnerable under the EPBC Act. Species recorded in Gold Coast waterways exceeding thresholds (refer Table 4 for details) between 2010 and 2016 are listed below (relative to the six broad regional areas of Gold Coast waterways shown in Figure 6):

- Double-banded Plover – Jumpinpin (5 records), Southport Wavebreak (5 records)

- Eastern Curlew – Jumpinpin (40 records), Southern South Stradbroke (1 record), Southport Wavebreak (39 records)
- Bar-tailed Godwit – Jumpinpin (1 record)
- Greater Sand Plover – Jumpinpin (2 records)
- Whimbrel – Southport Wavebreak (1 record)

Table 4: Relative importance of migratory shorebird populations in Gold Coast waterways represented by the number of times records (in two periods) exceeded the 0.1% of flyway population threshold limits. The 0.1% threshold numbers for each species are also provided.

Species (common name)	0.1% of Flyway population Nationally Important criteria threshold	Number of times observed exceeding 0.1% of Flyway population (1992 – 2009) (Number outside MBMP)	Number of times observed exceeding 0.1% of Flyway population (2010 – 2016) (Number outside MBMP)
Bar-tailed Godwit#	325	19 (7)	1 (0)
Black-tailed Godwit	160	0	0
Broad-billed Sandpiper	25	0	0
Common Greenshank	60	0	0
Common Sandpiper	25	0	–
Curlew Sandpiper#	180	0	0
Double-banded Plover	50	25 (16)	10 (5)
Eastern Curlew#	38	241 (93)	80 (39)
Great Knot#	375	0	0
Greater Sand Plover#	110	7 (1)	2 (0)
Grey Plover	125	0	0
Grey-tailed Tattler	50	0	0
Latham's Snipe	36	0	0
Lesser Sand Plover#	140	8 (6)	0
Marsh Sandpiper	100	0	0
Pacific Golden Plover	100	0	0
Red Knot#	220	0	0
Red-necked Stint	325	0	0
Ruddy Turnstone	35	0	0
Sanderling	22	1 (0)	0
Sharp-tailed Sandpiper	160	3 (2)	0
Terek Sandpiper	60	1 (0)	0
Whimbrel	100	2 (2)	1 (1)

Legend:
Nationally Important criteria threshold: Refer to section 2.2
MBMP: Moreton Bay Marine Park
#: Listed threatened species under the EPBC Act
– : Species not recorded during this period.

Importantly, these data and areas may also underestimate the relative importance of Gold Coast waterways for migratory shorebirds, given that survey effort was inconsistently applied across all potential shorebirds habitats. A greater consistency in survey effort is required among existing survey sites while additional novel sites may also require surveys.

As stated previously any future survey strategy needs to be based on a scientifically rigorous research methodology.

5. Threats to shorebirds in Gold Coast waterways

Shorebirds face many threats throughout their global range. Sutherland et al. (2012) identified 45 threats to shorebirds and broadly categorised these as:

- natural events (e.g. cyclones, tsunamis)
- gradual drivers (e.g. climate change, altered sediment flow, algal blooms, infectious disease)
- current anthropogenic factors (e.g. loss and degradation of breeding and wintering habitat, agricultural intensification, tidal habitat reclamation, river regulation, pollution, disturbance)
- future issues (e.g. microplastics, novel recreation, changing primary productivity in key staging and wintering habitats).

Habitat loss and degradation remains one of the leading causes of shorebird declines (MacKinnon et al. 2012). This can have significant impacts on migratory shorebirds, especially where habitats in breeding / staging grounds are lost. This is of particular concern for Australian migratory shorebird populations within the East Asian-Australasian Flyway (EAAF) where drivers outside Australia are contributing to population declines (Clemens et al. 2016). One of the principle drivers behind these declines are the land reclamation works causing habitat loss in the Yellow Sea (Murray et al. 2014; Murray et al. 2015; Piersma et al. 2016). Due to the recent declines seen in many shorebird species in the EAAF (Gosbell and Clemens 2006; Wilson et al. 2011), any threats to the birds in Australia need to be considered in the context of the heightened vulnerability of these species (Atkinson 2003; MacKinnon et al. 2012; Australian Government 2015b). While there is an urgent need for conservation actions overseas, the effective management of Australian shorebird habitat remains important (Clemens et al. 2016).

The following seven key threats have been identified as affecting shorebird populations in Australia (Australian Government 2015a):

1. habitat loss
2. habitat modification
3. anthropogenic disturbance
4. climate variability and change
5. harvesting of shorebird prey
6. fisheries bycatch
7. hunting

The manner in which these threats impact shorebirds can vary depending on their residence or migration patterns as well as the nature, extent and severity of the threat. For example,

studies investigating behavioural responses of migratory shorebirds to disturbance at roost sites showed that the flight initiation distance (i.e. the distance at which birds change their behaviour to avoid the disturbance, often through flight) varied according to the size, age, and flock size (Burger and Gochfeld 1991; Koch and Paton 2014; Lilleyman et al. 2016). However, the type of disturbance (e.g. walker, walkers with dogs, group size, etc.) can also affect the flight initiation distance (Burger and Gochfeld 1991; Glover et al. 2011; Weston et al. 2012a). For example, the presence of dogs or runners increases the flight initiation distance for some species when compared to walkers alone (Glover et al. 2011).

The threats faced by shorebirds in Gold Coast waterways are similar to those faced along other developed coastlines in Australia (Glover et al. 2011; Weston et al. 2012a). For example, resident shorebirds may be particularly threatened by free-roaming dogs, especially during times of breeding and nesting. However, as Weston and Stankowich (2014) explain, there is little research that has been completed to specifically unravel the potential impacts of free-roaming dogs. This paucity of information should not preclude recognising free roaming dogs as a potential threat to shorebirds. For example, eggs or chicks may be trampled or predated upon by dogs or other predators (e.g. goanna, gulls) when adults are flushed from nests (Williams et al. 2009). While natural predation of shorebird nests is to be expected, populations of some predatory species (e.g. gulls, see O'Connell and Beck 2003), can become artificially elevated due to anthropogenic influence (e.g. feeding of gulls and pelicans in coastal areas, see Newsome and Roger 2008). Similarly, migrant species that are disturbed from foraging and roosting by dogs may experience excessive expenditure of energy due to the requirement to evade any perceived predation risk. West et al. (2002) have previously described dogs as a form of major disturbance to shorebirds when modelling the effects on mortality due to the relatively large area disturbed as well as the nature of the shorebird response (i.e. moves frequently and/or rapidly). This can negatively affect their ability to complete their northward migration to their breeding grounds in Siberia or Alaska (Atkinson 2003).

The threats to Gold Coast populations of shorebirds are summarised from the literature and focus group consultation (Table 5) and each is discussed in the following subsections. The threat assessment framework used in this study is based on the same framework used by both BirdLife International and the International Union for Conservation of Nature (IUCN), and is based on a specially designed framework for threatening processes affecting biodiversity (Salafsky et al. 2008). Certain threatening processes that cause declines in shorebirds elsewhere in Australia (Purnell et al. 2012) are not deemed a significant threat to shorebirds in Gold Coast waterways; for example, the presence of introduced predators (i.e. cats and foxes). The intertidal sand bars and islands of the Gold Coast waterways (including South Stradbroke Island) that are not connected to the mainland are largely free of these species (Vertebrate Pest Research Unit 2012).

Table 5: Threat risk assessment for Gold Coast waterways populations of shorebirds.

Threatening Process	Timing	Scope	Severity	Impact*	Level of confidence**
Dredging – existing boating channels	Continuing	1	1	Low	High
Dredging – new sites used by birds (sand sourcing for nourishment activities)	Short term	1	3	Medium	High
Nourishment – open-exposed beaches	Short term	1	1	Low	High
Nourishment – sheltered intertidal habitats used by birds	Short term	1	1	Low	Medium
Nourishment – creation of new sheltered intertidal habitats	Short term	1	1	Low	Medium
Recreational disturbance – non-motorised (human only) (Summer)	Continuing	2	2	Medium	Medium
Recreational disturbance – non-motorised (human only) (Winter)	Continuing	2	2	Medium	Medium
Recreational disturbance – non-motorised (domestic dogs) (Summer)	Continuing	2	2	Medium	Medium
Recreational disturbance – non-motorised (domestic dogs) (Winter)	Continuing	2	2	Medium	Medium
Recreational disturbance – motorised (high speed) (Summer)	Continuing	2	2	Medium	High
Recreational disturbance – motorised (high speed) (Winter)	Continuing	2	2	Medium	Medium
Recreational disturbance – motorised (low speed) (Summer)	Continuing	2	2	Medium	High
Recreational disturbance – motorised (low speed) (Winter)	Continuing	2	2	Medium	Medium
Contamination of intertidal waters – stormwater etc.	Continuing	2	2	Medium	n/a
Climate Change – sea level rise	Long term	3	3	Medium	High
Climate Change – storm surge erosion	Short term	2	2	Medium	Medium
Climate Change – changes ecological processes (i.e. prey availability)	Long term	3	3	Medium	High

Legend:
Timing: Continuing (continuous/ongoing threat); Short term (threat may occur/return in the short term); Long term (threat may occur/return in the long term) – see Appendix C for details.
*Impact: Medium [orange]; Low [yellow] (values/rating based on agreement among focus group participants).
**Level of confidence: Low <40%, Medium 40-70%, High > 70% (values/rating based on agreement among focus group participants).
Note: No threats were assessed as High Impact.

5.1 Shorebird habitat loss and degradation from dredging and nourishment activities

Impacts

Habitat loss and degradation continues to threaten shorebirds, both in Australia (ABS 2010; Australian Government 2011) and overseas (Murray et al. 2014; Murray et al. 2015). With multiple instances of smaller scale habitat removal or degradation happening frequently across shorebirds distributions, the associated impacts on shorebirds have been likened to a 'death by a thousand cuts' (Milton and Harding 2011). Coupled with the large scale habitat loss in East Asia (Murray et al. 2014; Murray et al. 2015), the outlook for migratory shorebirds is concerning.

The effects of channel dredging for maintenance of navigation routes and its effects on shorebirds are poorly explored in the literature. Channel dredging has the potential to alter macrobenthic communities (Quigley and Hall 1999; Ponti et al. 2009), or modify tidal range with resultant changes to available shorebird habitat (Brereton and Taylor-Wood 2010). The response by biota to disturbance of the sediment as well as modification of habitats could result in cascading effects that affect shorebirds, such as changes to prey assemblages and sediment particle sizes (see VanDusen et al. 2012). Apart from the potential negative impacts of dredging activities, there is also the potential to use the sediment removed during dredging campaigns, such as dredging navigation channels, to create novel habitats for shorebird use (Scarton et al. 2013). A project focussed on the beneficial re-use of dredged sediment is currently being undertaken as part of the GCWA's broader Scientific Research and Management Strategy (SRMS) and accompanying Scientific Research and Management Program (SRMP).

Dredging of areas not actively used by shorebirds (i.e. subtidal zone) probably has negligible impacts, providing the dredging does not have significant negative effects on the tidal flow and inundation pattern of the adjacent shorebird habitat areas in the short or medium-term. Changes in tidal flow can cause instability in sand banks, reducing available shorebird habitat (see Brereton and Taylor-Wood 2010), as well as creating conditions conducive to erosion of the mainland via increased wave frequency and height (Jensen and Morgensen 2000 cited in Erftemeijer and Lewis 2006; Demir et al. 2004). Dredging activities for maintaining navigation channels may alter sediment movement and tidal flow within waterways that could affect shorebird foraging sites. However, we were not able to identify foraging sites from the available data used in the review and the identification of such sites remains a knowledge gap. Nevertheless, important shorebird feeding areas may act as a trigger for flagging some areas of the GCWA navigation channel network as 'yellow' trigger areas (*i.e.* areas requiring further investigation) under their '*Environmental Management Framework for Managing Sand Resources in Gold Coast Waterways*' (BMT WBM 2015). While the Framework report states that '*In general, the channels in the network are not important waterbird habitats and as such will not be adversely affected by channel dredging*'

(pg. 59, BMT WBM 2015), there may still be the potential for channel maintenance activities to result in hydrodynamic or ecological effects beyond the immediate channel system, and that these effects may potentially impact upon shorebirds. A further consideration is the ultimate destination chosen for the dredged sediment if it is to be used for nourishment purposes. For example, works in areas such as the Jumpinpin Bar Channel to the west of Horseshoe Bay (refer Figure F29 for detail), may provide the necessary trigger should the dredged sediment associated with a dredging campaign be used for foreshore nourishment activities in areas used by shorebirds for foraging.

Nourishment (using sand or sediment dredged from elsewhere) is growing in popularity as a management tool to protect open-exposed beaches and property in the face of increased wave action and severe storm activity along developed coastlines (Speybroeck et al. 2006; Cooke et al. 2012). When compared to building hard-engineered infrastructure, nourishment is a cost-effective strategy (Cooke et al. 2012). On the Gold Coast, nourishment activities to date have taken place on open-exposed beaches and at development sites where land reclamation activities have ensued (Strauss et al. 2009). Despite suggestions that nourishment can increase habitat for coastal fauna (including shorebirds) (Yozzo et al. 2004), there are few data to demonstrate that current nourishment activities on the Gold Coast provide suitable enhanced habitat availability for shorebirds. A review of the value of these nourishment activities may be required following the conclusion of the 'beneficial re-use of dredged sediment project' mentioned above that is currently being undertaken as part of the GCWA's SRMS/SRMP. For example, there can be too much human activity on open-exposed beaches for birds to use these areas as habitat (Meager et al. 2012) and this is similar for Gold Coast beaches (Noriega 2007). While Gold Coast beaches are outside the Gold Coast waterways they may be used for nourishment (i.e. dredged sediment disposal) purposes where appropriate. For example, much of the previously mentioned Jumpinpin Bar Channel to the west of Horseshoe Bay area is part of a 'Fish Habitat 'A' Area' where nourishment is not permitted (see BMT WBM 2015 for example). Areas developed on reclaimed sites (e.g. Sovereign Island) are characterised by predominantly built infrastructure, and are unlikely to support shorebird habitat. Additional research also points to negative impacts of nourishment activities affecting shorebirds (Peterson et al. 2006; Speybroeck et al. 2006), often resulting from a reduction in prey availability and density (Peterson et al. 2006). Nourishment activities at Palm Beach have been found to have negative impacts on invertebrate abundance (Schlacher et al. 2012). Furthermore, work by Peterson and Bishop (2005) found that many studies reporting positive or nil effects of nourishment on the environment are based on flawed scientific experimental designs, for example, in selecting appropriate control and disturbed sites. Australian nourishment activities are rarely monitored for their biological impacts (Cooke et al. 2012). However, any future deleterious impacts on beach infauna may need to be considered alongside the potential economic costs from the loss of urban infrastructure should such nourishment not proceed.

Frequency and extent

Gold Coast waterways are used by a range of commercial and recreational mariners. These waterways require maintenance, including dredging, to ensure safe and navigable passage for users. Maintenance may have ongoing effects on shorebirds but this is expected to be restricted to placement of dredged material as the channels are not considered to be important habitats (BMT WBM 2015). The potential disturbance to birds (i.e. flushing) caused by dredging is also considered to be minimal due to the nature of dredge operations (e.g. dredge vessel stationary to extremely slow moving, low levels of noise emitted, etc.) and restricted both spatially and temporally as dredging is only completed periodically. Nonetheless, some areas that require dredging are in close proximity to shorebirds and/or their habitats, e.g. Jumpinpin Bar Channel, Labrador / Wavebreak Island (western side) channels, and potentially creeks and rivers in the northwest (predicted in the absence of more survey effort). Refer threat assessment in Table 5 for further detail.

5.2 Recreational disturbance by humans and domestic dogs

Impacts

The localised threat that recreational activities pose to migratory species in southeast Queensland is higher during the austral spring to autumn as this is when these birds occupy habitats after arriving on their southern migration (see Chan and Dening 2007). However, disturbance threats to resident species may potentially occur year round given that the subtropical climates of southeast Queensland allow for recreational activities in coastal environments throughout the year. For example, Maguire et al. (2011) found that residents used local beaches on a year round basis. Weekends are also a time of greater recreational disturbance (three times higher) than weekdays (see Milton et al. 2011 for example) due to higher visitation rates. Motorised activities (especially beach driving) have been demonstrated as having serious negative effects on shorebirds in Australia, often resulting in direct mortality of birds and destruction of nests (see Schlacher et al. 2013 for example), or damage to the broader coastal habitat (Schlacher and Thompson 2009). Fortunately, for shorebirds and other coastal fauna, the use of vehicles on most Gold Coast beaches and intertidal areas is generally uncommon and/or prohibited. However, boat and personal watercraft (PWC such as jet skis) activity (especially travelling at high speeds) represents a potential source of disturbance to birds (Burger 1998; Rodgers and Schwikert 2002; Milton et al. 2011). In Gold Coast waterways there is considerable boating and PWC activity and this may be elevated during peak periods (*e.g.* long weekends, school holidays, *etc*.), particularly within the Jumpinpin and Southport Wavebreak areas (City of Gold Coast 2013). While disturbance from PWC may be low compared to other forms of disturbance (e.g. walkers)(Milton et al. 2011), such disturbance may be largely unreported and unquantified for Gold Coast waterways. In their study assessing the requirements for set-back distances to minimise shorebird disturbance from foraging and roosting sites, Rodgers

and Schwikert (2002) suggested that, depending on the species involved, buffer zones of between 100 m and 180 m would be required to minimise disturbance from PWC and outboard-powered boats. This may warrant further investigation in Gold Coast waterways, potentially as part of a broader shorebird monitoring program based on scientifically rigorous research methodologies.

Non-motorised activities also pose a threat to resident and migratory shorebirds (Steven et al. 2011). Substantial research examining the various recreational activities and subsequent responses by birds exists (see Burger 1998; Rodgers and Schwikert 2002; Milton et al. 2011; Weston et al. 2012a; Koch and Paton 2014). Disturbance created by people on foot and people with dogs (especially off leash) are a management concern for shorebirds, since these activities can result in birds vacating roosting, foraging and nesting sites (Blumstein et al. 2005; Banks and Bryant 2007; Williams et al. 2009; Kyne 2010; Glover et al. 2011). However, our understanding of these potential impacts on shorebird populations in Gold Coast waterways is limited and further research is required to expand our knowledge in this area. Recreational activities can impact shorebirds by reducing time spent foraging and roosting (all species) (Buckley 2004; Kyne 2010) and flushing adults from nests (Lord et al. 2001) resulting in predation on eggs and chicks (resident species) (Bolduc and Guillemette 2003). For migratory shorebirds, human disturbance can also result in additional expenditure of the energy required for them to complete their northward migration (Rogers et al. 2006; Geering et al. 2007). Given the rapid loss of habitat in staging and stopover habitats *en route* for most migrants, the importance of adequate rest and recovery in their Australian habitats remains critical (Aharon-Rotman et al. 2016). Ultimately, if shorebirds are exposed to excessive disturbance, they will be forced to leave an area (Pfister et al. 1992; Navedo and Herrera 2012) and this may place additional energetic costs associated with the dispersal on the birds (Rogers et al. 2006), while alternative habitats might also not be readily available (Lilleyman et al. 2016).

Studies assessing the effects of disturbance on shorebirds typically use the flight initiation distance (Weston et al. 2012a; Koch and Paton 2014; Lilleyman et al. 2016). Flight initiation distances may vary according to the disturbance or activity the bird is exposed to and the species being disturbed (Weston et al. 2012a) (Figure 26). Generally, there is a positive relationship between bird body size and the distance at which flight initiation occurs (i.e. bigger birds flush at greater distances) (Glover et al. 2011). For migratory as well as resident species listed as threatened in the EPBC Act such disturbance could compromise the survival of these birds. For example, Beach Stone-curlews are especially vulnerable during the breeding season of September to February (Clancy 1986; Milton 2003).

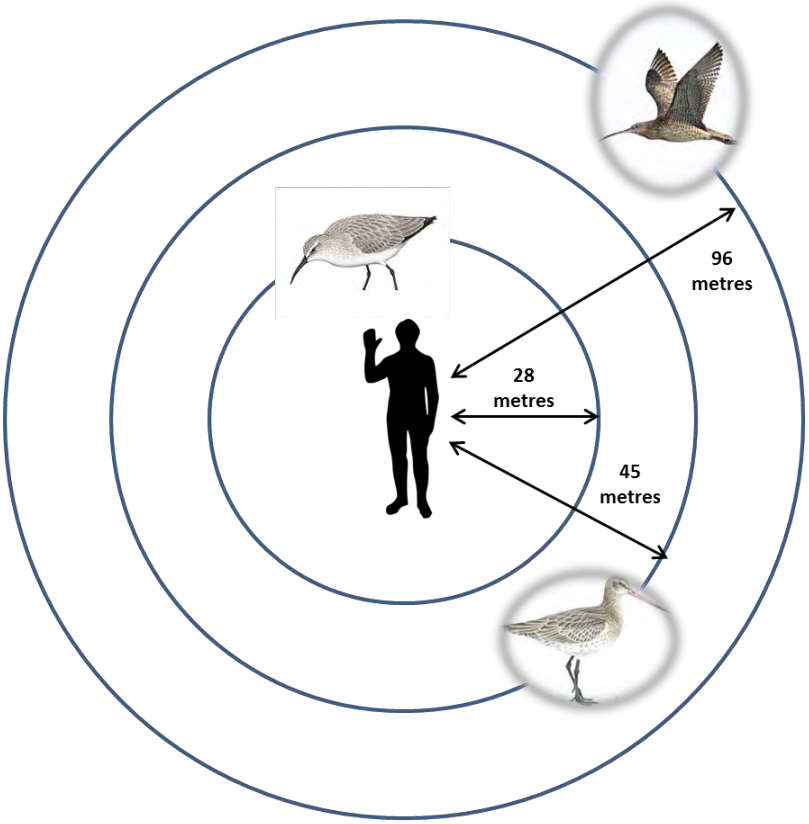

Figure 26: Average flight initiation distances (FIDs) for human disturbance (single walker, non-motorised, excluding dogs) for Curlew Sandpiper (28 m), Bar-tailed Godwit (45 m) and Eastern Curlew (96 m) (Figure based on data from Weston et al. 2012a).

Where domestic dogs are a part of these human recreation activities, the threat perception among the birds is higher still (Banks and Bryant 2007; Glover et al. 2011). Despite claims by some owners that their dogs are harmless (Williams et al. 2009) (Figure 27), in reality their mere presence can substantially increase the probability of shorebirds not occupying habitats (Stigner et al. 2016). In fact, birds have been found to avoid areas that are frequented by dogs, leading to localised population declines (Stigner et al. 2016). Research also finds birds express greater responses to walkers with leashed dogs, compared to walkers alone (Glover et al. 2011). Furthermore, Stigner et al. (2016) also noted that when people were walking with dogs the majority (84%) were unrestrained, potentially posing an even greater source of disturbance to shorebirds than leashed dogs.

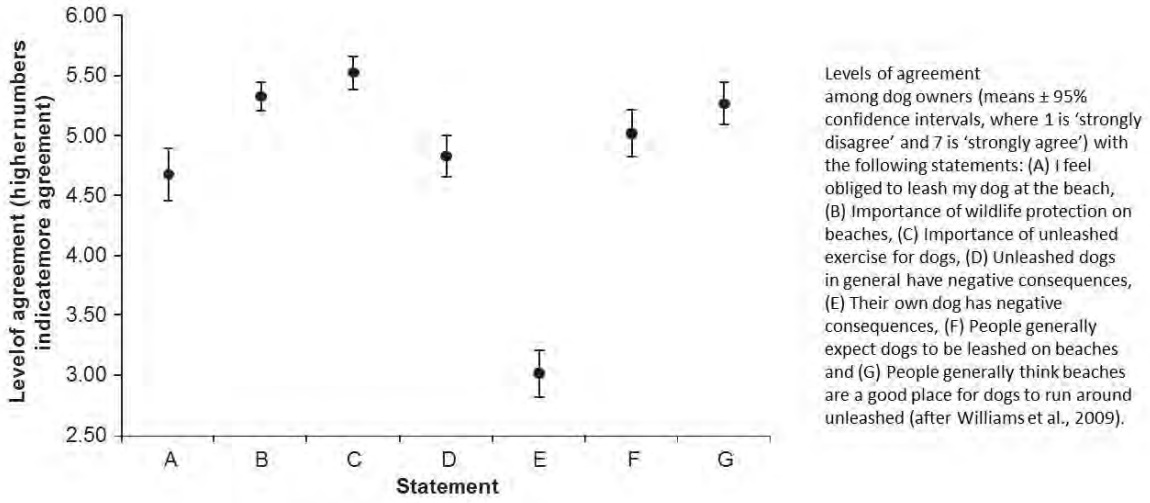

Figure 27: Dog-owners perceptions of how dogs affect shorebirds in coastal environments (Source: Miller et al. 2014).

Frequency and extent

Theoretically, almost the full extent of the Gold Coast waterways is available for use by recreational and commercial vessels and/or PWC operators. However, while the full spatial extent may be theoretically available to such users, the actual levels and patterns of use may vary greatly due to different areas and locations being popular for vastly different reasons and at different times throughout the day, week, month and/or year. Recreationists may also undertake various activities with their pet dogs in their company such as walking, bait collection and fishing on the various sand banks, bars and island in Gold Coast waterways. There is potential for this to pose a threat to shorebirds in areas where the two overlap (i.e. recreationists with dogs and shorebirds). This potential risk to shorebirds is largely unquantified in Gold Coast waterways. As such, further research may be required to assess these sources of disturbance within Gold Coast waterways in a manner that captures the extent, duration and intensity of potential disturbance sources as well as any species-specific responses of shorebirds (see threat assessment in Table 5 for further details).

5.3 Climate Change

Impacts

Quantitative predictions about climate change impacts on natural systems are fraught with uncertainty (Kerr 2011) and thus often receive little prioritisation among policy makers (Lemos and Rood 2010). However, there is a higher degree of certainty for coastal erosion due to increased storm activity (Sano et al. 2011). The Gold Coast community has already started seeing the effects of storm surge and king tides in recent years. For example, studies have shown that storm events can cause significant coastal erosion to Gold Coast

beaches (Castelle et al. 2007; Castelle et al. 2008), but that there is also currently insufficient adaptive capacity within local government (i.e. CoGC in this instance) to cope with these challenges (Sano et al. 2011). Despite the potential for extreme coastal beach erosion as a result of these storm events, the impact on shorebirds may be relatively low as these areas are not heavily frequented by shorebirds. Therefore, anecdotal evidence seems to suggest that under current hydrological conditions, intertidal shorebird habitats in Gold Coast waterways appear to be resilient to storm events and are still able to provide habitat for shorebirds.

The tidal nature of many shorebird habitats suggests that sea level rise may become important under a warming climate, with some studies estimating that for a 50 cm rise in sea level, there will be a corresponding reduction of shorebird habitat in south-eastern Australia of 22% (Iwamura et al. 2013). At present, however, there are gaps in the quantification of wetland surface elevation changes globally and this limits our ability to assess the relative vulnerability to sea level rise (Webb et al. 2013). It may, therefore, be difficult to predict the impacts of sea level rise at spatial scales needed for site-specific management. However, a recent study by Runting et al. (2013) has suggested that future models using high-resolution elevation data may be able to effectively prioritise areas for conservation.

Any planning for sea level rise may also need to consider the potential gain and loss of habitat, where existing habitats may be lost through inundation and new habitats are created through transitions in vegetation communities (Erwin et al 2004; Runting et al. 2017). Loss of coastal habitats to rising seas levels can have negative consequences for many shorebird populations (Iwamura et al. 2013; Clausen and Clausen 2014). However, Clausen and Clausen (2014) suggest that some gains in coastal habitats affected through sea level rise could be achieved through managing shoreline retreat (e.g. deconstruction of built structures). Whether this option is possible in southeast Queensland is debatable (see Abel et al. 2011), as the coastal urban development profile has already transformed much of the coastal environment. If anything, built infrastructure along the coast is likely to increase further (Taylor et al. 2014), thereby exacerbating the loss of natural coastal environments. Another factor related to both sea level rise and temperature is the availability of prey for shorebirds. For example, it is predicted that climate change will affect the seasonality of invertebrate assemblages (i.e. spawning and recruitment) that shorebirds rely on for food (Stutzman and Fontaine 2015). The combination of these factors suggests that climate change is likely to have a deleterious effect on shorebirds in the long-term in general, including in Gold Coast waterways. However, as noted by Stutzman and Fontaine (2015), '*climate change is spatially and temporally heterogeneous, which makes predicting ecological consequences difficult and designing effective mitigation strategies challenging*'.

Frequency and extent

Virtually all intertidal areas will be subject to sea level rise in the long-term and the associated impacts, including changes to ecological processes. The impacts to shorebirds in these areas are deemed negligible in the short-term as sea level rise in Moreton Bay since 2000 is in the order of 2.36 mm / year (Lovelock et al. 2011), but will require review in the medium- to long-term. See threat assessment in Table 6.

6. Management measures for Gold Coast waterways shorebird populations

The following sections outline management measures that may be suitable in addressing the identified threatening processes. These are summarised in Table 6 below before being discussed in greater detail. It should be remembered that Gold Coast Waterways Authority (GCWA) has responsibilities in regard to maintaining navigational access in Gold Coast waterways and as such, the measures outlined below need to be considered in this context and also in context of the other entities that have various shorebird related management responsibilities in and around Gold Coast waterways, including:

- City of Gold Coast
- Department of Environment and Heritage Protection
- Department of National Parks, Sport and Racing.

Table 6: Management measures for threatening processes affecting shorebirds in Gold Coast waterways.

Threatening process	Management measure
Dredging and associated dredged sediment management[5]	• Maintain existing navigation channel dimensions in areas actively used by shorebirds. • Avoid dredging sand banks, bars and islands actively used by shorebirds (without providing a suitable alternative where/when feasible, appropriate and/or possible). • Avoid dredging/nourishing activities that may negatively impact migratory shorebirds at specific locations actively used for roosting or feeding during the austral Spring/Summer (September–April). • Assess the potential of using material dredged from the navigation channels to create new 'novel', or extend existing, habitat areas (e.g. new sand banks, bars or islands, nourish existing shoreline areas – especially those experiencing accelerated rates of erosion) to support shorebird species where/when feasible, appropriate and/or possible.[6]
Motorised recreation activities	• Investigate the feasibility of amending speed limits in close proximity to shorebird foraging and roosting sites where necessary (e.g. 'Go Slow' zones within 100 m of specified areas). Also need to consider whether such measures need to be applied permanently or only at specific times (e.g. May–June, summer months, daylight hours, etc.). • Investigate the feasibility of introducing management measures that aim to limit access, such as 'no landing' zones (e.g. constructed post barrier systems) at specific beaches with high

[5] Various terms are used to describe the management of the sediment that has been removed during the dredging process (*e.g.* '*nourishment*', '*foreshore nourishment*', '*dredge spoil disposal*', '*dredged sediment re-use*', *etc*.).

[6] A project is currently being undertaken as part of the GCWA's broader Scientific Research and Management Strategy (SRMS) and accompanying Scientific Research and Management Program (SRMP) to determine potential options and methods for the beneficial re-use of dredged sediment, with a focus on re-use to enhance resilience, improve seagrass habitat, secure shorebird habitat and ensure long term waterways sustainability (T Byrnes, GCWA, pers. comm.).

Threatening process	Management measure
	shorebird activity where necessary. Also need to consider whether such measures need to be applied permanently or only at specific times (e.g. May–June, summer months, daylight hours, etc.).
Non-motorised recreation activities	• Increase education and engagement with Gold Coast waterways users about the significance of shorebirds and how to minimise disturbing them. • Consider introducing specific management measures aimed at limiting shorebird disturbance (e.g. the establishment of 'dog on-leash areas' for sandbars and sand islands, both inside and outside the MBMP) where necessary in specific areas where shorebirds forage and roost. Also need to consider whether such measures need to be applied permanently or only at specific times (e.g. May–June, summer months, daylight hours, etc.). • Consider temporary closures for important shorebird habitats through the use of education programs, barriers and wardens (see Weston et al. 2012b).
Climate change (including habitat creation / offsetting)	• Investigate the feasibility of (i) reviewing the modelling of changes to intertidal habitats as a result of sea level rise and (ii) undertaking further fine-scale modelling if required • Investigate the viability of creating additional shorebird habitat that will withstand potential climate-change related impacts (e.g. incremental storm surge)[6] • Ensure any habitat creation is done with the correct/best available information about habitat characteristics and requirements for invertebrates and shorebirds[6].

6.1 Dredging

The Gold Coast Waterways Authority (GCWA) has an ongoing responsibility under the *Gold Coast Waterways Authority Act 2012* (Part 3, Division 2, Section 12) to improve or maintain navigational access to Gold Coast waterways. In giving effect to this function, GCWA may dredge areas as required to maintain navigational access channels. As such, the measures outlined in Table 6 and below need to be considered in this context.

Dredging of existing navigation channels to ensure Gold Coast waterways are safe and navigable can result in the alteration of the hydrology of the localised area. Dredging of navigation channels and the associated changes in tidal flows have been identified as factors that can contribute to changes in wetland habitats, where saltmarshes convert to mangroves (Brereton and Taylor-Wood 2010). Therefore, a more detailed assessment of the environmental impacts may be required. In areas that are dredged, any immediate disturbance dredging may have on shorebirds can be minimised by conducting these activities in winter (May-August). At this time, resident shorebirds are not nesting, and thus are less vulnerable to such disturbance. Additionally, migratory species are not usually present in Gold Coast waterways at this time (except possible over-wintering individuals). From the perspective of protecting shorebirds, this would be the least hazardous season to undertake dredging where it is required. The potential to conduct dredging at times when disturbance to shorebirds will be reduced may be feasible given the rotation times required to dredge certain sites. For example, a report prepared in 1998 stated that the Labrador Channel area to the west of Wavebreak Island only required dredging once in every 10 years (GCHA 1998). However, caution should be exercised in this regard as there are myriad elements interacting in this environment and changes in dredging requirements may occur at much shorter timeframes in highly dynamic environments, or potentially even greater timeframes in highly stable environments. Additionally, changes in the size of vessels using these waterways, particularly in regard to their draft (*i.e.* the distance from the waterline to the bottom of the boat), in the 19 years that have passed since this report was prepared, may potentially require an amended dredging regime.

6.2 Recreation disturbance

Managing recreation in natural environments is essential to maintain the recreational opportunity of these areas while ensuring the long-term sustainability of environmental values, including shorebird populations and their habitats. The preceding review has highlighted that anthropogenic disturbance is one of the key threats affecting shorebird populations (refer to section 5.2). Therefore, a central management measure arising from this review in relation to any form of recreational activity, is that disturbance to shorebirds should be minimised.

However, the social context of these human-wildlife interactions increases the complexity of management practice. Given the potential sensitivities around some activities and their

potential impacts on shorebirds (e.g. dog walking on beaches), a strategic adaptive management approach may be useful in guiding management action. The overlapping jurisdictional responsibilities (i.e. GCWA, City of Gold Coast, Department of Environment and Heritage Protection, Department of National Parks, Sport and Racing, Department of Natural Resources and Mines, Maritime Safety Queensland) associated with managing the environments associated with the Gold Coast waterways highlights the potential benefits of a more collaborative approach in this context. Such collaboration would also need to consider input from the Department of Agriculture and Fisheries (Queensland Boating and Fisheries Patrol) and Queensland Police Service (Gold Coast Water Police) as they are the Queensland state government entities responsible for on-water enforcement. This approach would provide an opportunity for wider communication and consultation on issues related to shorebird disturbance as well as any measures proposed to address these. Here the many stakeholder perspectives and values could be used to help inform and assist in the decision-making process by helping to identify common objectives.

The conservation value of shorebirds and their habitats in Gold Coast waterways is recognised internationally as the waterways form part of the larger Moreton Bay Ramsar Site (Bamford et al. 2008). Furthermore, the listing of eight species as threatened species (see section 3.4 and 4 for detail), as well as the listing of migratory species under the EPBC Act (see section 2.2 and 3.4 for detail) highlights their importance as matters of national environmental significance. This importance warrants attention to managing the potential impacts that may occur in specific heavily exploited recreational areas of Gold Coast waterways (e.g. Wavebreak Island, Jumpinpin, see City of Gold Coast 2013) on these species. As such, management of both motorised and non-motorised recreation may be required. However, as previously mentioned, it is highly unlikely that responsibility for implementing any recreational management action will be limited to a single agency in relation to the Gold Coast waterways. Boat traffic management to minimise disturbance to shorebirds could include enforcement of current speed limits (see comments above in regard to Queensland Boating and Fisheries Patrol and Gold Coast Water Police) or an investigation into the feasibility of amending speed limits in close proximity to important shorebird habitat areas (e.g. 'Go Slow' zones within 100 m of specified areas). Other considerations may also include potential restrictions on the landing / mooring of boats at specific key shorebird sites. Any of these potential options also need to consider whether such measures need to be applied permanently or only at specific times (e.g. May–June, summer months, daylight hours, etc.). The issue of speed limits in Gold Coast waterways is complex, as highlighted by a recent review (GCWA 2014). However, despite this review identifying a number of issues, shorebirds and the potential disturbance by vessels was not addressed. In a more recent report (GCWA 2016), the need to maintain an existing six knot speed zone adjacent a shorebird feeding area was identified during the community consultation phase of a program to develop a speed and behaviour management strategy for Gold Coast waterways. One of the major issues in regard to speed limits in this context

is that they are set under legislation that focusses on marine safety (*i.e.* the *Transport Operations (Marine Safety) Act 1994* and its subordinate Regulation 2016) in contrast to legislation containing provisions that allow for speed limits to be set based on environmental considerations (*e.g.* 'Go slow areas for turtles and dugong' and 'Go slow areas for natural values' in the *Marine Parks (Moreton Bay) Zoning Plan 2008*).

Regulated access to some areas at certain times of year is often considered the most effective way to mitigate negative impacts of non-motorised disturbance to shorebirds (Pfister et al. 1992; van Polanen Petel and Bunce 2008). While the presence of wardens generated similar levels of compliance with other forms of temporary beach closures (e.g. signs, fences) to protected Hooded Plovers (*Thinornis rubricollis*), having wardens present resulted in the lowest probability that eggs would be crushed (Weston et al. 2012b). Given that general compliance was similar across all closure types (Weston et al. 2012b), the use of wardens may only be necessary at certain times / locations (typically the breeding season for resident species such as the Beach Stone-curlew) or for certain species (e.g. aggregation of threatened species such as Eastern Curlew) given the potential costs involved in having wardens present.

Communication and education are a means to manage and promote environmentally responsible actions (Monroe 2003; Weinstein et al. 2015). However, as Weinstein et al. (2015) show pro-environment action is greater when people are presented with connecting communication/education messages (i.e. positive) as opposed to those that portray threatening messages. The development and circulation of information fact sheets about shorebirds may contribute to raising this general awareness of shorebirds in Gold Coast waterways. For example, Sunshine Coast Council has educational tools to increase awareness about responsible dog walking in coastal habitats (Sunshine Coast Council 2016a, b). However, in some cases, unrealistic views about one's own pet can result in non-receptiveness to diplomatic messages about disturbance to shorebirds (Miller et al. 2014).

For certain sites in Gold Coast waterways (e.g. at Jumpinpin at the northern tip of South Stradbroke Island) there is justification for strategic educational and enforcement activities such as temporary site closures (i.e. Spring / Summer days when high tide is approx. midday) as this corresponds with peak recreational usage (J. Searle, CoGC, pers. comm.). Horseshoe Bay to the west of the Jumpinpin area on South Stradbroke Island (refer Figure F29 for detail) may also merit additional management action, especially given that it falls within the MBMP and shorebirds are likely to have been a key element of the biodiversity supporting its designation as a protected area in the first place. There are currently multiple local and state government agencies with varying levels of responsibility over this area that potentially confounds any strategic ownership of the shorebird disturbance issues, and the focus group conducted for this study confirmed that this site requires further collaborative management action. However, given that it falls within the MBMP and the potential role that shorebirds played in its initial designation, it would seem

logical to assume that those responsible for its management (*e.g.* the Department of National Parks, Sport and Racing (DNPSR), Queensland Parks and Wildlife Service (QPWS)) would want to take the lead role for such action.

Promotion of the City's off-leash dog exercise areas (City of Gold Coast 2015) as an alternative to using sand islands and sand banks in the Southport Broadwater and Jumpinpin could be very effective. This would require collaboration with the relevant CoGC department to create an awareness strategy around the location and benefits of these areas for residents and their pets. Off-leash dog exercise areas represent a good alternative, as they are already known to be popular. The ability of these sites to support increased levels of use requires investigation to determine whether future increase in use will be sustainable. Given the clearly negative relationship between dogs and shorebirds (refer to section 5.2), strategies to increase the viability of shorebird habitats are needed. Stigner et al. (2016) have recently shown that strategic zonation of permitted activities may provide a mechanism to achieve shorebird conservation objectives while minimising costs to recreational opportunity. However, their analysis was completed for northern areas in Moreton Bay (Deception Bay to Wynnum) and a similar analysis would be required to assess these zoning trade-offs for Gold Coast waterways.

6.3 Adapting to climate change via habitat creation / offsets

There have been mixed results demonstrating the utility of re-created intertidal habitat for shorebirds. For example, constructed habitats may provide alternative sites that are utilised by shorebirds along developed coastlines (Harding et al. 1999; Kitchen and Young 2007; Scarton et al. 2013). However, while shorebirds may use these sites they do not necessarily offset population declines associated with the loss of the original habitat (Burton et al. 1996). Although as alluded to by Burton et al. (1996), this may be related to the design of the site and how well it mimics the requirements of the original habitat. The need for compensatory sites for shorebirds may be in response to the loss of existing habitat through development (see Kitchen and Young 2007), but may also be a consideration under future sea level rise scenarios (Mander et al. 2007; Scarton and Montanari 2015). Requirements for such interventions are likely to change from one location to the next, making extrapolation to the Gold Coast waterways challenging for recommending specific strategies in designing re-created shorebird habitat. At a broad level, positive ecological outcomes from offset and nourishment activities depend on the physico-chemical characteristics of the material deposited (Peterson et al. 2006; Finn et al. 2008). This is because shorebirds are known to prefer certain sediment types for foraging (Finn et al. 2007; Pandiyan and Asokan 2016), and that substrate resistance also affects prey availability (Finn et al. 2008). Therefore, the decision of where to place dredge spoil with the desired outcome of habitat creation requires extensive research into the local conditions of the source and deposition site for the sand or sediment (refer previous comments regarding GCWA's current SRMS/SRMP

sediment re-use project). Where nourishment is a method of offsetting for removal of habitat from other sites, extreme caution is required to ensure high quality habitat is not offset with low quality re-created habitat (Atkinson 2003). Where compensatory habitat is provided, monitoring will be required to ensure that these meet desired objectives in providing long-term ecological outcomes, including those for shorebirds (Zedler and Callaway 2000). In such situations where this option is viewed as a viable management measure, care needs to be taken to ensure that any newly created habitat is representative of the habitat that it is designed to either extend or replace.

Where intertidal habitat is created with comprehensive consideration of critical factors (e.g. sediment particle size, tidal flow), there is potential for this to act as important refuge habitat in a changing climate (Scarton and Montanari 2015). The timing of providing compensatory habitats may also be a factor (e.g. provision of novel sites before the peak migration period). Completing these activities during low-use periods for shorebirds (e.g. over winter) would minimise potential impacts on shorebirds but also allow for spring-associated recruitment of invertebrates and other biological processes (Peterson and Bishop 2005). Furthermore, any re-created habitat (foraging or roosting) should be protected as much as possible from other key threatening processes identified in this report (e.g. human disturbance) (Milton et al. 2011).

7. Conclusions and research recommendations

This review of existing knowledge about shorebird habitats, distribution and threats in Gold Coast waterways identified that information is lacking in some key areas. For example, the approach to shorebird monitoring has not been comprehensive throughout the waterways and there was no existing shorebird habitat assessment that permitted the differentiation of habitat use by shorebirds. There remains a need to identify key foraging and nesting sites within Gold Coast waterways. The review of likely threats followed a rapid assessment where the potential risk from such threats was assessed using focus group evaluations and ensuing discussions. Consequently, this study did not quantify threats empirically, or their likelihood of occurrence, within Gold Coast waterways.

Conclusions

The review identified important shorebird populations and habitats within Gold Coast waterways. Thirty shorebird species are found in Gold Coast waterways: eight species are listed as threatened under the EPBC Act., twenty-two species are migratory and eight species are resident (see Table 2 for details). Shorebirds were recorded from 40 separate locations across six broad regional areas of Gold Coast waterways (refer Figure 6 and Table D11 for details). Importantly, the abundance of five species (i.e. Eastern Curlew, Double-banded Plover, Bar-tailed Godwit, Greater Sand Plover and Whimbrel), exceeded one of the threshold criteria required for nationally important habitats for migratory shorebirds (i.e. supports 0.1% of the flyway population of a single species of migratory shorebird, see Table 4) at three of the six broad regional areas (i.e. Southport Wavebreak, Jumpinpin and Southern South Stradbroke) (see Table 4 and Figure 6 for details). This highlights the fact that there are important shorebird habitats in Gold Coast waterways and that these need to be considered as part of the decision making process to ensure the persistence of the species that they support.

The Gold Coast waterways form part of a larger shorebird area of international significance (i.e. Moreton Bay, see Bamford et al. 2008). The boundary of the Pumicestone Passage Shorebird Area (refer to Figure 2), used by BirdLife Australia as part of its Shorebirds 2020 monitoring program (refer to Figure 1), extends from the Nerang River bridge in the south to Bribie Island in the north and encompasses shorebirds habitats of the greater Moreton Bay region. Portions of this region are also recognised as Ramsar wetlands of international importance (see Figure G34 for details). The relative importance of the Gold Coast waterways needs to be considered in light of this regional and national context, as parts of the Gold Coast waterways, particularly those north of the Gold coast seaway, fall within the Moreton Bay Marine Park and Ramsar site (refer Appendix G for detail).

The Moreton Bay region is one of 118 internationally significant shorebird sites within Australia, but one of only 15 others in Queensland (see Figure 1 and Bamford et al. 2008 for information). Eight shorebird species in Moreton Bay meet the threshold criteria for listing

as sites of international significance, as outlined in Bamford et al. (2008) (i.e. Terek Sandpiper, Whimbrel, Grey-tailed Tattler, Pacific Golden Plover, Bar-tailed Godwit, Curlew Sandpiper, Lesser Sand Plover and Eastern Curlew). Three of these species exceed the thresholds for national significance within Gold Coast waterways areas that are outside the Moreton Bay Marine Park, notably the Southport Wavebreak broad regional area (i.e. Eastern Curlew, Bar-tailed Godwit and Whimbrel). More recently the Shorebird 2020 Program (BirdLife Australia 2016a) has identified more than 435 shorebird areas throughout Australia (see Figure 1), of which 106 (24%) fall within Queensland. The 'Pumicestone Passage' shorebird area is the largest site recorded from southeast Queensland (at approximately 82 km^2), with smaller sites identified at Tallebudgera Creek on the southern Gold Coast, Eagleby Sewage Works, Ewan Maddock Dam, Maroochy River and Noosa (BirdLife Australia 2016b). While the number of sites and abundance of shorebird habitats within Queensland, and the Shorebirds 2020 'Pumicestone Passage' region (including in Gold coast waterways) in particular, may not be as high as other areas around Australia, they are the highest in Queensland during both summer and winter seasons (Scholten et al. 2012). As shorebird population trends are heterogeneous across Australia (Clemens et al. 2016), the importance of managing a suite of sites across multiple spatial scales, particularly at non-breeding sites within the EAAF, needs to be considered (Szabo et al. 2016).

Research Recommendations

This project was based on a review of existing information on shorebird habitats, distribution and threats in Gold Coast waterways. As such, no additional survey or monitoring data was generated to validate shorebird records or to identify new shorebird habitat sites. Similarly, threats were not quantified empirically, nor was their likelihood of occurrence determined. To help address these issues, additional survey effort and threat assessment based on scientifically rigorous research methodology, would provide a more comprehensive understanding of shorebird habitats, distribution and threats in Gold Coast waterways.

For example, the identification of important habitat is based primarily upon key species attaining specific threshold levels of abundance, rather than the key physical and environmental (and potentially even social, given the level of anthropogenic interaction with the natural environment globally) attributes that would generally be used to define and describe habitat *per se* (*i.e.* the natural environment of an organism). Management of species based on abundance patterns without identifying causal factors for variation may prove problematic. In this regard, and relative to the key species and areas identified in this report, it would be extremely beneficial to identify key habitat features (particularly as they relate to species-specific ecological requirements), such as:

- Sediment/soil type
- Flora and fauna

- Hydrological regime
- Temperature and rainfall patterns
- Food sources (*e.g.* prey type, availability, requirements)
- Predators
- Topography
- Spatial extent (*e.g.* GIS mapping polygons for each of the areas)

Additionally, the nature and extent of any potential fisheries related impacts on shorebirds and their prey in Gold Coast waterways has not been adequately determined. For example, information such as the target species, number of participants and estimated annual catch volumes for the following groups:

- licenced commercial bait gatherers/collectors (e.g. worms, yabbies, pippies, etc.)
- licenced commercial fisher (e.g. trawlers, line fishers, etc.)
- licenced recreational fishing charter operators (e.g. sport fishing, crabbing, etc.)
- recreational fishers
- recreational bait gatherers/collectors (e.g. worms, yabbies, pippies, etc.).

Empirical analysis of the sensitivity of shorebirds habitats to threats in Gold Coast waterways would provide greater detail and spatial resolution of potential site-specific impacts. Quantitative assessment of threats and habitats in Gold Coast waterways through primary data collection (shorebirds and habitat classification), predictive modelling and ground-truthing to validate model predictions would also be an important aspect of any further research (especially in regard to spatial representation of identified key habitat areas). This would provide valuable information to decision makers to help identify where, and ideally when, threatening processes may intersect with important shorebird habitat areas. This is an important consideration when suggesting additional or amended management actions (e.g. increased enforcement of, and/or changes to, speed limits) that are not currently supported by evidence that justifies the suggested approach.

Habitat sensitivity models and shorebird population trajectories could also be used to assess ecosystem level responses to various external perturbations should this be required. The versatility of any predictive modelling is dependent upon robust input data parameters. Available shorebird data (locations and abundance) as well as habitat mapping may therefore need to be reviewed to determine whether additional monitoring and mapping effort is required. Banks and Skilleter (2007) have highlighted the importance of fine-scale habitat data in coastal conservation planning, but it appears that these data are not yet available for the intertidal habitats of the Gold Coast waterways. Each species has specific habitat requirements for foraging, roosting and nesting, therefore habitat mapping would need to be conducted at a scale that accounts for these requirements.

In conjunction with activities envisaged for any potential further research related to shorebird habitats, additional surveys of under-examined areas in Gold Coast waterways

need to be completed. In particular, habitats identified by the focus group deemed worthy of additional systematic surveys should be targeted (e.g. areas around the entrance to and lower reaches of the Coomera River and southern Moreton Bay islands in the north-western reaches of the Gold Coast waterways). However, they would still require comparative surveys from existing sites to determine factors affecting the occupancy and abundance of shorebirds among these locations or to more accurately determine the species richness of the three broad regional areas mentioned in Section 3.2 that were under-represented in survey effort (i.e. Central West, Southern South Stradbroke and South Gold Coast). Again, any additional data collection in regard to shorebird habitats, distribution and threats needs to be firmly based on scientifically rigorous research methodology.

It may be appropriate to engage other stakeholders to initiate this (e.g. City of Gold Coast, Queensland Wader Study Group, Department of Environment and Heritage Protection, Department of National Parks, Sport and Racing), with a collaborative approach to ensure adequate data are obtained and the financial and resource burden is shared appropriately. Quantifying anthropogenic disturbance (e.g. boats, personal watercraft, dogs, and pedestrians) at these shorebird monitoring sites would also enable the prioritisation of sites to target for strategic management action (e.g. education programs).

Further research may also be required to quantify the effects of specific management activities (e.g. dredging) in Gold Coast waterways. Dredging may affect shorebirds and their habitats (refer to section 5.1). Regular monitoring (annually or once every two or three years) of key natural resources, including important shorebird habitats, to build a more complete database of values and condition over time has been identified as an important part of the environmental management framework for managing the sand resources in Gold Coast waterways (BMT WBM 2015). The creation of dredge islands could also provide new habitat for shorebirds (Scarton et al. 2013). Again, GCWA's SRMS/SRMP project on the beneficial re-use of dredged sediment may provide some valuable information in this regard. While dredging was not considered to be a high threat to shorebirds in Gold Coast waterways, any proposed activities that could impact on migratory shorebirds and their habitats may require specific impact assessment.

8. Summary

The key findings from this report are summarised in the list below and should be considered in the broader context of the preceding text.

- 30 shorebird species were identified at 40 sites within Gold Coast waterways:
    - 8 are resident species and 22 are migratory species
    - 8[7] species are listed as threatened—
        - 5 species 'Critically Endangered'
        - 1 species 'Endangered'
        - 3 species 'Vulnerable'
    - 5 species met the criteria for recognising areas of Gold Coast waterways as nationally important habitat for migratory shorebirds.
- Based on the 6 broad regional shorebird areas of Gold Coast waterways:
    - 2 were identified as important for threatened species—
        - Jumpinpin (3 species)
        - Southport Wavebreak (2 species)
    - 3 met the criteria for recognition as nationally important habitat for migratory shorebirds—
        - Jumpinpin (4 species)
        - Southport Wavebreak (3 species)
        - Southern South Stradbroke (1 species)
    - 1 is not within the boundary of a protected area, such as the Moreton Bay Marine Park (*i.e.* Southport Wavebreak).
- Monitoring data contained insufficient detail to:
    - discriminate among foraging, roosting or nesting sites and identify those that were important for shorebirds
    - spatially identify the geographical extent of important habitat areas to enable their mapping.
- Information on the nature and extent of many of the potential threats to shorebirds in Gold Coast waterways is extremely limited.
- The identified information gaps should be addressed through additional research, such as:
    - validation of existing data and potential identification of additional sites and/or species
    - quantifying the spatial extent of key foraging, nesting and roosting sites
    - assessing the nature and extent of potential threats, as well as responses by shorebirds.

[7] The Bar-tailed Godwit has two listed subspecies, *i.e.* the Western Alaskan Bar-tailed Godwit (Vulnerable) and the Northern Siberian Bar-tailed Godwit (Critically Endangered).

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11. Appendices

Appendix A: Summary of key provisions in international agreements related to the recognition and conservation of migratory shorebirds

Table A7: Summary of key provisions in international agreements related to the recognition and conservation of migratory shorebirds

Bonn Convention – Convention on the Conservation of Migratory Species of Wild Animals (1991)
Article II, 1. – "The Parties acknowledge the importance of migratory species being conserved and of Range States agreeing to take action to this end whenever possible and appropriate…" Article II, 2. – "The Parties acknowledge the need to take action to avoid any migratory species becoming endangered." Article II, 3a. – "should promote, co-operate in and support research relating to migratory species;" Article II, 3b. – "shall endeavour to provide immediate protection for migratory species included in Appendix I:" Article II, 3c. – "shall endeavour to conclude Agreements covering the conservation and management of migratory species included in Appendix II." Article III, 4a. – "to conserve and, where feasible and appropriate, restore those habitats of the species which are of importance in removing the species from danger of extinction;" Article III, 4c. – "to the extent feasible and appropriate, to prevent, reduce or control factors that are endangering or are likely to further endanger the species, including strictly controlling the introduction of, or controlling or eliminating, already introduced exotic species."
JAMBA – Japan-Australia Migratory Bird Agreement (1974)
Article III, 1. – "Each Government shall take special protective measures, as appropriate, for the preservation of species or subspecies of birds which are in danger of extinction." Article V – "Each Government shall endeavour to establish sanctuaries and other facilities for the management and protection of migratory birds and birds in danger of extinction

and also of their environment."

Article VI – "Each Government shall endeavour to take appropriate measures to preserve and enhance the environment of birds protected under the provisions of this Agreement. In particular, it shall:

(a) seek means to prevent damage to such birds and their environment;

(b) endeavour to take such measures as may be necessary to control the importation of animals and plants which it determines to be hazardous to the preservation of such birds;

(c) endeavour to take such measures as may be necessary to control the introduction of animals and plants which could disturb the ecosystems of unique island environments."

CAMBA – China-Australia Migratory Bird Agreement (1986)

Article IV – "Each Contracting Party shall endeavour, in accordance with its laws and regulations in force, to:

(a) establish sanctuaries and other facilities for the management and protection of migratory birds and also of their environment.

(b) take appropriate measures to preserve and enhance the environment of migratory birds. In particular, each Contracting Party shall:

(i) seek means to prevent damage to migratory birds and their environment, and

(ii) endeavour to take such measures as may be necessary to restrict or prevent the importation and introduction of animals and plants which are hazardous to the preservation of migratory birds and their environment."

ROKAMBA – Republic of Korea-Australia Migratory Bird Agreement (2007)

Article IV – "Each Party shall endeavour to manage and conserve the habitat of migratory birds through activities such as the designation of conservation areas in its territory."

Article V – "Each Party shall endeavour to take the appropriate measures to conserve and improve the environment of birds protected under Article 1 of this Agreement. In particular, it shall:

(a) seek means to prevent damage to such birds and their environment;"

(b) endeavour to take measures to control the impact of invasive animals and plants on the conservation of such birds and their environment; and"

(c) endeavour to participate in regional cooperative activities for the conservation of migratory birds in the Asia-Pacific region"

In addition to these provisions for the conservation and management of shorebirds and their habitats all three bilateral agreements also make provisions for research collaboration as typically designated by statements to the effect of:

Each Government/Contracting Party/Party shall encourage…..
"…..the exchange of data and publications regarding research on migratory birds"
"…..the formulation of joint research programs on migratory birds"
"…..the conservation of migratory birds".

EAAFP – East Asian-Australasian Flyway Partnership (2006) – see Appendix I

The EAAFP is an informal and voluntary partnership initiative aimed at the protection of migratory waterbirds, their habitats and local communities that depend on them (see http://www.eaaflyway.net). The goal is to recognise and conserve migratory waterbirds and their habitats within the East Asian – Australasian Flyway. To achieve this goal the EAAFP has developed an Implementation Strategy (see http://www.eaaflyway.net/about/the-partnership/strategies/implementation-strategy/).

As part of the Implementation Strategy the initiating EAAF Partners agreed on the following goal and five objectives for the Partnership:

Goal:

Migratory waterbirds and their habitats in the East Asian-Australasian Flyway are recognised and conserved for the benefit of people and biodiversity.

Objectives

1. Develop the Flyway Network of sites of international importance for the conservation of migratory waterbirds, building on the achievements of the Asia-Pacific Migratory Waterbird Conservation Strategy networks.
2. Enhance communication, education and public awareness of the values of migratory waterbirds and their habitats.
3. Enhance flyway research and monitoring activities, build knowledge and promote exchange of information on waterbirds and their habitats.
4. Build the habitat and waterbird management capacity of natural resource managers, decision makers and local stakeholders.
5. Develop, especially for priority species and habitats, flyway wide approaches to enhance the conservation status of migratory waterbirds.

Appendix B: Internationally important sites and migratory shorebirds in Australia.

Table B8: List of internationally important sites with the number of species for which these are important by period (Source: Bamford et al. 2008).

Site Code	Site Name	State	Lat.	Long.	Total Species	SM	NB	NM	B
102	Roebuck Bay	WA	-18.07	122.33	18	8	12	5	2
32	Eighty Mile Beach	WA	-19.23	121.42	16	14	10		
107	SE Gulf of Carpentaria	QLD	-17.47	140.76	16	2	16	2	
28	Chambers Bay	NT	-12.26	131.63	8	4		1	
84	**Moreton Bay**	**QLD**	**-27.25**	**153.33**	**8**	**3**	**8**	**4**	**1**
46	Great Sandy Strait	QLD	-25.67	152.93	7	1	7		
30	Corner Inlet	VIC	-38.73	146.22	6	2	6		
36	Eastern Port Phillip Bay	VIC	-38.00	144.60	6	2	5	1	2
49	Hunter Estuary	NSW	-32.84	151.78	6	1	6	1	
83	Milingimbi coast	NT	-12.00	135.00	6		1	1	1
96	Port McArthur	NT	-15.78	136.67	6	3			
110	Shoalwater Bay and Broad Sound	QLD	-22.12	150.04	6		6		
6	Ashmore Reef	WA	-12.23	123.08	5	2	5		
27	Ceduna Bays	NT	-32.28	133.68	5		5		
42	Fog Bay	NT	-12.87	130.32	5		2		1
52	Kakadu National Park	NT	-12.28	132.46	5	1	2	2	1
94	Port Hedland Saltworks	WA	-20.24	118.94	5	2	4		1
108	Shallow Inlet/Sandy Point	VIC	-38.80	146.15	5	1	5		
120	Western Port Bay	VIC	-38.42	145.33	5	2	4		
15	Boullanger Bay/Robbins Passage	TAS	-40.75	144.87	4		4		
112	The Coorong & Coorong National Park	SA	-35.74	139.22	4		3		2
3	Anderson Inlet	VIC	-38.65	145.79	3		3		
8	Barrow Island	WA	-20.75	115.39	3	3	3	1	
53	Kangaroo Island	SA	-35.71	137.62	3		3		
64	Lake George	SA	-37.40	140.00	3		2		1
70	Lake MacLeod	WA	-24.05	113.59	3	3			
89	Ocean Grove to Barwon Heads	VIC	-38.27	144.51	3		2	1	
91	Peel-Harvey system	WA	-32.58	115.73	3		3		
82	Pioneer River – McEwan's Beach	QLD	-21.20	149.20	3		3		
104	Roper River area	NT	-14.72	135.42	3		3		
2	Albany Harbours	WA	-35.05	117.88	2		2		
14	Boucat Bay	NT	-12.02	134.50	2			2	
17	Buckingham Bay	NT	-12.21	135.68	2			1	1
19	Bynoe Harbour	NT	-12.67	130.55	2	2			
23	Cape Bowling Green	QLD	-19.30	147.38	2	1	1		
31	Dampier Saltworks	WA	-20.73	116.73	2	1	1		
45	Gippsland Lakes	VIC	-38.00	147.62	2	1	2		

Site Code	Site Name	State	Lat.	Long.	Total Species	SM	NB	NM	B
56	Lacepede Islands	WA	-16.85	122.10	2	2	1		
60	Lake Cooloongup	WA	-32.29	115.79	2		2		
66	Lake Gregory	WA	-20.22	127.47	2		2		
69	Lake Machattie	SA	-24.80	139.88	2	2			
72	Lake Murdeduke	VIC	-38.18	143.90	2		2		
75	Lake Sylvester	NT	-18.83	135.67	2		1		1
77	Lake Yamma Yamma	QLD	-26.33	141.42	2	2			
79	Logan Lagoon, Flinders Island	TAS	-40.17	148.28	2		2		
90	Parry floodplain, Wyndham	WA	-15.55	128.25	2		1	1	
47	Penrice Saltfields	SA	-34.70	138.50	2		3		
97	Port Pirie coast	SA	-33.26	137.80	2		2		
99	Port Wakefield - Webb Beach	SA	-34.33	138.21	2		2		
101	Rivoli Bay	SA	-37.55	140.10	2	1		1	1
103	Roebuck Plains	WA	-18.00	122.50	2		2		
118	Vasse Wonnerup Estuary	WA	-33.63	115.42	2		2		
1	Adelaide River Floodplain	NT	-12.25	131.27	1				1
4	Anna Plains	WA	-19.21	121.50	1		1		
5	Anson Bay, south	NT	-13.52	129.97	1				
7	Astrelba Downs National Park	QLD	-24.04	140.56	1		1		
9	Beachport National Park	SA	-37.45	139.97	1		1		
11	Blanche Point	TAS	-41.28	148.33	1		1		
12	Blue Mud Bay	NT	-13.31	136.16	1	1			
16	Brown Bay (Green Point)	SA	-38.05	140.87	1	1		1	
18	Burdekin River delta	QLD	-19.67	147.55	1		1		
20	Cairns Foreshore	QLD	-16.92	145.77	1		1		
21	Camballin	WA	-17.95	124.35	1				1
22	Canunda National Park	SA	-37.75	140.30	1	1	1		
24	Carpenter Rocks, Pelican Point	SA	-37.93	140.42	1		1	1	
26	Cedar Hill and Hexham Swamp	NSW	-32.87	151.62	1		1		
29	Coffin Bay National Park	SA	-34.52	135.30	1	1	1	1	
32	Derby Sewage Ponds	WA	-17.33	123.65	1	1			
33	Derwent Estuary - Pittwater	TAS	-42.83	147.33	1		1		
411	Diamantina floodplain, Birdsville-Betoota	QLD	-25.70	140.27	1		1		
34	Discovery Bay Conservation Park	VIC	-38.19	141.27	1		1		
37	Edithvale-Seaford	VIC	-38.09	145.14	1		1		
39	Elcho Island	NT	-11.84	135.88	1			1	
40	Esperance Bay	WA	-33.87	121.90	1		1		
41	Fivebough Swamp	NSW	-34.53	146.43	1		1		
43	Forrestdale Lake Nature Reserve	WA	-32.16	115.94	1		1		
44	Garden Island	WA	-32.21	115.68	1		1		
50	Islands off False Orford Ness	QLD	-11.30	143.00	1		1		

Site Code	Site Name	State	Lat.	Long.	Total Species	SM	NB	NM	B
51	Joseph Bonaparte Bay (Turtle Pt)	NT	-14.85	129.25	1				1
54	King Island	VIC	-39.87	143.92	1		1		
12	Kununurra irrigation area	WA	-15.72	128.73	1		1		
57	Lake Bathurst	NSW	-35.05	149.69	1		1		
58	Lake Buloke	VIC	-36.27	142.97	1		1		
59	Lake Cawndilla	NSW	-32.48	142.23	1		1		
62	Lake Eyre	SA	-28.50	137.25	1		1		
63	Lake Finniss	NT	-12.36	131.48	1	1			
65	Lake Gol Gol	NSW	-34.13	142.23	1		1		
67	Lake Hawdon south	SA	-37.22	139.94	1		1		
68	Lake Hindmarsh	VIC	-36.05	141.91	1				1
71	Lake Martin	VIC	-38.07	143.57	1		1		
73	Lake Numalla	QLD	-28.73	144.32	1		1	1	
74	Lake Preston	WA	-32.97	115.69	1		1		
76	Lake Tutchewop, Kerang	VIC	-35.51	143.75	1		1		
78	Limmen River mouth	NT	-15.11	135.71	1				1
80	Lough Calvert	VIC	-38.17	143.69	1		1		
81	Low Island, Arnhem Bay	NT	-12.32	136.17	1		1		
85	Nericon Swamp	NSW	-34.22	146.04	1		1		
86	Notch Point	QLD	-21.73	149.47	1	1			
87	Nungbalgarri Creek	NT	-11.93	134.07	1		1		
88	Ocean Beach, Strahan	TAS	-42.13	145.27	1		1	1	
92	Pelican Island and nearby islands	QLD	-13.92	143.83	1		1		
93	Port Fairy to Warrnambool coast	VIC	-38.38	142.25	1		1		
95	Port MacDonnell coast	SA	-38.05	140.70	1		1		
98	Port Stephens	NSW	-32.70	152.10	1		1		
13	Price Saltfields/Clinton Cons. Park	SA	-34.22	138.03	1		1		
100	Ringarooma Bay/Cape Portland	TAS	-40.86	147.88	1		1		
106	Rottnest Island	WA	-32.00	115.52	1		1		
109	Shoal Bay: Tree Pt to Lee Pt (Hope Inlet)	NT	-12.33	131.00	1	1			
111	Swan River Estuary, Perth	WA	-32.02	115.81	1		1		
113	Thomsons Lake Nature Reserve	WA	-32.15	115.83	1		1		
114	Torry Plains Station	NSW	-34.50	144.07	1		1		
115	Tuckerbil Swamp	NSW	-34.49	146.36	1		1		
116	Tuggerah lakes	NSW	-33.28	151.51	1		1		
58	Tullakool Evaporation Ponds	NSW	-35.37	144.18	1		1		
59	Wilson Inlet	WA	-35.00	117.42	1		1		
62	Yantabulla Swamp	NSW	-29.20	144.85	1	1			
63	Yantara Lake	NSW	-29.92	142.28	1		1		
65	Yokinup Bay, Cape Arid National Park	WA	-33.87	123.09	1		1		

Legend:
SM = southern migration; NB = non-breeding season; NM = northern migration; B = breeding season
Moreton Bay highlighted as a site with specific relevance to this review.

Table B9: List of migratory shorebirds and the number of internationally important sites for these species at different periods (Source: Bamford et al. 2008).

Species	Total Sites	SM	NB	NM	B
Japanese Snipe	1		1		
Black-tailed Godwit	14	2	6	3	1
Bar-tailed Godwit	9	3	8	2	
Little Curlew	8	3	6		
Whimbrel	7	1	6		
Far Eastern Curlew	18	6	12	2	2
Marsh Sandpiper	4	1	1	1	
Common Greenshank	8	3	6		
Terek Sandpiper	11	2	8	1	2
Common Sandpiper	2		2		
Grey-tailed Tattler	16	8	10	3	2
Ruddy Turnstone	16	7	12	3	
Asian Dowitcher	1			1	
Great Knot	10	4	5	3	1
Red Knot	8	2	6	1	
Sanderling	17	5	12	4	2
Red-necked Stint	32	9	25		3
Sharp-tailed Sandpiper	39	4	30	5	3
Curlew Sandpiper	24	9	22		1
Broad-billed Sandpiper	1	1	1		
Pacific Golden Plover	1		1	1	
Grey Plover	6	2	3		
Double-banded Plover	9		9		
Lesser Sand Plover	6		6		
Greater Sand Plover	5	2	4		1
Oriental Plover	6	1	5		
Oriental Pratincole	2		2		
Australian Pratincole	9	2	3	1	3

Legend:
SM = southern migration; NB = non-breeding season; NM = northern migration; B = breeding season.

Appendix C: Risk assessment framework for threatening processes to shorebirds on the Gold Coast

Threat Impact

For each threat it is recommended that the timing of the threat (i.e. past, ongoing or future), its scope (i.e. the proportion of the total population affected) and severity (i.e. the overall declines caused by the threat) should be recorded.

Table C10: Risk Assessment Framework (Source: IUCN/BirdLife International).

Timing Options	
First column in matrix	Continuing threat
Second column in matrix	Threat may occur/return in the short term
Third column in matrix	Threat may occur/return in the long term
Scope Options	
3	Affects the whole population (>90%)
2	Affects the majority of the population (50-90%)
1	Affects the minority of the population (<50%)
0	Unknown
Severity	
3	Causing or likely to cause very rapid declines (>30% over 10 years or three generations; whichever is the longer)
2	Causing or likely to cause rapid declines (20-30% over 10 years or three generations; whichever is the longer)
1	Causing or likely to cause relatively slow but significant declines (<20% over 10 years or three generations; whichever is the longer) **OR** Causing or likely to cause fluctuations
0	Causing or likely to cause negligible declines **OR** No declines **OR** Unknown

a) Continuing threat

Scope		Severity	*Very rapid* Score 3	*Rapid* Score 2	*Slow* Score 1	*Negligible* Score 0
Whole	Score	3	6	5	4	3
Majority	Score	2	5	4	3	2
Minority	Score	1	4	3	2	1
Negligible	Score	0	3	2	1	0

b) Threat may occur/return in the short term

Scope		Severity	*Very rapid* Score 3	*Rapid* Score 2	*Slow* Score 1	*Negligible* Score 0
Whole	Score	3	6	5	4	3
Majority	Score	2	5	4	3	2
Minority	Score	1	4	3	2	1
Negligible	Score	0	3	2	1	0

c) Threat may occur/return in the long term

Scope		Severity	*Very rapid* Score 3	*Rapid* Score 2	*Slow* Score 1	*Negligible* Score 0
Whole	Score	3	6	5	4	3
Majority	Score	2	5	4	3	2
Minority	Score	1	4	3	2	1
Negligible	Score	0	3	2	1	0

Impact Coding:

High Impact

Medium Impact

Low Impact

Negligible/No Impact

Appendix D. Shorebird survey sites and broad regional areas.

Table D11: Relative locations of shorebird survey sites in six broad regional areas of Gold Coast waterways.

No.	Site	Area
1	North Coomera River	Central West
2	Pimpama foreshore	Central West
3	Jacobs Well - Habitat Reserve, Harrigans Lane, Queensland	Central West
4	Incidental Sightings – TB (Todd Burrows)	Coombabah
5	Coombabah Lake-Mangrove Boardwalk, Queensland	Coombabah
6	Gold Coast Sewage Treatment Plant	Coombabah
7	Coombabah Lake	Coombabah
8	Coombabah Lakelands Conservation Area, Queensland	Coombabah
9	Coombabah wetland	Coombabah
10	Coombabah	Coombabah
11	Jason Searle Incidental Fauna 2011	Jumpinpin
12	South Stradbroke Is (north)	Jumpinpin
13	Horseshoe Bay	Jumpinpin
14	Horseshoe Bay, S Stradbroke Is	Jumpinpin
15	South Stradbroke Is tip	Jumpinpin
16	The Pin	Jumpinpin
17	Swan Bay Nth Stradbroke Is	Jumpinpin
18	Swan Bay	Jumpinpin
19	Incidental Sightings - CMU	S South Stradbroke
20	Crab Island North sandbars, Queensland	S South Stradbroke
21	Currigee South S Stradbroke Is	S South Stradbroke
22	Incidental Sightings - TB	S South Stradbroke
23	Todd Burrows Incidental	S South Stradbroke
24	Bird List - Tallebudgera CA Currumbin Reach	South Gold Coast
25	Currumbin Creek, Queensland	South Gold Coast
26	Jason Searle Incidental Fauna 2011	South Gold Coast
27	Incidental Sightings - NAMU	South Gold Coast
28	Fauna Site 2 - Palm Beach	South Gold Coast
29	Beach Third Street Burleigh Heads	South Gold Coast
30	Broadwater Shoreline, Queensland	Southport Wavebreak
31	Broadwater, Queensland	Southport Wavebreak
32	Island just south of Wavebreak Island A	Southport Wavebreak
33	Island just south of Wavebreak Island B	Southport Wavebreak
34	Incidental Sightings - TB	Southport Wavebreak
35	Jason Searle Incidental Fauna 2011	Southport Wavebreak
36	Island just south of Wavebreak Island., Queensland	Southport Wavebreak
37	Broadwater Shoreline/South-west wall, Queensland	Southport Wavebreak
38	Incidental Sightings - TB	Southport Wavebreak
39	Carter Banks, Broadwater	Southport Wavebreak
40	Southport 10' Cell, Queensland	Southport Wavebreak

Legend: S South Stradbroke = Southern South Stradbroke (see Figure 6 for details).

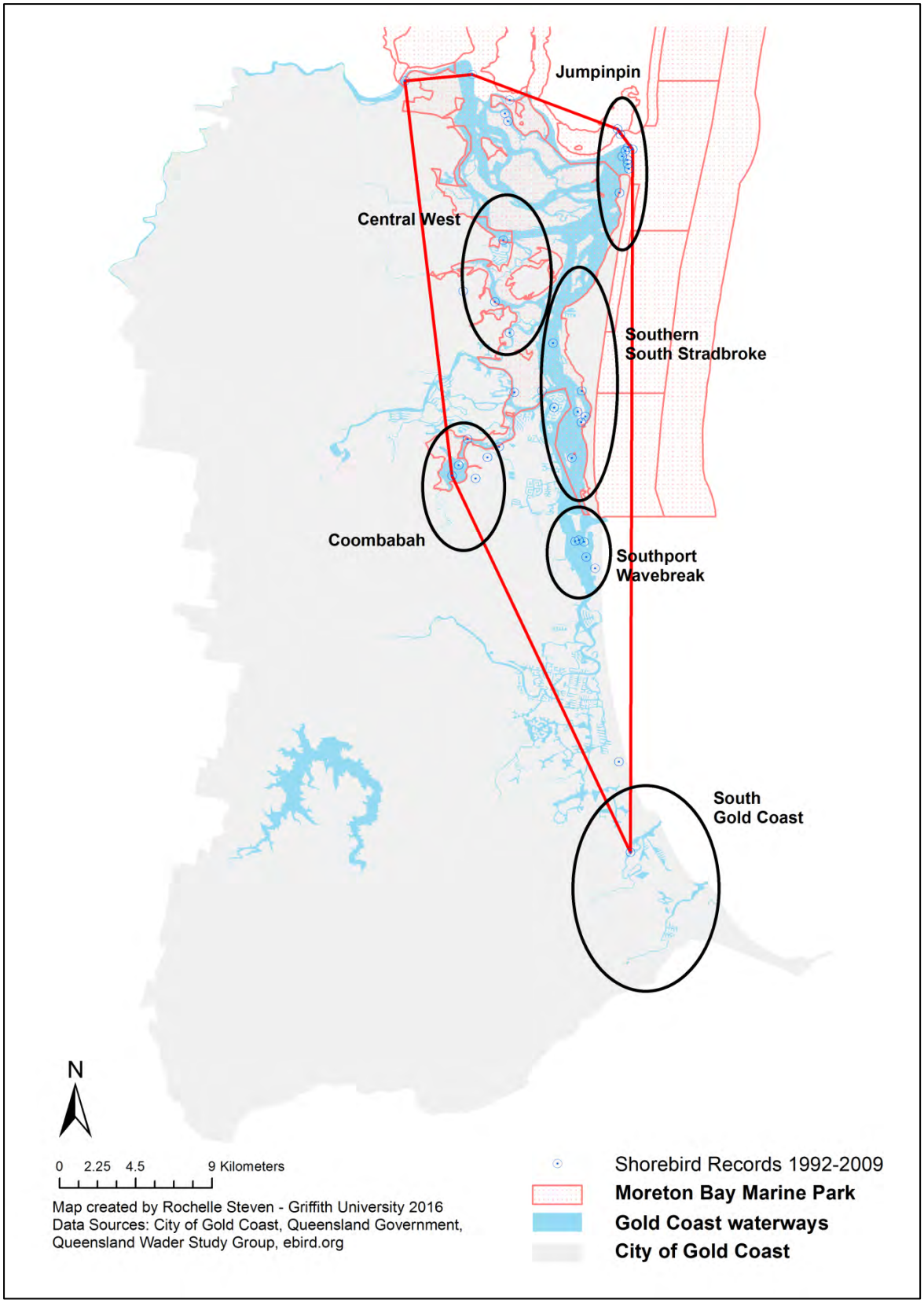

Figure D28: Locations in Gold Coast waterways with shorebirds records between 1992 and 2009. The bold red bounding polygon represents the minimum convex polygon encompassing these locations. Broad regional areas identified from records recorded from 2010 onwards are also depicted (refer Figure 6).

Appendix E: Shorebird scientific names.

Table E12: Shorebirds found within Gold Coast waterways.

Species (common name)	Scientific name
Australian Pied Oystercatcher	*Haematopus longirostris*
Banded Stilt	*Cladorhynchus leucocephalus*
Bar-tailed Godwit	*Limosa lapponica*
Beach Stone-curlew	*Esacus magnirostris*
Black-fronted Dotterel	*Elseyornis melanops*
Black-tailed Godwit	*Limosa limosa*
Black-winged Stilt	*Himantopus himantopus*
Broad-billed Sandpiper	*Calidris falcinellus*
Common Greenshank	*Tringa nebularia*
Curlew Sandpiper	*Calidris ferruginea*
Double-banded Plover	*Charadrius bicinctus*
Eastern Curlew	*Numenius madagascariensis*
Great Knot	*Calidris tenuirostris*
Greater Sand Plover	*Charadrius leschenaultii*
Grey Plover	*Pluvialis squatarola*
Grey-tailed Tattler	*Tringa brevipes*
Latham's Snipe	*Gallinago hardwickii*
Lesser Sand Plover	*Charadrius mongolus*
Marsh Sandpiper	*Tringa stagnatilis*
Pacific Golden Plover	*Pluvialis fulva*
Red Knot	*Calidris canutus*
Red-capped Plover	*Charadrius ruficapillus*
Red-kneed Dotterel	*Erythrogonys cinctus*
Red-necked Avocet	*Recurvirostra novaehollandiae*
Red-necked Stint	*Calidris ruficollis*
Ruddy Turnstone	*Arenaria interpres*
Sanderling	*Calidris alba*
Sharp-tailed Sandpiper	*Calidris acuminata*
Terek Sandpiper	*Xenus cinereus*
Whimbrel	*Numenius phaeopus*

Appendix F: Geographical features in the northern and southern Broadwater regions of the Gold Coast waterways.

Figure F29: Location of Horseshoe Bay in the Jumpinpin area of northern South Stradbroke Island (Source: Google Earth).

Figure F30: Recently named geographical features in the southern Broadwater region of the Gold Coast waterways shown in yellow text (Sources: (a) Map taken from Google Earth; (b) Recent names: Place Name Proposal Notice (No 04) 2015 Queensland Department of Natural Resources and Mines).

Appendix G: The Moreton Bay Marine Park and Ramsar site.

Marine Park

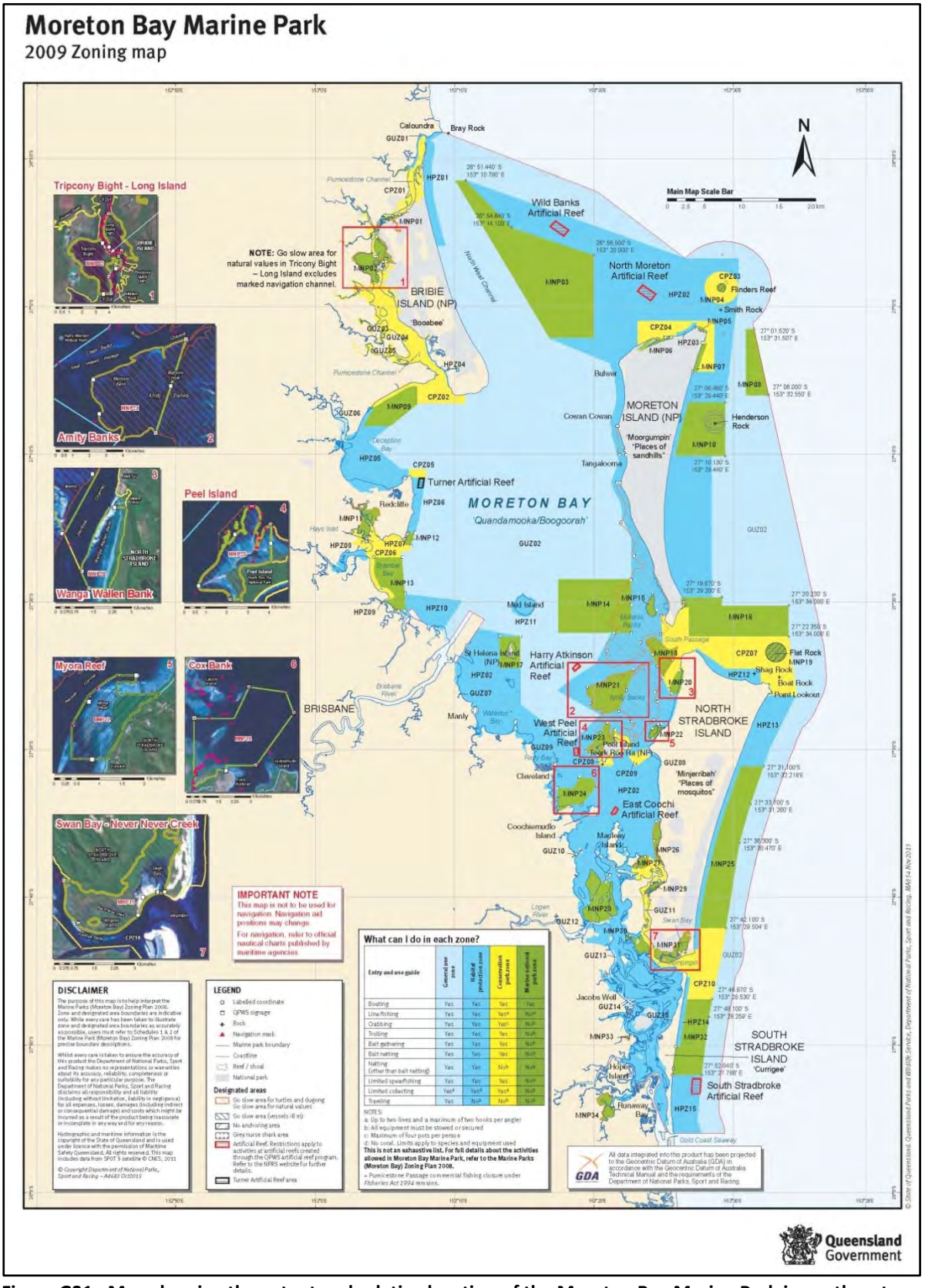

Figure G31: Map showing the extent and relative location of the Moreton Bay Marine Park in southeast Queensland, Australia (Source: Queensland Government 2016a).

Ramsar site

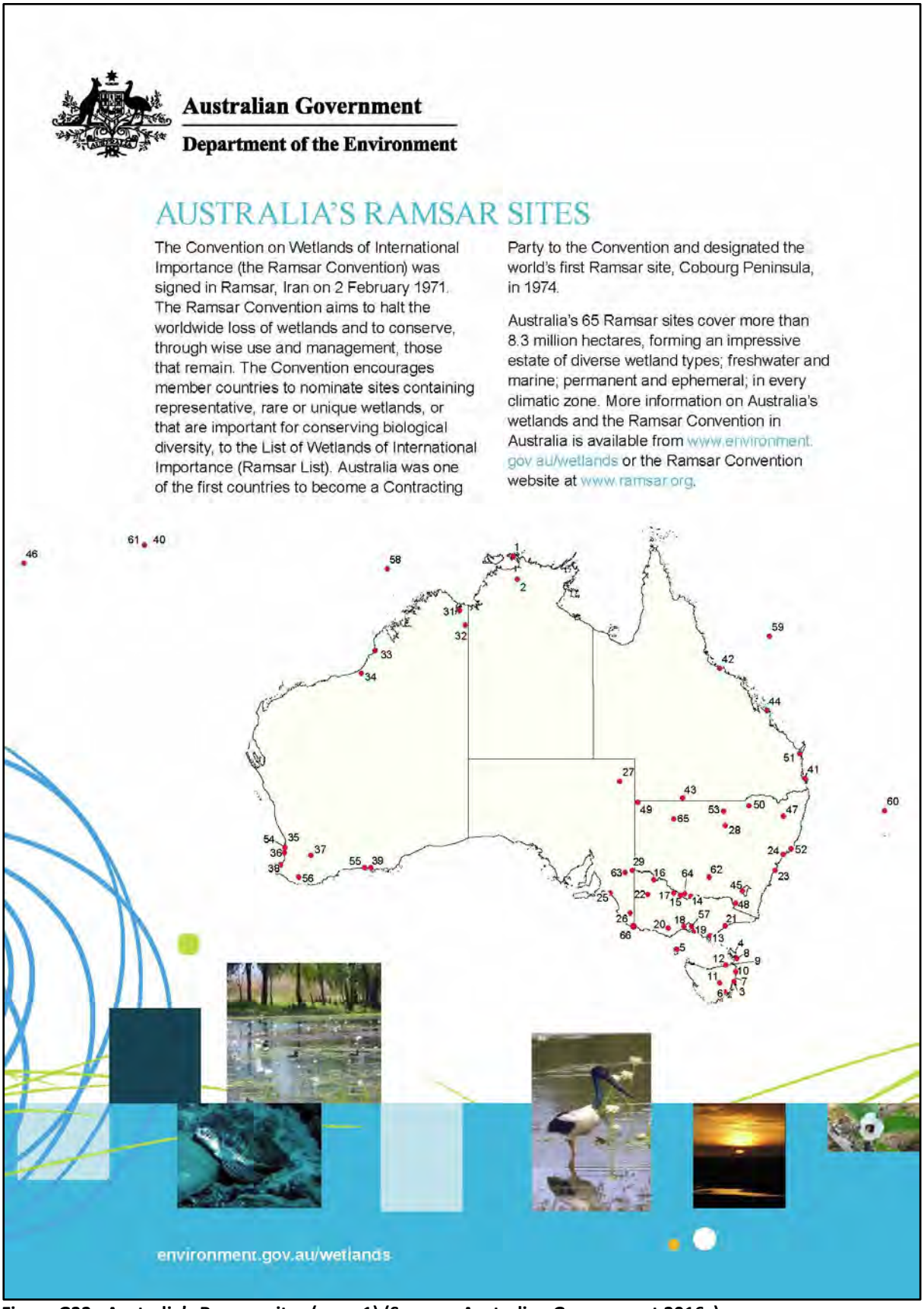

Figure G32: Australia's Ramsar sites (page 1) (Source: Australian Government 2016c).

Ramsar site	Area (ha)
1. Cobourg Peninsula	220 700
2. Kakadu National Park	1 979 766
3. Moulting Lagoon	4 507
4. Logan Lagoon	2 257
5. Lavinia	7 034
6. Pitt Water-Orielton Lagoon	3 334
7. Apsley Marshes	880
8. East Coast Cape Barren Island Lagoons	4 473
9. Flood Plain Lower Ringarooma River	3 519
10. Jocks Lagoon	19
11. Interlaken	517
12. Little Waterhouse Lake	56
13. Corner Inlet	67 186
14. Barmah Forest	28 515
15. Gunbower Forest	19 931
16. Hattah-Kulkyne Lakes	955
17. Kerang Wetlands	9 419
18. Port Phillip Bay (Western Shoreline) and Bellarine Peninsula	22 645
19. Western Port	59 297
20. Western District Lakes	32 898
21. Gippsland Lakes	60 015
22. Lake Albacutya	5 731
23. Towra Point Nature Reserve	604
24. Hunter Estuary Wetlands	2 969
25. The Coorong and Lakes Alexandrina and Albert	140 500
26. Bool and Hacks Lagoon	3200
27. Coongie Lakes	2 178 952
28. The Macquarie Marshes	19 850
29. 'Riverland'	30 640
30. There is no site with this number*	
31. Ord River Floodplain	141 453
32. Lakes Argyle and Kununurra	117 495
33. Roebuck Bay	34 119
34. Eighty-mile Beach	175 487
35. Forrestdale and Thomsons Lakes	784
36. Peel-Yalgorup System	26 530
37. Toolibin Lake	493
38. Vasse-Wonnerup System	1 115
39. Lake Warden System	1 999
40. Hosnies Spring	202
41. Moreton Bay	113 314
42. Bowling Green Bay	35 500
43. Currawinya Lakes (Currawinya National Park)	151 300
44. Shoalwater and Corio Bays (Shoalwater Bay Training Area, in part – Corio Bay)	239 100
45. Ginini Flats Wetland Complex	368
46. Pulu Keeling National Park	2 602
47. Little Llangothlin Nature Reserve	258
48. Blue Lake	338
49. Lake Pinaroo (Fort Grey Basin)	800
50. Gwydir Wetlands: (Gingham and Lower Gwydir (Big Leather) Watercourses)	823
51. Great Sandy Strait	93 160
52. Myall Lakes	44 612
53. Narran Lake Nature Reserve	5 531
54. Becher Point Wetlands	677
55. Lake Gore	4 017
56. Muir-Byenup System	10 631
57. Edithvale-Seaford Wetlands	261
58. Ashmore Reef National Nature Reserve	58 300
59. Coral Sea Reserves (Coringa-Herald and Lihou Reefs and Cays)	1 728 920
60. Elizabeth and Middleton Reefs Marine National Nature Reserve	187 726
61. The Dales	583
62. Fivebough and Tuckerbil Swamps	689
63. Banrock Station Wetland Complex	1 375
64. NSW Central Murray State Forests	84 028
65. Paroo River Wetlands	138 304
66. Piccaninnie Ponds Karst Wetlands	862
Total area (ha)	**8 314 125**

* In May 2010, two separate Ramsar sites in Kakadu National Park were expanded and merged to form the Kakadu National Park Ramsar site. See site 2.

Photo credits: R. Thorn, J. Mollison, B. Furby, S. Stuart-Smith, J. Muirhead

Figure G33: Australia's Ramsar sites (page 2) (Source: Australian Government 2016c).

Figure G34: Map showing the relative location of the internationally important wetlands of the Moreton Bay Ramsar site in southeast Queensland, Australia (Source: Australian Government 2016d).

Figure G35: Map showing the relative location and extent of the nationally important wetlands of the Moreton Bay region of southeast Queensland, Australia (Source: Australian Government 2016f).

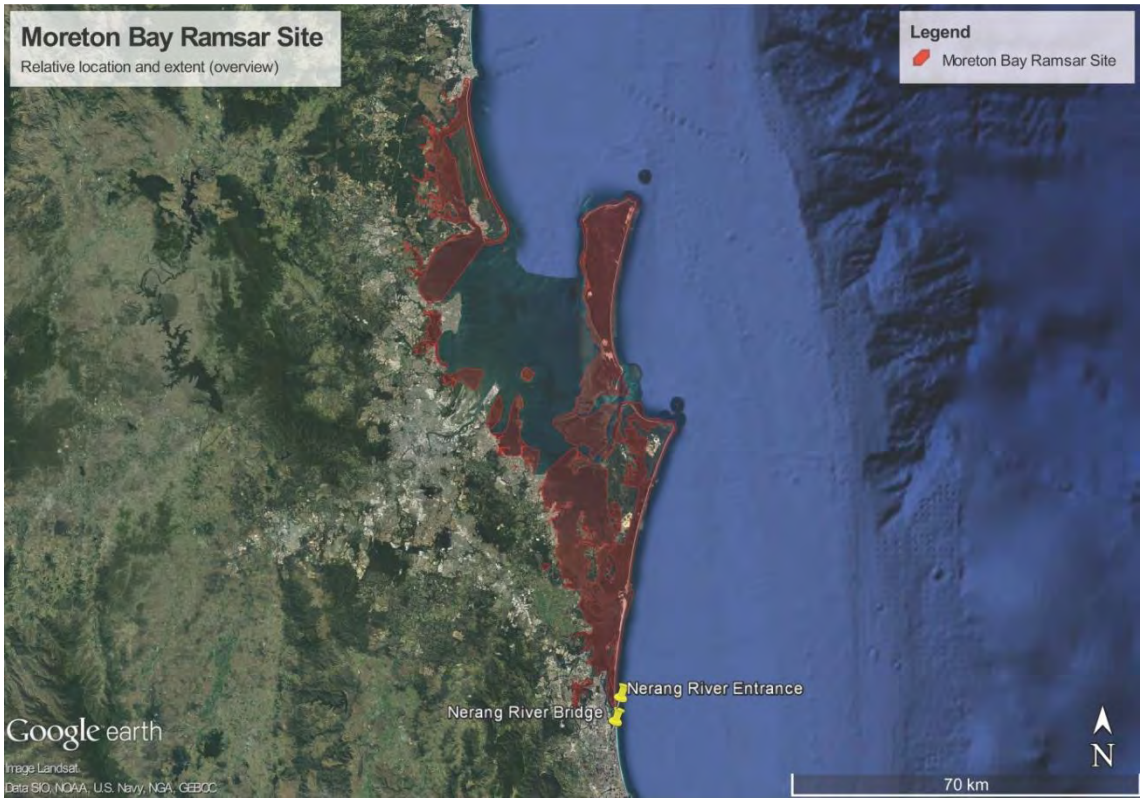

Figure G36: Map showing the relative extent and location of the Moreton Bay Ramsar site – 'general overview' (Source: (a) Map taken from Google Earth; (b) Boundary data (KML file) downloaded from Queensland Government 2016b).

Figure G37: Map showing the relative extent and location of the Moreton Bay Ramsar site – 'southern boundary zoom' (Source: (a) Map taken from Google Earth; (b) Boundary data (KML file) downloaded from Queensland Government 2016b).

The following information on the Moreton Bay Ramsar site is taken from the Australian Wetlands Database (Australian Government 2016g).

MORETON BAY

Key features of the site:

The Moreton Bay Ramsar site is located in and around Moreton Bay, east of Brisbane in Queensland. Moreton Bay is a semi-enclosed basin bounded on its eastern side by two large sand islands. Islands in the site include all of Moreton Island, and parts of North and South Stradbroke Islands, Bribie Island and the Southern Bay Islands.

Other parts of the site include waters and tributaries of Pumicestone Passage, some intertidal and subtidal areas of the western bay, southern bay and sandy channels of the Broadwater region, marine areas and sand banks within the central and northern bay and some ocean beach habitats.

Wetlands on the site include seagrass and shoals in the eastern banks, tidal flats and associated estuarine assemblages within the Pumicestone Passage, mangroves and saltmarsh in the southern bay, coral communities of the eastern bay, freshwater wetlands and peatland habitats on the Bay Islands and ocean beaches and foredunes on Moreton island.

The extensive Mangrove and tidal flats provide a nursery for fish and crustaceans, and also support birds and other marine life. The sandflats provide roosting sites for migratory birds.

The seagrass areas provide food and habitat for fish, crustaceans, the internationally vulnerable Dugong, and the nationally threatened Loggerhead Turtles, Hawksbill Turtle and Green Turtle. Other nationally threatened species that occupy the site include the Oxleyan Pygmy Perch and Honey Blue-eye, Water Mouse and the Australia Painted Snipe.

The site supports more than 50,000 migratory waders during their non-breeding season. At least 43 species of wading birds use the intertidal habitats, including 30 migratory species listed on international conservation agreements.

The close proximity of the wetlands to Brisbane and other populated areas makes the site a popular recreation area for tourism, birdwatching, water based recreation, scuba diving, four wheel driving, camping and boating. Parts of the site are conservation reserves. Commercial activities such as shipping, transport and fishing also occur within the site.

Moreton Bay Ramsar site lies in the traditional estate of a number of Indigenous groups including the Kabi Kabi, Jagera and Turrbal, Quandamooka (Ngugi, Noonucle, Gorenpul), and Yugambeh and Ngarang-Wal/Kombumeri. Evidence from these excavations and other archaeological sites discovered in Moreton Bay indicates that fishing, the collection of shellfish and the gathering of local food plants were important activities for Indigenous peoples living in the region.

Justification of the listing criteria:

The Moreton Bay Ramsar site meets six of the nine criteria—

Criterion 1: *The Moreton Bay Ramsar site is located in the North-east Coast Australian Drainage Division. It is one of the largest estuarine bays in Australia which are enclosed by a barrier island of vegetated sand dunes. Moreton Bay protects the local area from oceanic swells, providing habitat for wetland development. The site receives and channels the flow numerous rivers and creeks east of the Great Dividing Range.*

Criterion 2: *Moreton Bay supports large numbers of the nationally threatened Green Turtle, Hawksbill Turtle, Loggerhead Turtle. Other nationally threatened species that the site supports are the Oxleyan Pygmy Perch, Honey Blue-eye, Water Mouse and the Australia Painted Snipe. The site is ranked among the top ten habitats in Queensland for the Internationally vulnerable Dugong.*

Criterion 3: *The Moreton Bay Ramsar site supports over 355 species of marine invertebrates, at least 43 species of shorebirds, 55 species of algae associated with mangroves, seven species of mangrove and seven species of seagrass. At least 43 species of shorebirds use intertidal habitats in the Bay, including 30 migratory species listed by international migratory bird conservation agreements.*

Criterion 4: *Moreton Bay is a significant feeding ground for the threatened Green Turtle and is a foraging and breeding ground for the Dugong. The Bay also has the most significant concentration of the young and mature Loggerhead Turtle in Australia.*

Criterion 5: *The Moreton Bay Ramsar site supports more than 50,000 wintering and staging shorebirds during the non-breeding season.*

Criterion 6: *The Moreton Bay Ramsar site regularly supports more than 1% of the population the wintering Eastern Curlews and the Grey-tailed Tattler.*

Appendix H: Glossary of shorebird monitoring terminology.

Table H13: Descriptions of the various shorebird monitoring related terms as used in this report.

Term	Description
absolute abundance	An estimate of the number of individuals of a species from a surveyed area. This term can also be applied to species, populations or areas and may therefore be similar to the 'total abundance'
abundance	A general term relating to the number of individuals observed
count area	A BirdLife Shorebirds 2020 term used to identify key areas for shorebird counts. Specifically "Count Areas… are often small, discrete areas that cover the main roosting and feeding areas and can feasibly be counted by one or more observers in four hours or less. Data collected in each individual Count Area will be aggregated to give the total number of birds observed in the entire Shorebird Area."
count records	The number of shorebirds records made during any one count at a survey area
field surveys	Surveys completed at various locations within the environment
mean abundance	Abundance data averaged over any number of surveyed areas
Minimum Convex Polygon	In the context of this report, a spatial area depicted on a map that encloses the geographic locations of all of the known shorebird records by linking the outermost points to form an enclosed polygon (such as shown in Figure 6 for example)
number of surveys	The total number of surveys completed for any surveyed area
record	A shorebird recorded during a survey / count on a particular date at a particular survey area
records per unit effort	An index to allow comparisons of shorebird records to be made when the effort (i.e. counts) may not be consistent among survey areas
relative abundance	Similar to the standardised abundance where an index of the number of individuals (i.e. abundance) is calculated using some comparative measure (e.g. numbers / year; numbers / survey etc.)
reporting rate	The number of times a particular species is reported for counts from a single survey area. For example if a species is recorded 4 times out of 10 surveys the reporting rate is 0.4
richness	Standard species richness, a count of the number of species recorded
seasonal counts	Counts completed at different times of the year to capture seasonal variation in shorebird numbers

Shorebird 2020	A BirdLife Australia national shorebird monitoring program – see http://birdlife.org.au/projects/shorebirds-2020
shorebird abundance	See 'abundance' but in this context the term relates to multiple species
shorebird area	A BirdLife Shorebirds 2020 term used to identify key shorebird areas. Specifically "*A Shorebird Area is defined as a habitat used by the same group of shorebirds. A Shorebird Area does not need to be contiguous*."
shorebird records	A shorebird recorded during a survey / count on a particular date at a particular survey area
site	Any location identified as a potential area to conduct a field survey
species observations	Shorebird species observed from surveyed sites. Observations can be made from repeated counts at various times.
species richness	Standard species richness, a count of the number of species recorded. Often referred to as 'richness'
standardised	Values (e.g. abundance) that have been transformed in some way to enhance their comparison
standardised counts	In this context this refers to the use of a standardised survey methodology to survey shorebirds at count areas. This provides comparable data given the similar effort for each survey
standardised records	A standardisation of the number of records as a function of the total effort to provide a more equitable comparative basis
survey	A count of shorebirds at a single location on a particular date
survey effort	The amount of effort made to complete surveys of any particular area, i.e. number of surveys. For example, if two shorebird count areas have six and eleven surveys completed at these locations, then the latter has had a greater survey effort
survey locations	Sites identified where surveys are to be completed
total abundance	The sum of the abundance values for all species observed within a surveyed area
total effort	The total number of surveys completed. This can apply to a survey site / location or a particular period (e.g. one season)
total records	The sum of the number of times a shorebird species was recorded during counts
total species richness	The sum of the number of unique species for multiple survey sites / locations. For example, if Site 1 had 5 species and Site 2 had 7 species and there were three species in common between the two sites then the total species richness for both sites would be nine
total survey effort	The sum of the survey effort across all sites / locations surveyed

Appendix I: East Asian-Australasian Flyway (EAAF).

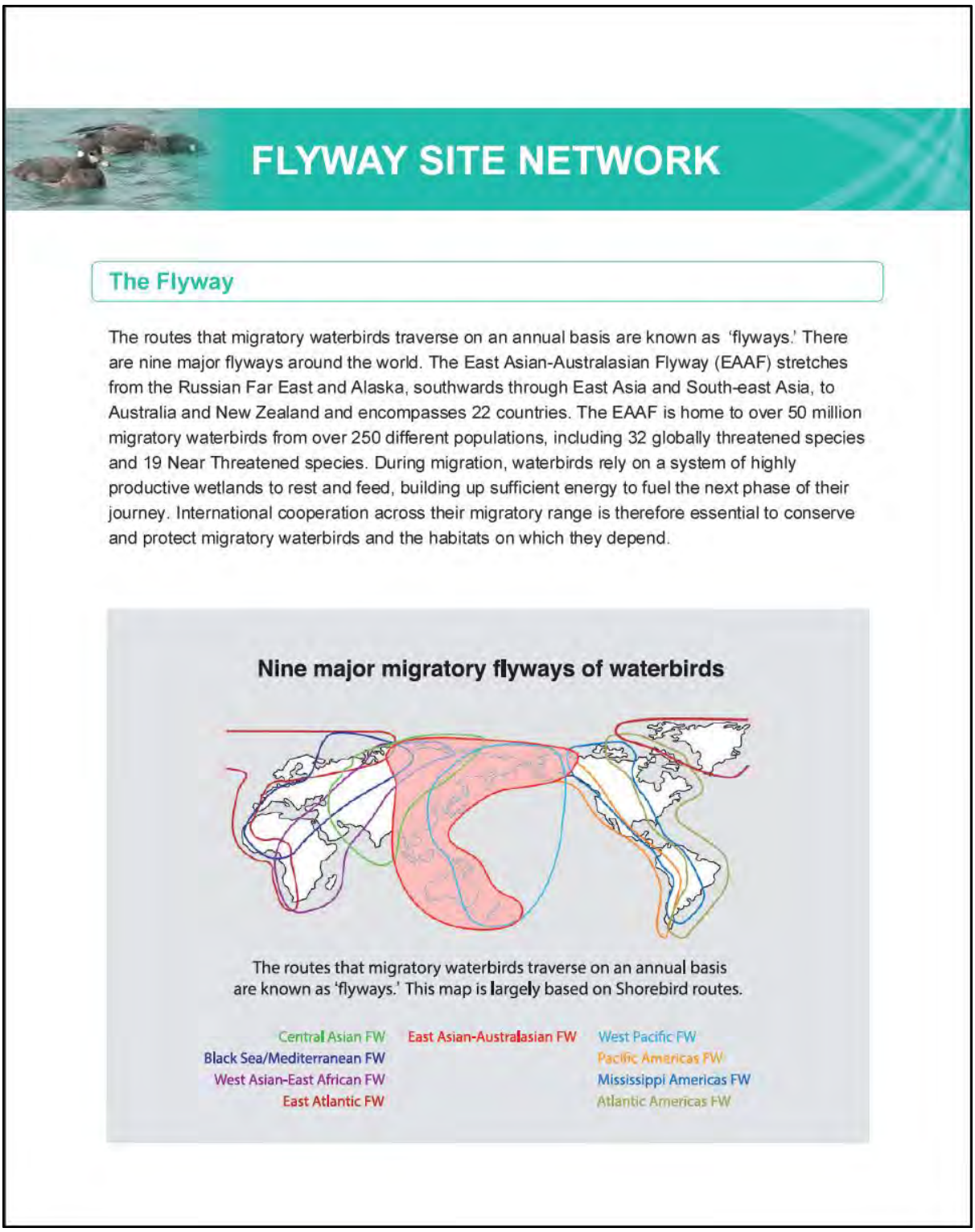

Figure I38: East Asian-Australasian Flyway (EAAF) (page 1) (Source: EAAFP 2015).

Flyway Site Network

Establishment of an East Asian-Australasian Flyway Waterbird Site Network is a critical element of the Partnership and will ensure that a network of internationally important sites are sustainably managed to support the long-term survival of migratory waterbirds within the EAAF. The 'Flyway Site Network' draws attention to the interconnectedness of migratory waterbird sites through shared species and populations throughout the EAAF.

Each site meets criteria for nomination that demonstrate its international importance for migratory waterbirds. More than 700 wetlands are known to meet one or more of the criteria and so far 123, spread over 17 countries, have been included in the Flyway Site Network.

Only government partners can nominate new sites to the Network. The Partnership's Secretariat and other experts advise on candidate sites and criteria met and the Secretariat administers and promotes the Network.

Green dots indicate important sites for migratory waterbirds and red dots indicate sites in the Flyway Site Network.

Figure I39: East Asian-Australasian Flyway (EAAF) (page 2) (Source: EAAFP 2015).

Flyway Network Site Nomination Criteria

To be considered for inclusion in the Flyway Site Network, this Partnership adopts the following criteria:

A. Convention on Wetlands (Ramsar, Iran, 1971) criteria for internationally important sites for migratory waterbirds. That is:
   Criterion 2: A wetland should be considered internationally important if it supports Vulnerable, Endangered, or Critically Endangered migratory waterbird species according to IUCN criteria.
   Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more migratory waterbirds.
   Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of migratory waterbird.

B. Staging criteria as applied under the Asia-Pacific Migratory Waterbird Conservation Strategy. That is:
   I. A staging site should be considered internationally important if it regularly supports 0.25% of individuals in a population of one species or subspecies of waterbirds on migration.
   II. A staging site should be considered internationally important if it regularly supports 5,000 or more waterbirds at one time during migration.

C. Under exceptional circumstances a site can be nominated if it supports migratory waterbirds at a level or stage of their life cycle important to the maintenance of flyway populations. Justification of such nominations will be considered by the Partnership on a case by case basis.

Figure I40: East Asian-Australasian Flyway (EAAF) (page 3) (Source: EAAFP 2015).

Flyway Network Site Nomination Process

1 Government/Management Authority, NGOs and Academe

- Identification of potential sites for the Network, by reviewing available data and determining which sites meet the Criteria

2 Government Partner

- For the selected site, preparation of a Site Information Sheet including a boundary map

3 Local Government/Management Authority

- Consultation on site nomination at the local scale, with stakeholders including site mangers, management authorities and relevant organisations

4 National Government Partner

- Consultation on site nomination at the state/national scale with stakeholders including scholars and relevant authorities
- Finalizing the Site Information Sheet and boundary map for the site nomination
- Submission of Site Information Sheet and map to the EAAFP Secretariat with a letter requesting that the site be included in the Network

5 EAAFP Secretariat

- Science Officer conducts an in-house review, then refers the nomination to the Working Group chairs and/or at least three relevant experts (for 14 days) to seek comments on the provided justification of the criteria met and other scientific aspects of the nomination

6 EAAFP Secretariat & nominating National Government Partner

- Communication to finalize the Site Information Sheet with further clarification or additional information as dictated by outcomes of the referral

7 EAAFP Chair

- The Secretariat advises the Chair of the Partnership on the nomination, showing the results of the review process, and requests the Chair to endorse the nomination by writing formally to the nominating Partner about the official inclusion of the site in the Network

8 EAAFP Secretariat

- The Certificate of Participation for the new Network Site is prepared and delivered to the nominating Partner at around the same time as the notification
- Notification to all Partners about the inclusion of the site in the Network

9 National Government Partner & Local Government/Management Authority

- Announcement of the inclusion of the site in the Network
- Delivery of the Certificate to the local government and/or management authority, with a small presentation ceremony where possible

Figure I41: East Asian-Australasian Flyway (EAAF) (page 4) (Source: EAAFP 2015).

List of Flyway Network Sites (123 sites as of 31 October 2015)

Country	Code	Name of site	Year of joining
Russia (10)	EAAF001	Moroshechnaya Estuary	1996
	EAAF020	Daursky Nature Reserve	1997
	EAAF021	Khingansky Nature Reserve and Ganukan Game Reserve	1997
	EAAF022	Kytalyk Nature Reserve	1997
	EAAF023	Lake Khanka Nature Reserve	1997
	EAAF035	Biosphere Reserve and Zapovednik "Taimyrski"	1999
	EAAF036	Site Ulug-kol of Hakasskiy Zapovednik	1999
	EAAF037	Lena Delta	1999
	EAAF038	Selenga Delta in Lake Baikal	1999
	EAAF039	Torey Lakes	1999
Alaska, USA (1)	EAAF109	Yukon Delta National Wildlife Refuge	2012
Mongolia (6)	EAAF024	Mongol Daguur Strictly Protected Area	1997
	EAAF040	Ugii Nuur	1999
	EAAF041	Terhiiyn Tsagaan Nuur	1999
	EAAF074	Khurkh-Khuiten Valley	2003
	EAAF075	Ugtam Nature Reserve	2003
	EAAF114	Dashinchilen Tsagaan Wetlands	2014
China (19)	EAAF002	Chongming Dongtan Nature Reserve	1996
	EAAF003	Mai Po - Inner Deep Bay	1996
	EAAF004	Shuangtai Hekou National Nature Reserve	1996
	EAAF005	Yancheng National Nature Reserve	1996
	EAAF006	Yellow River Delta National Nature Reserve	1996
	EAAF025	Poyang Hu Nature Reserve	1997
	EAAF026	Xingkai Hu Nature Reserve	1997
	EAAF042	Sanjiang National Nature Reserve	1999
	EAAF043	YaluJiang National Nature Reserve	1999
	EAAF064	Dalai Hu National Nature Reserve	2001
	EAAF067	Cao Hai National Nature Reserve	2002
	EAAF068	Shengjin Hu National Nature Reserve	2002
	EAAF069	Xiang Hai National Nature Reserve	2002
	EAAF070	Zhalong National Nature Reserve	2002
	EAAF082	Anqing Yangtze Riverine Wetland Nature Reserve	2005
	EAAF083	Dashanbao Black-necked Crane National Nature Reserve	2005
	EAAF085	Hengshui Lake National Nature Reserve	2006
	EAAF086	Nandagang Wetland Nature Reserve	2006
	EAAF087	Nanjishan Wetland Nature Reserve	2006
Democratic People's Republic of Korea (2)	EAAF044	Kumya Wetland Reserve	1999
	EAAF045	Mundok Wetland Reserve	1999
Republic of Korea (11)	EAAF027	Cheolwon Basin	1997
	EAAF028	Han River Estuary	1997
	EAAF046	Cheonsu Bay	1999
	EAAF078	Gumi Haepyung Wetland	2004
	EAAF079	Suncheon Bay	2004
	EAAF095	Junam Reservoir	2008
	EAAF096	Upo Wetland	2008
	EAAF097	Nakdong Estuary	2009
	EAAF100	Geum River Estuary	2010
	EAAF101	Yubu-do Tidal Flat	2011
	EAAF107	Chilbaldo Islet	2011
Japan (32)	EAAF029	Akkeshi-ko & Bekambeushi-shitsugen	1997
	EAAF030	Arasaki	1997
	EAAF031	Kiritappu Marsh	1997
	EAAF032	Kushiro-shitsugen	1997
	EAAF033	Yashiro	1997
	EAAF047	Biwa-ko	1999
	EAAF048	Biwase-wan	1999
	EAAF049	Fukushimagata	1999
	EAAF050	Hyouko-suikin-koen	1999
	EAAF051	Kabukuri-numa	1999
	EAAF052	Katano Kamoike	1999
	EAAF053	Kutcharo-ko	1999
	EAAF054	Manko Tidal Flats	1999

Figure I42: East Asian-Australasian Flyway (EAAF) (page 5) (Source: EAAFP 2015).

see http://www.eaaflyway.net/about/the-flyway/flyway-site-network/

Country	Code	Name of site	Year of joining
Japan	EAAF055	Miyajima-numa	1999
	EAAF056	Otomo-numa	1999
	EAAF057	Sakata	1999
	EAAF058	Shiroishi-gawa	1999
	EAAF059	Yatsu Tidal Flats	1999
	EAAF060	Yonago-Mizudori-koen	1999
	EAAF061	Yoshino Estuary	1999
	EAAF063	Tokyo Port Wild Bird Park	2000
	EAAF071	Kashima Shingomori	2002
	EAAF072	Utonai-ko	2002
	EAAF076	Osaka Nankou Bird Sanctuary	2003
	EAAF080	Fujimae-Higata	2004
	EAAF081	Kumagawa Estuary	2004
	EAAF088	Hachirogata-Kantakuchi	2006
	EAAF098	Kejo-numa	2010
	EAAF099	Furen-ko and Shunkuni-tai	2010
	EAAF113	Arao-higata	2013
	EAAF115	Izu-numa and Uchi-numa	2014
	EAAF116	Notsuke-hanto and Notsuke-wan	2014
Myanmar (3)	EAAF117	Gulf of Mottama	2014
	EAAF118	Indawgyi Wildlife Sanctuary	2014
	EAAF119	Moeyungyi Wetland Wildlife Sanctuary	2014
Bangladesh (5)	EAAF102	Nijhum Dweep National Park	2011
	EAAF103	Sonadia	2011
	EAAF104	Hakaluki Haor	2011
	EAAF105	Tanguar Haor	2011
	EAAF106	Hail Haor	2011
Philippines (3)	EAAF007	Olango Island Wildlife Sanctuary	1996
	EAAF062	Naujan Lake National Park	1999
	EAAF123	Tubbataha Reefs Natural Park	2015
Thailand (3)	EAAF084	Krabi Estuary and Bay	2005
	EAAF121	Pak Thale - Laem Phak Bia	2014
	EAAF122	Khok Kham	2014
Malaysia (2)	EAAF077	Kapar Power Station Ash Ponds	2003
	EAAF112	Bako Buntal Bay	2013
Singapore (1)	EAAF073	Sungei Buloh Wetland Reserve	2002
Indonesia (2)	EAAF008	Wasur National Park	1996
	EAAF108	Sembilang National Park	2012
Papua New Guinea (1)	EAAF034	Tonda Wildlife Reserve	1998
Australia (20)	EAAF009	Corner Inlet	1996
	EAAF010	Hunter Estuary Ramsar Site	1996
	EAAF011	Kakadu National Park	1996
	EAAF012	Logan Lagoon	1996
	EAAF013	Moreton Bay	1996
	EAAF014	Orielton Lagoon	1996
	EAAF015	Parry Lagoons	1996
	EAAF016	The Coorong, Lake Alexandrina & Lake Albert	1996
	EAAF017	Thomsons Lake	1996
	EAAF065	Port Philip Bay (Western Shoreline) and Bellarine Peninsula	2001
	EAAF066	Western Port	2001
	EAAF089	Bowling Green Bay	2006
	EAAF090	Currawinya National Park	2006
	EAAF091	Discovery Bay Coastal Park	2006
	EAAF092	Great Sandy Strait	2006
	EAAF093	Shallow Inlet Marine and Coastal Park	2006
	EAAF094	Shoalwater Bay	2006
	EAAF110	Eighty-Mile Beach	2013
	EAAF111	Roebuck Bay	2013
	EAAF120	South-East Gulf of Carpentaria: Karumba-Smithburne (Delta Downs)	2014
New Zealand (2)	EAAF018	Farewell Spit	1996
	EAAF019	Firth of Thames	1996

Figure I43: East Asian-Australasian Flyway (EAAF) (page 6) (Source: EAAFP 2015).