Shorebird Population Monitoring within Gulf St Vincent: July 2011 to June 2012 Annual Report

Chris Purnell, John Peter, Robert Clemens and Kerryn Herman

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EXECUTIVE SUMMARY

Shorebirds (also known as “waders”) appear to be declining throughout the world, and their long-term survival will require managers and planners to identify and protect their habitats, to identify and reduce the impacts of any threats to their long-term survival, and to identify population declines in shorebirds sufficiently early to limit the severity of any declines through management. The importance of conservation of migratory shorebirds has been confirmed, as they have been recognised as species of national significance in Australia’s *Environment Protection and Biodiversity Conservation Act* (1999), and also in several international conservation agreements to which Australia is a signatory.

This report: (a) repeats an overview of shorebirds, habitats and threats; (b) provides details of the 2011/12 counts; (c) reports on workshops (to workshops to recruit and train counters and raise awareness of shorebirds and the threats to their populations; (e) reports on the refined shorebird habitat mapping of Gulf St Vincent; (f) provides detailed summaries of the shorebird habitat in the Adelaide region that was identified as gaps in the 2011 report (Purnell *et al*. 2011); and (g) provides information that is relevant to the management of shorebirds and the threats they face in Gulf St Vincent, including initial explorations into how management and planning can improve shorebird conservation in the region.

The results of the 2011/12 summer counts were down on the results from 2011 due to inconsistent coverage and dispersal of birds to inland wetlands. Habitat mapping completed over the past 4 years has been consolidated into this report including new mapping of suppratidal habitats of the Samphire Coast.

As a result of further fieldwork, literature reviews, a review of development proposals, and a managers’ and stakeholders’ workshop, it seems clear that: (a) disturbance and habitat loss or degradation are the two greatest threats to shorebirds in the Adelaide region; (b) the artificial wetlands of Dry Creek Saltfields support the greatest abundance of migratory shorebirds in the region, and informed adaptive management of these habitats will be required to maintain shorebird populations, especially if existing management practises change; (c) reinstating pre-mining lease habitat conditions, namely coastal saltmarsh, to the Dry Creek Saltfields will not provide sufficient suitable habitat for the current population of shorebirds to persist in Gulf St Vincent; (d) potential feeding areas on intertidal zones surrounding the Bolivar Treatment Outlet have been degraded to the point that they have become functionally useless for shorebirds; (e) many of the proposed developments in the region are unlikely to have significant impacts to shorebirds on their own, but their cumulative impact could result in drastic impacts without cross-jurisdictional cooperation and planning; and (f) Many areas of intertidal habitat are under risk from rising sea levels however there areas of the Samphire Coast may provide room for habitat retreat; (g) current councils, land managers and the Adelaide and Mount Lofty Natural Resources Management Board should be commended for the progressive steps they have already taken to protect shorebirds in Gulf St Vincent.

We look forward to another year in which we can further inform on how to optimise shorebird monitoring and conservation effort in Gulf St Vincent.

INTRODUCTION

Gulf St Vincent has long been recognised as an internationally significant area for shorebirds (Bamford *et al.* 2008) and over the last 25 years, counts of migratory shorebirds have been conducted by volunteer counters from organisations such as the Australasian Wader Studies Group and Birds South Australia throughout wetlands of the region.

The importance of migratory shorebird conservation is widely documented, and as indicators of wetland health they are considered to be good flagship species for wetland habitats, both nationally and internationally. There has been an increased need for shorebird conservation in recent years, with evidence that migratory shorebird populations are declining throughout the world (Morrison *et al*. 2001; IWSG 2003; Olsen *et al*. 2003; CHSM 2004; van de Kam *et al*. 2004), including a growing body of evidence that suggests populations are declining in Australia (Gosbell and Clemens 2006; Nebel *et al*. 2008; BirdLife Australia unpublished data). With this in mind, the Adelaide and Mount Lofty Ranges Natural Resources Management Board (NRM) provided funding to BirdLife Australia for the coordination of a complete count of the shorebirds within Gulf St Vincent, including supplementary surveys of poorly known shorebird habitat. Commencing in 2009, the project aimed to reinvigorate shorebird population monitoring and identify important shorebird habitats in the region. The resulting report and associated GIS layers provided an inventory of shorebird habitats and highlighted the distribution and abundance of shorebirds in Gulf St Vincent, as well as identifying current and potential threats to shorebirds in the region. Work also included conducting shorebird training workshops to recruit, train and inform counters. Additional funding from the Adelaide and Mount Lofty NRM Board will allow this work to continue through 2012.

This report highlights the results to July 2012. Work between July 2009 and June 2012 has increased the number of active, trained volunteers required to carry out shorebird surveys in Gulf St Vincent, increased the spatial resolution of mapping and filled some of the gaps in our knowledge about the distribution of shorebirds in Gulf St Vincent. Work in 2011 also included the coordination of three simultaneous counts of shorebirds in Gulf St Vincent, a workshop to recruit and train counters, and a shorebird management workshop. We have also increased our understanding of the threats to shorebirds in Gulf St Vincent as well as the types of management required to ensure long-term shorebird conservation.

Specifically, work this year has included:
Refined shorebird-habitat mapping in the Adelaide region, including:

- Supratidal zone from Port Prime to Port Parham
- Port Wakefield Proof Range and Experimental Establishment

Workshops and field trips:

- A workshop to train and recruit shorebird counters
- Meetings with Birds South Australia and other key data contributors

The reinvigoration of shorebird monitoring in Gulf St Vincent is providing valuable information to BirdLife Australia’s Shorebirds 2020 Program, which coordinates national shorebird population monitoring. Shorebirds 2020 was initiated in 2007 in response to growing concern over declining shorebird populations in Australia and the need to reliably determine population trends for the various species of shorebirds. The aim of Shorebirds 2020 is to collect data on the populations of shorebirds, and this can be used to aid their conservation and management. Specifically, the aim is to understand national (and, where possible, site-based) population trends, and explore the potential causes of change through increasing our understanding of the relationship between habitat, habitat quality and threats, and how they interact to affect the distribution and abundance of shorebirds in Australia.

Recent work has identified a need to conduct annual surveys at over 150 sites throughout Australia to detect the national population trends of migratory shorebirds and resident species of shorebirds. Gulf St Vincent is considered the second-most important shorebird area in South Australia due to the abundance and diversity of species of shorebirds that occur there, and it is crucial in terms of areas that must be surveyed to determine national population trends.

With projected growth estimates predicting that Adelaide's population will increase to 560,000 people (including 160,000 in the northern Adelaide region) in the next 30 years, it is vital to inform managers and planners about how to ensure the long-term conservation of shorebirds in Gulf St Vincent. This project has delivered some of the first steps required to achieve that long-term aim. First, most of Gulf St Vincent's shorebird habitat has been identified, mapped at fine scale and described with regard to the relative importance for shorebirds in each area. This should allow improved planning and threat minimisation. Awareness of the need for shorebird conservation has been raised within the birdwatching community and stakeholders involved in the management of shorebird habitat through workshops. These workshops, together with work by Birds South Australia, have also increased the number of skilled shorebird counters. Shorebird monitoring has been reinvigorated within Gulf St Vincent and steps are being taken to optimise that monitoring to inform on adaptive management of shorebird habitats. Results from recent analyses suggest current monitoring is sufficient to detect national shorebird trends, but significantly more counts would be required to identify anything other than a catastrophic (>70%) decline of shorebirds within Gulf St Vincent over 20 years. Fieldwork, a literature review and stakeholder discussions have increased our understanding of the specific threats to shorebirds in Gulf St Vincent, and highlighted some of the management and conservation measures required to limit the impact of those threats. These threats are growing and it is clear that some pristine areas, such as the northern beaches, will need to be protected, while other areas will require active management to maintain shorebird populations. This report highlights the progress towards these required steps for long-term shorebird conservation in Gulf St Vincent, but ultimately shorebird conservation in the region will depend on the role that local planners and managers adopt.

Background Information on Shorebirds, Habitats and Threats

What are shorebirds?

Shorebirds (also known as "waders") in Gulf St Vincent include sandpipers, plovers, stints, oystercatchers, godwits, curlews, knots and greenshanks. All shorebirds are characterised by their long legs and their general association with wetlands. There is no agreed taxonomic or morphological definition of a shorebird; they are a bit of an arbitrary group within the Order Charadriiformes. This order also includes non-shorebirds such as gulls, terns, auks and button-quail. In Australia, shorebirds are categorised as either migratory or resident: 36 species of migratory shorebirds regularly spend their non-breeding season in Australia, having flown up to 13,000 kilometres from their breeding grounds; 18 resident shorebird species breed in Australia, remaining throughout the year (Geering *et al*. 2007).

The two million migratory shorebirds that visit Australia each year hatch in the arctic tundra of Russia and Alaska, in meadows within the belt of boreal forests in the northern hemisphere, or in the rugged deserts and steppes of the middle-northern latitudes, in places such as Mongolia and northern China. Many shorebirds hatch into the care of a male and female which travel to breed in the same place, year after year. Others hatch in areas where food was plentiful at that time, where either the male or the female may mate with many partners, leaving the parental care to their many mates. A few hatch into families where the male takes care of one clutch of eggs while the female cares for a second. No matter where they were born, or the type of family they come from, all grow up quickly before they embark on a remarkable journey (Fig 1).

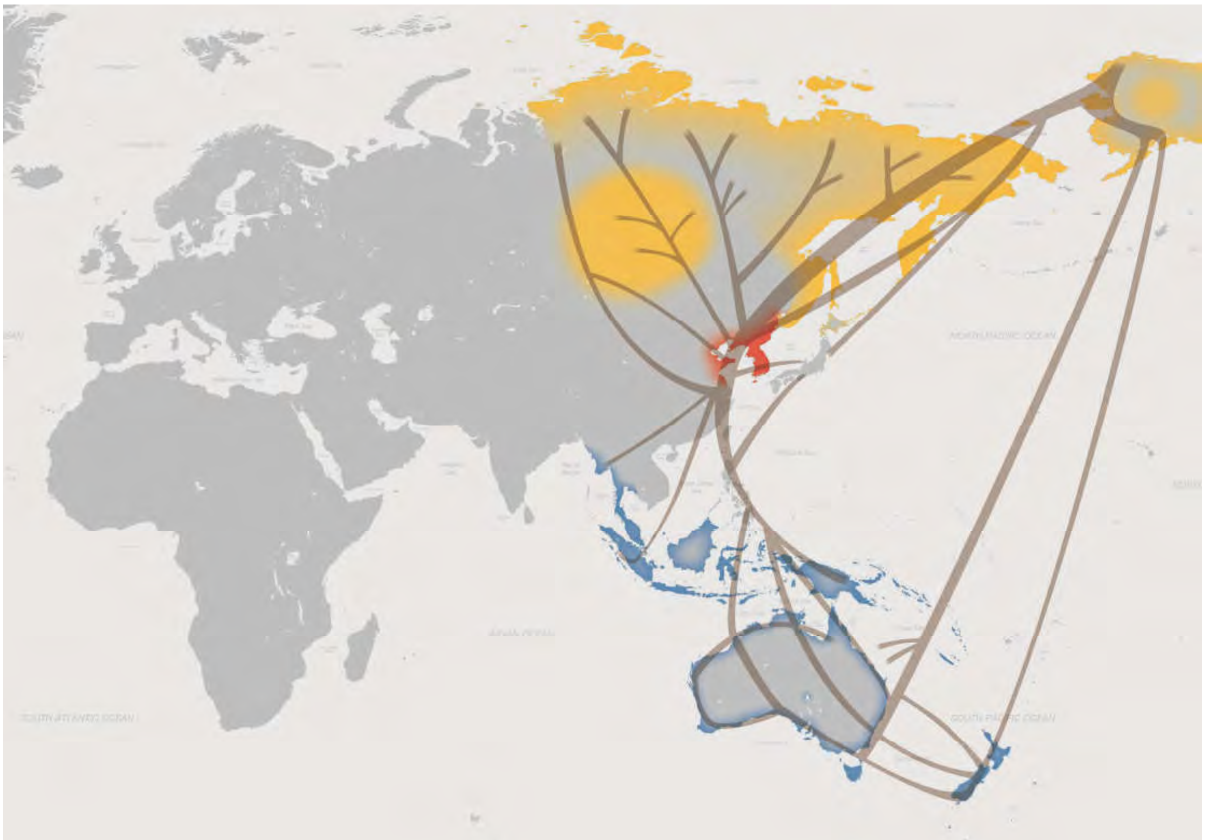


Figure 1. Every year more than 10 million shorebirds travel back and forth between their Acrtic breeding grounds (yellow) and their Australiasian non-breeding homes (blue). They travel along migration routes (dark grey). These routes are complex and numerous and are only stylised in this representation. BirdLife Australia

Almost as soon as a shorebird hatches it is able to walk and forage on its own. Parental care consists mostly of distracting predators, such as Arctic Foxes or Snowy Owls, and leading young to patches of food. When the chicks are only 6 weeks old, the mother often leaves on her migration to the southern hemisphere, and the father often follows about a week later. The chicks are fully grown just 8 weeks after hatching, and they must fly south without their parents or risk freezing in the coming snows. In a physiological frenzy, the young birds may increase in mass by up to 80% until their body mass comprises 55% fat, their weight increasing by 2–5% each day. Just before they leave on migration, the young birds' feeding organs shrink, their heart expands and their blood thickens. Then they set off south, burning their accumulated fat at a rate of up to 1 gram each hour, flapping constantly as their body, heart and muscles atrophy. Avoiding aerial predators and poor weather along the way, the most difficult aspect of the journey is navigating distances of up to 13,000 kilometres by instinct, as there are no older birds to guide them. They fly non-stop for days at time, and most are only able to last about half the journey before they need to stop to feed so that they can again increase their body mass to provide enough energy to complete the journey. The areas they stop at must be rich intertidal ecosystems with abundant food sources.

A few shorebirds have been shown to complete the flight in one hop. Some Bar-tailed Godwits were tracked flying directly from Alaska to New Zealand over nine days, comprising a non-stop 11,000-kilometre trip across the Pacific Ocean. On such long flights, there is evidence which suggests that: these birds can rest different parts of their brains independently; they can see lines of polarity in the sky (like seeing a compass); they can sense low-frequency, long-distance travelling sounds called infrasound (a sound made by crashing waves among other things); and they can navigate by the position of the sun and moon and the movement of the stars.

After completing their first migration by the time they are 3–4 months old, these juvenile birds inhabit the tidal flats and wetlands of Australia, where they may remain for up to five years before migrating north again to breed. Meanwhile, adults migrate back and forth each year, building up their weight before each migration, and most appear to stop over to feed along the way. An extra refuelling stop on the northward migration may be necessary because their destinations in the high latitudes of the northern hemisphere are still cold when the birds arrive, and they need to have sufficient energy to breed successfully.

Unfortunately, these critical stop-over sites used to refuel are being destroyed at an alarming rate, and this appears to be driving both long- and short-term population declines in migratory shorebirds. In the past 25 years, some of these species have declined by 50–80%, and at least one species has experienced declines of 20% in just 5 years (BirdLife Australia pers comm.). Up to 150,000 shorebirds of various species went missing in a single year after the destruction of just one vital tidal ecosystem in the Yellow Sea (represented in red in Fig 1) (Rogers *et al*. 2009). The Eastern Curlew and Great Knot were both listed as Vulnerable on the IUCN Red List recently after major population declines were detected, but more work is needed to monitor any further changes and explore how widespread these declines might be.

Given the size of the area migratory shorebirds rely on to survive each year, their conservation is not simple. It requires a level of international cooperation to maintain the vital habitats that occur from Siberia to Australia which shorebirds rely on to survive.

However, Australia is uniquely placed to use good science to understand how shorebird populations may be changing. Without such knowledge it is difficult to make the case for the protection of shorebird habitats, to discover what is driving some of these declines, and what can be done to ensure shorebird populations can persist into the future.

Global shorebird population trends

Throughout the world, many populations of shorebirds appear to be declining (Wilson 2000; Morrison *et al*. 2001; IWSG 2003; Olsen *et al*. 2003; CHSM 2004; van de Kam *et al*. 2004). In 2003, trend estimates were available for 41% of the 499 populations of shorebirds around the world. Of these, 44% appeared to be decreasing, 13% were increasing, 39% were stable and 4% had become extinct (Delaney 2003; IWSG 2003). The population declines that were detected coincide with accelerating loss and degradation of shorebird habitat (UNEP 2006; Rogers et al 2009). In the East Asian–Australasian Flyway, a disproportionately high number of shorebird species have been classified as threatened, and many are under increasing threat from habitat destruction (IWSG 2003). Of the species that are resident in Australia, the species of most concern is the Hooded Plover, populations of which appear to be declining, due mainly to human disturbance during their nesting period, as well as degradation of their habitats (Weston 2003). Recent population-trend analysis of the National Shorebird Database held at BirdLife Australia shows strong evidence of declines in the Australian populations of an additional 12 species of migratory shorebirds, and evidence of declines evident in another eight species of shorebirds (BirdLife Australia unpublished data).

Global and national recognition of the importance of shorebirds

Recognising that the long-term conservation of viable populations of the world's species requires the identification, protection and management of their habitats, many governments have initiated conservation measures and signed international conservation agreements. The international agreements pertaining to Australia's shorebirds include the Ramsar Convention, the World Heritage Convention, the Bonn Convention, the Convention of Biological Diversity, the Asia–Pacific Migratory Waterbird Conservation Strategy and the East Asian–Australasian Shorebird Reserve Network. There are also several bilateral agreements, including the China–Australia Migratory Birds Agreement (CAMBA), the Japan–Australia Migratory Birds Agreement (JAMBA) and, most recently, the Republic of Korea–Australia Migratory Bird Agreement (ROKAMBA). In addition, Australia's *Environment Protection and Biodiversity Conservation Act* (1999) recognises migratory shorebirds as species of National Environmental Significance (NES), further highlighting the importance of shorebird conservation. All of these agreements require the identification and protection of areas for conservation.

Shorebird needs in Gulf St Vincent

Gulf St Vincent provides a diverse range of shorebird habitats that are vital for shorebirds to survive and reproduce. All shorebird habitats must provide a combination of feeding areas that are rich in food and nearby roosting areas that allow shorebirds to rest without losing too much energy due to disturbance. Further, shorebird habitat must minimise the risk of predation by providing sufficiently open areas to allow shorebirds to detect and avoid predators. For resident shorebirds, the wetlands surrounding the Gulf must provide also sufficient suitable habitat for successful breeding.

Conservation status of shorebird areas in Gulf St Vincent

Most of the important shorebird sites in Gulf St Vincent are legally protected within the reserve system that is administered by the Department of Environment, Water and Natural Resources (DEWNR), or occur within protected Australian Defence Force land or on commercial saltfields. The classified conservation areas include Clinton Conservation Park, Torrens Island Conservation Park, Port Gawler Conservation Park, Barker Inlet Aquatic Reserve, St Kilda–Chapman Creek Aquatic Reserve, Adelaide Dolphin Sanctuary and the Upper Gulf St Vincent and the Lower Yorke Peninsula Marine Parks.

Clinton Conservation Park is situated at the northern end of the Gulf and is recognised in the Directory of Nationally Important Wetlands. It covers over 18 km^2 and supports mangroves, tidal flats, samphire and chenopod shrublands. It is the largest reserve in Gulf St Vincent, and one of the most significant sites in terms of shorebirds (Close and McCrie 1986; Watkins 1993). Large areas are leased from the State Government for salt harvesting, providing havens for shorebirds at Dry Creek Saltfields on the Gulf's east coast and Price Saltfields on the west coast.

The coastline between Clinton Conservation Park and Dry Creek Saltfields is known as the "Samphire Coast" and it includes a variety of habitats that support many species of shorebirds. The area also has small townships scattered along the coast and areas of agricultural land. These developed areas are interrupted by an undeveloped 18.5-kilometre stretch of coast which is reserved for the Australian Defence Force Proof Range and and Experimental Establishment; it extends from north of Port Parham to south of Port Wakefield. This area has a public exclusion zone which extends beyond the tidal flats into the waters of the Gulf.

Much of the Samphire Coast's intertidal flats fall under the protection of the 971-km^2 Upper Gulf St Vincent Marine Park. The Park includes the coast up to the median tide line and waters of the Gulf north of a line joining Parara Point and the northern end of Port Gawler Beach. The Lower Yorke Peninsula Marine Park is located around the 'heel' of the Yorke Peninsula, from Point Davenport Conservation Park to Stansbury, covering an area of 874 km^2. Troubridge Island, located within the Marine Park, provides feeding and roosting sites for a large number of shorebirds.

Adjacent areas include private land and foreshore reserves, and these receive varying levels of protection, though some are subject to disturbance and degradation of habitat, mainly from off-road vehicles. The potential impacts on important shorebird areas are greatest in these unprotected areas. If viable populations of shorebirds are to be maintained, protected areas and threats from adjacent unprotected areas require careful management.

In 2012 the Adelaide Mount Lofty Ranges Natural Resources Management Board and DEWNR will commence the *Samphire Coast Icon Project* supported through fundin from the Australian Government's Clean Energy Future Bidiverstity Fund. The Samphire Coast Icon Project seeks to improve community stewardship for the samphire and shorebird areas, and provide a framework to boost strategic efforts across agency, local government and community and industry partners to address the long-recognised need to ensure the conservation of this area for the future.

Project outcomes include:

- Improved conservation and rehabilitation of nationally threatened samphire species and migratory shorebird roosting and feeding habitats.
- Assessment and trialling of samphire and saltmarsh rehabilitation techniques.
- Implementation of priority on-ground works to maintain and rehabilitate threatened coastal samphire and shorebird habitats identified in Coastal Action Plan, Shorebird Population Monitoring studies and Estuary Action Plans, and local action to implement the national Wildlife Conservation Plan for Migratory Shorebirds and conserve regionally threatened coastal butterfly habitats.
- Coordination of strategic efforts across agency, local government and community and industry partners for coastal habitat conservation.
- Development and trialling of habitat retreat strategies maintain coastal samphire and shorebird habitat.
- Assessment of significant artificial wetlands to scope and trial habitat modifications to optimise benefit for migratory shorebird species.
- Implementation of community stewardship and awareness initiatives to increase public knowledge and appreciation of saltmarsh and migratory shorebird habitat
- Liaison with key mining industry partners (salt and shell grit) to scope and (where possible) undertake optimisation of mining lease areas for the benefit of shorebird habitats.
- Scope the feasibility and seek to progress dialogue with stakeholders for the nomination of the areas under the National Shorebird Network and Ramsar Convention on Wetlands of International Importance. In-kind contribution will cover AMLR officers, hosting and some site works.

Key shorebird habitats in Gulf St Vincent

The coastal wetlands of Gulf St Vincent consist of a mosaic of artificial and natural shorebird habitats. The suitability and selection of roosting or feeding habitat by shorebirds is governed by ambient factors, including environmental, human, structural and abiotic features. It is important to determine the extent to which these factors affect the use of various habitats and the associated implications for shorebird habitat protection, so that conservation strategies and informed management of human recreational use of these habitats can be formulated (Peters and Otis 2007; Oldland *et al*. 2008).

Five categories of habitat types have been identified as being of priority conservation value for the protection of shorebirds in Gulf St Vincent and mapped (Appendix B). They are: tidal flats; sandy shores; saltmarsh; saltpans; and commercial saltfields/artificial wetlands. These sites are used according to temporal variations in prey abundance, tide conditions, human interference and the diversity and abundance of the shorebirds themselves.

Figure 2. The Bar-tailed Godwit is one of the intertidal specialists which visit the beaches of Gulf St Vincent in summer. Photo Jon Irvine

a) Tidal flats

A combination of sediments, currents, low relief and tidal range can produce large areas of tidal flats. In Gulf St Vincent, these factors have combined to form many expansive areas of tidal flats; for example, between Barker Inlet and Clinton Conservation Park, the tidal flats stretch for nearly 100 kilometres, and some of them are more than 250 metres wide.

The sand flats and mudflats which occur along Australia's coastlines are inhabited by abundant and diverse small burrowing invertebrates. These benthic bivalves, worms and crabs can be difficult to find, let alone catch, but shorebirds are expert at obtaining them. Accordingly, they are the most common birds on tidal flat systems around Australia.

In Australia, 14 of the most regularly occurring shorebirds, including species such as Red Knot, Bar-tailed Godwit (Figure 2) and Eastern Curlew, specialise in feeding on tidal flats. These species, all of which occur in Gulf St Vincent, have evolved to exploit different food sources within tidal flats (Figure 3), and during the non-breeding period feed almost exclusively in those habitats.

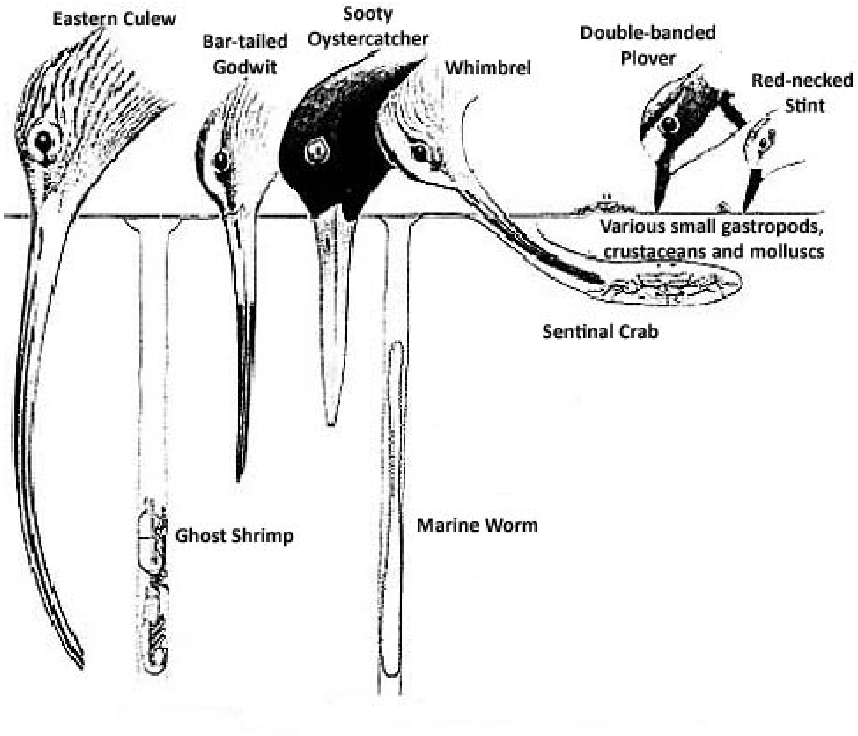


Figure 3. Shorebird bill adaptations to feeding in intertidal substrate. Reproduced from Lane (1987), with permission.

Significant areas of tidal flats in Gulf St Vincent support an array of invertebrates that are regularly eaten by shorebirds. Apart from the tidal flats of the Clinton Conservation Park, the most significant areas of shorebird feeding habitat occur between Light Beach and Bald Point, where thousands of foraging shorebirds congregate.

b) Sandy shores

Much of Australia's coastline comprises beaches, consisting of predominantly sandy shores of varying steepness and width. Beaches often occur on high-energy shorelines, and they support fewer burrowing invertebrates than tidal flats. Nevertheless, they provide a diversity of prey for a few species of shorebirds that specialise in foraging in these habitats. For example, species such as the Ruddy Turnstone and Red-capped Plover are adept at picking invertebrates from the tidal wrack of decomposing seaweed that is washed up on some beaches.

In general, shorebirds occur in low densities in these habitats, with the exception of high-tide roosts where large flocks of shorebirds sometimes congregate (Figure 4). Such large flocks usually occur when the expansive flats are covered by the high tide, forcing birds to rest in open areas (without cliffs or trees in all directions) that have not been inundated.

Some species of shorebirds, such as the Hooded Plover and Red-capped Plover, are true ocean-beach specialists, foraging and nesting on beaches. They are less numerous than many other species of shorebirds, and a beach supporting only a few pairs may be of considerable conservation importance.

Sandy beaches often experience intensive recreational use, and some coastal parks record millions of visitors each year. However, few Australians consider beaches to be important habitat for wildlife and, as a result, the impacts that coastal development, exploitation, modification and recreation have on shorebirds on beaches are often overlooked. If this trend continues unabated, many areas that are currently considered good habitat for shorebirds could be rendered unsuitable.

Although vast stands of mangroves line the coast between Barker Inlet and Light Beach, most of Section Banks consist of sandy shores. Sandy shores occur from Light Beach north to Bald Hill, where they form the dominant intertidal buffer between tidal flats and saltmarsh. They are often covered in thick layers of beachcast seaweed.

Figure 4. Red-necked Stints and Red-capped Plovers (foreground) roost along the sandy shoreline of Light Beach, while larger Eastern Curlews prefer to roost on the tide line. Photo Chris Purnell

c) Saltmarsh

Characterised as a mostly treeless plant community comprising a mosaic of low succulent shrubs and herbs, salt-tolerant grasses and sedges, saltmarsh is considered by some to be a lifeless wasteland. As a result, many saltmarshes have been in-filled, used as rubbish tips and places for recreational off-road vehicles (DECC 2008). Ignorance of the ecological value of saltmarsh has been reflected in the relative lack of protection afforded to the habitat when compared with most other ecosystems. Until recently, saltmarsh was the least studied of all of Australian marine habitats, even though the habitat occupies up to 16,000 km^2 of the Australian coastline and supports more than three times the number of vascular plant species than occur in mangrove forests (Saintilan and Williams 2000). There are 1,270 km^2 in Gulf St Vincent, comprising 600 km^2along the eastern side, 200 km^2at the head of the Gulf and 470 km^2 along the western shoreline.

Migratory and resident shorebirds feed and roost in saltmarshes, and in the absence of freshwater wetlands they are the preferred habitat of species such as the Common Greenshank, Marsh Sandpiper, Black-winged Stilt and Pacific Golden Plover. These sites are especially crucial during spring tides and other periods of high tidal inundation, when regular feeding and roosting sites are rendered unsuitable for most shorebirds. The birds are forced inland to feed or roost in saltmarshes and saltpans, such as those at Third Creek. Thus, with the threat of rising sea levels, these sites are valuable for shorebird conservation.

As with tidal flats, saltmarshes provide wide open spaces which allow shorebirds uninterrupted views, providing increased surveillance for predators, which enables more time to be spent feeding. Some tidal creeks and runnels which criss-cross saltmarsh open up into large saltpans which may support large flocks of feeding or roosting shorebirds. Similarly, small, shallow pools and streams may also provide areas where shorebirds can feed while roosting.

Much of the destruction of coastal saltmarsh in Australia has occurred through reclamation for agricultural, industrial, transport and residential development (Kratochvil *et al*. 1972; Finlayson and Rea 1999). Significant alterations to the hydrology of saltmarshes have followed the construction of levees, culverts and floodgates, leading to the loss of ecological function and alteration of the floristic composition. The discharge of storm-water in coastal areas also alters salinity regimes, increases nutrient levels and facilitates the spread of invasive weeds as well as the expansion of mangrove communities (Saintilan and Williams 1999). Similarly, unrestricted access into saltmarsh by walkers, cyclists, off-road vehicles (Figure 4) and grazing animals also adversely affects saltmarsh communities; for example, wheel ruts from off-road vehicles and trail bikes persist for many years in saltmarsh, even after vehicles have been excluded (DECC 2008; Figure 8). Faced with these threats, the NSW Department of Environment and Climate Change (DECC) recently classified Coastal Saltmarsh as an Endangered Ecological Community (EEC).

The eastern coast of Gulf St Vincent supports fragmented patches of low-lying saltmarsh which are used by shorebirds. Further north, mangroves dominate the shoreline, and saltmarsh and saltpans of varying size and condition are bound by either mangroves or sandy shores on the seaward side, and, on the landward side, by higher land, ridges or development (Coleman and Cook 2009).

d) Saltpans

Saltpans are also characteristically open and free of tall vegetation, and, like saltmarsh, they also remain vastly under-studied and under-protected in Australia. Formed in supratidal areas of low-lying, dry regions, they are seldom inundated by water (Coleman and Cook

2009). However, when they become covered with water, cyanobacterial mats are able to grow, forming the basis of a food web in which shorebirds are the top predators.

As with saltmarshes, the lack of tall vegetation and largely supratidal nature of saltpans provide ideal roosting habitat and should be considered as a crucial refuge with the threat of sea level rises.

e) Commercial saltfields and artificial wetlands

Though many migratory shorebirds inhabit intertidal habitats while they are in Australia during the non-breeding season, their use of saltpans indicates that supratidal habitats can also provide suitable habitat for wintering shorebirds.

In Gulf St Vincent, the most significant supratidal habitats are artificial ones. Of these, the series of salt evaporation ponds (salinas) found within Cheetham Salt's Dry Creek Saltfields provide the greatest amount of shorebird habitat.

The presence of supratidal habitats can increase the number of shorebirds that a region can sustain, or reduce the detrimental impacts of the loss of intertidal habitats (Velasquez and Hockey 1992; Masero 2003; Dias 2009). The reduction in area of intertidal foraging sites often results in an increase in the density of shorebirds in the remaining areas, which, in turn, leads to an increase in both the impact on shorebird food supplies and interference between foraging birds (Velasquez 1992). The presence of supratidal habitats, such as the Dry Creek Saltfields (Figure 5), which resemble intertidal habitats can provide alternative foraging areas for shorebirds and other species of waterbirds (Weber and Haig 1996). Several studies have suggested that the availability of high-tide foraging areas contribute significantly to the maintenance of both high foraging densities of shorebirds on intertidal mudflats and overall stability of non-breeding populations (Velasquez and Hockey 1992).

Figure 5. Several species of shorebirds thrive on the high densities of invertebrates found in the hypersaline ponds of Dry Creek Saltfields. Photo Chris Purnell

Commercial saltworks are man-made supratidal habitats managed for the production of salt. By the predictable manipulation of water depth and salinity used for salt production, these areas attract many species of shorebirds, as the fluctuations in water depth and salinity provide a variety of foraging habitats, each of which suits a particular guild of shorebirds. Because these artificial supratidal areas have salinity, fluvial dynamics and benthic substrates that differ from tidal communities, they support distinct invertebrate communities. Consequently, these habitats can provide both supplemental high-tide and preferential feeding habitats for different species of shorebirds (Masero *et al.* 2000).

Shorebirds represent about 25% of the more than 200 species of birds recorded in and around the Dry Creek Saltfields. Since 1976, 52 species of shorebirds have been recorded in the region (including nine of them in numbers considered to be of international significance). Together with the Price Saltfields, these artificial supratidal habitats are a major factor in Gulf St Vincent being an important shorebird area in South Australia, second in importance only to The Coorong.

Other supratidal habitats used by shorebirds include low-intensity aquaculture ponds, sewage treatment plants and artificial wetlands, such as Barker Inlet Wetlands, Magazine Road Wetlands and Globe Derby Wetlands. Unlike intertidal mudflats, time spent foraging in these habitats is not restricted by tidal inundation, allowing shorebirds to spend longer periods foraging for invertebrate prey (Velasquez and Hockey 1992; Weber and Haig 1996). The above-mentioned wetlands also provide an open, shallow freshwater habitat for shorebirds such as Wood Sandpipers and the Endangered Australian Painted Snipe, which prefer feeding and roosting in freshwater or brackish conditions.

Importantly, these habitats are not accessible to the public and remain largely undisturbed, apart from occasional operational staff or birdwatchers (both of whom are aware of the implications of disturbance).

A literature review discussing the importance of saltfields for shorebirds can be found in the 2010/11 Population Monitoring Report.

Threats to shorebirds in Gulf St Vincent

The threats to shorebird populations and their habitats in Gulf St Vincent include human-induced habitat loss or degradation, disturbance, invasive species, pollution and human-induced mortality or breeding failure. The severity of these threats depends on the scale and cumulative effect of human actions throughout the area, and the degree to which shorebird populations are currently limited in the area. Previous reviews of wader populations in Gulf St Vincent have been limited by a shortage of data and are therefore subject to sampling error, and probable declines in shorebird numbers may be also be attributed largely to factors independent of the Gulf (Close 2008). These conclusions are based on a 50% decline (from 59,851 to 29,929) in numbers of northern hemisphere (or Palaearctic) breeding species recorded in the Gulf between 1979 and 2008. In contrast, resident species declined overall by only 12%. However, within the category of residents, the number of Red-necked Avocets declined by 96%, and numbers of Black-winged Stilts, Red-kneed Dotterels, Red-capped Plovers, Masked Lapwings and Banded Lapwings also declined greatly (Close 2008). The Shorebird Population Monitoring Program has recognised declines in both resident and migratory birds throughout south-eastern Australia (Gosbell and Clemens 2006), and recommends that threats to local shorebird habits must be identified.

The potential for development along the Gulf's coastline introduces all of the above-mentioned threats to the stability of shorebird habitats and creates irreversible flow-on effects.

a) Habitat loss or degradation

Habitat loss and degradation is the prime long-term threat to migratory and resident shorebird populations in Gulf St Vincent. The urbanised stretch of coast south of Adelaide has historically supported a healthy number of shorebirds, including breeding Hooded Plovers, but since extensive development and increasingly intensive use by people, shorebird numbers in the area have plummeted (Close 2008) and beach-nesting birds, especially the Hooded Plover, have become increasingly uncommon.

This is the scenario now facing shorebird habitats north of Adelaide, with the projected population growth of the northern Adelaide region to exceed 160,000 over the next 30 years. Apart from direct habitat loss, it is the cumulative indirect affects that population growth has on shorebirds which will threaten populations in Gulf St Vincent. For example, large areas of tidal mudflats at St Kilda have been reclaimed and built upon, including a boat launch and marina. This has not only removed historic feeding and roosting sites and degraded surrounding habitats (Coleman and Cook 2003) but has also increased levels of disturbance from boat traffic, the occurrence of exotic predators, the potential for pollution and the introduction of coastal weeds.

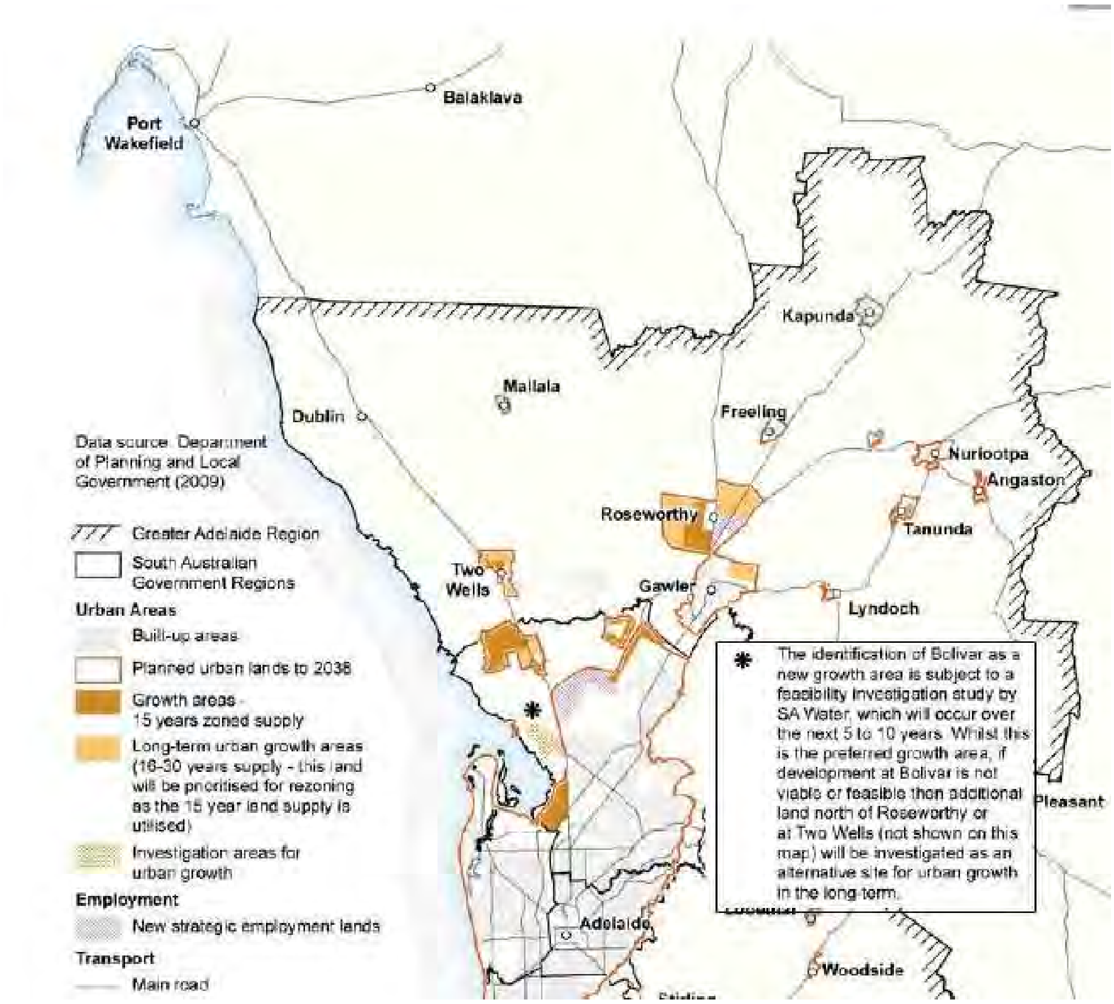


Figure 6. Urban expansion priorities. Image from *The 30-Year Plan for Greater Adelaide*

When considering habitat loss or degradation on its own there are two major areas of consideration: the Dry Creek Saltfields–Buckland Park; and the Samphire Coast.

The habitats that the Dry Creek Saltfields create as an active operation support an average population of nearly 15,000 shorebirds. However, it occupies valuable land along one of northern Adelaide's key growth areas (Figure 6). Developments proposed for the southern part of the Saltfields and the Buckland Park area have been recently reconsidered. Similarly, an expansion of the Northern Expressway has been redirected. Previously, the Expressway had been planned to bisect the Saltfields and jeopardise the Magazine Road and Barker Inlet Wetlands as well as the operational future of the Saltfields themselves. Given their proximity to both the city and the coast, there are likely to be similar proposals for these valuable parcels of land in the future. Although it is difficult to gauge the extent to which such developments would impact on the shorebird population, migratory birds which congregate in large feeding and roosting flocks are likely to experience mass displacement and consequent population reductions throughout the Gulf. The disturbance created by such a large-scale development would displace many species, not only in construction areas, but also in adjacent habitat (Kellog and Root 2003). Scenarios for alterations of operation and potential decommission of the saltfields are the subject of a pending Program for Environmental Protection and Rehabilitation (PEPR) which is to be provided by

Cheetham Salt. Discussion surrounding this document is referred to elsewhere in this report.

Other notable shorebird areas along the Samphire Coast are susceptible to pressure from habitat loss or degradation. While development may not be a short-term priority in the northern coastal towns of Port Parham, Webb Beach and Thompsons Beach, an influx of off-road vehicles accessing areas of saltmarsh, intertidal flats and claypans from Port Gawler to Port Parham threaten to reduce the value of the habitats as feeding areas. Off-road vehicles can compact sediment and the benthic macrofauna contained within (Schlacher *et* al. 2008), drastically reducing the availability of shorebird prey. When driven in saltmarsh, four-wheel drives and motorbikes can also destroy the samphire flora and change the structure of the habitat (Fig 7). The increased disturbance caused by four-wheel drives and dirt-bikes in roosting and feeding areas can have the same effects on shorebirds as habit loss if birds are disturbed to the point where the energy costs of surveillance behaviour and disturbance flights outweigh the energy gained from the habitat (West *et al*. 2002; Goss-Custard *et al*. 2006; Rogers *et al*. 2006; Peters and Otis 2007). If disturbance is sustained, shorebirds may abandon even the most productive of habitats within and across seasons (West *et al*. 2002, Goss-Custard *et al*. 2006).

Figure 7. Off-road vehicle damage to saltmarsh. Photo Glenn Ehmke

It is, therefore, important that the potential impacts of any development, proposed management or proposed activity within 1 kilometre of these important shorebird areas should be fully assessed.

Significant habitat loss is also likely to occur through the effects of global warming. Since the early 1990s, southern Australia has experienced sea level rises of 2–7 millimetres per year (Edyvane 1999; Harris 2011) and it is expected that a further rise of over 10cm can be expected by 2030 (Clarke, B. & Simpson, N. 2010). Recent studies into the effects climate change will have on shorebird habitat suggest that 21st century sea-level rise will lead to the loss of a quarter of the habitat area used by these species, but cause the overall population to decline by about two-thirds across ten taxa because of the way the migration networks are structured (R. Fuller unpublished).

In Gulf St Vincent, this will include beach recession of between 5–30 metres by 2050 (variation dependant on beach topography, sand supply and littoral sediment movement). Supratidal communties will be displaced by intertidal communities and those that fail to migrate upslope will be lost (Clarke, B. & Simpson, N. 2010). An increase in water tempreture and the regularity of storm surges and turbity is also likely to negatively impact the abundance and distribution of shorebird prey assemblages.

b) Disturbance

The largest ongoing threat to the survival of migratory shorebirds in Gulf St Vincent is disturbance. Further, as Adelaide grows, increasing numbers of people are likely to visit the coastal and wetland habitats used by shorebirds, and this threat is likely to escalate if thoughtful adaptive management of recreation is not applied.

Studies have shown that human disturbance of roosting shorebirds is related to local population declines (Pfister *et al*. 1992; Tubbs *et al*. 1992; Burger *et al*. 2004), lowered body condition (Durell *et al*. 2005), regional habitat shifts (Burton *et al*. 1996) and local avoidance behaviour (Kirby *et al*. 1993). Species with high roost-site fidelity and minimal movement between roosts are most at risk from human disturbance and require particular attention (Rehfisch *et al*. 1996).

Occasional disturbance to shorebirds, such as those caused by the appearance of a raptor, are common, but generally there tends to be a balance between the energy lost during these natural periodic disturbances and the ability to offset those losses by foraging for longer or on supplemental prey. In an increasing number of areas, however, human disturbance appears to be too great to be offset by supplemental feeding (West *et al*. 2002). Modelling suggests that some patterns of disturbance can result in net energetic losses at habitats that remain occupied, and in some cases these energetic losses are greater than would have occurred if the habitat had been lost entirely (West *et al*. 2002; Rogers *et al*. 2006; Gill 2007). These energetic losses can potentially affect species at the population level, and the relationship between disturbance and population declines in non-breeding areas have been shown conclusively overseas in populations of the Pink-footed Goose (Tombre *et al*. 2005; Gill 2007). The level of knowledge required to determine conclusively to what degree disturbance may impact on shorebird populations is far from being met.

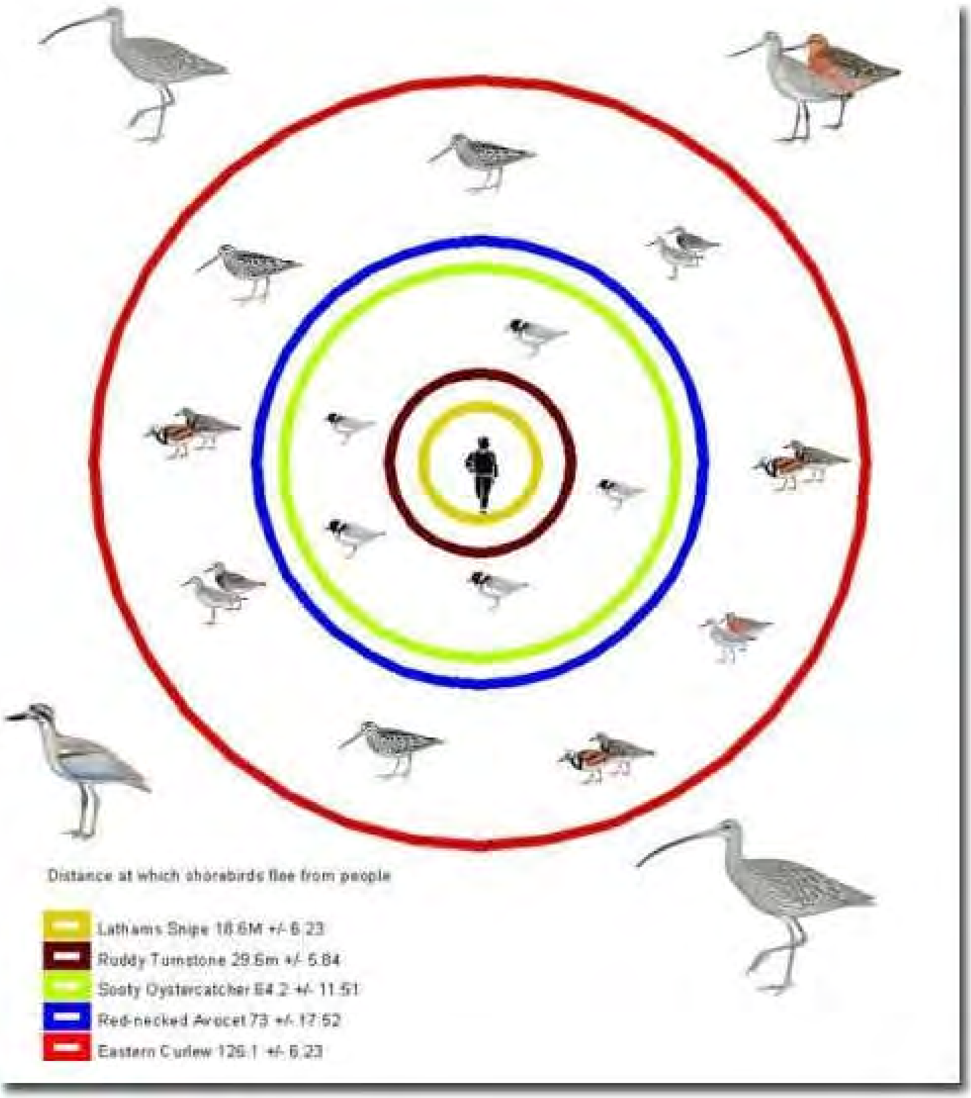


Figure 8. Each species of shorebird has its own tolerance to disturbance to human approaches. Distances given are from prelimanry data, but further study may reveal larger buffers are required. Illustrations Jeff Davies

A major complication in determining the impact of disturbance is the difficulty in determining the energetic cost of the wide variety of disturbances that may occur. Much work has been done to determine the distance at which different bird species flush when confronted with different kinds of disturbance, and results vary from 50 metres to 250 metres, with Eastern Curlews more likely to fly off at greater distances (Figure 8); most birds respond at greater distances to unleashed dogs or noisy and fast watercraft (Paton *et al*. 2000; Blumstein 2003; Yasué 2005; Gill 2007; Glover 2009). Unfortunately, this intuitive measure of disturbance probably underestimates the true energetic impacts of disturbance.

The shorebird habitat in and around the populous and much-visited Samphire Coast has been identified as the habitat most effected by disturbance. The frequency of disturbance necessary to cause shorebirds to abandon an area is unclear. It is clear, however, that disturbance has energetic costs that could potentially reduce a shorebird's chances of survival or its ability to reproduce. Pine Point on the western shores of the Gulf provides a good example. At this site, boats are continually launched by being towed by a tractor across shorebird feeding areas on the rocky reef and mudflat. The remaining edges of the tide line are patrolled by people catching crabs, many of whom are accompanied by dogs which constantly disturb feeding birds. Without historic counts for these areas it is difficult to gauge the effect of increased human activity on shorebirds over time, but a comparison with similar relatively undisturbed rocky reef/mudflat habitats at Black Point, 5 kilometres further south, shows a drastic difference. Although it receives limited disturbance, the small reef at Black Point is one of the most diverse sites in the Gulf, despite its remoteness.

Non-vehicular recreational activities

The most readily identified cause of disturbance to feeding and/or roosting shorebirds in Gulf St Vincent arises from non-vehicular recreational activities. These activities can be static (e.g. fishing, sunbaking, picnicking) or mobile (e.g. walking, jogging, walking dogs).

Static activities may not initiate flight but can cause habitat avoidance and increased surveillance behaviour among feeding and roosting shorebirds. Alternatively, mobile activities are of lower temporal impact but have greater likelihood of initiating flight. Of these activities, dog walking, especially of unleashed dogs, causes the greatest levels of disturbance (Figure 9). This is due to the unpredictable behaviour and non-linear paths that dogs walk, as well as their obvious similarities to traditional shorebird predators. In a study of the Western Snowy Plover in North America, people with dogs were found to cause flushing of birds 100% of the time once they were within 50 metres, and 52% of the time when they were within 100 metres (Page *et al*. 1977).

Figure 9. An unleashed dog causing disturbance. Photo Mike Weston

A steady increase in fishing is also contributing to high levels of disturbance as well as the destruction of habitat around the Gulf (Fitzpatrick and Bouchez 1998). The upper sections of Gulf St Vincent provide important breeding and nursery areas for a number of key marine species, including King George Whiting *Sillaginodes punctata* and Blue Swimmer Crab

Portunus pelagicus, both of which are fished recreationally and commercially. In particular, crabbing seasons coincide with the arrival of thousands of migratory shorebirds in Gulf St Vincent. The Blue Swimmer Crab season begins in September and runs through summer as the crabs congregate in inshore areas to breed, peaking in February; they then disperse back into deeper water by April. Hundreds of crabbers may patrol the tide line, creating a constant disturbance for feeding and roosting birds. One popular crabbing technique, known as "dabbing", involves patrolling the tide line of shallow sandy beaches or mudflats. This overlap with shorebird habitat causes continual interaction and disturbance of feeding and roosting shorebirds. Fishermen may also compete directly with shorebirds when collecting benthic invertebrates to use as bait (Carpenter 2008).

Boating

Boating traffic is a major source of disturbance to shorebirds, and it has been linked to long-term abandonment of roosts (Burton *et al*. 1996). Red Knots, which occur in great abundance in Gulf St Vincent, have been recorded avoiding roosts in areas where high boating activity occurs within 1 kilometre (Peters and Otis 2007). Apart from feeding and roosting sites situated on sandbars adjacent to boating channels (Section Banks, Middle Beach and Port Wakefield), most shorebird areas in the Gulf do not currently receive high levels of boating traffic, but if the level was to increase it would reduce the number of coastal sites available for roosting by some species.

Off-road vehicles

Continuous stretches of sandy coastline allow access by recreational off-road vehicles (four-wheel drives and dirt bikes) to remote areas and unutilised fishing sites (Figure 10). This disturbs roosting and feeding shorebirds, and potentially causes resident shorebirds to abandon their nests. The use of off-road vehicles also has an impact on macrobenthic assemblages on sandy beaches (Schlacher *et al*. 2008).

Figure 10. An off-road vehicle emerges from saltmarsh onto a tidal flat at Port Gawler. Photo: Chris Purnell

The closure of the Port Gawler Off-road Vehicle Park in late 2006 resulted in an increase in the number of off-road vehicles using shorebird habitat. In particular, dirt-bike riders regularly gain access to protected areas by flattening fences, and they not only destroy habitat but also create disturbance at inland roosts. Recently, the Off-road Park was reopened, attracting considerable attention from the dirt-bike and four-wheel drive community: a Facebook page run by the managers has attracted over 1,300 members. However, with a $40 entry price, limited opening hours (Saturday and Sunday), and no four-wheel drive facilities, there is still a large number of drivers using adjacent shorebird habitat in saltmarsh, most notably the Port Gawler intertidal foreshore. Off-road-vehicle drivers cause repeated disturbances, impacting on habitat quality and potentially causing accidental mortality to the two species of beach-nesting shorebirds that use the site. Research into the use of four-wheel drives in shorebird areas shows that only a small proportion (15%) of off-road drivers heed signs asking them to avoid these sensitive areas (McGrath 2006). This problem has escalated due to the increasing affordability and accessibility of off-road vehicles.

Other recreational activities, such as jet skis and para-surfing, at various sites in the Gulf all discourage shorebird feeding and roosting. These activities have caused multiple disturbances at many sites, including Port Parham, Port Gawler, Light Beach and throughout the Samphire Coast, especially Thompsons Beach and the saltpan at Third Creek.

The evidence of increased disturbance can be more tangibly measured in resident beach-nesting shorebirds then on migratory shorebirds. Preventable sources of breeding failure or mortality arise from people, vehicles or dogs on the beach; all of these can disturb birds to the point that they are unable to incubate eggs or brood their chicks to maintain a suitable temperature or to ensure they are fed. Populations of Hooded Plovers (listed as Vulnerable under the *National Parks and Wildlife Act* [1972]) breed on the beaches of the southern Fleurieu Peninsula, from Sellicks Beach to Port Willunga. They and the more widespread Red-capped Plover and Masked Lapwing are threatened by human-induced breeding failure or mortality, and other pressures such as predation by foxes (Dowling and Weston 1999; Weston 2000).

Some form of disturbance occurs in most shorebird areas, but their effects are not fully understood, as birds may be able to find refuge in nearby habitat. Observations suggest that disturbance often occurs in many areas throughout Gulf St Vincent, forcing shorebirds to continually move and compounding the effect of each disturbance. This is likely to increase as coastal development expands. It is, therefore, important to set buffers to disturbance around these important shorebird areas now, before more areas become adversely affected.

A literature review discussing shorebird disturbance and habitat management can be found in the 2009/10 Population Monitoring Report.

c) Introduced mammals

In natural ecosystems, there is a co-evolution between predator and prey species, with prey species evolving evasive or defensive behaviour in concert with evolving prey-capturing behaviour by predators. However, when exotic predators are introduced into the ecosystem, they often thrive in these environments, reaching high population densities. Because native species of prey have not evolved to cope with the strategies of these predators, their impacts can be severe (Maguire 2008).

Introduced animals pose a readily identifiable threat to shorebirds in Gulf St Vincent. Rats, dogs, foxes and cats have all been observed in shorebird habitat during the study period, and are likely to pose a threat to resident (beach-nesting and wetland-nesting) shorebirds in the Gulf. These exotic predators give rise to increased disturbance and surveillance behaviour among all shorebirds, and this is ultimately manifested in reduced feeding rates, increased energy expenditure and reduced breeding success.

Foxes

There is considerable variation in the impact of foxes on shorebirds. It is thought that even though urban development can encourage population densities of foxes that are three or more times greater than in rural areas (Coman *et al*. 1991; Marks and Short 1996), it is in relatively pristine areas that foxes become the dominant local threat to shorebirds, particularly beach-nesting birds. On the Victorian coast, for example, rates of nest failure of Hooded Plovers of between 17% and 27% were attributed to predation by foxes (Weston 2003; G. Maguire unuplished data). Elsewhere, in Western Australia, the contents of one fox's stomach contained the remains of 38 Red-capped Plovers (Geering *et al*. 2007).

Mapping of active fox dens adjacent to high value shorebird habitats Port Gawler to Port Parham was undertaken in 2010-11 through the AMLRNRM Board and identified 6 fox dens (Greening Australia, 2011). Ongoing control is planned throughout the region.

Dogs

Domestic dogs are not only the greatest source of disturbance to shorebirds but they have also been recorded preying on both eggs and birds (Buick and Paton 1989). However, even when leashed, dogs are recognised as a greater cause of major disturbance to shorebirds than people (Figure 9).

d) Invasive plants

Coastal sand dunes and surrounding habitat are under threat from environmental weeds. This threat is recognised by local councils and control measures are in place. Rice or Cord Grass *Spartina sp*, Marram Grass *Ammophila arenaria*, Sea Spurge *Euphorbia paralias*, African Boxthorn *Lycium ferrocissimum* and Tree Mallow *Lavatera arborea* are hardy opportunistic colonisers which threaten to choke shorebird habitat.

In the region Spartina spp is a potential threat to coastal wetlands. It is considered a threat to waders due to its impacts on mudflat habitats. A sterile variety of Spartina was planted out by the Waite Institute in the 1930s at Pt Gawler. This infestation occurred at the mangrove edge, with less than one hectare recorded in 1997. The species appears to have been successfully eradicated at Pt Gawler through in weedicide and its known occurrence manual removal in 2006 (Fotheringham,D. pers comm.2007)

Marram Grass was introduced from Europe in the 19th century to stabilise mobile sand dunes, and it has successfully colonised areas of open substrate throughout Gulf St Vincent, displacing indigenous vegetation. Chosen for its strong vertical growth and capacity to hold a large volume of sand, Marram Grass has changed the morphology of foredune systems from low, terraced dunes to higher dunes with steeper sides. Lower-terraced dunes are preferred by resident shorebirds such as Hooded Plovers and Red-capped Plovers, as are sparse native grasses which provide incubating birds with uninterrupted surveillance (Park 1994). Marram Grass is most common on beaches south of Outer Harbour, where it dominates, and has probably contributed to the decline of shorebirds in that area.

Sea Spurge, a native of the Mediterranean coasts, occurs on free-draining sandy beaches, around estuaries, on dunefields and in other associated coastal habitats (Wilcock 1997). It is widespread throughout the Gulf, especially north of Middle Beach. Infestation by this plant may impact on beach-nesting birds such as terns, Hooded Plovers and Red-capped Plovers (Park 1994; Rudman 2003) and may result in steep dunes that are susceptible to wave erosion. Sea Spurge has received much attention on the southern beaches, and the Seacliff to Brighton Beach Sand Dune Restoration Project has targeted the aggressive spread of the weed with a routine of spraying and hand weeding.

African Boxthorn and Tree Mallow are woody weeds that occur on ridges and dunes. Although more confined to urban beaches, they threaten to proliferate along coasts throughout Gulf St Vincent and have already impacted areas surrounding Middle Beach, Thompsons Beach and Buckland Park Lake (Jensen 2004; Carpenter 2008). Infestations of these plants have blanketed bare sites favoured by nesting terns on Section Banks, and have caused significant problems in coastal habitats elsewhere, including the loss of valuable shorebird areas on Mud Islands in Victoria and West and Encounter Islands in South Australia (Veitch and Clout 2002; Carpenter 2008) and the displacement of nesting puffins in the northern hemisphere (McKie 2005). When mature, these plants also provide preferred nesting habitat for Silver Gulls *Chroicocephalus novaehollandiae* (Carpenter 2008) and cover for introduced predators such as foxes and feral cats.

e) Encroachment onto habitat by native vegetation

Some native plants also pose a threat to shorebird habitat in Gulf St Vincent, with incursion by mangroves occurring in many coastal areas. Mangrove and saltmarsh habitats are seral — that is, their boundaries do not stay the same over time, but change to reflect factors such as changes in sea level and supply of sediment. In some parts of the Gulf, areas vegetated with Grey Mangrove *Avicennia marina* are expanding at an unprecedented rate (Saintilan and Williams 1999, Harris 2011), and many young mangroves are sprouting among the saltmarsh plants (Fig 11). This is especially prevalent in Barker Inlet, where the saltmarsh is confined to an area between the mangroves and the seawalls, and has been gradually encroached upon since the 1940s so that now little remains.

There are many possible explanations for this trend of mangrove expansion. It has been suggested that the increased annual rainfall in the area since 1945 may have diluted salt levels within saltmarsh soils to the extent that mangrove colonisation was enhanced (Saintilan and Williams 1999). Increased nutrient levels and sedimentation from agriculture are also considered a possible cause of increased colonisation by mangroves (Hughes 2003; Straw and Saintilan 2006).

The expansion of mangroves can limit the availability of the open spaces that shorebirds use for roosting and feeding. Shorebirds prefer the security of open spaces with high visibility for the easy detection of approaching predators (Straw and Saintilan 2006). To illustrate shorebirds' preference for open areas, in a survey of 63 intertidal mudflats in nine estuaries in New South Wales, 90% of ground-roosting sites used by shorebirds were more than 10 metres from 2-metre-tall trees and shrubs, and 83% were at least 30 metres from 5-metre-tall trees (Lawler 1996).

The expansion of the Grey Mangrove is viewed as unnatural in south-eastern Australia. Pressure is currently being exerted by residential, coastal development, planning and management authorities to remove and destroy mangroves, partly to protect and reinstate other impacted habitats such as saltmarsh and mudflats. Estuary management planning is a useful tool that can integrate and balance policy directions for mangroves and other estuarine habitats in a strategic manner. Options for management intervention, such as the controlled removal of mangrove seedlings and saplings from key shorebird feeding grounds, as well as the restoration and creation of mudflat and saltmarsh habitat, are currently being undertaken to conserve shorebird habitat in Hong Kong (Straw and Saintilan 2006). Mangroves should not be considered as "bad" in isolation, but viewed as part of the mosaic of tidal habitats that are important for estuary function and health. In some areas of Gulf St Vincent, such as Dry Creek Saltfields, natural die-off of mangroves is exceeding expansion.

Figure 11. Satellite imagery reveals the extent of mangrove incursion in intertidal shorebird habitat at Port Gawler. Adapted from Google Earth imagery

f) Potential impacts of native birds

Locally nesting shorebirds are also under threat from expanding populations of opportunistic native birds. An increase in food resources, such as coastal rubbish tips and urban rubbish bins, may sustain artificially high populations of Little Ravens *Corvus mellori* and Silver Gulls.

Ravens

Ravens, which are also attracted by fruiting events of coastal shrubs, have been identified as the major predator of the eggs of beach-nesting birds and, to a lesser extent, their chicks (Weston and Morrow 2000; Maguire 2008). In New South Wales, Victoria and Tasmania, ravens have been identified as predators of Hooded Plover and oystercatcher chicks, accounting for up to 11% of nest failures (Hanisch 1998; Weston 2000; Weston and Morrow 2000; Berry 2001; Keating and Jarman 2003; Maguire 2008).

Gulls

Numbers of Silver Gulls have increased substantially throughout Australia (Blakers *et al*. 1984; Higgins and Davies 1996, BirdLife Australia Atlas of Australian Birds), and this has been mirrored in the Gulf over the last 50 years, reflecting the increased availability of food at rubbish tips (Carpenter 2008). Generally, beach-nesting birds are effective at defending their eggs and chicks against Silver Gulls (Weston 2000). However, Silver Gulls are able to approach nests more closely when the attending adults are disturbed and have moved away from the nest. This may suggest that gull predation is more likely to be a factor in highly disturbed areas (Weston 2000; Maguire 2008).

The negative impact that Silver Gulls have on nesting shorebirds has, in the past, prompted active gull control in Gulf St Vincent (Baxter 2003). Changes to the management of Wingfield Rubbish Tip since 2005 have reduced the amount of food available to gulls, which has resulted in a reduction of their numbers and restricted their breeding opportunities, but, nevertheless, they still occur in enormous numbers around the Gulf, and the Integrated Waste Services northern landfill site at Dublin provides an attraction near key shorebird areas.

g) Human-induced mortality or breeding failure

The resident shorebirds that occur on several sandy beaches around Gulf St Vincent are under threat of accidental human-induced mortality or breeding failure. In these areas the threat is primarily due to shorebirds' well-camouflaged eggs or chicks that are accidentally stepped on or run over by vehicles. Eggs of Hooded Plovers and Red-capped Plovers (Fig 12) are well camouflaged and are laid directly onto the sand, so they are especially susceptible to accidental crushing. Chicks are also easy to overlook and trample.

Figure 12. Red-capped Plovers forage, roost and nest on tracks in Dry Creek Saltfield. The eggs and chicks are vulnerable to being crushed by vehicles. Photo Chris Purnell

Vehicles are also a problem for breeding Red-capped Plovers at the Dry Creek and Price Saltfields. Access tracks running between the evaporation ponds in the Dry Creek Saltfields are favoured by Red-capped Plovers as nesting sites, and during car-based monitoring surveys in February 2009, only vigilant driving prevented many chicks from being run over. The narrow width of these roads means that chicks have few escape routes, and some were seen trying to outrun cars. Cheetham Salt's staff has been trained to be aware of wildlife on the tracks, and visiting birdwatchers have also been alerted to the threat.

h) Pollution

The main sources of pollutants to Gulf St Vincent include sewage effluent discharges (organic matter, nutrients, pathogens), storm-water runoff (heavy metals, oils, litter), agricultural runoff (fertilisers, pesticides, suspended solids) and industrial wastes (Edyvane 1999). Some contaminants, particularly heavy metals, can persist and become increasingly concentrated in higher trophic level organisms, including birds.

Nutrient pollution

Sewage outfall into marine habitats has been linked to various effects on native flora and fauna. Of particular note, sediments near nutrient-rich sewage discharge points are believed to support high densities of invertebrates, and the species composition of these sites differs from those at sites further away (Poore and Kudenov 1978; Davies and Brown 1995; Rogers *et al*. 2007). As a consequence, this enhanced production may support large numbers of shorebirds and it has been noted that improvements in sewage treatment and disposal may lead to a decline in shorebird numbers (van Impe 1985, Raffaelli and Hawkins 1999).

Recent studies which took into account only shorebird prey have had varying results, with the number of certain species such as polycheates (common prey of species such as godwits and knots) showing a clear gradient extending out from the sewage outfall, whereas other species show reverse or no gradients at all (Rogers *et al*. 2007; Alves *et al*. 2011).

While moderate organic enrichment might be seen as having a beneficial effect on shorebird habitat, nutrient enrichment by sewage can also stimulate blooms of opportunistic benthic macroalgae, especially the green *Enteromorpha*, *Cladophora* and *Ulva*

(Knox 1986; Rafaelli and Hawkins 1999; Mackenzie 2000). Nutrient enrichment or coastal eutrophication, as elsewhere in Australia and the world, has been recognised as the highest priority marine issue in Gulf St Vincent (DELM 1993; Edyvane 1999). The most obvious symptom of eutrophication has been the loss and degradation of seagrass (Larkum *et al*. 1989). Such losses are evident at the site of the Bolivar Sewage Outfall, where 470 tonnes of nitrogen, 27 tonnes of ammonia and 190 tonnes of phosphorus where discharged into the Gulf in 2007 alone (EPA 2009). These levels represent reductions of 68%, 72% and 9% in the levels of nitrogen, ammonia and phosphorus discharged since 1999, but fall well short of the EPA's projected reductions to 318 tonnes by 2010 (EPA 2005).

The increased nutrients and turbidity caused by the discharge from the Outlet has been linked to a die-off of seagrass communities (most notably *Amphibolis* and *Posidonia*) in a 19-kilometre stretch from St Kilda to Middle Beach (Kinhill *et al*. 1995; Edyvane 1999; Coleman and Cook 2000; Fox *et al*. 2007; P. Coleman pers. comm.). The loss of seagrass equates to a loss of local biodiversity. An approximate 40-fold difference exists between biodiversity in seagrass and bare-sand communities (Fox *et al*. 2007). The absence of seagrass meadows and an increase in nutrients has seen this area of intertidal mudflats now colonised by mats of Sea Lettuce *Ulva lactuca*. Sea Lettuce is well-known nitrogen scavenger, and if dense algal mats are able to become established they can have catastrophic effects on the underlying invertebrate assemblages through deoxygenation of sediment (Raffaelli and Hawkins 1999; Mackenzie 2000). Such a decline in benthic prey species would explain the surprising absence shorebirds feeding in the intertidal zone between Middle Beach and St Kilda (detailed in Section 5). The greatest rate of loss of seagrass occurred in the early 1970s, about 8 years after the maximum rate of population growth in the metropolitan region was recorded (Kinhill *et al*. 1995).

Agricultural, industrial and storm water pollution

Run-off from the area's water catchments or storm-water outfalls that are contaminated with phosphorous, nitrogen or other nutrients or chemicals could have a great impact on shorebird feeding areas, and they have already been linked to a die-off in seagrass in the Gulf (Close 2008). In addition, in some areas, increased agricultural run-off with high nitrogen content has been shown to lead to an initial increase in the diversity of invertebrates in the mudflats used by foraging shorebirds, but excess nitrogen leads to eutrophic conditions, which kills the food species (van de Kam *et al*. 2004). Initial seagrass condition monitoring commissioned by the AMLR NMR Board shows seagrasses on valuable shorebird habitat off the Light River delta to be in very good condition, and they do not appear to be degraded due to discharges from the Light River.

The potential impacts of run-off from the proposed intake of toxic chemicals and heavy metals at Dublin's Integrated Waste Services (IWS) northern landfill is a current matter of contention between the local council, residents and IWS. The installation of a high-temperature waste-disposal system would drastically reduce the risk of waste held on site leaching into the Gulf and surrounding areas. Thermal pollution, industrial run-off, effluent disposal, ballast water, heavy metals and other toxicants have all been identified as factors that are likely to impact on the Port River–Barker Inlet area, including valuable feeding areas such as Section Banks (Bryars 2003). Although the site is more than 4 kilometres from the coast, there is still potential for pollutants to leach into the waters of Gulf St Vincent in both the short and long term. The landfill site also borders stretches of saltmarsh, including areas potentially used as high-tide roosts by shorebirds.

Munitions

The coastline encompassed by the Port Wakefield Proof Range and Experimental Establishment is exposed to a different suite of potential threats due to its use as a munitions testing ground. Surveys conducted by Sinclair Knight Merz in 2007 uncovered many expended artillery shells on the tidal mudflats and many impact sites where the subsurface material had been exposed. The potential impact of this munitions testing on shorebirds remains unclear, with critical factors being firing regimes and the chemical composition of the munitions.

Oil Spill

The South Australian Marine Spill Contingency Action Plan (SAMSCAP) has designated Gulf St Vincent as a high-risk area (EPA 2006). The threat of pollution in the shorebird areas of Gulf St Vincent is focused around Port Adelaide. With the closure of the Pt Stanvac refinery, the entry of very large crude carriers into the gulf has reduced. However fuel is now transported to facilities in Port Adelaide and this has increased the risks in that area. Flinders Ports records indicate that in 2004/2005 there were 103 vessels that unloaded over 2 million tonnes of petroleum product at Port Adelaide (Flinders Ports Web site http://www.flindersports.com.au).

The boat traffic in the upper Gulf is relatively low, but should an oil spill occur, the effects could be catastrophic and have long-lasting effects on shorebird populations. Further, industrial development or increased capacity for more boats would increase the threat of a spill in these areas (Clemens *et al*. 2007a).

The Inter-Governmental Agreement on the National Plan to Combat Pollution of the Sea by Oil and Other Noxious Substances (2002) includes the process for recovering clean-up costs from the polluter. The State Government is committed to ensuring that all costs from oil spills, including environmental rehabilitation and monitoring, are met by those responsible. The South Australian Environment Protection (Sea Dumping) Act was passed by Parliament in 1984 to mirror Commonwealth legislation, but has not been proclaimed. Therefore, the regulation of sea dumping in coastal waters currently rests with the Commonwealth. The Environment Protection Authority is currently reviewing the South Australian Act to align it — with subsequent modifications — to the Commonwealth's sea-dumping legislation. The State Government will negotiate with the Commonwealth to bring 'coastal waters' within the control of the South Australian Government by demonstrating compliance with the London Protocol (NCHD 2004).

2011/12 SHOREBIRD COUNT

Count methods

In 2010, power analysis was undertaken to establish how long it would take to deliver high levels of statistical confidence in shorebird declines within Gulf St Vincent. The results indicated that if the present level of monitoring were to continue for 20 years, a statistically significant change would be likely to be detected only if the population had declined by more than 70%. To improve on this, BirdLife Australia recommended two or three simultaneous counts to be conducted each season in Gulf St Vincent (Purnell *et al* 2010). Following this recommendation, Birds South Australia organised three simultaneous counts for the summer of 2011–12. If sustained, this level of monitoring would increase the sensitivity of our trend analysis to a level where declines of 47%–64% would be detected within a 20-year period.

Counts are conducted in line with the Shorebirds 2020 count methodology outlined at:
http://www.birdlife.org.au/projects/shorebirds-2020/counter-resources
Counters are encouraged to contribute to simultaneous counts in which every *count area* within the *shorebird area* is covered within the smallest window of time. Counters are then asked to submit their result either by paper form (Appendix A) or through the Shorebirds 2020 online data entry portal (Fig 13):
http://data.shorebirds.org.au/birds/manage/home.action

The 2011/2012 counts were organised for 3 December 2011, 12 January 2012 and 14 March 2012 (Table 1). These dates were chosen to identify temporal changes in habitats used by shorebirds. However, as a result of inclement weather and subsequent access issues, only a fraction of the count areas could be covered on the count dates. Notably, the second-most significant shorebird sites in Gulf St Vincent, the Price Saltfields, was omitted from the counts altogether. Other notable exceptions from count coverage in 2011 were the Clinton Conservation Park and the Section Banks, where over 3500 and 2200 shorebirds, respectively, were recorded as recently as 2009.

A shorebird area is the boundary around the total area used by the same group of shorebirds during the peak of the non-breeding season (November–March). Regular bird movement may be observed between habitats within a shorebird area, but birds seldom move in or out of the shorebird area during the peak of the non-breeding season.

A count area is a fixed boundary which defines the area within which a count of all shorebirds is made during any repeated monitoring survey. These areas are predefined and are based on identified roost or feeding habitats. There may be one or many count areas within a shorebird area. Count areas tend to be marked by boundaries of readily identifiable geographic features, and include areas easily surveyed by one counter in less than 4 hours.

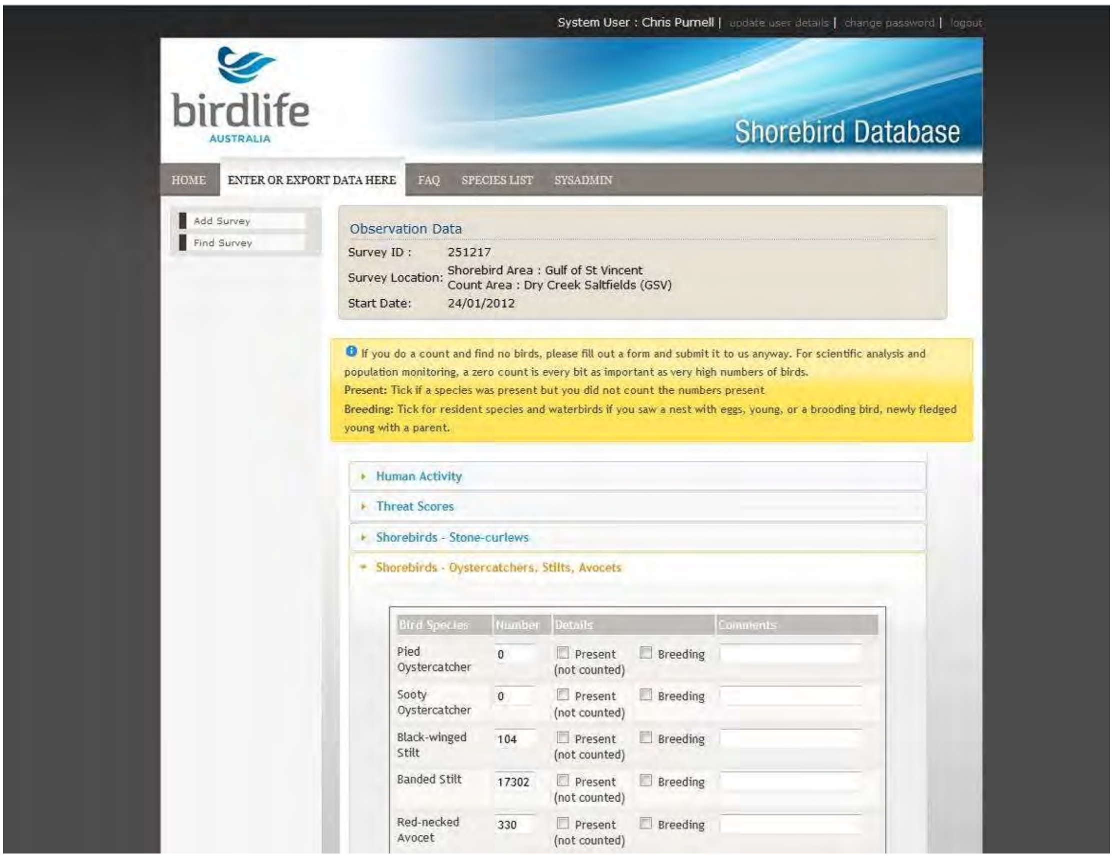


Figure 13. The Shorebirds 2020 online data entry portal not only provides feedback to counters and allows them to reveiw and manage their counts but saves hundreds of hours of data entry time.

Five count areas could be covered in the November–December counts (Table 2), six in the January counts (Table 3) and 11 in the March counts (Table 4), comprising 15 unique count areas. Unfortunately this is the worst coverage since the project was undertaken and has resulted in non representative species abunances and totals for the region. Although areas like Clinton Conservation Park and Price Saltfields, are not within the AMLR study area, they contribute to the same “Shorebird area” and are therefore critical monitoring sites when tring to identify large scale trends.

During the peak of the non-breeding season, shorebirds tend to remain within a defined region, moving between proximate feeding and roosting sites in accordance with variations in habitat conditions, such as tide height. Shorebirds often return to these same areas within and between seasons (Peters and Otis 2007). Shorebirds were observed moving greater distances within Gulf St Vincent during the study, but it has been suggested that there was little movement beyond the boundaries of the shorebird area as mapped in 2009, which extend north from Section Banks and around Gulf St Vincent to a point south of the Price Saltfields (Purnell *et al*. 2009). The site fidelity observed in most shorebirds suggests that any count conducted in Gulf St Vincent during the peak of the non-breeding season would encounter the same population of birds.

It is critical to conduct a coordinated survey within Gulf St Vincent so that multiple areas can be surveyed simultaneously. Birds are likely to be either missed or double-counted if counts are not conducted simultaneously throughout the gulf. Further, these counts should be conducted during the peak of the non-breeding period, in the same month as previous summer counts. In terms of national population monitoring, counts conducted outside the November–February window risk a measurement error at a national scale, with entire populations of shorebirds potentially being counted twice or not counted at all (Clemens *et al*. 2007).

Figure 14. A Shorebirds 2020 counter covering Thompsons Beach. Photo Chris Purnell

Data analysis methods

Given the paucity and inconsistent count coverage in GSV, effective trend analyses for the entire system is still not achievable (Purnell *et al* 2010). In an attempt to give a representation of what is happening on a larger scale, trend analyses were completed for the largest dataset and most significant site in the gulf; the Dry Creek Saltfields. Data for the site was split into two survey periods based on what was available and includes all counts (not just simultaneous counts); the first period covered 1979-1990 and the second period 1999-2012.

Only spring/summer counts were considered for the analysis, and the maximum count for each year was extracted. These data were then assessed to determine which species were appropriate for analysis. A cut off level of 60% was applied to data; that is a species needed to have > 0 counts for at least 60% of the survey years. Anything below this threshold was considered to small a sample size to give biologically meaningful results. For the 1979-1990 survey period data was missing for four years (no spring/summer surveys), and applying the 60% criteria, analysis was limited to 18 of the 34 species recorded during this survey period. The second survey period (1999-2012) had no missing years, however only 16 of the 34 species recorded met the 60% criteria (Table 5).

Generalised Linear Models (GLM) were used to determine if statistically significant trends in the maximum counts were occurring (Appendix D). Count numbers were regressed against years to detect trends. Analysis was undertaken using GenStat 13.0 software. Data was assessed for fit to assumptions of GLM (normality, spread etc). For species that were found to greatly violate these assumptions, log transformation was undertaken. If species had zero counts, rather than exclude data as outliers (and thus reducing the already small sample sizes) counts were transformed using the formula: log(0.5+M) where M is the maximum count data. Where no zero values occurred log(M) was used. Transformations of data were undertaken in Genstat 13.0.
For one species (Curlew Sandpiper) an outlier was removed from the second survey period to try and improve the fit of the model.

2011/12 Count Results

Table 1. Summary of three years of simultaneous counts of the shorebirds in Gulf St Vincent, including threshold values of international and national significance.

	Significance		Population Counts								
Species	1% EAA*	0.1% EAA*	29-Nov-08	28-Feb-09	23-Jan-10	04-Dec-10	16-Jan-11	13-Mar-11	03-Dec-11	12-Jan-12	14-Mar-12
Australian Painted Snipe**	12		0	0	0	0	0	0	0	0	0
Banded Lapwing**	270		0	90	0	0	65	0	0	0	0
Banded Stilt**	2060		12062	3252	2228	110	2	0	19843	11133	10771
Bar-tailed Godwit	3250	325	419	575	337	163	70	324	0	8	53
Black-fronted Dotterel**	170		25	0	1	0	0	4	0	0	2
Black-tailed Godwit	1600	160	0	0	0	0	0	0	0	0	0
Black-winged Stilt**	2660		310	99	408	7	47	0	254	218	571
Common Greenshank	600	60	154	703	367	241	36	19	104	169	170
Common Sandpiper	1000	100	1	4	27	0	1	0	3	1	0
Curlew Sandpiper	1800	180	228	535	259	126	3	58	16	0	63
Double-banded Plover	500	50	0	4	0	0	0	0	0	0	0
Eastern Curlew	380	38	9	36	29	12	0	1	11	6	0
Great Knot	3750	375	930	203	6	800	52	750	0	40	0
Greater Sand Plover	1100	110	2	8	10	8	0	2	0	0	15
Grey Plover	1250	125	164	291	122	46	47	25	19	42	73
Latham's Snipe	360	36	0	0	0	0	0	0	1	0	0
Lesser Sand Plover	1400	140	7	8	0	0			0	0	0
Long-toed Stint	250	25	0	0	1	0	0	0	0	0	0
Marsh Sandpiper	1,000	100	20	7	3	6	3	0	6	1	3
Masked Lapwing**	2870		94	148	124	23	41	15	61	73	104
Pacific Golden Plover	1,000	100	5	2	1	1	0	0	0	0	0
Pectoral Sandpiper	100	10	1	0	0	0			0	0	0
Pied Oystercatcher**	110		23	125	118	10	7	6	14	24	22
Red Knot	2200	220	1150	1637	1103	200	4	1615	0	70	1097
Red-capped Plover**	950		608	4963	2026	80	119	19	1084	616	553
Red-kneed Dotterel**	260		152	121	79	0	0	0	108	5	37
Red-necked Avocet**	1070		555	285	27	23	0	0	424	262	481
Red-necked Stint	3250	325	8391	11791	6749	2324	2927	1372	3169	2820	3123
Ruddy Turnstone	350	35	57	91	70	41	7	23	0	40	5
Sharp-tailed Sandpiper	1600	160	1205	3224	3120	74	5	0	752	218	79
Sooty Oystercatcher**	40		0	160	61	0	0	3	0	1	0
Terek Sandpiper	600	60	0	2	1	1	0	0	0	0	0
Whimbrel	1000	100	6	26	4	3	0	0	0	0	0
Wood Sandpiper	1000	100	2	2	8	0	0	9	0	0	1

* 1% EAA = International Significance (threshold of 1% of the estimated population in the East Asian–Australian Flyway); 0.1% EAA = National significance (threshold of 0.1% of the estimated population in the East Asian–Australian Flyway; Clemens *et al*. 2010)
**Resident shorebird

Table 2. December/January counts

survey date	3/12/2011	3/12/2011	3/12/2011	13/12/2011	24/01/2012
shorebird_site	Magazine Road Wetlands	Middle Beach (GSV)	Barker Inlet Wetlands	Light Beach	Dry Creek Saltfields (GSV)
Australian Painted Snipe	0	0	0	0	0
Banded Lapwing	0	0	0	0	0
Banded Stilt	39	2	0	2500	17302
Bar-tailed Godwit	0	0	0	0	0
Black-fronted Dotterel	0	0	0	0	0
Black-tailed Godwit	0	0	0	0	0
Black-winged Stilt	50	22	18	60	104
Common Greenshank	0	9	0	11	84
Common Sandpiper	0	2	0	0	1
Curlew Sandpiper	0	0	0	0	16
Double-banded Plover	0	0	0	0	0
Eastern Curlew	0	0	0	0	11
Great Knot	0	0	0	0	0
Greater Sand Plover	0	0	0	0	0
Grey Plover	0	0	0	0	19
Latham's Snipe	0	0	0	0	1
Lesser Sand Plover	0	0	0	0	0
Marsh Sandpiper	2	0	0	0	4
Masked Lapwing	3	3	2	7	46
Pacific Golden Plover	0	0	0	0	0
Pectoral Sandpiper	0	0	0	0	0
Pied Oystercatcher	0	2	0	12	0
Red Knot	0	0	0	0	0
Red-capped Plover	2	0	0	520	562
Red-kneed Dotterel	50	1	19	1	37
Red-necked Avocet	6	1	87	0	330
Red-necked Stint	3	5	0	900	2261
Ruddy Turnstone	0	0	0	0	0
Sharp-tailed Sandpiper	107	3	60	200	382
Sooty Oystercatcher	0	0	0	0	0
Terek Sandpiper	0	0	0	0	0
Whimbrel	0	0	0	0	0
Wood Sandpiper	0	0	0	0	0
total	262	50	186	4211	21160

Table 3. February 2012 counts

survey date	10/02/2012	12/02/2012	12/02/2012	12/02/2012	12/02/2012	12/02/2012
shorebird_site	Light Beach	Middle Beach (GSV)	Dry Creek Saltfields (GSV)	Barker Inlet Wetlands	Thompson's Beach South	Thompson's Beach (GSV)
Australian Painted Snipe	0	0	0	0	0	0
Banded Lapwing	0	0		0	0	0
Banded Stilt	3550	140	7248	75	120	0
Bar-tailed Godwit	0	0	7	0	0	1
Black-fronted Dotterel	0	0	0	0	0	0
Black-tailed Godwit	0	0	0	0	0	0
Black-winged Stilt	0	0	68	150	0	0
Common Greenshank	50	1	76	0	15	27
Common Sandpiper	0	0	1	0	0	0
Curlew Sandpiper	0	0	0	0	0	0
Double-banded Plover	0	0	0	0	0	0
Eastern Curlew	6	0	0	0	0	0
Great Knot	40	0	0	0	0	0
Greater Sand Plover	0	0	0	0	0	0
Grey Plover	16	0	0	0	2	24
Latham's Snipe	0	0	0	0	0	0
Lesser Sand Plover	0	0	0	0	0	0
Marsh Sandpiper	0	0	1	0	0	0
Masked Lapwing	15	6	48	0	0	4
Pacific Golden Plover	0	0	0	0	0	0
Pectoral Sandpiper	0	0	0	0	0	0
Pied Oystercatcher	0	1	0	0	20	3
Red Knot	70	0	0	0	0	0
Red-capped Plover	430	0	186	0	0	0
Red-kneed Dotterel	0	0	5	0	0	0
Red-necked Avocet	0	0	162	100	0	0
Red-necked Stint	840	0	1795	0	35	150
Ruddy Turnstone	0	0		0	0	40
Sharp-tailed Sandpiper	33	0	184	0	0	1
Sooty Oystercatcher	0	0	0	0	1	0
Terek Sandpiper	0	0	0	0	0	0
Whimbrel	0	0	0	0	0	0
Wood Sandpiper	0	0	0	0	0	0
total	5050	148	9781	325	193	250

Table 4. March 2012 counts

survey date	9/03/2012	10/03/2012	11/03/2012	13/03/2012	14/03/2012	14/03/2012	14/03/2012	14/03/2012	21/03/2012	21/03/2012	21/03/2012
shorebird_site	Light Beach	Dry Creek Saltfields (GSV)	Magazine Road Wetlands	Barker Inlet Wetlands	Thompson's Beach North	Thompson's Beach South	Webb Beach (GSV)	Saint Kilda	Middle Beach (GSV)	Port Gawler seafront next to ICI saltworks	Magazine Road Wetlands
Australian Painted Snipe	0	0	0	0	0	0	0	0	0	0	0
Banded Lapwing	0	0	0	0	0	0	0	0	0	0	0
Banded Stilt	3122	5894	5	0	750	1000	0	0	0	0	0
Bar-tailed Godwit	0	30	0	0	13	10	0	0	0	0	0
Black-fronted Dotterel	0	0	2	0	0	0	0	0	0	0	0
Black-tailed Godwit	0	0	0	0	0	0	0	0	0	0	0
Black-winged Stilt	0	257	52	10	0	0	0	100	0	0	152
Common Greenshank	19	95	0	0	32	0	0	0	19	5	0
Common Sandpiper	0	0	0	0	0	0	0	0	0	0	0
Curlew Sandpiper	26	37	0	0	0	0	0	0	0	0	0
Double-banded Plover	0	0	0	0	0	0	0	0	0	0	0
Eastern Curlew	0	0	0	0	0	0	0	0	0	0	0
Great Knot	0	0	0	0	0	0	0	0	0	0	0
Greater Sand Plover	0	0	0	0	15	0	0	0	0	0	0
Grey Plover	67	0	0	0	4	2	0	0	0	0	0
Latham's Snipe	0	0	0	0	0	0	0	0	0	0	0
Lesser Sand Plover	0	0	0	0	0	0	0	0	0	0	0
Marsh Sandpiper	0	0	1	0	0	0	0	0	0	0	2
Masked Lapwing	0	89	2	0	1	0	2	2	4	2	2
Pacific Golden Plover	0	0	0	0	0	0	0	0	0	0	0
Pectoral Sandpiper	0	0	0	0	0	0	0	0	0	0	0
Pied Oystercatcher	20	0	0	0	2	0	0	0	0	0	0
Red Knot	60	2	0	0	435	600	0	0	0	0	0
Red-capped Plover	110	260	2	0	30	100	0	0	1	50	0
Red-kneed Dotterel	0	4	21	1	0	0	0	0	0	0	11
Red-necked Avocet	0	481	0	0	0	0	0	0	0	0	0
Red-necked Stint	720	1182	5	0	305	350	0	0	10	540	11
Ruddy Turnstone	0	0	0	0	5	0	0	0	0	0	0
Sharp-tailed Sandpiper	14	65	0	0	0	0	0	0	0	0	0
Sooty Oystercatcher	0	0	0	0	0	0	0	0	0	0	0
Terek Sandpiper	0	0	0	0	0	0	0	0	0	0	0
Whimbrel	0	0	0	0	0	0	0	0	0	0	0
Wood Sandpiper	0	0	1	0	0	0	0	0	0	0	0
total	4158	8396	91	11	1592	2062	2	102	34	597	178

Trend analysis results

Table 5. Trend analysis results for all counts conducted in the Dry Creek Saltfields, 1976-1990 and 1999-2012.

Species	Year	P value	R squared	Trend	Mean count	Max Count	% change
Banded Stilt	1979-1990	0.956	#	Log transformed	9415.25	29110	
	1999-2012	0.881	#	Log transformed	5271	16914	
Black-tailed Godwit	1979-1990	0.246	0.085		87	152	
	1999-2012			◊	11	60	
Black-winged Stilt	1979-1990	0.034*	0.482	Decline	425	840	↓68%
	1999 - 2012	<0.001*	0.71	Decline then increase	154	402	↓↑100%
Common Greenshank	1979-1990	<0.001*	0.844	Decline	350	527	↓55%
	1999 - 2012	0.511	#	Log transformed	119	500	
Common Sandpiper	1979-1990	0.005*	0.715	Decline	7	17	↓88%
	1999 - 2012	0.254	0.032		1	4	
Curlew Sandpiper	1979-1990	0.323	0.109		2688	6256	
	1999 - 2012	0.558	#		143	998	
Eastern Curlew	1979-1990	0.057	0.394	Strong decline	33	95	↓70%
	1999 - 2012				9	36	
Grey Plover	1979-1990	0.138	0.216		37	80	
	1999 - 2012	0.354	#		29	68	
Marsh Sandpiper	1979-1990	0.876	#		55	90	
	1999 - 2012	0.020*	0.323	Decline	9	41	↓72%
Masked Lapwing	1979-1990	0.702	#		120	280	
	1999 - 2012	0.208	0.112		35	130	
Pacific Golden Plover	1979-1990	0.174	0.164		2	5	
	1999 - 2012			◊	0	2	
Pied Oystercatcher	1979-1990			◊	2	7	
	1999 - 2012	0.005*	0.545	Decline then significant increase	4	20	↓↑
Red-capped Plover	1979-1990	0.019*	0.711	Significant decline	1615	2700	↓87%
	1999 - 2012	0.234	0.042		244	567	
Red-kneed Dotterel	1979-1990	0.231	0.125		65	320	
	1999-2012	0.216	0.051		34	150	
Red-necked Avocet	1979-1990	0.183	0.153	Log transformed	538	1240	
	1999-2012	0.559	#	Log transformed	163	601	
Red-necked Stint	1979-1990	0.110	0.264	Log transformed	15455	29000	
	1999-2012	0.667	#	Log transformed	2889	8000	
Ruddy Turnstone	1979-1990	0.311	0.031		8	15	
	1999-2012			◊	3	14	
Sharp-tailed Sandpiper	1979-1990	0.037*	0.467	Decline	6026	9800	↓52%
	1999-2012	0.643	#		855	3000	
Wood Sandpiper	1979-1990	0.058	0.390	Strong decline	8	20	↓88%
	1999-2012			◊	0	2	

*indicate statistically significant trends.
Residual variance exceeds variance of response variate (which in laymans terms means that the R2 value is negative, indicating model being a poor fit)
◊ Observed in too few surveys to detect trends.

i **The General Linear Models (GLM) listed above can be found in Appendix D.**

Count results discussion

This is the third year in which Birds South Australia and BirdLife Australia's Shorebirds 2020 Program have cooperated in the coordination of simultaneous counts of shorebirds in Gulf St Vincent. Simultaneous counts have been an important factor in reinvigorating the monitoring program across the region and have aided in identifing several internationally and nationally significant areas for shorbirds (outlined in habitat accounts). They have brought the community together, and have enhanced the mentoring program for new or inexperienced shorebird surveyors. With the finalisation of the boundaries of count areas and an increase in the number of experienced counters, a rapid reduction in the variability of counts should be achieved.

A comparison of results from the six simultaneous counts conducted since 2008 provides an insight into the variation one might expect from repeated counts in Gulf St Vincent (Table 1). There are three possible sources of discrepancies: (1) shorebirds' behavioral variation; and (2) count error.

A high variation in counts, such as that observed in resident species including Banded Stilts, Black-winged Stilts and Red-necked Avocets, suggests that these resident shorebirds may move in and out of the study area, which is inconsistent with the concept of a shorebird area in which birds remain over the peak summer months. This is perhaps not surprising considering the life history of each of these species. These resident shorebirds are generally associated with sudden, episodic increases in the availability of prey in coastal or inland wetlands. The use of flooded inland habitats by these shorebirds is often opportunistic, and sudden inland flooding sometimes results in rapid and dramatic breeding events involving many birds. For example, this was the situation in winter 2010, when 150,000 Banded Stilts descended on Lake Torrens to breed, with an estimated 200,000 chicks hatching. Many of these birds reportedly remained in nearby pastoral areas, where they bred again 7 months later when water generated from Tropical Cyclone Yasi once again inundated Lake Torrens. On this occasion an estimated 25,000 Banded Stilts were observed at the site. In 2011/12 the nearly 20,000 Banded Stilts returned to eatern GSV. Similarly, migratory shorebirds, such as the Sharp-tailed Sandpiper, are thought to utilise episodic flood events which may save them a flight of more than 150 kilometres further south to terminal non-breeding sites on Australia's southern coastline. This event was reflected in a 98% decline in Sharp-tailed Sandpipers observed in the Gulf between January 2010 and January 2011. Such events may account for some of the natural variation in counts which occurs over short time scales.

The second cause of variation in counts stems from incomplete or excessive count coverage. For example, the numbers of Pied and Sooty Oystercatchers recorded in 2008 and 2011 were low and probably did not capture the whole population. This possibly arose because Section Banks, where most oystercatchers are usually recorded in intervening years, was not surveyed in 2008 and 2011. Similarly, large numbers of

Common Greenshanks, Red-capped Plovers, Sharp-tailed Sandpipers and Red-necked Stints were recorded in 2009; these numbers were inflated by a survey which was conducted at low-tide, while birds were feeding on the extensive mudflats of the Clinton Conservation Park, and may have resulted in double counts of birds that roosted at high tide in nearby count areas, such as Price Saltfields.

Variation in counts of small, common waders, such as Red-capped Plovers, Red-necked Stints and Sharp-tailed Sandpipers, may also be caused by difficulties in surveying areas of high shorebird abundance and diversity, such as Dry Creek Saltfields, where the sheer number of birds makes it difficult to count them. Due to the supratidal nature of such sites, birds may remain feeding throughout the day and often move throughout the saltponds to access different feeding and roosting areas. This sometimes results in either double counts or birds not being counted at all. To reduce this problem, counters work in teams, with the counting of a common species delegated to one person who is more able to keep track of movements and overall abundance. In addition, counters are encouraged to collect data which allows the completeness of a count to be assessed.

Alternatively, counts of regularly recorded and conspicuous species (such as Bar-tailed Godwits and Red Knots, which occur mainly on the northern beaches and Price Saltfields) show remarkable consistency in the total number observed in each complete survey of Gulf St Vincent. These results are encouraging as they demonstrate that with consistent coverage, sufficient counter experience and standardised methods, resulting data will have notably less variation than observed in previous shorebird surveys in Gulf St Vincent.

Birds South Australia and its volunteers should be commended for their excellent efforts in continuing to undertake shorebird monitoring in Gulf St Vincent. Although the advent of the Shorebirds 2020s online data entry portal will be beneficial in the long run it has also caused initial coordination confusion as some observers circumnavigate the regional coordinator giving less chance for feedback, accountability and retention. BirdLife Australia will need to work more closely with regional coordinators and counters in the future to overcome this shortfall. If Birds SA and BirdLife are keen to further reduce the variation between counts, which would enable researchers to detect population trends more quickly, a number of refinements could be made:

- Conduct surveys at the same time of year each year. This ensures that site conditions are similar each time and further increases the chances of counting the same group of birds.

- Conduct surveys within a tighter time-frame, both within the week and within daily tide cycles, especially at proximate sites where there is a frequent exchange of birds. Tighter survey times would address the effects of daily movements between roosting and feeding sites and reduce the risk of counting birds twice or missing them altogether. This has not been accomplished yet, as there were insufficient counters with suitable experience available to cover each site simultaneously. Ideally, all count areas should be surveyed over the same four-hour high-tide period.
- Provide volunteers with up-to-date maps marked with the boundaries of count areas to ensure that the areas being surveyed remain consistent.
- Foster good count and identification techniques among counters through workshops and mentoring.

Trend Analysis discussion

The number of counts available in the GSV dataset differs strongly between sites. Therefore trend estimates for the entire population using data across all sites was impossible (as the 2010 power analyis predicted). Instead trend analysis was based on one frequently counted site, providing a larger data set and smaller amount of missing values, but less optimal spatial coverage. Results of trend analysis have been found to be more robust when trends are only based on more regularly counted sites (AEWA 2009, BirdLife unpublished). However selecting only the frequently counted sites has the risk of presenting unrepresentative trends because of a biased selection of habitats. There are numerous methods used in bird monitoring to obtain yearly indices of abundance and trends over time despite missing data: chain index, indexing according to the Mountford method, route regression, imputing of missing data and loglinear Poisson regression (Ter Braak *et al* 1994.) Given the Dry Creek Saltfields dataset is not only more consistent than that of any other sites but also includes an additional 11 year period of data (1979-1990), it was decided that this site alone would provide the best chance of identifying trends. Trend analysis using more sites in GSV will be attempted once consistant coverage is achieved.

When considering the site bias involved in using the Dry Creek counts exclusively; there may be several sources of variation from real trends in the system. Variation observed in shorebird numbers at the saltfields may be a syptom of changes in condition of other sites in the shorebird area rather than total population abundance. For example an increase in disturbance by off-road vehicles at the Port Gawler intertidal zone may cause an increase in birds utilizing undisturbed conditions at the saltfields. Conversely, the completion of the Magazine Rd Wetland in 1995 created alternate feeding and roosting habitat and may have resulted in a reduction in birds utilizing the saltfields and manifesting in the data as population decline.

It must also be noted that although Dry Creek saltfields contains variety of habitat types utilized by shorebirds, it is not representative of all functional groups (table 6). Therefore there is insufficient data to comment on intertidal specialists (e.g. Bar-tailed Godwit and Red Knot).

There have been 52 shorebird species recorded in the Dry Creek Saltfields since 1979, however this analysis only included the most common 29 found in GSV. A comparison between the last 6 simulataneous count totals and their Dry Creek components shows the significance of the site for several species (table 6). Although there has been varying coverage over the simultaneous counts Dry Creek has accounted for an average of 48% of the shorebird population.

The following species have undergone significant declines in the Dry Creek Saltfields:

Black-winged Stilt.

In the early 80's this species numbered over 500 in 3 consecutive counts (max 840) however, had declined by 68% by 1990. As a resident nomadic species this could be symptom of changed wetland conditions inland and the local condition of Buckland Park Lake (a known breeding site for the species). The quadratic trend of the population apparent in the 1999-2012 data is likely to relate to the condition of the Buckland Park Lake which remained dry for the period for several years in the peak of the drought.

Common Greeshank

This species underwent a significant 55% decline in the 1979-1990 period. Regularly numbering over 400 in the early 80's (max 527) the Dry Creek population has fluctuated throughout the last 10 years averaging 119 birds. This is representative of the declines in the study area and on a larger scale. Recent data analysis conducted by BirdLife Australia identified some significant decline evident (21% over 30 years) across southern Australia (BirdLife unpublished).

Common Sandpiper

This species was once a regular visitor to the saltfields (max 17) inhabiating creeklines and outfall points (Day 1997) however after an 88% decline in the population in the period between 1979 and 1990 it is uncommon to see more than 1 individual in the study area. This is representative of the decline in the region.

Eastern Curlew

An intertidal specialist, this species has a large daily range and the same birds that forage on the Samphire Coast may be observed roosting in the saltfields. The 70% decline in population from a maximum of 94 birds in period of 1979-1990 is representative of the declines in the study area and on

Table 6. The average proportion of total GSV species populations observed at the Dry Creek saltfields across 4 years of simultaneous counts (2008-2012).

Species	Proportion
Banded Lapwing	0%
Banded Stilt	62%
Bar-tailed Godwit	2%
Black-fronted Dotterel	15%
Black-tailed Godwit	0%
Black-winged Stilt	70%
Common Greenshank	45%
Common Sandpiper	39%
Curlew Sandpiper	59%
Double-banded Plover	0%
Eastern Curlew	25%
Great Knot	0%
Greater Sand Plover	0%
Grey Plover	53%
Latham's Snipe	17%
Lesser Sand Plover	0%
Marsh Sandpiper	53%
Masked Lapwing	59%
Pacific Golden Plover	17%
Pied Oystercatcher	6%
Red Knot	0%
Red-capped Plover	32%
Red-kneed Dotterel	19%
Red-necked Avocet	50%
Red-necked Stint	49%
Ruddy Turnstone	0%
Sharp-tailed Sandpiper	42%
Sooty Oystercatcher	0%
Whimbrel	6%
Wood Sandpiper	0%

a larger scale. Recent data analysis conducted by BirdLife Australia identified significant strong national declines (40% over 30 years) in the Eastern Curlew population (BirdLife unpublished). These findings prompted the listing of the species as Endangered on the IUCN Red List.

Marsh Sandpiper

As a species which prefers fresh to brackish water, this species is most common in the saltfields and Magazine Rd Wetlands. The significant 72% decline in Marsh Sandpiper in the saltfields over the last 12 years, is likely to be a true representation of the population in the region. National trend analysis for the species identified mixed results across disperate regions (BirdLife unpublished).

Red-capped Plover

The saltfield's Red-capped Plover population underwent an 88% decline in the 1979-1990 period this is in line with greater declines in the south east of Australia where a 56% decline has been observed (BirdLife unpublished). Population numbers for the last 10 years appear to be stable at saltfields. As a resident ground-nester the saltfields will (and may have already) provided sanctuary from threats to breeding success occurring elsewhere in the region.

Sharp-tailed Sandpiper

This species is the second most abundant migratory wader that occurs in Australia. In the early 80's Sharp-tailed Sandpipers regularly numbered over 9,000 in the saltfileds. However a significant 52% decline observed over the following 10 years is still evident in the population and there have been just 2 counts exceeding 2,000 birds in the last decade. This decline is a function of the greater national decline in the species. BirdLife trend analysis identified mixed results across disperate regions, with an overall decline of 60% over 30 years. If we include all the areas in southern Australia which have "good" data (49 sites) we can see a net loss of over 27,000 birds in 30 years. This represents a loss of 17% of the total Flyway population.

Wood Sandpiper.

As a species which prefers fresh to brackish water, this species is most common in the saltfields and Magazine Rd Wetlands. The significant 88% decline in the Wood Sandpipers at the saltfields from the 1979- 1990 can be attributed partly to greater declines region, although a preference for the Magazine Rd Wetlands over the last 10 years has also contributed to the total absence of the species from the saltfields.

To achieve a level of data which will enable us to detect trends:

1. at a larger spatial scale
2. with greater sensitivity
3. across all species

It is imperative that we improve our count coverage and consistency for GSV (Purnell *et al* 2010). This can only be achieved by continuing to build upon the volunteer network through further community engagement.

WORKSHOPS

Shorebird Training Workshops

In the 2011–12 season, a Shorebirds Workshop was conducted in the Greater Adelaide region to educate the local communities about shorebird conservation and identification, and to expand the pool of experienced counters in the Gulf St Vincent area. Unfortunately, a second workshop planned for 8 December 2011 was cancelled to enable the research officer to facilitate resident shorebird wardening at the Vivonne Bay Surf Pro. A community workshop at Thompsons Beach in September 2012 will be held to make up for this shortfall.

The Shorebirds Workshop, conducted on 22 January 2012 at St Kilda, was attended by 42 participants and addressed the ecology of migratory waders and the threats they face globally, nationally and within Gulf St Vincent. Online survey feedback regarding the 2010 workshops indentified that the majority of “beginner” and “intermediate” shorebirders required more time spent on the identification section of the workshop. With this in mind, the majority of the session was dedicated to working through the diagnostic characteristics, behaviour and typical habitat choices of the 30 most common shorebird species observed in Gulf St Vincent. Presentation materials were also supplemented with shorebird identification sheets and a more in-depth identification tips document. This information was followed up by field trips to Thompson Beach and Magazine Road Wetlands, where participants were given hands-on experience in the use of optics and identifying and counting shorebirds.

The main goals of the workshops were to: (1) recruit counters to the shorebird monitoring program; and (2) train them as counters. Since the introduction of the program in 2008, recruitment has been successful, with approximately 80 counters becoming involved with shorebird monitoring in Gulf St Vincent in the summer of 2009–10. This represented a marked increase in counters over the 28 counters who participated the previous summer, and resulted in the most comprehensive survey coverage in Gulf St Vincent so far. However, as mentioned previously, volunteer participation fell off drastically in the 2010–11 counts and remained low for the 2011–12 counts. In addition to the climatic and access issues mentioned, insufficient volunteer follow up on a coordination level in the lead-up to the season was a likely contributor to the poor participation levels. Shorebirds 2020’s move towards online data entry has also caused some confusion for coordination, as counters submit counts directly to BirdLife. By circumventing contact with the coordinator at the data submission point, it becomes difficult for the coordinator to keep track of which observers have counted and submitted and which areas have been covered. To address this problem, BirdLife Australia staff will work more closely with the coordinator and counters, both before and after the survey.

Future workshops will aim to coincide with periods of peak shorebird abundance in Gulf St Vincent to provide participants with a greater opportunity to be involved with simultaneous counts and maximise retention of active volunteers.

As the program grows we must insure that new counters receive appropriate training to equip them with the skills to conduct accurate surveys that can be replicated easily. This will continue to require providing counters with information on survey methodology as well as shorebird identification.

Training on wader identification has been developed with the knowledge that the superficial similarity between various species of shorebirds often causes frustration among potential surveyors and can lead to low rates of participation after initial contact. Identification tutorials, like the one given at St Kilda, are an effective introduction to general shorebird identification for beginners.

Elsewhere in Australia, shorebird mentor groups have successfully trained inexperienced observers in shorebird identification through planned field trips. This type of event is often advertised on forums and websites, such as www.shorebirds.org.au and www.birding-aus.com.au; locally, Birds South Australia advertises regular recreational field trips to shorebird sites around Gulf St Vincent at www.birdpedia.com. A more established program of dedicated shorebird identification field trips would be an effective means of following up on workshop attendees who indicate an interest. This type of effort would increase the retention of active counters and help further standardise data collection.

Shorebird Management Workshop

In 2010 and 2011 Shorebird Management workshops were conducted to facilitate discussions on best practice management of the Gulf St Vincent shorebird with the diverse range of stakeholders. A review of the outcomes of these meetings, including conservation options in the case of decommission of the Dry Creek Saltfields, can be found in the 2010 and 2011 Population Monitoring and Habitat Mapping Reports.

The 2012 Shorebirds of Gulf St Vincent Management Workshop will be conducted in conjunction with the Australian Wader Study Group Conference, to be held in Adelaide in late September 2012. By doing so, local stakeholders will have the opportunity to hear about national and international shorebird conservation initiatives, and experts will have a chance to comment on future management options for shorebird habitat in Gulf St Vincent.

> BirdLife Australia conducted several other shorebird related workshops during the period in the AMLR region. This included a Wetland Bird worshop and 6 Beach Nesting Bird workshops.
> Shorebirds 2020 workshops were also conducted in neighbouring NRM regions; Kangaroo Island, Northern and Yorke and SA Murray Darling Basin.

HABITAT MAPPING

Overview of methods and results

After fine-scale mapping of the Dry Creek Saltfields, objectives in the 2011 and 2012 mapping work has focused on identifying alternative supratidal feeding and roosting sites in the eastern Gulf St Vincent. Mapping also sought to identify shorebird habitat in the Department of Defence land north of Parham. These habitats were identified by Purnell *et al*. (2009, 2010, 2011) as being gaps in our knowledge of shorebird distribution and abundance in the region.

The following new areas were mapped in 2012: Light Beach to Port Prime claypan, Webb Beach to Parham claypan, and the Australian Defence Force Proof Range and Experimental Establishment at Port Wakefield.

Satellite imagery combined with GIS overlays of existing habitat mapping were used as references in the field. Shorebird habitats identified in the field were sufficiently recognisable from the satellite images, and it was possible to draw boundaries of feeding areas and roost sites directly onto the map. However, in nondescript, uniform habitats, such as sandy beaches (where the boundaries of roost sites were unclear), GPS points that bounded the area were collected.

Boundaries of count areas were digitised on screen-displayed digital ortho-photos in ArcMap 9.1, based on the hand-drawn boundaries on the field set of photos. The accuracy of these photos was confirmed by the comparison of GPS ground-control points with physical features. Shorebird feeding areas that had been determined in previous years were based mainly on a report which plotted polygons over shorebird areas (Close 2008). These were adjusted with reference to features visible on high-resolution digital ortho-photos, such as beds of seagrass, which provide a good indication of the boundaries of intertidal feeding areas. Due to the variable nature of some features in coastal environments, some of the polygons may not reflect the actual boundaries of shifting habitat features. For each polygon, a variety of attributes were added, such as latitude and longitude, positional accuracy of the polygon, the average and maximum count of each shorebird species recorded in the area and threat scores. A complete list of attributes, and further technical details of the GIS layers provided is available in the metadata which is separate to this report.

The distribution of shorebirds at all other sites has been comprehensively mapped, and the refinement of habitat boundaries has allowed new count areas to be defined accurately. Each count area has also been assigned a score rating of the threats it faces

a) Threat mapping

In Gulf St Vincent, potential threats fall into five categories:
Human-induced habitat loss or degradation
Human disturbance
Invasive species
Human-induced mortality or breeding failure
Pollution

These threats were scored by counters using a technique developed by the Western Hemisphere Shorebird Reserve Network. The maximum threat score from the five categories was reported, along with the sum of the five threat scores for each area (Table 5). While this technique is subjective and results varied between counters, it allows comparisons between potential threats (Clemens *et al*. 2007a). In Gulf St Vincent the greatest risks to shorebirds that observers have identified are habitat loss and disturbance. The relative scale of habitat loss or disturbance in different regions along the east coast of Gulf St Vincent have been mapped (Figures 15, 16) and reported. This mapping indicates that observers feel that the Dry Creek region is the area most threatened by habitat loss, while the northern beaches are most threatened by disturbance.

Table 5. Description of threats to shorebird areas and how threats were scored

Types of Threats Identified and their Scores:
- Human-induced habitat loss and degradation
- Human-induced disturbance
- Invasive species/habitat loss or degradation due to natural causes (vegetation encroachment)
- Pollution (oil spills, runoff, or anything that changes soil texture, elevation, acidity, toxicity, turbidity etc.)
- Accidental mortality (not including oil spills; primarily refers to direct or indirect mortality during breeding for species, such as crushing of nests by vehicles, people etc.)

Scoring:

Timing of each threat type:	Timing Threat Score
Happening now	3
Likely in the short term (<3 years)	2
Likely in the long term (>3 years)	1
May have happened in the past but not likely again	0
Scope of each threat type:	Scope Threat Score
Entire area/population (>90%)	3
Most of area/population (50–90%)	2
Some of area (10–49%)	1
Small area	0
Unknown	1
Severity of each threat type:	Severity Threat Score
Severe/very rapid deterioration (>30% over 10 years)	3
Rapid to moderate deterioration (10–30% over 10 years)	2
Slow but significant deterioration (1–9% over 10 years) or large fluctuations	1
No or imperceptible deterioration (<1% over 10 years)	0
Unknown	1

Overall impact of threat:
Add threat scores for timing, scope and severity to get an overall score of the impact of each kind of threat
Impact score for each threat: 8–9 = high, 6–7 = medium, 2–5 = low, 0–1 = negligible
Then maximum threat score was reported
and the sum of threat scores was reported across five threats (max = 45)

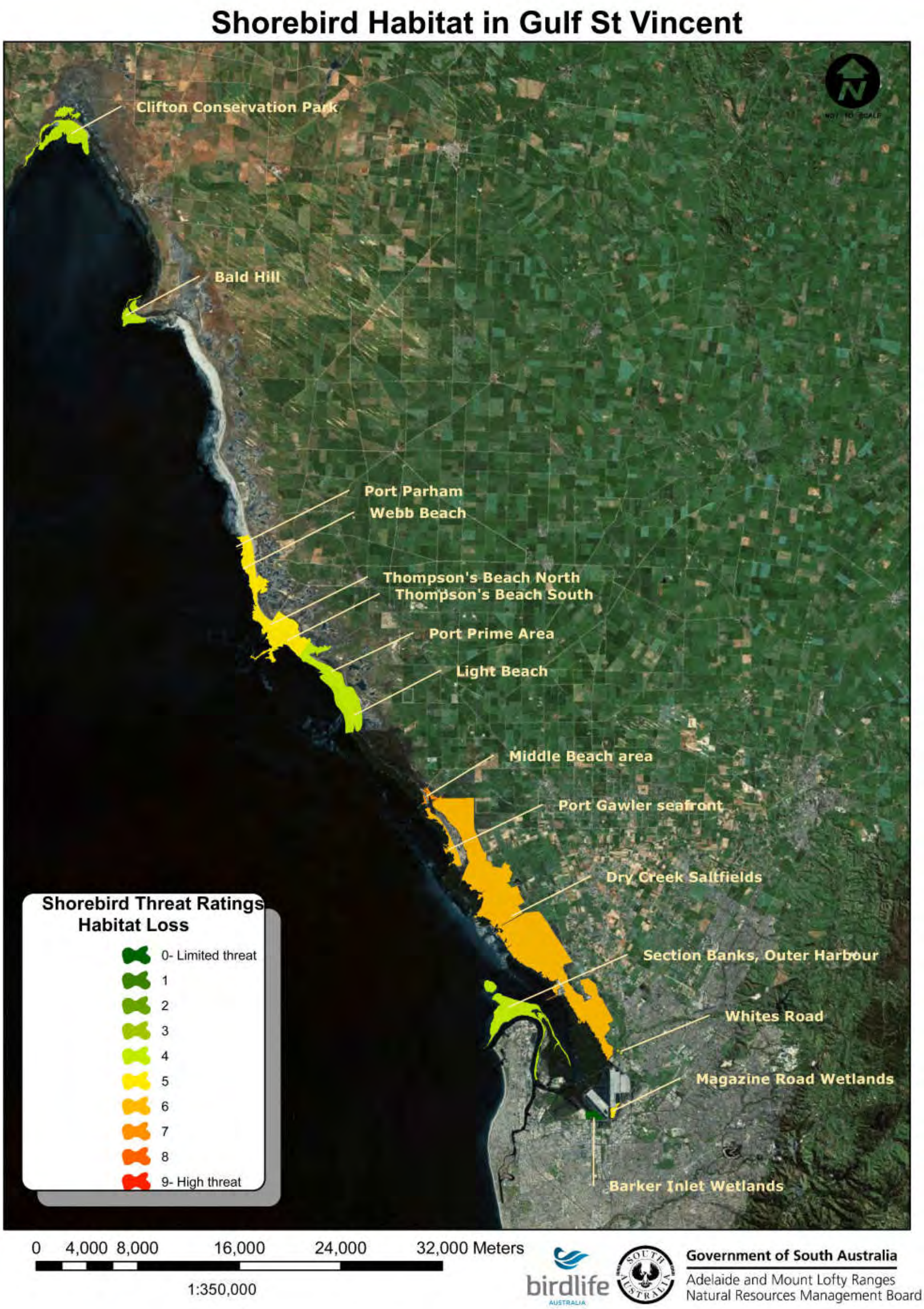


Figure 15. Relative threat of habitat loss to shorebird habitats in GSV

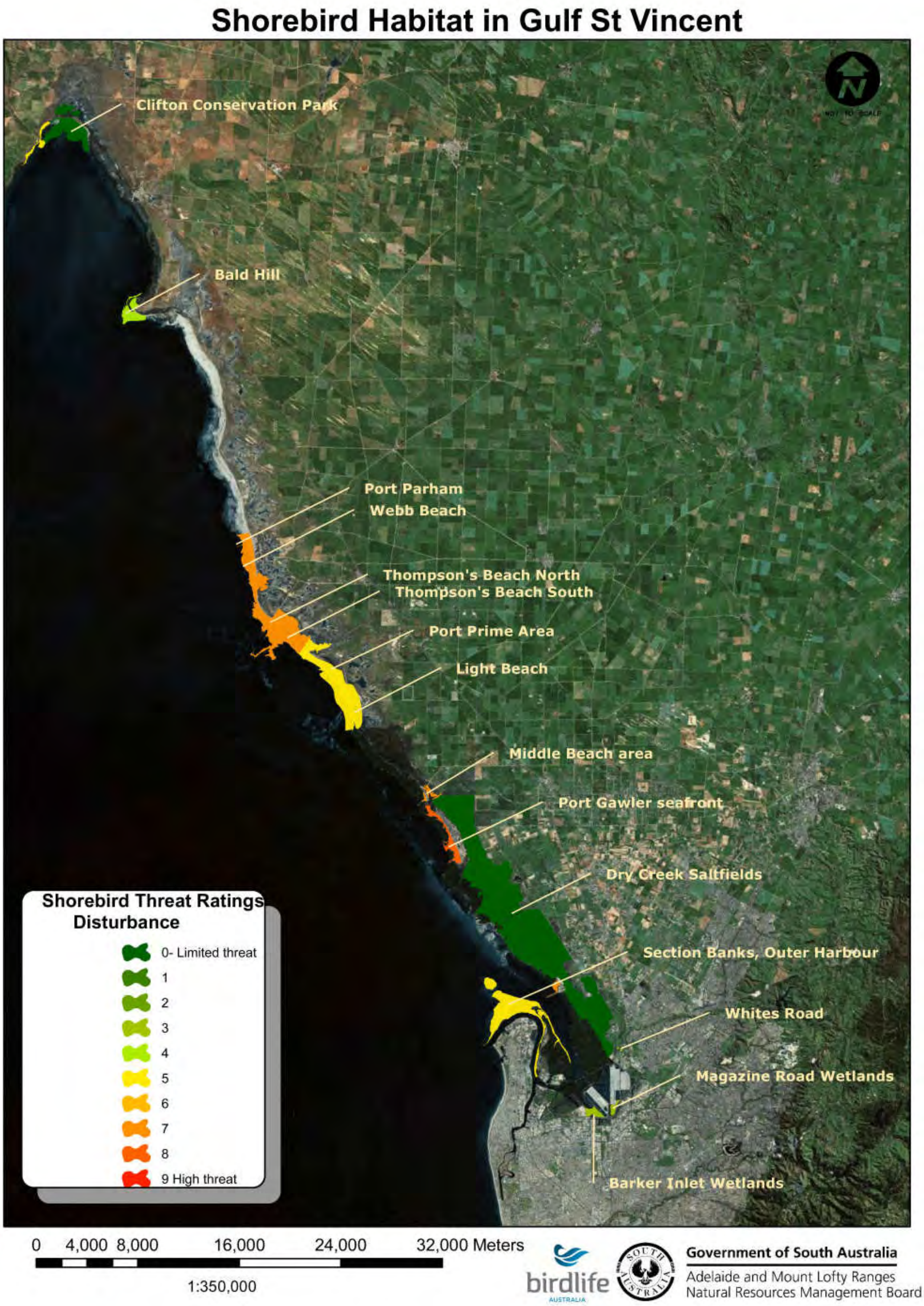


Figure 16. Relative threat of disturbance to shorebird habitats in GSV.

b) Accuracy of mapping and attributes

The supply of digital ortho-photos enabled relatively easy and accurate mapping. The extent of shorebird habitats was drawn directly onto printouts of digital ortho-photos from Google Earth with the assistance of GPS coordinates where obvious geological landmarks were absent. Digital ortho-photos were found to be spatially accurate after comparisons with GPS field points. GPS readings fluctuated by only up to 10 metres in the field, but some features such as sandbars or the edge of mudflats may shift over time by more than 100 metres. In a few remaining areas, the actual edge of the mapped shorebird habitat was uncertain, and boundaries were poorly defined. In these areas the discrepancy between our boundary and the boundary the birds used may be as off by as much as 50 metres. Despite this variation in spatial accuracy of digitised static boundaries, all spatial boundaries are believed to include the core of the important habitat.

For planners and managers requiring greater spatial resolution, some generalisations may assist in future interpretation of important shorebird areas. In general, roosting areas near the mouths of tidal creeks will continue to shift to wherever exposed sand remains at high tide. Further, they will be lost or diminished in importance as vegetation encroaches on roosting areas. Lastly, boundaries of feeding areas will change depending on where the channels shift to and as the distribution of benthic organisms shifts.

The number of shorebirds reported in attribute tables (provided sperately with GIS layers) also varies in accuracy depending on the number of times each area was surveyed, and how recently it was surveyed. Generally, however, the overall maximum and average numbers of shorebirds reported in the GIS attributes are relatively accurate. However, historically, shorebirds have been known to move significantly throughout Gulf St Vincent, so again the abundance figures may not be representative in areas where only a few surveys have been completed.

The surveys conducted in 2008–12 represent the most comprehensive counts of shorebirds in Gulf St Vincent. Therefore, the data presented in the GIS attribute tables represent the best available current information on the distribution and abundance of shorebirds in Gulf St Vincent.

c) Detailed accounts of the habitats in the Greater Adelaide region

The following detailed accounts have been consolidated from those found in the 2010 and 2011 reports (Purnell *et al*. 2010, 2011) and are based on fieldwork from 2009–12. The following areas featured in this section were not established count areas and therefore had no associated count data.

- Supratidal areas between Light Beach and Port Parham
- Sand spits
- Port Wakefield Proof Range and Experimental Establishment (limited data)

The lack of knowledge pertaining to shorebirds in these habitats is largely due to their inaccessibility. For this reason, the following accounts can only characterise sites by their condition at the time of the surveys in January 2010, 2011 and 2012. Buckland Park Lake is included within the Dry Creek Saltfields count area.

Accounts include:

- Detailed descriptions of the habitat in each area; a description of shorebird use of the area
- The relative importance of the area for shorebirds
- Threats to the habitat or shorebirds found in the area
- An overview of shorebird abundance and diversity, and noteworthy species

Vagrant species and transient species, such as the Red Knot and Black-tailed Godwit, which are thought to pass through Gulf St Vincent in the greatest numbers on migration during spring and autumn, may not be fully represented in these descriptions.

These accounts of discrete habitats are broken up into six areas within the Greater Adelaide region:

- Dry Creek Saltfields
- Buckland Park Lake
- Artificial wetlands of North Adelaide (Globe Derby, Barker Inlet and Magazine Road wetlands)
- The Samphire Coast (Light Beach, Port Prime, Thompsons Beach, Webb Beach, Port Parham, PWPEE, Bald Hill)
- Mangrove-lined creeks (St Kilda, Port Gawler, Middle Beach)
- Sand spits (Section Banks, Middle Beach to St Kilda, Port Wakefield,)

i. *Dry Creek Saltfields*

The Dry Creek Saltfields has a roughly north–south orientation (Appendix C, Map 2), and for ease of identification, channels, ponds and embankments are described according to this rough bearing. The names, or codes, used to identify the ponds are those used by Cheetham Salt (Appendix C). Each pond was allocated a habitat type based on its salinity (Coleman and Cook 2009) which dictates floral and faunal assemblages. The habitat types identified included: marine saltponds (39–65 g/L total dissolved salts [TDS]); low hypersaline saltponds (65–110 g/L TDS); medium hypersaline saltponds (110–175 g/L TDS); and highly hypersaline saltponds (175–330 g/L TDS). Areas outside the ponds were treated as another habitat type: "associated areas of saltmarsh, mudflats, and tidal creeks".

Marine saltponds cover 946 hectares of the Dry Creek Saltfields, extending from Buckland Park Lake to Middle Beach. These saltponds are similar to naturally occurring intertidal wetlands, and thus resemble a marine ecosystem, supporting all or most of the macro- and micro-organisms that usually occur in nearby seawater. Most of these ponds are shallow and sheltered, and they contain seagrass beds and high densities of invertebrates typical of rocky shores (Coleman and Cook 2009). In these ponds, shorebirds are likely to catch and eat gastropods, bivalves, crustaceans, insects, worms, echinoderms and fish.

Low hypersaline saltponds cover 1010 hectares between Buckland Park Lake and the midpoint of the Saltfields, while medium hypersaline saltponds cover 1069 hectares between the Fork Creek Flood Gap to the No. 1. Flood Gap. There is significant overlap between the low and medium hypersaline saltponds in the Saltfields: there are similarities in their salinity, prey assemblages, and they share adjoining walls. Not surprisingly, there is a regular interchange of shorebirds between the two types of saltponds. As salinity increases, many less-resilient aquatic species, such as fish, occur at lower densities, while other more resilient species become more abundant: i.e. plankton, crustaceans, molluscs and insects (Coleman and Cook 2009). The most hypersaline ponds in this habitat type are often inhabited by Brine Shrimps *Artemia franciscana* and *Parartemia zietziana*, along with larvae of brine flies *Ephydrella* (Coleman and Cook 2009). Shorebirds feeding in this habitat type find a wide variety of prey to eat, including gastropods, crustaceans, insects, worms and fish.

Highly hypersaline saltponds cover 458 hectares of the Saltfields from ponds 2 kilometres north of St Kilda Road south to Metro Road (9 kilometres south of St Kilda Road). As their salinity increases, the shallow edges of these ponds become increasingly littered with deposits of gypsum (Figures 14, 15), flos ferri and microbial mats. These mats sometimes grow into balls, accumulating at the edges of ponds and in other areas of shallow water, and often protrude above the water's surface, resembling stromatolites. Benthic mats and planktonic microalgae provide food sources for Brine Shrimps (Coleman and Cook 2009). While Brine Shrimps are sometimes abundant in this habitat type at times, other crustaceans, as well as insects and worms may also be available for shorebirds to eat.

The habitat type of “associated areas of saltmarsh, mudflats, and tidal creeks” form some of the most important shorebird habitat in the Saltfields. These saltmarsh and tidal creek habitats lie adjacent to the saltponds on the west side. These areas are generally low lying and sheltered on the seaward side by mangroves, while sheltered on the landward side by the embankments of saltponds. Saltmarshes and tidal creeks run almost the entire 25-kilometre length of the western seaward side of the Dry Creek Saltfields. In addition, the northern extremity of the Middle Beach section is also bordered by saltmarsh, as is the area between the northernmost saltpond and Salt Creek. A wide variety of prey for shorebirds is available in these habitats, including gastropods, crustaceans, insects, worms, fish and frogs.

Given the marked differences in available prey, it is not surprising that the shorebirds that occur in these different habitats vary in species composition and abundance. However, the abundance of shorebirds using these ponds will not vary solely based on salinity. Simply, shorebirds need sufficiently low water levels to be able to exploit the available prey and, as in any area, they also require places to rest (roost). At present, relatively undisturbed roost sites are abundant within the ponds, so the distribution of shorebirds in Dry Creek will be largely a function of water depth and salinity.

Below is a description of the habitats and relative importance of those habitats to shorebirds. Much of the information in this section was based on biodiversity surveys conducted by Birds South Australia shorebird monitoring, recent surveys by BirdLife Australia, Delta Environmental Consulting, and their recent discussion paper (Coleman and Cook 2009).

a) Marine Saltponds: Shellgrit Road–Middle Beach: Ponds XE1–3 and XF1–2 (Appendices B and C, Map 8 and 11)

<u>Shorebird abundance</u>: ~600
<u>Diversity</u>: Seven species recorded during this study; 12 recorded historically.
<u>Noteworthy species</u>: The site regularly supports >350 Sharp-tailed Sandpipers (nationally significant; >0.1% of estimated population in East Asian–Australian Flyway [EAA]; see Table 1).
Important Feeding and Roosting Habitats:
Description Ponds XE2–3 and XF1 have: large areas of shallow water (<10cm); islands and embankments with gradually sloping banks; complex shorelines; and little or no vegetation.
Use High-tide feeding and roosting areas used by seven species; used by three species of small shorebirds throughout the tide cycle.
Relative importance One of the largest, continuous areas of shallow mudflats available for feeding in the Saltfields.
Threats Water levels: If water levels in these ponds increase, the water will become too deep for shorebirds to forage in. If water levels remain too low for too long, it may encourage the vegetation to grow, and if it was to cover the islands and banks they would be rendered unsuitable as roosting sites for shorebirds. This is a common threat among all saltponds.

b) Marine Saltponds: Port Gawler Road–Shellgrit Road: Ponds XE4–5 (Appendices B and C, Map 8 and 11)

Shorebird abundance: ~350
Diversity: Seven species recorded during this study; 12 recorded historically.
Noteworthy species: The site regularly support >300 Red-necked Stints, Red-kneed Dotterels (locally uncommon), breeding Masked Lapwings, Ringed Plover (vagrant species).
Important Feeding and Roosting Habitats:
Description **(a)** The eastern side of XE5 is shallow with low, scattered, thinly vegetated islands, and is bordered by gradually sloping banks and complex shorelines. **(b)** A shallow channel and associated pools, which run between an elevated boundary fence and interior access roads on the south-western boundary. **(c)** High, densely vegetated islands and banks in XE4.
Use **(a)** Seven species of shorebirds use this area as a high-tide feeding and roosting area, and three species of small shorebirds use it throughout the tide cycle. **(b)** Sheltered feeding and roosting habitat for five species of shorebirds. **(c)** Breeding site for Masked Lapwings.
Relative importance Birds displaced from the adjacent Port Gawler foreshore (displaced either by high tides or disturbance) often use this section as a substitute feeding and roosting area.
Threats Water levels (see (a) Marine saltponds: Shellgrit Road–Middle Beach, above, for details).

c) Marine Saltponds: Chapman's Creek–Port Gawler Road: Ponds XE6–7 (Appendices B and C, Map 8)

Shorebird abundance: ~50 (more when Buckland Park Lake is inundated)
Diversity: Seven species recorded during this study; 20 recorded historically.
Noteworthy species: Wood Sandpipers and Common Sandpipers (both locally uncommon) are regularly present.
Important Feeding and Roosting Habitats:
Description **(a)** Vegetated islands surrounded by shallow banks. **(b)** Ponds XE6 and XE7 are bisected by the Gawler River overflow, which is lined with mangroves.
Use Seven common species of shorebirds roost in the area; four long-legged species of shorebirds feed there regularly.
Relative importance Use of this area is greatly influenced by the state of Buckland Park Lake: when Buckland Park Lake is at peak productivity, Ponds XE6–7 are used as a substitute roosting and feeding site due to increased shorebird abundance and competition.
Threats Water levels (see (a) Marine saltponds: Shellgrit Road–Middle Beach, above, for details).

d) Low and Medium Hypersaline Saltponds: XA1–4, XB4–6, XD1, XA7, XB8, XB8–South, XC2, XC2–South, XC3 and PA3–5 (Appendices B and C, Maps 9 and 12)

Shorebird abundance: Up to 16,000
Diversity: 15 species recorded in this study; 50 recorded historically.
Noteworthy species: The sites regularly support Red-necked Avocets, Eastern Curlews, Whimbrels, Pacific Golden Plovers, Grey Plovers, Red-kneed Dotterels, Ruddy Turnstones, Grey Plovers, Bar-tailed Godwits and Marsh Sandpipers. Less commonly, Black-fronted Dotterels, Black-tailed Godwits, Terek Sandpipers, Pectoral Sandpipers, Broad-billed Sandpipers, Great Knots and Red Knots are recorded. Vagrant species recorded in these saltponds include Hudsonian Godwit, American Golden Plover, Red-necked Phalarope, Little Curlew, Common Redshank, Cox's Sandpiper, Lesser Yellowlegs, Ruff and Long-toed Stint. Large, irruptive flocks of Banded Stilts (16,000 >1% EAA in 2012).

Figure 17. Thousands of Banded Stilt feed in pond XC 2 in early 2012.

Important Feeding and Roosting Habitats:
Description **(a)** The northern edges of Ponds XA2, 3 and XC 3 are bordered by a network of low-lying, unvegetated islands with gently sloping banks; associated shallows run east–west. The narrow embankments between the ponds also lack vegetation. **(b)** Ponds XC2 and XC2–South are shallow and have sloping banks. The most important habitat of these saltponds is created by the presence of a disused fence-line along the western shore of the shallow XC2–South where sediment and minerals accumulate into small islands around fence posts (Figure 18). Accumulations of gypsum and flos ferri are associated with a fine cyonabacterial mat, ideal for shorebirds to roost on. **(c)** The northern and eastern banks of Pond XC3 consist of unvegetated islands and mudflats which extend into the centre of the pond. Two small islands with little vegetation occur at the south-eastern end of the pond. **(d)** The eastern shoreline of Pond XD1 consists of large areas of low, gently sloping sediment with a complex shoreline, including shallow bays and inlets. Most of the islands are vegetated with low, dense samphire. **(e)** Pond XB8A is surrounded by sloping banks. There is a low island in the shallows on the seaward side of the pond where sediment has accumulated around the remains of an old pump-house. **(f)** Ponds XB4 and XB5 are separated by a narrow, low embankment which has been colonised by short vegetation. The edges of the embankment slope gently into the shallows and the western end terminates in a series of small shallow islands. **(g)** The

two parallel embankments separating XB4–5 and XB6 are similar in structure with a small outflow channel running between them. Although the embankments are steep sided and well vegetated, they are bordered by shallow islands. **(h)** The Saltworks are bisected by Thompson Drain, which runs roughly east–west, running parallel to the Bolivar effluent channel, and is situated south of Ponds XB3 and XD1. This shallow, slow-flowing stream of water from the Bolivar Sewage Treatment Plant is characterised by its soft sediment. It is 40 metres wide and about 2 kilometres long, and is bordered by areas of samphire.

Figure 18. Sharp-tailed Sandpipers, Curlew Sandpipers and Red-necked Stints roost on accumulations of gypsum in Pond XC2–South. Photo Chris Purnell

Use **(a)** The islands, embankments and surrounding shallows of Ponds XA2, XA3 and XC3 are regularly used by 15 species of shorebirds as high-tide roosting and feeding areas, and are occasionally used by another four species. **(b)** There is much interchange of five species of shorebirds between Ponds XC2 and XC2–South and the nearby Pond XC3. Three species regularly roost in their hundreds (up to 500) along the fence-line and on associated banks, and forage in the shallows. **(c)** Shallow water and islands in Pond XC3 provide feeding and roosting habitat for eight species. Masked Lapwings and Red-capped Plovers breed on the islands at the south-eastern end of the pond. **(d)** The sheltered inlets and shorelines of Pond XD1 are used by seven species of shorebirds as feeding and roosting habitat, and Masked Lapwings breed on the islands. **(e)** Ponds XB8A and XB8B are used as roosting and feeding sites for eight common species of shorebirds, two less-common species and seven vagrants. **(f)** The vegetation on the embankment between Ponds XB4 and XB5 is used by four species of small waders as a sheltered roosting site and by Red-capped Plovers as a nesting site. The ponds' shallows and islands are regularly used by roosting Australian Pelicans, as well as by six species of shorebirds, which roost and forage there. **(g)** Ponds XB4–6 provide sheltered feeding habitat for seven species of shorebirds, including Masked Lapwings, which also nest among the vegetation. **(h)** Thompson Drain is used regularly for feeding by five species of shorebirds, and another seven vagrant species have also been recorded there.
Relative importance **(a)** Ponds XA2, XA3 and XC3 are the only sites in the Saltfields where Grey Plovers and Bar-tailed Godwits (both nationally declining species) regularly roost. The sites are occasionally used by Great Knots, Eastern Curlews (both on the IUCN Red List) and Red Knots (another declining species). **(b)** Ponds XC2 and XC2–South provide feeding and roosting sites for small shorebirds throughout the tide cycle, including the highest densities of Curlew Sandpipers (a rapidly declining species) within the Saltfields. **(c)** The islands in the north-east of Pond XC3 are the only regular roost sites used by Red-necked Avocets in the

Saltfields. **(d)** Feeding throughout the tide cycle and breeding habitat for Masked Lapwings. **(e)** Ponds XB8A and XB8B provide important roosting and foraging sites for small shorebirds; a number of vagrants have been recorded in these ponds. These include Long-toed Stint, Pectoral Sandpiper, Terek Sandpiper, Broad-billed Sandpiper, Cox's Sandpiper, Ruff, Red-necked Phalarope and Lesser Yellowlegs. **(f)** Because Ponds XB4 and XB5 are relatively inaccessible for terrestrial predators, they provide excellent nesting sites for resident shorebirds. **(g)** Feeding throughout the tide cycle and breeding habitat for Masked Lapwings. **(h)** Thompson Drain is the only source of low-salinity water in the Saltfields, and it attracts species that require fresh to brackish water.

Threats Water levels (see (a) Marine saltponds: Shellgrit Road–Middle Beach, above, for details).

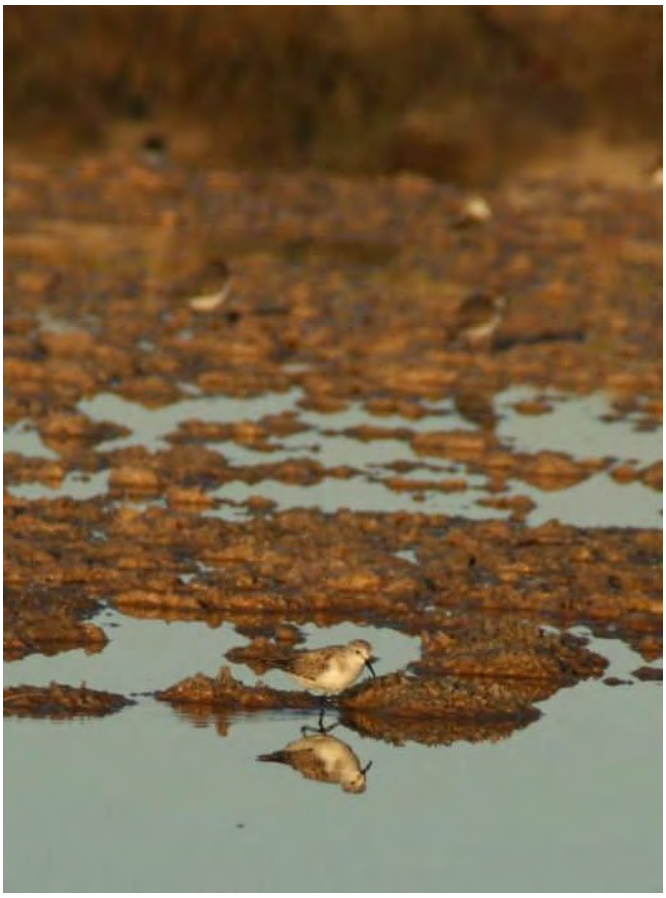


Figure 19. Red-necked Stints and Red Capped-Plovers feed and roost on deposits of gypsum. Photo Chris Purnell

e) Highly Hypersaline Saltponds: Ponds XA1, 7 and PA3–4 (Appendices B and C, Map 9)

<u>Shorebird abundance</u>: >1000
<u>Diversity</u>: Nine species recorded in this study
<u>Noteworthy species</u>: Preferred roosting and feeding sites for Red-capped Plover, Sharp-tailed Sandpiper and Red-necked Stint throughout the tide cycle. Large, irruptive flocks of Banded Stilts (10,000 [>1% EAA] in 2008, 2012; 30,000 in 1985).

Important Feeding and Roosting Habitats:

Description **(a)** The northern and eastern banks of Pond PA4 and its associated inflow pond to the east are lined with gypsum and coated with microbial mats containing layers of cyanobacteria, diatoms and bacteria which often form balled growths (Coleman and Cook 2009). There is an extensive accumulation of gypsum precipitates in the narrow intake channel to the east of the main pond, and microbial mats have created a large, unvegetated platform (Fig 19). **(b)** The southern and western boundaries of Pond PA3 are bordered by shallow sloping banks, and there is a large mudflat on its eastern shore. There is a small depression south of this pond which is designated as a flood gap, and is filled with open sediment with patchy pooling. **(c)** The majority of Pond XA1 is deeper than 10 centimetres, with surrounding embankments of piled rocks.

***Use* (a)** Pond PA4 is used by five species of shorebirds, mainly for feeding throughout the tide cycle, though the island in the associated intake pond is often used by most of these birds for roosting. **(b)** Seven species of shorebirds feed and roost along the shores of Pond PA3 throughout the tide cycles. **(c)** Historically, ponds XA1 and PA3 have been used as feeding areas for large flocks of Banded Stilts which have been observed swimming in order to feed in the deep water. The embankments around the saltpond are also used for roosting by four species of shorebirds.
***Relative importance* (a)** The highest concentrations of Red-capped Plovers and Red-necked Stints in the Saltfields have been recorded at Pond PA4, with over 150 Plovers and 350 Stints (>0.1% EAA) observed. **(b)** High densities of Brine Shrimp and Nektonic Brine Fly larvae sometimes occur in Pond PA3; these invertebrates support flocks of Banded Stilts during occasional irruptions. **(c)** If alternative natural Banded Stilt flocking sites are degraded, these ponds will become increasingly important for the species.
Threats Water levels (see (a) Marine saltponds: Shellgrit Road–Middle Beach, above, for details).

NB. The highly hypersaline ponds south of St Kilda Road are utilised less often by shorebirds than those discussed above, but they regularly support low densities of common species of shorebirds, such as Sharp-tailed Sandpipers, Red-necked Stints, Red-capped Plovers, Common Greenshanks and Masked Lapwings. The benthic mats and planktonic microalgae that exist in these conditions fuel occasional population explosions of Brine Shrimps (Coleman and Cook 2009), and these may attract large flocks of opportunistic Banded Stilts.

f) Highly Hypersaline–Saturated Saltponds (Appendices B and C, maps 10 and 13)

The saturated saltponds of Dry Creek Saltfields have salinity levels at approximately 300g/L TDS and cover a 316-hectare area which has been earmarked for residential development. Although this area is only occasionally used by low densities of common shorebirds, the loss or isolation of these ponds would have implications across the entire network of saltponds throughout the Saltfields.

A literature review discussing the importance of saltfields for shorebirds can be found in the 2010/11 Population Monitoring Report. Prioritization of ponds in terms of their significance can for shorebirds can be found in Appendix C

g) Associated areas of saltmarsh, mudflats and tidal creeks (Appendix B and C Maps 8, 9, 10, 11 and 12)

Shorebird abundance: 500–700
Diversity: 20 species recorded in this study. 23 historically
Noteworthy species: Red Knots (locally uncommon), Double-banded Plovers (winter migrants), Pacific Golden Plovers, Wood Sandpipers, Marsh Sandpipers, Banded Stilt, Pied Oystercatcher and Eastern Curlews have all been recorded, as have two vagrant species (Little Stint and Long-toed Stint).

Important Feeding and Roosting Habitats:
Description **(a)** East of Pond XB3, on the seaward side of the access track, is a large open area of saltmarsh that is bordered by dense mangroves (Figure 16), and is often inundated by high tides. **(b)** A large mudflat near the north-western corner of Pond XB8B, known as 'Wader Flat', has more than 1 kilometre of open tidal flats which are protected by an embankment and access road on the landward side and by large stands of mangroves on the seaward side.
Use **(a)** Pond XB3 is a favourite roost site for Black-winged Stilts, and flocks of about 50 birds regularly roost at the site; three other common species of shorebirds also often roost here. **(b)** The saltmarsh and mudflats adjacent to the XB8 ponds provide productive feeding sites and sheltered roost sites for six species of shorebirds. "Wader Flat" is a regular feeding and roosting site for large flocks of Red-capped Plovers and Red-necked Stints, and is used less regularly by various other species; it is one of a few sites in the Saltfields where Red Knots are thought to stage on their arrival and departure on annual migration. Red-capped Plovers often nest nearby. Double-banded Plovers, winter migrants from New Zealand, also use this site.
Relative importance Saltmarsh and associated tidal creeks supply sheltered feeding areas to shorebirds throughout the tidal cycle (Fig 20).
Threats: *Mangrove incursion & sea level rise*. These

Figure 20. Black-winged Stilts, Banded Stilt, Sharp-tailed Sandpiper and Red-kneed Dotterel are just 4 of the 8 species which regularly feed and roost in the saltmarsh. Photo Chris Purnell

ii. Buckland Park Lake (Appendix, Map 8)

Buckland Park Lake is situated to the west of salina XE7, and was established by ICI in the 1920s by daming the deltaic mouth of the Gawler River to prevent floodwaters from spilling into the saltwater evaporation ponds. The Lake is listed with Port Gawler in the Directory of Important Wetlands for the following criteria:

1. *it is a good example of a wetland type occurring within a biogeogrphic region in Australia.*

3. The wetland supports 1% or more of the national populations of any native plant or any tax.

5. The wetland supports native plant or animal taxa or communities which are considered endangeredor vulnerable at the national level.

6. The wetland is of outstanding historic or cultural significance

Shorebird populations in and around the lake depend both on its level and the timing of its inundation (Figure 21). Due to reduced environmental flows and accumulated sediment (among other factors), the lake has changed from being a permanent wetland to being ephemeral (P. Coleman and R. Attwood pers. comm.). The heavy rains of late 2010 and early 2011 filled the lake, resulting in a freshwater wetland covering over 2 km^2.

Figure 21.Aerial imagery of Buckland Park Lake in varying levels of inundation. Image adapted from Google Earth imagery

<u>Shorebird Prey Species</u>: Crustaceans, insects, spiders, water mites and worms.
<u>Shorebird abundance</u>: <150
<u>Diversity</u>: 10 species recorded during this study, 20 species historically.
<u>Noteworthy species</u>: Red-kneed Dotterels, Black-fronted Dotterels, Banded Stilts, Red-necked Avocets, Latham's Snipe, Common Greenshanks, Marsh Sandpipers, Black-tailed Godwits, Wood Sandpipers, Common Sandpipers and Pectoral Sandpipers (all locally uncommon) have all been recorded here, as have Broad–billed Sandpipers and Long-toed Stints (both rare species), and four vagrant species (Cox's Sandpiper, Baird's Sandpiper, Ruff and Little Ringed Plover). The Endangered Australian Painted Snipe has also been recorded at this site.

Important Feeding and Roosting Habitats:
Description Buckland Park Lake is an ephemeral wetland which is inundated only when the Gawler River is flooded. It was formerly a permanent wetland.

Use The lake occasionally fills during winter, and by late spring the effects of evaporation and seepage sometimes cause the water level to recede to an attractive depth for shorebirds. Under these conditions, muddy edges suitable for shorebird foraging are revealed, coinciding with an increase in invertebrate abundance and accessibility just as migratory shorebirds arrive. At the time of the 2011 and 2012 surveys, the region had received higher-than-average summer rains on the back of a wet winter. This resulted in complete inundation of the lake. The shallow, freshwater environment created is the preferred feeding habitat for eight locally uncommon species of shorebirds.

Figure 22. Black-winged Stilts and Masked Lapwings both breed at Buckland Park Lake. Photo Glenn Ehmke

Relative importance Buckland Park is the only substantial freshwater habitat on the Adelaide Plains and is also the single most important breeding habitat for a range of waterfowl within th Adealaide region (Australian Nature Conservation Agency 1996). Flocks of Black-tailed Godwits (a species that is declining rapidly throughout the East Asian–Australasian Flyway) stage in this area on arrival and departure on their annual migration. Although it is unclear where these flocks spend most of the non-breeding season, the recent extended drought meant that the species was seldom recorded in the region; there have been 3 records in the past 6 years. Red-kneed Dotterels, Black-fronted Dotterels, Red-capped Plovers, Masked Lapwings and Black-winged Stilts (fig 22) all breed in the lake. Large flocks of Banded Stilt also visit the lake in some years. The shallow complex shorelines and surrounding low vegetation of the lake have supported the endemic Endangered Australian Painted Snipe, as well as some vagrant species (Ruff, Long-toed Stint).

Threats If left unmanaged, due to the natural hydrology of the area, Buckland Park Lake will seldom experience inundation.

iii. *Artificial wetlands*

The Barker Inlet Wetlands (Figure 24), which cover 172 hectares, and Magazine Road Wetlands (40 hectares) form part of a series of artificial wetlands, including Greenfields and Connector Wetlands at Salisbury and the Range Wetlands at Gilman. The combined area of these wetlands is 337 hectares, making them the largest artificial wetlands in Australia.

<u>Shorebird Prey Species</u>: Crustaceans, insects, worms, amphibians and fish.

a) Barker Inlet Wetlands (Appendix B, Map 10*)*

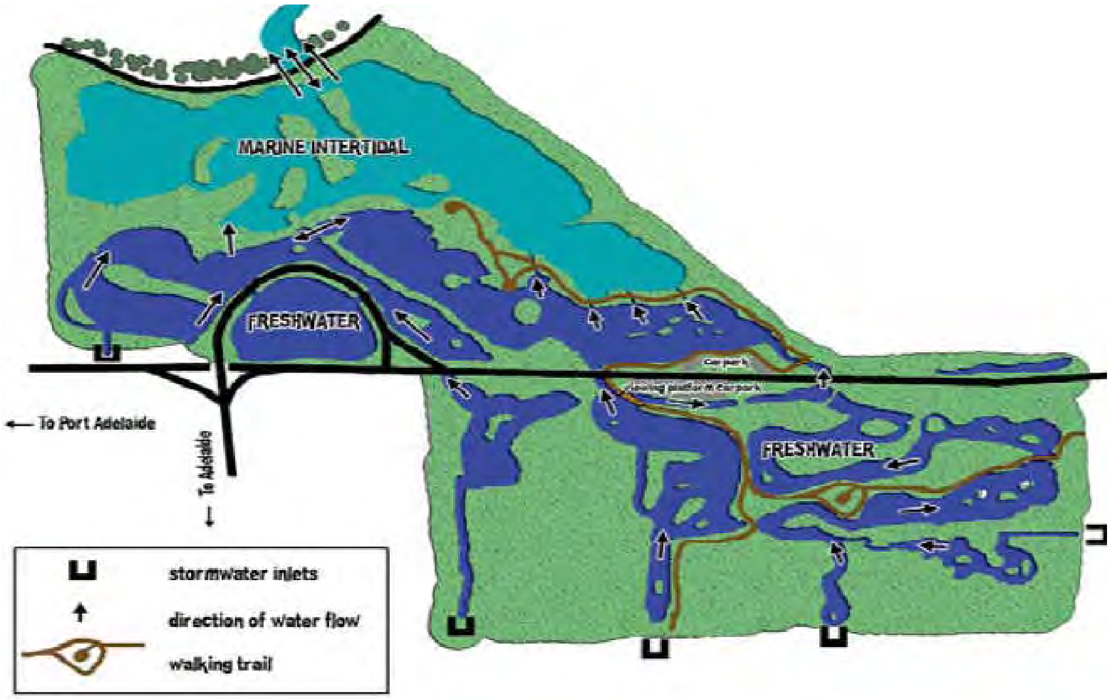


Figure 23. The Barker Inlet Wetlands. Diagram from www.waterwatchadelaide.net.au

<u>Shorebird abundance</u>: ~400
<u>Diversity</u>: 13 species recorded in this study; 23 recorded historically
<u>Noteworthy species</u>: Red-necked Avocet, Sharp-tailed Sandpiper (>0.1% EAA).
Important Feeding and Roosting Habitats:
Description The wetlands to the north of the Highway are divided by weirs into freshwater and saltwater (intertidal) ponds, and account for most of the shorebird habitat in the system. The recently filled freshwater ponds are managed for shorebirds, and the water in them is, on average, <0.5 metres deep, whereas those south of the highway are 2.5 metres deep. The intertidal section includes a large lagoon on the north-eastern corner and a series of tidal creeks and channels which wind through the saltmarsh.
Use A total of 12 species regularly occur in the shallow, freshwater lagoons, tidal creeks, saltmarsh and large intertidal mudflat in the north-eastern corner.

Relative Importance Whereas the nearby Greenfields Wetlands comprise deep, well-vegetated water bodies, the Barker Inlet Wetlands provide an open, shallow habitat, important for shorebirds that prefer fresh water to brackish water.
Threats Disturbance: The site is near current and proposed housing estates, which increases the probability of shorebirds being disturbed by intended recreational use*, which is expected to intensify with the expansion of the population of Greater Adelaide. Recreational activities undertaken in the area include dog walking, birdwatching and unauthorised trail-bike riding.

*Barker Inlet Wetlands are managed by the City of Port Adelaide Enfield. Currently, the area is not open to the general public, but viewing platforms and interpretive signs are installed on either side of the South Road Connector. The Council runs guided sunset tours between November and January.

b) Magazine Road Wetlands (Appendix B, Map 10)

<u>Shorebird abundance</u>: ~250
<u>Diversity</u>: 14 species recorded during this study; 23 recorded historically
<u>Noteworthy species</u>: Australian Painted Snipe (Endangered), Long-toed Stint, Wood Sandpiper and Common Sandpipers (all locally uncommon) have been recorded at the site.
Important Feeding and Roosting Habitats:
Description Stage 3 of the wetlands was completedin 1995. A storm-water treatment area, these wetlands comprise a system of freshwater channels and lagoons which vary from <10 centimetres deep in the summer to over 1 metre deep in winter. The lagoons and channels have shallow edges and complex shorelines with a few dense reedbeds.
Use A total of 14 species of shorebirds, including many that prefer freshwater lagoons, feed and roost in the shallow lagoons and channels.
Relative importance These wetlands provide a mix of open, shallow freshwater and vegetated marsh habitats that are scarce in the region and are preferred feeding and roosting habitat for 3 migratory species.
Threats Disturbance: The site is near current and proposed housing estates, and it likely that shorebirds will experience increased levels of disturbance from recreational activities (such as dog walking, birdwatching and unauthorised trail-bike riding) in the future.
Habitat loss: Currently bare, shallow and muddy edges used for both feeding and roosting by shorebirds are under threat from encroaching vegetation. This can be a passive process but is more often a part of active management.

c) Whites Road Wetland, Globe Derby (Appendix B, Map 10)

<u>Shorebird abundance</u>: >50
<u>Diversity</u>: 7 species recorded during this study; 7 recorded historically
<u>Noteworthy species</u>: Australian Painted Snipe (Endangered) recorded in 2012 (Fig 24). Locally uncommon Red-kneed Dotterels breed at the site.

Important Feeding and Roosting Habitats:
Description these wetlands are part of the Little Para Linear Park and comprise of 2 freshwater lagoons surrounded by shallow brackish marshes on the western side. The lagoons and channels have shallow edges and complex shorelines.
Use A total of 14 species of shorebirds, including many that prefer freshwater lagoons, feed and roost in the shallow lagoons and channels.
Relative importance These wetlands provide open, shallow freshwater habitats that are scarce in the region. The shallow vegetated areas also provide breeding habitat for 3 resident shorebird species.
Threats Disturbance: The site is near current and proposed housing estates, and it likely that shorebirds will experience increased levels of disturbance from recreational activities (such as dog walking, birdwatching and unauthorised trail-bike riding) in the future.
Habitat loss: Currently bare, shallow and muddy edges used for both feeding and roosting by shorebirds are under threat from encroaching vegetation. This can be a passive process but is more often a part of active management.

Figure 24. The shollow vegetated edges of Whites rd Wetland are used by seven resident shorebirds, includeing the endangered Australian Painted Snipe. Photo Chris Purnell

iv. *Mangrove-lined creeks and ports*

a) St Kilda (Appendix B, Map 9)

St Kilda formerly consisted of three low-lying islands that were covered with shell grit and saltmarsh, and were surrounded by mangroves and more saltmarsh. However, with the establishment of a coastal township, an associated marina and the adjacent Dry Creek Saltfields, there has been a drastic loss of natural habitat (Coleman and Cook 2003).

Shorebird Prey Species: Gastropods, crustaceans, insects, worms, bivalves, bryazoans, cnidarians, echinoderms and fish.
Human Population: 247
Shorebird abundance: ~400 species in this study; historic records of over 1600
Diversity: 7 species recorded during this study
Noteworthy species: Red-necked Stint (>0.1% EAA), Sharp-tailed Sandpiper (>0.1% EAA).
Important Feeding and Roosting Habitats:
Description Areas of remaining habitat consist of around 40 hectares of tidal mudflat in the bay and small saltpans between the township and the Saltfields.
Use The saltmarsh and associated saltpans are occasionally used by four species of shorebirds, while the mudflats are regularly used by five species.
Relative importance A readily used source of intertidal feeding for flocks of over 400 Sharp-tailed Sandpipers, which roost in the nearby Saltfields.
Threats Habitat Loss: Invertebrate assemblages have declined due to ongoing nutrient-induced degradation of the mudflats.
Disturbance: St Kilda receives a high level of visitation from tourists and boat traffic; forms of disturbance include walkers, dogs, fishermen and bait collectors.

b) Port Gawler Seafront (Appendix B, Map 8)

Covering 195 hectares adjacent to the Dry Creek Saltfields andPort Gawler seafront consists of vast intertidal flats and frining mangrove forests that are crossed by a multitude of tidal chanels. To the east, within 500m lie the Dry Creek Salinas. A slatmarsh asmphire community occupies the area between the flats and the salinas. The Two Wells District Council and Trade Association has, in association with the WWF, identified the area as being important for shorebirds. It is also listed with Buckland Park Lake in the *Directory of Important Wetlands* under the following criteria:

1. It is a good example of a wetland type occurring within a biogeogrphic region in Australia.
3. The wetland supports 1% or more of the national populations of any native plant or any tax.
5. The wetland supports native plant or animal taxa or communities which are considered endangeredor vulnerable at the national level.
6. The wetland is of outstanding historic or cultural significance

Shorebird Prey Species: Gastropods, crustaceans, insects, worms, bivalves, bryazoans, cnidarians, echinoderms and fish.
Shorebird abundance: ~1600
Diversity: 19 species in this study
Noteworthy species: Maximum counts of >1200 Red-necked Stints (>0.1% EAA); also important for Grey Plovers and Eastern Curlews; Double-banded Plover occur in winter.
Important Feeding and Roosting Habitats:
Description The Port Gawler Seafront consists of a large intertidal mudflat, low saltmarsh and areas of sandy beach.

Use The tidal flat is used regularly by six species of shorebirds for roosting and foraging.
Relative Importance: At low tide the area provides a sheltered feeding and roosting alternative to the more exposed habitats of the adjacent marine saltponds.
Threats Habitat Loss: This area and its surrounding saltmarsh have been degraded by the use of off-road vehicles and trail-bikes.
Disturbance: Off-road vehicles (Figure 5) and trail-bike riders (Figure 25) see the saltmarsh and the adjoining areas of tidal flats as a cheap alternative to the facilities at the nearby Port Gawler Off-road Park. Fishermen also use the gap in the mangroves to launch their boats or gain access to the tidal flat to collect bait.

Figure 25. Feeding Red-necked Stints disturbed by trail-bike riders at Port Gawler.

c) Middle Beach (Appendix C, Map 7)

This small coastal community has a population of 367 residents. Visitation to the area by tourists is quite low due to the encompassing mangroves which separate the small sandy beach from the ocean, though the boat launch is regularly used by visiting fishermen.

<u>Shorebird Prey Species:</u> Gastropods, crustaceans, insects, worms, bivalves, bryazoans, cnidarians, echinoderms and fish.
<u>Human Population</u>: 367
<u>Shorebird abundance</u>: usually ≤100, though there has been a record of 1000
<u>Diversity</u>: 15 species in this study.
<u>Noteworthy species</u>: Lesser Sand Plovers and Grey-tailed Tattlers are recorded occasionally.
Important Feeding and Roosting Habitats:
Description The habitat consists of a creek line, which is used to launch boats, and a long stretch of tidal flats that are separated from the ocean by mangroves. Houses are built on the foredune, and some back onto areas of low-lying saltmarsh and saltpans.
Use: The intertidal flats are used regularly by seven species of shorebirds, and the saltmarsh and saltpans are regularly used by three species.
Threats Habitat Loss: Degradation of the shorebird habitats has occurred as a result of coastal development on the foreshore and from the use of off-road vehicles on the intertidal zone.
Disturbance: Activities such as boat traffic, people walking their dogs or collecting bait, as well as the use off-road vehicles all disturb shorebirds at this site.

v. *The Samphire Coast*

North of Middle Beach, the mangrove-dominated coastline gives way to open tidal flats and sandy beaches. These habitats comprise most of the shorebird habitat at Light Beach, Port Prime, Thompsons Beach, Webb Beach, Port Parham, the Proof Range and Experimental Establishment at Port Wakefield and Bald Hill. Small stands of mangroves line the tidal creeks which intersect these beaches and flow into areas of saltmarsh and small lagoons, but large areas of supratidal saltpans are the dominant habitat beyond the dunes.

These beaches create a continuous habitat for various species of shorebirds that specialise in foraging in intertidal flats, and they may utilise any of these count areas, resulting in variation in count data. These beaches are unique in that they provide high densities of some shorebird prey species, such as shellfish, which in turn support the high numbers of species, including Red Knot, that occur in the area. Other prey in the area includes gastropods, crustaceans, insects, worms, bryazoans, cnidarians, echinoderms and fish.

Increasing disturbance to shorebirds along the northern beaches is thought to be the greatest threat to shorebirds in the region, potentially excluding shorebirds from otherwise suitable habitat. Shorebird habitats in close proximity to coastal communities like Port Parham, Webb Beach, and Thompsons Beach all have the potential to be disturbed to the point of excluding shorebirds, or exacting high energetic costs to migratory shorebirds with high energetic requirements. Sources of disturbance along the northern beaches and surrounding areas include walking, dog walking, fishing (land and sea based), boating, digging for bait, catching crabs, off-road vehicles, trail-bike riding, para-surfing and jet-skiing. These activities often spill over into neighbouring shorebird habitats at Light Beach and Port Prime and are likely to intensify as human populations expand.

Habitat Loss has been identified as a threat in these areas. Shorebird habitats surrounding the coastal towns of Port Parham, Webb Beach and Thompsons Beach are under threat from development, including residential expansion and possible relocation of the saltfields. An increased human population also makes the threat of habitat loss through degradation (which can spill over into neighbouring areas such as Port Prime and Light Beach) more likely.

The District Council of Mallala Coastal Advisory Committee now superseded by the Environmental Management Advisory Committee (EMAC) has recently highlighted their concerns regarding threats to shorebirds, and are investigating the feasibility of closing roads that bisect or lead to important shorebird habitat (District Council of Mallala Coastal Advisory Committee 2010):
The issue of coastal access for motor vehicles along the District Council of Mallala coastline has been an ongoing struggle in which Council has put towards in the past. In recent times this issue has come to the forefront with the steady increase in vehicles gaining access to reserve land and private property for illegal recreational

use of two-wheel drive vehicles, four-wheel drive vehicles, trail bikes, quad bikes and specialised vehicles such as dune buggies.

In 2003 the Samphire Coast Conservation strategy was drafted by Council staff and highlighted the unique and valuable assets of the Mallala Coastline and the need to better manage the coastal environment. Included in the report is an objective to have "sensitive coastal environments free of off-road vehicle and motorbike use."

a) Light Beach (Appendix B, Map 6)

<u>Shorebird Prey Species:</u> Gastropods, crustaceans, insects, worms, bivalves, bryazoans, cnidarians, echinoderms and fish.
<u>Shorebird abundance</u>: ≤3500
<u>Diversity</u>: 16 species in this study
<u>Noteworthy species</u>: Red Knots (>1% EAA), Red-capped Plovers (>1% EAA), Red-necked Stints (>0.1% EAA), Eastern Curlews, Bar-tailed Godwits and Grey Plovers have all been recorded. The site was also where the largest-known congregation of Banded Lapwings in the Greater Adelaide area was recorded.
Important Feeding and Roosting Habitats:
Description Large intertidal mudflats with some small raised islands vegetated with saltmarsh. Open sandy beaches in the south become progressively covered with wrack near Port Prime.
Use Sandy beaches and intertidal mudflats are used for feeding and roosting by 16 species of shorebirds, with preference for roosting on islands formed by accumulated wrack.
Relative importance A key feeding and roosting area for Red Knots, Grey Plovers and Black-tailed Godwits.
Threats Disturbance and habitat loss or degradation.

b) Port Prime (Appendix B, Map 6)

<u>Shorebird Prey Species:</u> Gastropods, crustaceans, insects, worms, bivalves, bryazoans, cnidarians, echinoderms and fish.
<u>Shorebird abundance</u>: ~2000 recently; up to 4200 historically
<u>Diversity</u>: 18 species in this study
<u>Noteworthy species</u>: Red-capped Plover (>1% EAA), Bar-tailed Godwit (>0.1% EAA) Curlew Sandpiper (>0.1% EAA), Red-necked Stint (>0.1% EAA), Grey Plover (>0.1% EAA), Red Knot (>0.1% EAA), Common Greenshank (>0.1% EAA), Sharp-tailed Sandpiper (>0.1% EAA), Eastern Curlew; Black-tailed Godwits and Great Knots have also been recorded at this site, and Whimbrels and Greater Sand Plovers are occasional visitors.
Important Feeding and Roosting Habitats:
Description The southern section of the beach has much accumulated tidal wrack which extends well into the intertidal zone.
Use Sandy beaches and intertidal mudflats are used for feeding and roosting by 16 species of shorebirds, with preference for roosting on islands formed by accumulation of wrack (Figure 26).

Relative importance A key feeding and roosting area for Red Knots, Grey Plovers and Black-tailed Godwits.
Threats Disturbance and Habitat loss or degradation

Figure 26. Raised accumulations of wrack on tidal flats at Port Prime and Light Beach. Photo Chris Purnell

c) Thompsons Beach (Appendix B Map 5)

Human Population: 290
Shorebird abundance: ~2000 recently; up to 4200 historically
Diversity: 18 species in this study
Noteworthy species: Bar-tailed Godwits (>0.1% EAA), Red Knots (>0.1% EAA), Red-necked Stints (>0.1% EAA), Ruddy Turnstones (>0.1% EAA), Common Greenshanks (>0.1% EAA), Great Knots and Grey Plovers have also been recorded at the site, and Greater Sand Plovers, Lesser Sand Plovers, Double-banded Plover (winter) and Pacific Golden Plovers are occasional visitors.
Important Feeding and Roosting Habitats:
Description The central and northern sections comprise sandy beaches and extensive tidal flats covered with wrack. Further south, Third Creek is tidal, and linked to an inland saltpan which is bordered by vegetated ridges, and its seaward reaches are inundated by high tides.
Use The sandy beaches and tidal flats are used by 16 species of shorebirds, and the saltpan is used by eight species, both for roosting and feeding on incoming tides.
Relative importance A key feeding and roosting area for Red Knots, Grey Plovers and Black-tailed Godwits.
Threats Disturbance and habitat loss or degradation

d) Webb Beach (Appendix B, Map 5)

Shorebird Prey Species: Gastropods, crustaceans, insects, worms, bivalves, bryazoans, cnidarians, echinoderms and fish.
Human Population: 204
Shorebird abundance: ~400
Diversity: 13 species in this study.
Noteworthy species: The area regularly supports Curlew Sandpipers, Bar-tailed Godwits and Grey Plovers; Greater Sand Plovers, Great Knots and Lesser Sand Plovers are occasionally recorded, as are Marsh Sandpipers, which are locally uncommon.
Important Feeding and Roosting Habitats:
Description Webb Beach is characterised by sandy beaches and tidal mudflats. Baker Creek, to the south, is a tidal watercourse with sandy islands, and is bordered by coastal saltmarsh.
Use The sandy beaches and tidal flats are used by 10 species of shorebirds for feeding and roosting. The banks of Baker Creek and the islands within it are used by six species, as is the saltmarsh.
Relative importance Baker Creek provides an important roosting area for Curlew Sandpipers, a species that is declining rapidly in south-eastern Australia.
Threats Disturbance and habitat loss or degradation.

e) Port Parham (Appendix B, map 5)

Shorebird Prey Species: Gastropods, crustaceans, insects, worms, bivalves, bryazoans, cnidarians, echinoderms and fish.
Human Population: 213
Shorebird abundance: ~1500
Diversity: 24 species in this study
Noteworthy species: Bar-tailed Godwit (>0.1% EAA), Red Knot (>0.1% EAA), Common Greenshank (>0.1% EAA), Curlew Sandpiper (>0.1% EAA), Red-necked Stint (>0.1% EAA), Sharp-tailed Sandpiper (>0.1% EAA). Great Knots, Eastern Curlews, Grey Plovers and Whimbrels are also regularly recorded at this site, and Banded Lapwings, Pacific Golden Plovers, Greater Sand Plovers, Lesser Sand Plovers, Double-banded Plover (winter) and Oriental Plovers are all occasional visitors. Marsh Sandpipers and Common Sandpipers, both of which are locally uncommon, are also occasionally recorded.
Important Feeding and Roosting Habitats:
Description The area comprises sandy beaches and tidal flats covered with wrack, extending north onto restricted land managed by the Australian Defence Force.
Use Used regularly for feeding by 16 species of shorebirds.
Relative importance Key feeding areas for many intertidal specialists and bordering on the Port Wakefield Proof Range and Experimental Establishment coastline which is essentially free of disturbance.
Threats Disturbance and habitat loss or degradation

f) Saltpans between Light Beach & Port Parham (Appendix B, Map 5 and 6)

Vast areas of hind-marsh are dominated by saltpans throughout the Samphire Coast, including areas adjacent to the coastal towns of Thompsons Beach, Webb Beach and Port Parham.

Shorebird Prey Species Crustaceans and insects.
Shorebird abundance > 1600
Diversity Nine species recorded during this study; no historical data.
Noteworthy species Red-capped Plover nesting site; Banded Lapwings, Lesser Sand Plovers, Greater Sand Plovers, Double-banded Plovers (during winter) are all recorded here; Red-necked Avocet and Banded Stilt flocking site.

Figure 27. Red-necked Stints and Red-capped Plovers feed on an inundated saltpans south of Bakers Creek. Photo Chris Purnell

Description The continuous saltpans are the dominant landform north of Middle Beach and vary in condition, depending on their connectivity to tidal creeks, relative distance from the coast, weather and tidal action.
Use Shorebird habitat use throughout this area depends on the condition of the saltpans. The most fertile feeding habitat utilised by shorebirds are the areas inundated by Third Creek and those south of Bakers Creek (Figure 22).
In the saltpans at Third Creek, shorebirds feed on the edge of the incoming tides and across the cyanobacterial mats formed in areas affected by natural evaporative pumping. These areas are also commonly used by roosting shorebirds and waterbirds during high tides and one species (the Red-capped Plover) has been recorded nesting (Figure 27).
The saltpans immediately to the south of Bakers Creek are also inundated at varying times by evaporative pumping and tidal creeks (Figure 16). These areas provide feeding and roosting habitat for up to 1,000 shorebirds of five species. Red-capped Plovers are readily recorded nesting in the area.
Areas further from the coast/tidal creeks are inundated only by the highest tides, or they may hold water temporarily after rain events, but remain dry for most of the year. Nevertheless, these barren, harsh landscapes, such as those found to the east of Thompsons Beach, support shorebirds, though they occur in smaller numbers than elsewhere in the Gulf. Two species were recorded in the area. One species, the Red-capped Plover, nests in the area (Figure 28.)

Relative importance Located within a short flight from productive feeding habitats of the intertidal zone, the Samphire Coast's saltpans provide crucial high-tide roosting and feeding sites for a number of species of shorebirds. This will become increasingly important with sea-level rises threatening to render intertidal mudlflats functionally redundant to shorebirds (see Discussion, Article VI). The large open areas also provide the surveillance and hydrological predictability referred by nesting Red-capped Plover.

Threats Habitat Loss*:* While the habitats described above are more resilient to the effects of off-road vehicles than the neighbouring saltmarsh, increased levels of disturbance can result in abandonment of the site, which equates to loss of habitat. Rising sea levels are also a threat to these characteristically low lying areas, however their extent and proximity to agricultural land provides ample opportunity for habitat retreat.

Figure 28. Resident Red-capped Plovers nest on the claypans to the north-east of Thompsons Beach. This area is, however subject to disturbance and degradation from off-road vehicles (top).

Disturbance: Frequent use by off-road vehicles can disturb birds as they feed or roost, resulting in unnecessary energy expenditure and loss of feeding time due to extra surveillance behaviour or flight initiation.
Accidental mortality: Off-road vehicles may crush chicks or eggs of Red-capped Plovers.

g) Port Wakefield Proof Range and Experimental Establishment (Appendix B, Map 3, 4)

The Port Wakefield Proof Range and Experimental Establishment covers a 19.5 kilometres of coastline from Port Parham to Bald Hill.

<u>Shorebird Prey Species</u> Unsurveyed, however assumed- Gastropods, crustaceans, insects, worms, bivalves, bryazoans, cnidarians, echinoderms and fish
<u>Shorebird abundance</u> ~2500; up to 7,500 historically.
<u>Diversity</u> 10 species recorded during this study.
<u>Noteworthy species</u> This study: Eastern Curlew, Bar-tailed Godwit (>0.1% EAA), Red-necked Stint (>0.1% EAA). Historically: Sharp-tailed Sandpiper (>1% EAA), Curlew Sandpiper (>0.1% EAA), Grey Plover (>0.1% EAA).
Important Feeding and Roosting Habitats:

Description The habitat is consistent with that of the Samphire Coast, but a lack of tidal creeks restricts the abundance and distribution of intertidal habitats. Surveying of the claypans and lagoons was not possible due to access restrictions.
Use Tidal flats, beaches and low islands that have been colonised by saltmarsh species provide feeding and roosting habitats.
Relative importance Key feeding areas for many intertidal specialists, as this stretch of coastline is essentially free of disturbance and unlikely to be developed.
Threats Accidental mortality/pollution: The effect of munitions testing on shorebird habitat is unknown.

h) Bald Hill (Appendix B, Map 3)

Sometimes referred to as Sandy Point, Bald Hill is a low-energy, south-facing beach and tidal flat which juts out into the Gulf. It is situated on the northern border of the Port Wakefield Proof Range and Experimental Establishment.

Shorebird Prey Species Unsurveyed, however assumed- Gastropods, crustaceans, insects, worms, bivalves, bryazoans, cnidarians, echinoderms and fish
Shorebird abundance ~1500
Diversity 20 species in this study. No historic data.
Noteworthy species Eastern Curlew, Red Knot, Great Knot, Bar-tailed Godwit; Sharp-tailed Sandpiper (>1% EAA), Curlew Sandpiper (>0.1% EAA), Grey Plover (>0.1% EAA). Locally uncommon speciesrecorded: Grey-tailed Tattler; Pacific Golden Plover, Greater Sand Plover.
Important Feeding and Roosting Habitats:
Description This small bluff extends into the Gulf and is bordered by extensive intertidal mudflats, sandy beaches and small islands on its southern coast. Tidal creeks and lagoons criss-cross the saltmarsh dominated post dune habitat.
Use Extensive tidal flats, beaches and low islands that have been colonised by saltmarsh provide feeding and roosting habitats for intertidal specialists. Tidal creeks and saltmarshes provide alternate feeding areas for some species at high tide.
Relative importance Key feeding areas for many intertidal specialists. This stretch of coastline's remoteness and proximity to the Port Wakefield Proof and Experimental Establishment ensures it is relatively free of disturbance and unlikely to be developed.
Threats *Disturbance:* Occasional use by off-road vehicles and fisherman can disturb birds as they feed or roost, resulting in unnecessary energy expenditure and loss of feeding time due to extra surveillance behaviour or flight initiation.

vi. *Sand Spits and Islands*

a) *Section Banks*, Outer Harbour (Appendix B , map 10)

The Section Bank is an artificial island located at the northern end of the Northern Revetment mound (a rock breakwater), about 700 m offshore from Outer Harbour. The Section Bank was created from sediments dredged from the Port River in about 1976. At that time, the Section Bank was separated from the Northern Revetment by about 160 metres, but they have now become joined. The Section Bank is slowly growing to the north-east as sand accumulates from the northern movement of sand along the coast, but it is still occasionally flooded or breached by high tides and storms. The bank is a combination of intertidal flat, saltmarsh and mangrove on finer sediments on the eastern side (Carpenter 2008).

Shorebird abundance: ~6000 individuals
Diversity 14 species recorded in this study. No historic data.
Noteworthy species Curlew Sandpiper (>0.1% EAA), Sharp-tailed Sandpiper (>0.1% EAA), Red-necked Stint (>1% EAA), Red-capped Plover (>1% world), Pied Oystercatcher (>1% world), and Sooty Oystercatcher (>1% world)
Important Feeding and Roosting Habitats:
Discription North of Outer Harbour, the Section Banks cover around 700 hectares of habitat.
Use Most of the large intertidal area is used by shorebirds at some stage during the tidal cycle.
Relative importance The isolation of the banks creates a safe high-tide roost for waders that feed on the adjacent mudflats of Barker Inlet. It is the only regularly utilised roosting site for large numbers of Pied and Sooty Oystercatchers in the Gulf.
Threats *Disturbance:* Visitation by boats, fisherman and bait diggers.

Habitat loss: Should Light Passage be expanded to accommodate increased shipping as the city expands, there is potential for habitat loss on the banks. The low profile of the banks also makes it susceptible to sea-level rise.

Pollution: The waters surrounding the banks are highly trafficked by commercial and private boats. This increases the chance of chemical and biological pollution.

b) Intertidal zone between Middle Beach and St Kilda (Appendix B, Maps 7, 8 and 9)

This intertidal area is directly east of the Dry Creek Saltfields, and was not surveyed or mapped before 2011 due to its inaccessibility from both land and sea. The dense mangrove forest, 1.5 kilometres wide in places, extends north from Barker Inlet and taper off at Light Beach, creating a barrier to access by land. Similarly, the shallow waters of this section of the intertidal zone limit access by boat. For these reasons, surveys were completed by kayak in 2011.

Shorebird Prey Species: Unknown.
Shorebird abundance: <400

Diversity Six species recorded during this study; no historical data.
Noteworthy species Eastern Curlew.
Important Feeding and Roosting Habitats:
Description The intertidal flats traditionally supported meadows of *Zostera* seagrasses, interspersed with smaller amounts of green algae (*Ulva* and *Enteromorpha*). The calm water, fine sediment and dense growth of seagrass associated with these beaches would normally provide excellent habitat for invertebrates and small fish, but increased water turbidity caused by the Bolivar Waste Water Treatment Plant Outlet has caused a rapid die-off of seagrass meadows and encouraged the formation of large algal mats of Sea Lettuce (Coleman and Cook 2003; Fox *et al*. 2007).

Figure 29. The sand spit on the seaward side of the mangroves adjacent to pond XB 8. Photo Chris Purnell

These extensive mats are interrupted by sand spits which have formed in and along the edges of two tidal creeks within the region (Figure 29). These sand spits are located on the seaward side of the mouth of Salt Creek (Middle Beach) and on the seaward side of the mangroves adjacent to salina XB 8 (4 kilometres north of St Kilda and 3 kilometres from Section Banks).
Use Although this site has never been mapped, mapping of similar areas of intertidal seagrass meadows throughout southern Australia (e.g. Clemens 2007; Herrod 2010; Maurer 2010) has led to the assumption that the seagrass beds were utilised by shorebirds for feeding at low tide. However, this was not the case in the 2011 surveys. Although the intertidal zone supplied feeding habitat for wading waterbirds, shorebird feeding and roosting was confined to the sand spits. These areas are functionally identical to the nearby sand spits of Section Banks.
Relative importance The presence of intertidal habitats near the Dry Creek Saltfields provides alternate feeding areas for shorebirds using the Saltfields' supratidal salinas. This is particularly important for small waders and may become increasingly

important if habitat within the Saltfields becomes compromised by either the loss of habitat or increased disturbance (e.g. earthworks).

Threats Habitat Loss: Sea-level rise and consequent deepening of areas that currently provide low-tide habitat is likely to be the greatest long-term impact caused by climate change, as these areas will be rendered functionally useless to shorebirds.

Pollution: The sewage outfall has been linked to the die-off of seagrass meadows and the colonisation of the nitrogen-scavenging algae Sea Lettuce. This has had a drastic impact on benthic invertebrate communities and, consequently, use by shorebirds (see Section 2.07.).

Disturbance: Boats coming to and from Middle Beach cause minor disturbance to birds roosting on the Salt Creek sand spit.

c) Port Wakefield Sand Spit

This area has not been surveyed or mapped previously due to its inaccessibility from land. The dense mangrove forest, 1.5 kilometres wide in places, extends north from Bald Hill (Sandy Point) and tapers off towards the head of the Gulf, where it gives way to extensive tidal mudflats adjoining Clinton Conservation Park. Observations made from the northern banks of Bald Hill and the southern tidal flats of Clinton Conservation Park concluded that the areas on the seaward side of this forest are too deep to provide habitat for shorebirds. However, aerial imagery identified a sand spit on the southern edges of the Port Wakefield boating channel which could provide habitat.

<u>Shorebird Prey Species</u> Gastropods, crustaceans, insects, worms, bivalves, bryozoans, cnidarians, echinoderms and fish.

Shorebird abundance <400

<u>Diversity</u> Two species recorded during this study; no historical data.

Noteworthy species None.

Important Feeding and Roosting Habitats:

Description At low tide, the unvegetated sand spit is only approximately 200m^2.

Use Two species of shorebirds were observed roosting beside flocks of terns, gulls and cormorants. As the tide rose, the birds flew south, probably to roost or continue feeding at Bald Hill.

Relative importance A short flight from the vast feeding areas of the Clinton Conservation Park intertidal mudflats (7.3 kilometres to the north) and Bald Hill (7.4 kilometres to the south), the sand spit at Port Wakefield provides a secure low-tide roost that is isolated from disturbance and risk of predation from terrestrial predators.

Threats Habitat Loss: Sea-level rise and consequent deepening of areas that currently provide low-tide habitat is likely to have the greatest long-term impact caused by climate change, as these areas will be rendered functionally useless to shorebirds.

Disturbance: Boats coming to and from Middle Beach cause minor disturbance to birds roosting on the Port Wakefield sand spit.

DISCUSSION:
Migratory shorebirds and the predicted rise in sea level

The spectre of climate change will affect different suites of birds throughout the world in different ways. Because of the mobile nature of migratory shorebirds, moving between different habitats in different regions of the world, many aspects of their life cycles will be influenced. Their ability to find suitable nesting sites as the distribution of suitable breeding habitat shrinks, their ability to breed successfully, the timing of their migratory flights and their ability to successfully fly from one side of the world to the other will all be affected by changes to the climate, which may, in turn, influence other environmental variables, such as the availability of food (Galbraith *et al*. 2002; Piersma and Lindström 2004; Sutherland 2004; Murphy-Klassen 2005; Crick and Sparks 2006; Maclean *et al*. 2007; Dept Climate Change 2009; De Leon *et al*. 2011).

While in their non-breeding grounds, such as in Australia, migratory shorebirds do not have to contend with altered breeding cycles, but their feeding and roosting activities are likely to be affected by climate change. The most likely source of this change is a shift in the sea level, particularly sea-level rise and its associated effects.

It has been estimated that the oceans absorb up to 80% of the heat that is added to the climate system. This heat causes the seawater to expand slightly, and when this is extrapolated up to a global scale, it will result in a rise in sea level. Acting in concert with this effect is the melting of the global ice sheets and glaciers under the influence of increased atmospheric temperature. As the fresh water that was previously locked up in the Arctic and Antarctic ice shelves is gradually returned to the sea, the substantial additional amount of water will also contribute to sea-level rises (Galbraith *et al*. 2002; Dept Climate Change 2009; Williams *et al*. 2009).

Rising sea levels do not simply mean that the water will gradually become deeper along our coastlines (Dept Climate Change 2009). The degree of sea-level rise will not be constant throughout the world, and its extent and effects will vary with a number of climatic, geological and local factors that are at play simultaneously (Galbraith *et al*. 2002; Titus and Strange 2008). Although many of its effects remain unclear on a local scale, as there are many different variables (Piersma and Lindström 2004), it is likely that they will lead to an associated increase in the frequency and severity of storm surges and similar extreme sea-level phenomena which will have an additional impact on coastal environments, especially by altering the complex balance between the erosion and deposition of sediment, which affects the extent and quality of coastal intertidal habitats (Galbraith *et al*. 2002; Maclean *et al*. 2007; Mitchell *et al*. 2007; Dept Climate Change 2009).

Shorebirds are likely to be affected profoundly by these changes because they mostly inhabit low-lying and intertidal coastal habitats — migratory shorebirds during their non-breeding period, and resident shorebirds throughout the year (Smart and Gill 2003; Austin and Rehfisch 2003; Rehfisch *et al*. 2004; Mitchell *et al*. 2007).

The two most important characteristics of a site for shorebirds on their wintering grounds, including Australia, are the availability of suitable habitats for foraging and roosting. As sea levels become higher, habitats that are essential for the survival of shorebirds are likely to be modified profoundly or lost altogether. Intertidal mudflats and similar environments that are essential for foraging are likely to be exposed for shorter periods, restricting the time available for foraging. Roosting sites, such as beaches and supratidal saltmarsh, are likely to be inundated more regularly and frequently, rendering them less suitable. In addition, as sea-level rises change the conditions at these sites, these environments may be damaged through erosion and other processes.

Roosting habitat

Shorebirds require supratidal habitats (that is, those that are not inundated by normal tidal action) where they can roost during the high-tide period when foraging habitats are unavailable. Such habitats often include areas of low saltmarsh. However, this habitat is likely to be adversely affected by rising sea levels, and is likely to be among the first habitats to be affected by it. Saltmarsh plants that are adapted to being inundated by sea water only occasionally will eventually die if they are flooded too often. As sea levels (and associated tidal amplitudes) change, the lower limits of the potential niche of each saltmarsh plant species moves up the landward slope, away from the water. As habitat is lost by inundation on the seaward edge, new habitat should develop at the landward edge. When this occurs, there is a virtual retreat to higher ground to 'escape' the sea water, known as 'inland migration' (Robinson *et al*. 2005). Under normal circumstances, the total area of the different habitats should remain relatively constant, as the inland migration keeps pace with any changes in sea level. However, a rise in sea level under the predicted regime is likely to be too rapid for the plants to keep up, as it were. If they are unable to maintain a suitable rate of inland migration, saltmarsh plants may become waterlogged due to increased tidal flooding, causing them to die, and the vegetation is killed off eventually rather than retreating. As saltmarshes tend to be situated in flat landscapes with low gradients, a retreat onto higher ground may not occur at the same rapid rate as the sea level rises, and the tidal action is likely to override the rate of relocation of the saltmarsh (Hughes 2004; Titus and Strange 2008; Dept Climate Change 2009).

As the saltmarsh plants die off, the entire area of habitat may be lost, and this process may result in the conversion of saltmarsh into additional areas of mudflat, providing additional foraging habitat for shorebirds (Galbraith *et al*. 2002; Titus and Strange 2008). However, as the suitable shorebird roosting habitats are lost, the birds will need to expend increased levels of energy by flying between foraging areas and roost sites if they are too far apart, thus using up valuable energy stores.

Even if the inland migration of the saltmarsh is able to keep pace with rising sea levels, it may not be able to retreat as far from the seawater as necessary if it encounters some adverse habitat forming an insurmountable barrier on the landward edge. Such barriers, especially 'hard' infrastructure such as sea walls, roads or settlements, prevent saltmarsh from colonising new areas of land simply because they are in the way. When this occurs, the area of saltmarsh becomes progressively smaller in a process known as 'coastal squeeze'. Eventually, squashed between the impregnable barrier and the rising sea water, the habitat will become trapped and no longer be able to survive, and it will be lost (Galbraith *et al*. 2002; Hughes 2004; Robinson *et al*. 2005; Rehfisch and Austin 2006; Maclean *et al*. 2007; Titus and Strange 2008; Dept Climate Change 2009; Jones *et al*. 2009).

Beaches, tidal creeks and claypans are also used regularly as roosting sites. These characteristically low areas are likely to be inundated more regularly, and the erosive effects of increased frequency and severity of storm surges is likely to render them unavailable and unsuitable as roosting sites for shorebirds (Dept Climate Change 2009).

It is important to note that beaches, claypans and saltmarshes are often used as breeding sites for resident shorebirds, so these effects will also have an impact on these species as well as on the non-breeding migratory shorebirds. They will be affected by the loss of breeding habitat in areas that become permanently flooded, while in formerly good habitat that has been downgraded to marginal habitat by regular though not permanent inundation, though they will still be able to find ground suitable for nesting, their nests in these low-lying areas are likely to be flooded more often as sea levels rise (Robinson *et al*. 2005; Maclean *et al*. 2007).

It is less clear how rising sea levels will affect salt ponds which act as roosting sites for shorebirds. Their bunds could potentially act as barriers to the inland migration of saltmarsh, and so facilitate the process of coastal squeeze, assisting in the elimination of alternate roosting habitats. Alternatively, their bunds may be breached by sea water, and with their water levels becoming too deep and impossible to maintain, they could possibly no longer provide suitable sites for roosting. A third possibility is that their bunds could protect the ponds from inundation and thus they could remain as sanctuaries which continue to provide suitable roosting habitat.

Foraging habitat

Although they have different habitat requirements, most migratory shorebirds forage in intertidal habitats, especially on mudflats. These habitats are exposed at low tide, making their invertebrate fauna available for foraging birds. However, under the regime presented by rising sea levels, the time that the foraging habitat is likely to be exposed could potentially be decreased greatly, making it difficult for the birds to eat enough food to provide sufficient energy (Hughes 2004; Durell *et al*. 2006; Titus and Strange 2008).

Further, because coastal mudflats occur in sheltered, low-energy environments, when faced with rising water levels, they may not be able to increase their vertical profile through deposition at a sufficient rate to keep pace with water levels, and thus are likely to become submerged and converted into areas of open water (Gesch *et al*. 2009; Jones *et al*. 2009). This would eliminate a rich source of invertebrate food for many species of shorebirds (Titus and Strange 2008). Because different species of shorebirds fill different foraging niches, some will be adversely affected more than others by this inundation. For example, larger birds such as Eastern Curlews are able to forage in deeper water than smaller, shorter-legged species such as Red Knots, meaning that different species will be affected more than others. Also, different water depths may also affect the types of prey species that are present, again disadvantaging some species more than others (Titus and Strange 2008).

If the area of exposed intertidal mudflats declines due to sea-level rise, remaining areas could become overcrowded with foraging shorebirds, leading to a decline in foraging efficiency and, ultimately, lower populations (Jones *et al*. 2009).

An increase in storm surges associated with a rise in sea levels is likely to increase the level of erosion of intertidal mudflats (Dept Climate Change 2009). Not only are mudflats likely to be damaged or destroyed, the amount of sediment suspended in the water column will also change. Because mud particles are finer than grains of sand, they are likely to remain suspended in the water column for longer, while heavier sand will settle more readily, thus changing the nature of the substrate, and therefore, potentially changing the communities of invertebrates that inhabit it. In this scenario, invertebrates that prefer sandier environments will be favoured over species that are mud specialists, and this change in the assemblage of prey species may affect some shorebirds as their preferred prey species occur at decreasing densities (Yates *et al*. 1996; Austin and Rehfisch 2003).

The availability of food on mudflats may also be affected by the disturbance or loss of other nearby coastal habitats. For example, many of the benthic invertebrates eaten by shorebirds on intertidal mudflats spend a portion of their life cycles in either coastal saltmarsh or on offshore flats vegetated by seagrass or eelgrass. These habitats are likely to be damaged by rising sea levels — saltmarsh through inundation and erosion, and seagrass beds by both erosion and increased water turbidity, which will inhibit photosynthesis — which may, in turn, cause the biomass of the mudflats to decline and therefore affect the productivity of the nearby mudflats and their capacity to nourish shorebirds (Hughes 2004; Erwin *et al*. 2006; Rehfisch and Austin 2006; Maclean *et al*. 2007; Titus and Strange 2008; Dept Climate Change 2009; Jones *et al*. 2009).

Although the loss of some mudflats may be offset by the natural creation of new ones as the saltmarsh retreats inland (Galbraith *et al*. 2002; Durell *et al*. 2006; Titus and Strange 2008; Jones *et al*. 2009), it seems unlikely that this will favour many shorebirds, as it will be offset by the loss of roosting habitat, and only a small proportion of lost habitat will be replaced. In a similar situation to saltmarsh, mudflats are also subject to inundation and coastal squeeze, and even newly created mudflat habitat could eventually disappear under the same process, leaving it unavailable for foraging shorebirds (Titus and Strange 2008).

Because some shorebirds forage in salt-production ponds, it is worthwhile considering the effects of rising sea levels on those wetlands regarding their suitability as wader feeding habitat. If the banks of the ponds are breached by the sea, then the salinity of the water within the ponds would be compromised, thus potentially affecting the prey that is available to the foraging shorebirds. As mentioned with respect to salt-production ponds as roosting habitat, the ability to control water flow between ponds may be lost, thus losing the ability to manipulate the water levels and salinity levels, which would also affect the availability of prey.

There are many questions regarding solutions to the issues surrounding rising sea levels, but at this stage there are few answers, as the rate of sea-level rise is still unknown and the degree of local variation is still unclear, and, therefore, so is the extent of its effects, both overall and on a more local scale.

Managed Realignment

There are methods of active coastal management that can be used in an effort to minimise the habitat-related effects of sea-level rise on migratory shorebirds.

In coastal areas, policy regarding the management of flood risk has the potential to have a substantial impact on the degree to which biodiversity can accommodate climate change. The effects of a rise in sea level will be minimised, however, by regarding sea-level rise as an inevitable process, and overall loss of important coastal habitats can be achieved by using appropriate management (Atkinson *et al*. 2003 Crooks 2004; Hughes 2004; Mitchell *et al*. 2007).

One of the most widely used strategies is managed realignment of coastal habitats, also known as 'managed retreat' or 'managed realignment' (Maclean *et al*. 2007; Mitchell *et al*. 2007). This has been used at a number of sites in the Northern Hemisphere, especially along the Atlantic Ocean coasts of Europe. It involves removing artificial coastal infrastructure which acts as a barrier, or at least allowing the sea water to penetrate it, thus allowing the sea to reach areas that were not previously exposed to inundation. In this way, inland migration can be facilitated and coastal squeeze can be overcome. In such instances, however, coastal realignment could lead to the loss of other habitats that occur further inland, but is likely that these are mostly of a lower conservation value. If the physical obstacles are removed, allowing the landward movement of coastal habitats, then the effects of a rise in sea level on biodiversity will be minimal (Atkinson *et al*. 2003; Maclean *et al*. 2007; Mitchell *et al*. 2007). It should be noted that although coastal realignment is often driven by the desire to create more habitat (Möller n.d.), it is also often used as a means of improving coastal protection from erosion, flooding, storm surges and the like, and for other economic reasons (e.g. French 2006; Turner *et al*. 2007; Möller n.d.).

Key coastal habitats can be maintained or created by controlling the amount of inundation by sea water (Maclean *et al*. 2007). There are many examples of this, especially in the United Kingdom*, though the method has also been widely used in Germany, Denmark and the Netherlands as well. Although the effects of rising sea levels are well understood in the USA (e.g. Titus and Strange 2008; Gesch *et al*. 2009; Gutierrez *et al*. 2009; Jones *et al*. 2009; Williams *et al*. 2009; US Fish and Wildlife Service 2012), the incidence of managed realignment appears to be far less widespread (e.g. National Oceanographic and Atmospheric Administration 2007).

For example, in the Humber Estuary on the east coast of England, managed realignment of the coast by allowing the sea water to breach a sea wall and inundate adjacent coastal farmland has created 80 hectares of new habitat, comprising saltmarsh and mudflats. After the wall was breached in 2002, the saltmarsh community was the first habitat to become established, and within two years it was being used by good numbers of shorebirds as a roosting site. The newly developed habitat has become an internationally important site for Eurasian Golden Plovers *Pluvialis apricaria*, and a site of national importance for Pied Avocets *Recurvirostra avosetta* and Black-tailed Godwits. Within four years of the realignment, 19 species of shorebirds had been recorded at the site, and shorebirds were the most numerous group in the realignment area. Shorebirds also foraged on the newly formed mudflats, but as the diversity of a benthic community in the mudflats was slower to develop, more foraging occurred on adjacent, established mudflats. Many of the shorebirds moved into the saltmarsh habitat to roost at high tide after foraging elsewhere. However, as the mudflat community developed, four years after the realignment the number and diversity of shorebirds present increased (Mander and Cutts 2004; Halcrow Group Ltd 2005, 2007).

Large numbers of migratory shorebirds also quickly inhabited an area of newly created saltmarsh and mudflats after a sea wall was deliberately breached in three places at Freiston Shore in the Wash Embayment, Lincolnshire. It took less than three years for the most of area to be colonised by saltmarsh vegetation, and after that time it exhibited the same diversity as pre-existing areas of adjacent saltmarsh, providing excellent roosting habitat for migratory shorebirds (Badley and Allcorn 2006; Friess *et al*. 2008).

Creation of shorebird habitat was also achieved successfully at Orplands and Tollesbury in Essex in the United Kingdom, where mudflats and pioneer saltmarsh developed after coastal realignment, and these new habitats were quickly colonised by a diverse range of shorebirds. Within five years, the invertebrate and shorebird communities of the habitats resembled those of 'natural' mudflats, though even after many years, these communities differed from those of surrounding areas (Atkinson *et al*. 2004). However, at two other sites in the United Kingdom, similar coastal management at estuarine environments at the Deben in Suffolk and the Duddon in Cumbria saw the densities of shorebirds decline under similar strategies

Nottage, A. and Robertson, P. (2005) The Saltmarsh Creation Handbook: A Project Manager's Guide to the Creation of Saltmarsh and Intertidal Habitat, RSPB, Sandy.
Provides further examples of how managed realignment has benifited shorebird habitat throughout the United Kingdom.

(Austin and Rehfisch 2003). Clearly there is much variation, and there is no particular one-size-fits-all strategy that will be applicable to all sites and situations. At sites where coastal land has been the subject of urban or industrial development, there are reduced opportunities for managed coastal realignment to be undertaken (Austin and Rehfisch 2003).

Although the alternative of constructing extensive flood-defence barriers such as sea walls to protect existing dryland infrastructure may be preferred by people with more insular, local interests, it will simply exacerbate habitat loss from 'coastal-squeeze' and increased erosion, and many areas of important habitat will be lost as they are trapped between rising seas and hard defences — and along with the loss of the habitat will be the loss of the species associated with it (Galbraith *et al*. 2002; Atkinson *et al*. 2003; Crooks 2004; Hughes 2004; Mitchell *et al*. 2007).

Although there is much local variation in the effects of a rise in sea level on wintering populations of migratory shorebirds, scientists predict that there will be an overall reduction in available habitat, both for foraging and roosting (Titus and Strange 2008). Under this scenario, it is incumbent on responsible land managers to formulate effective plans and put them into action to ensure that there is sufficient suitable habitat for the survival of wildlife — including migratory and resident shorebirds — which relies on coastal habitats that are highly likely to be threatened by rising sea levels and other associated effects of global climate change.

Implications of sea-level rise for shorebird habitat in Gulf St Vincent.

Area	Shorebird habitat use	Implications of sea level rise
Samphire Coast and Port Wakefield Proof Range and Experimental Establishment	Intertidal mudflats, creeks, samphire and claypans (feeding and roosting)	Inland migration of mudflats and low saltmarsh. Hard infrastructure at coastal towns will impose a coastal squeeze and significant areas of habitat such as the Thompsons Beach intertidal mudflats will be lost. The tidal creeks and low lying claypans they feed may become permanently inundated creating coastal lagoons, reducing feeding and roosting area.
	Supratidal claypans (feeding and roosting)	The vast areas of low lying supratidal claypans will play a crucial role in habitat retreat as they are subjected to increased tidal action. Importantly the retreat of these habitats is not restricted by barriers or valuable land and is only bound on the landward side by poor quality agricultural land and mining lease. Dunes, chenier ridges and artificially raised areas such as levees and tracks which border low-lying areas will provide roosting sites.
Dry Creek Saltfields	Intertidal saltmarsh and creeks (feeding and roosting)	Tidal areas are likely to be lost permanently to inundation or incursion by mangroves .
	Supratidal salinas and tracks (feeding, roosting and breeding)	If levees are secured against breaches, these areas will remain critical feeding and roosting habitats for a significant proportion of the shorebird population that inhabits Gulf St Vincent.
Mangrove-lined creeks and ports	Intertidal mudflats (feeding and roosting areas)	The accumulative effects of the “Coastal squeeze” caused by hard infrastructure and mangrove retreat will result in the loss of habitat at St Kilda, Port Gawler seafront and Middle Beach.
Artificial and managed wetlands	Intertidal mudflats at Barker Inlet (feeding and roosting)	If levees are secured, appropriate management of inundation through the northern weirs could conserve habitat quality, providing critical refuge areas.
	Supratidal wetlands (feeding, roosting and breeding)	Unlikely to be affected thus providing crucial refuge habitat.
Sand spits	Intertidal (feeding and roosting)	Smaller spits and edges of Section Banks will be among the first habitat to be lost.

CONCLUSIONS

This project is raising the community's awareness of shorebirds. At the same time, it is actively engaging them through participation in gathering the information needed to conserve the birds.

The monitoring of shorebird populations in Gulf St Vincent provides the crucial data that demonstrates the importance of tidal ecosystems and strengthens the case for vital mitigating the destruction of these important habitats. It has also raised awareness of the increased importance supratidal habitats like saltfields and stormwater treatment wetlands will play in the conservation of shorebirds in the region. Further, monitoring shorebirds in Gulf St Vincent has the potential to provide crucial information about the efficacy of adaptive management to ensure shorebirds are conserved in Gulf St Vincent. The identification and description of important shorebird habitat in the Gulf have provided a greater understanding of its importance, and comprise a first critical step towards the long-term conservation of these habitats.

Researchers at the Shorebirds 2020 project believe that we can help secure a bright future for these birds by: (1) educating and engaging stakeholders; (2) building good science that informs on how and why shorebird populations are changing; and (3) working to increase the number of people in the community who care about shorebirds.

The greatest threats to shorebirds in Gulf St Vincent can all be mitigated through the actions of local planners and managers, and we have outlined some of the issues that must be considered, and have further recommended some ways to move forward. It is clear that without the decisive and informed actions of planners and managers in the region in the past, the threats to migratory shorebirds would be far greater, and shorebird populations could have been further reduced in the region. For example, the District Council of Mallala, the Mallala Council Environmental Management Advisory Committee (EMAC) and associated networks are all committed to the protection and environmental integrity of the Samphire Coast, and the Samphire Coast Conservation Strategy recognises the significance of this habitat for the conservation of shorebirds in Gulf St Vincent (Jensen 2004). The strategy outlines provisions which must be undertaken to sustain coastal environments and establish an interconnected system of proposed protected areas, including land- and marine-based parks and Ramsar listing within 5 years. The recent development of the Samphire Coast Icon Project is a prime example of the cross-jurisdictional planning needed to ensure the future of for shorebirds in the region. The initiative will see State Government and local councils working in conjunction with coast care groups and local residents to raise awareness of shorebird conservation and to encourage local stewardship. The project will also be critical in implementing key habitat restoration and threat mitigation works.

The creation and maintenance of wetlands near the Dry Creek Saltfields by the City of Port Adelaide Enfield is a good example of councils reclaiming land for conservation and educational purposes. These wetlands comprise the Barker Inlet wetlands (about 50 hectares), which always contain brackish and salt water, and the Greenfields Wetlands, which consist of 114 hectares of fresh water at fluctuating levels. Situated within 20 minutes' drive of Adelaide's Central Business District, this project spreads awareness of shorebird conservation.

To maximise the conservation of shorebirds in Gulf St Vincent, it is vital that all planners and land managers in the region are aware of the important shorebird areas, and are able to assign a high priority to the importance of the habitats that occur in the Gulf. Incorporating the spatial shorebird GIS layers into existing environmental overlays would be invaluable in informing decision makers in the region of which areas are most important for shorebirds. Further, by making the information about shorebirds readily available, the chance of planning and management activities adversely impacting shorebirds should be reduced. Finally, steps must be taken to ensure that sufficient buffers to disturbance of critical shorebird habitats are created, and that management sufficient to retain shorebird populations continues regardless of any changes in salt production.

RECOMMENDATIONS

- Develop strategies that facilitate cooperative cross-jurisdictional planning which is required to limit the likely cumulative impacts of increasing urban growth in the region.
- Work to ensure the protection of the habitats that support shorebirds in Gulf St Vincent, including the protection of habitats along the Samphire Coast as pristine, undisturbed places.
- Achieve complete coverage of all shorebird sites in 3 annual population monitoring surveys.
- Work in close consultation with Cheetham Salt and the Department for Manufacturing Innovation, Trade, Resouces and Energy Mineral (DMITRE) throughout the development of a Program for Environmental Protection and Rehabilitation (PEPR) for the Dry Creek Saltfields to ensure best-practice shorebird management is incorporated.
- Constantly evaluate the impacts on shorebird habitats by proposed developments and changes to infrastructure. This is especially relevant for the Dry Creek Saltfields and the Greenfield and Globe Derby wetland system.
- Set initial buffer distances around identified habitats at 250 metres to limit the impacts of disturbance, and use active monitoring to explore how to adjust those buffers with the understanding that buffers less than 250 metres may be sufficient in some areas, or for some forms of potential disturbance.
- Push for South Australian legislation banning the use of off-road vehicles in coastal wetlands and on beaches.
- Encourage dog walkers to keep their dogs leashed when in shorebird areas.
- Work to ensure sympathetic shorebird management of the Dry Creek Saltfields continues, regardless of any change to salt production.
- Protect existing samphire retreat zones using planning or other measures and provide additional, adequate, area for samphire retreat (Coleman & Cook 2009: Action 2.5, 2.7).
- Where development is approved in near coastal areas and allowance for floodwater escape to the sea is required, allow additional width for the flood escape routes, over that required to handle the 1:100 year ARI flood event, to provide area for shorebird habitat and a path for landward migration of saltmarshes (Coleman & Cook 2009: Action 2.7).
- Work with councils and planners to ensure stormwater wetlands are managed in a manner sympathetic to shorebirds needs, taking into account the necessity for open unvegatated areas for feeding and roosting and a dynamic regime of inundation.
- Steps must be taken to reduce the volume of wastewater, storm-water and industrial input into Gulf St Vincent, with a particular emphasis on re-establishing seagrass beds near the Bolivar Waste Water Treatment Plant Outlet. Recommendations on rehabilitation of seagrass meadows are included in the Adelaide Coastal Waters Study (Fox et al. 2007).

- Educate the public (through signs, brochures, meetings and the like) about the impacts of visiting important shorebird areas on resident and migratory shorebirds.
- Work to quantify the frequency of disturbance, the site-specific distances at which birds respond to disturbance, the time taken to resume feeding, and the distance shorebirds must fly to find an undisturbed feeding or roosting habitat.
- Continue conducting twice-yearly shorebird workshops to increase awareness of shorebird conservation and to expand the pool of experienced volunteer surveyors.
- Contact counters directly to provide feedback in order to retain their participation from year to year.
- Develop an understanding of how well monitoring informs adaptive management, and optimise monitoring to inform on threats as our understanding of the severity and the distribution of threats increases.
- Conduct field trips and counts with experienced mentors to foster appropriate count methods and familiarise new counters with shorebird identification and shorebird count areas. Scope opportunities for local stakeholders and operational staff to conduct surveys.
- Use the abundance, diversity and species composition (i.e. vulnerable species) to prioritise conservation efforts, focusing on those areas under greatest threat.
- Surveys of breeding shorebirds should be encouraged to identify and protect easily impacted breeding areas. BirdLife Australia's 'Beach-nesting Birds' project will work closely with DENR's Samphire Coast Icon Project to improve our knowledge of these populations and engage local communities.
- Investigate management of Grey Mangrove populations to minimise encroachment onto significant shorebird habitat.
- Continue to control and remove the invasive Sea Spurge from affected areas, and search for and eradicate any Sea Spurge, Tree Mallow, Marram Grass or African Boxthorn that appears in new areas. These invasive species spread rapidly and can be difficult to control once established.
- Incorporate shorebird-area spatial layers and attributes into existing spatial-planning layers, such as the environmental significance overlays, so that shorebirds can easily be incorporated into the planning process.
- Ensure that rigorous assessments of impacts to shorebirds are conducted for any planned activity or development that are likely to impact within 200 metres of these important shorebird areas, or any area of tidal flats.
- Continue to increase our understanding of both shorebird feeding habitat and the abundance and diversity of shorebirds using poorly understood habitats in the region.
- Work in cooperation with the Australian Defence Force to organise comprehensive, regular, summer and winter shorebird counts of the Port Wakefield Proof Range and Experimental Establishment.
- Re-assess the threats by computing threat scores regularly to determine whether shorebird numbers are changing in response to changes in threat levels.

APPENDIX A: Shorebird count forms

SHOREBIRD COUNT FORM

OFFICE USE
VISIT ID:

OBSERVER DETAILS *For detailed instructions on how to fill out this form refer to "Count Form Instructions"*

FULL NAME: ______ PHONE NUMBER: ______

If more than one observer, only name the count leader or main contact

EMAIL: ______ TOTAL NO. OBSERVERS: ______ YEARS OF COUNTING EXPERIENCE OF MOST EXP. COUNTER: ______

TIME & DATE

SURVEY DATE: DAY / MONTH / YEAR

TIME STARTED: *(24 hour clock)* HOUR / MINS

TIME FINISHED: *(24 hour clock)* HOUR / MINS

SURVEY DETAILS

IF COUNT *WAS* CONDUCTED IN A SHOREBIRDS 2020 COUNT AREA
(count area names and maps available at www.shorebirds.org.au)

SHOREBIRD AREA: ______ COUNT AREA: ______ COMPLETE COVERAGE OF MAPPED COUNT AREA? (YES or NO)

OR

IF COUNT WAS *NOT* CONDUCTED IN A SHOREBIRDS 2020 COUNT AREA:

SITE NAME: ______ LAT/LONG: ______

STATE: ______ SURVEY TYPE *(land, boat, air)*: L.B.A. TIDE HEIGHT *(Height in metres or rising, high, falling or low)*: ______ AREA UNDER WATER *(wetlands only)*: % WIND DIRECTION *(E.g. N, NE, NNE)*: ______

WIND SPEED:
- ◯ 0 - 5 kph *(flat to ripples / wind not felt on face)*
- ◯ 6 - 11 kph *(small wavelets, crests not breaking / wind felt on face)*
- ◯ 12 - 19 kph *(large wavelets, crests begin to break / leaves in motion)*
- ◯ 20 - 28 kph *(small waves / dust, small*
- ◯ 29 - 38 kph *(moderate waves, some foam & spray / small trees sway)*
- ◯ 39 - 49 kph *(large waves with foam crests and spray / large branches in motion)*
- ◯ >50 kph *(sea heaps up, foam beings to streak / strong resistance while walking)*

HUMAN ACTIVITY *Write down the number of times the following were observed during the count within the count area:*

PEOPLE MOVING		BOATS - AT ANCHOR		JET SKI	
PEOPLE FISHING		BOATS - MOVING		ATV/MOTORCYCLE	
DOGS - OFF LEAD		BOATS - WATERSKIING		CARS/TRUCKS	
DOGS - ON LEAD		BOATS - VERY LOUD/FAST		OTHER *(specify)*	

NUMBER OF FLIGHTS CAUSED BY DISTURBANCE: ______

THREATS *Add timing, scale and severity scores to obtain a total threat score for each threat type*

	TIMING		SEVERITY		SCALE		TOTAL THREAT SCORES
	3 = Occurring now 2 = Likely to occur within 1-3 years 1 = Likely to occur in >3 years 0 = Not occuring, not likely to in future		3 = Will persist for >10 years 2 = Will persist for 3-10 years 1 = Will persist for 0-3 years 0 = Will not persist		3 = >90% population decline 2 = 50-90% population decline 1 = 10-49% population decline 0 = 0-9 % population decline		0-5 = Low threat 6-7 = Medium threat 8-9 = High threat
HABITAT LOSS		+		+		=	
HUMAN DISTURBANCE		+		+		=	
INVASIVE SPECIES		+		+		=	
POLLUTION		+		+		=	
WATER LEVEL		+		+		=	

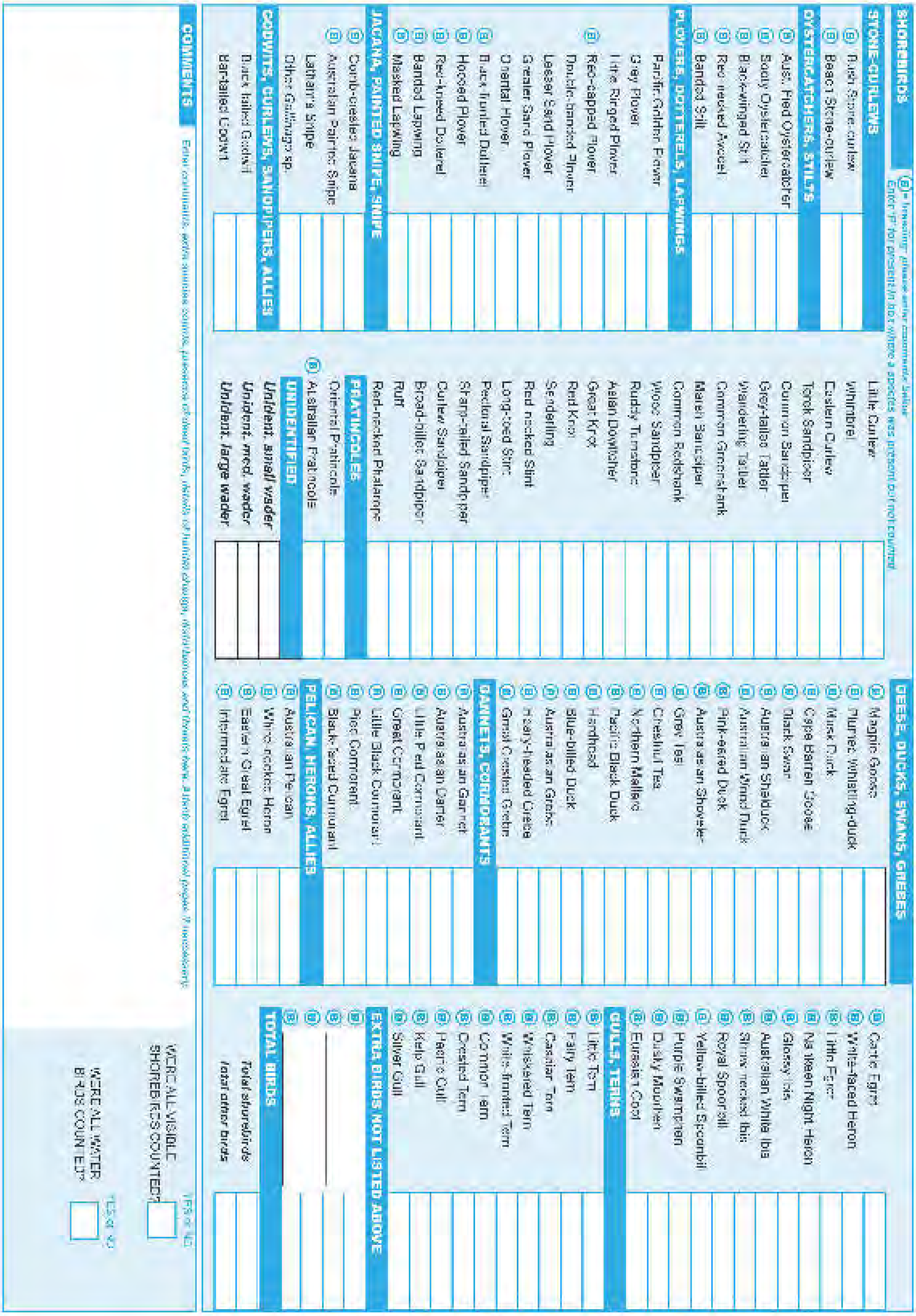
HABITAT CHANGE

HAS HABITAT CHANGED SINCE LAST COUNT?: (YES or NO) ______ AREA AFFECTED BY HABITAT CHANGE: *(area used by shorebirds only)* %

TYPE OF HABITAT CHANGE: *(mark all that apply)*
URBAN DEVELOPMENT (within 200m) ◯ RECLAMATION ◯ HARVESTING/FISHING ◯
FISH FARMING/AQUACULTURE ◯ CHANGE IN WATER LEVELS ◯ EROSION ◯ POLLUTION ◯
ENCROACHMENT FROM NATIVE VEGETATION ◯ INVASIVE SPECIES/INTRODUCED PESTS ◯ ALGAL BLOOMS ◯

Count forms, count area maps, instructions at www.shorebirds.org.au. Return form to Shorebirds 2020, Birds Australia, 60 Leicester Street, Carlton, Victoria, 3053. Ph (03) 9347 0757. Email: shorebirds@birdsaustralia.com.au.
Online data entry form at http://data.shorebirds.org.au/

Figure 30. Shorebirds 2020 counts form, observer and survey details.



SHOREBIRDS
(B) = breeding: please enter comments below. Enter 'P' for present in box where a species was present but not counted

STONE-CURLEWS
Bush Stone-curlew
Beach Stone-curlew

OYSTERCATCHERS, STILTS
Aust. Pied Oystercatcher
Sooty Oystercatcher
Black-winged Stilt
Red-necked Avocet
Banded Stilt

PLOVERS, DOTTERELS, LAPWINGS
Pacific Golden Plover
Grey Plover
Little Ringed Plover
Red-capped Plover
Double-banded Plover
Lesser Sand Plover
Greater Sand Plover
Oriental Plover
Black-fronted Dotterel
Hooded Plover
Red-kneed Dotterel
Banded Lapwing
Masked Lapwing

JACANA, PAINTED SNIPE, SNIPE
Comb-crested Jacana
Australian Painted Snipe
Latham's Snipe
Other Gallinago sp.

GODWITS, CURLEWS, SANDPIPERS, ALLIES
Black-tailed Godwit
Bar-tailed Godwit
Little Curlew
Whimbrel
Eastern Curlew
Terek Sandpiper
Common Sandpiper
Grey-tailed Tattler
Wandering Tattler
Common Greenshank
Marsh Sandpiper
Common Redshank
Wood Sandpiper
Ruddy Turnstone
Asian Dowitcher
Great Knot
Red Knot
Sanderling
Red-necked Stint
Long-toed Stint
Pectoral Sandpiper
Sharp-tailed Sandpiper
Curlew Sandpiper
Broad-billed Sandpiper
Ruff
Red-necked Phalarope

PRATINCOLES
Oriental Pratincole
Australian Pratincole

UNIDENTIFIED
Unident. small wader
Unident. med. wader
Unident. large wader

GEESE, DUCKS, SWANS, GREBES
Magpie Goose
Plumed Whistling-duck
Musk Duck
Cape Barren Goose
Black Swan
Australian Shelduck
Australian Wood Duck
Pink-eared Duck
Australasian Shoveler
Grey Teal
Chestnut Teal
Northern Mallard
Pacific Black Duck
Hardhead
Blue-billed Duck
Australasian Grebe
Hoary-headed Grebe
Great Crested Grebe

GANNETS, CORMORANTS
Australasian Gannet
Australasian Darter
Little Pied Cormorant
Great Cormorant
Little Black Cormorant
Pied Cormorant
Black-faced Cormorant

PELICAN, HERONS, ALLIES
Australian Pelican
White-necked Heron
Eastern Great Egret
Intermediate Egret
Cattle Egret
White-faced Heron
Little Egret
Nankeen Night Heron
Glossy Ibis
Australian White Ibis
Straw-necked Ibis
Royal Spoonbill
Yellow-billed Spoonbill
Purple Swamphen
Dusky Moorhen
Eurasian Coot

GULLS, TERNS
Little Tern
Fairy Tern
Caspian Tern
Whiskered Tern
White-fronted Tern
Common Tern
Crested Tern
Pacific Gull
Kelp Gull
Silver Gull

EXTRA BIRDS NOT LISTED ABOVE

TOTAL BIRDS
Total shorebirds
Total other birds

WERE ALL VISIBLE SHOREBIRDS COUNTED? YES or NO
WERE ALL WATER BIRDS COUNTED? YES or NO

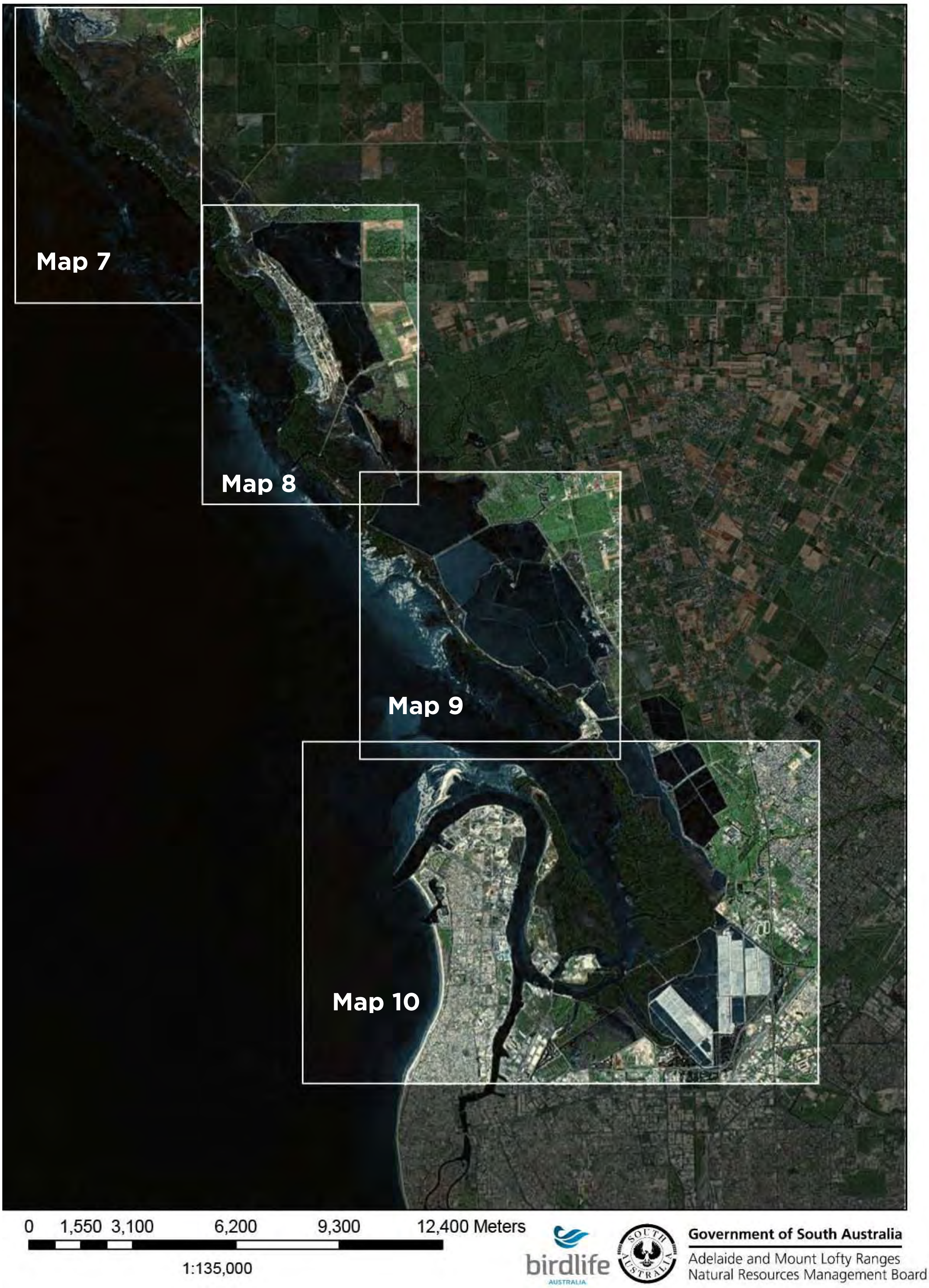
COMMENTS Enter comments, extra species counts, presence of chicks/young, details of habitat change, disturbances and threats here. Attach additional pages if necessary.

Figure 31. Shorebirds 2020 species count.

APPENDIX B: *Shorebird habitat use maps.*

Map 1. Index to the shorbird habits from Bald Hill to Light Beach.

Shorebird habitat in Gulf St Vincent



Map 2. Index of shorebird habitat between Light Beach and Barker Inlet Wetlands.

Map 3. Bald Hill and the northern intertidal areas of the Port Wakefield Proof and Experimental Establishment.

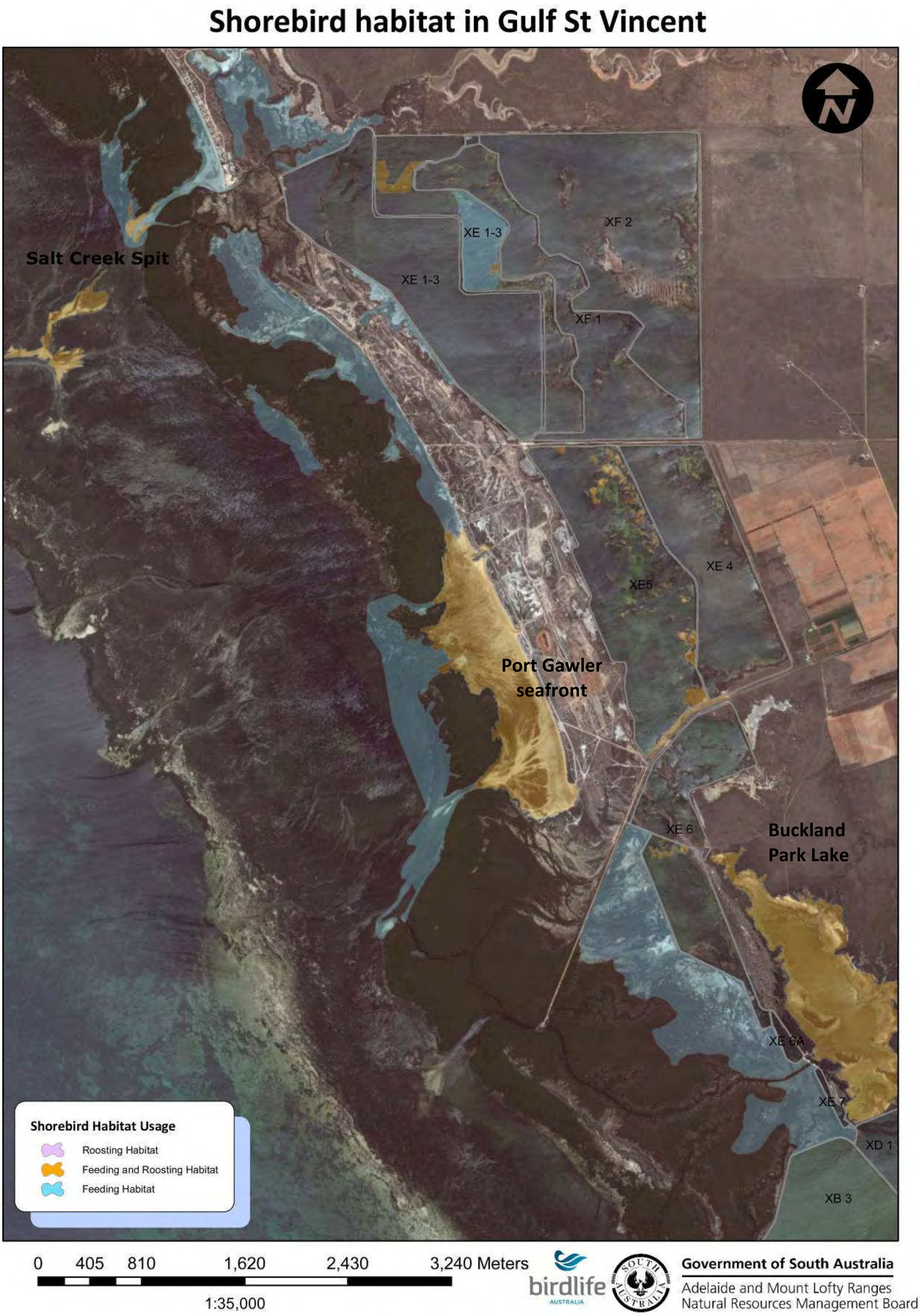
Map 4. The southern PWPEE intertidal zone to Pt Parham

Map 5. Webb Beach and Thompsons Beach.

Map 6. Third Creek , Pt Prime and Light Beach.

Shorebird habitat in Gulf St Vincent

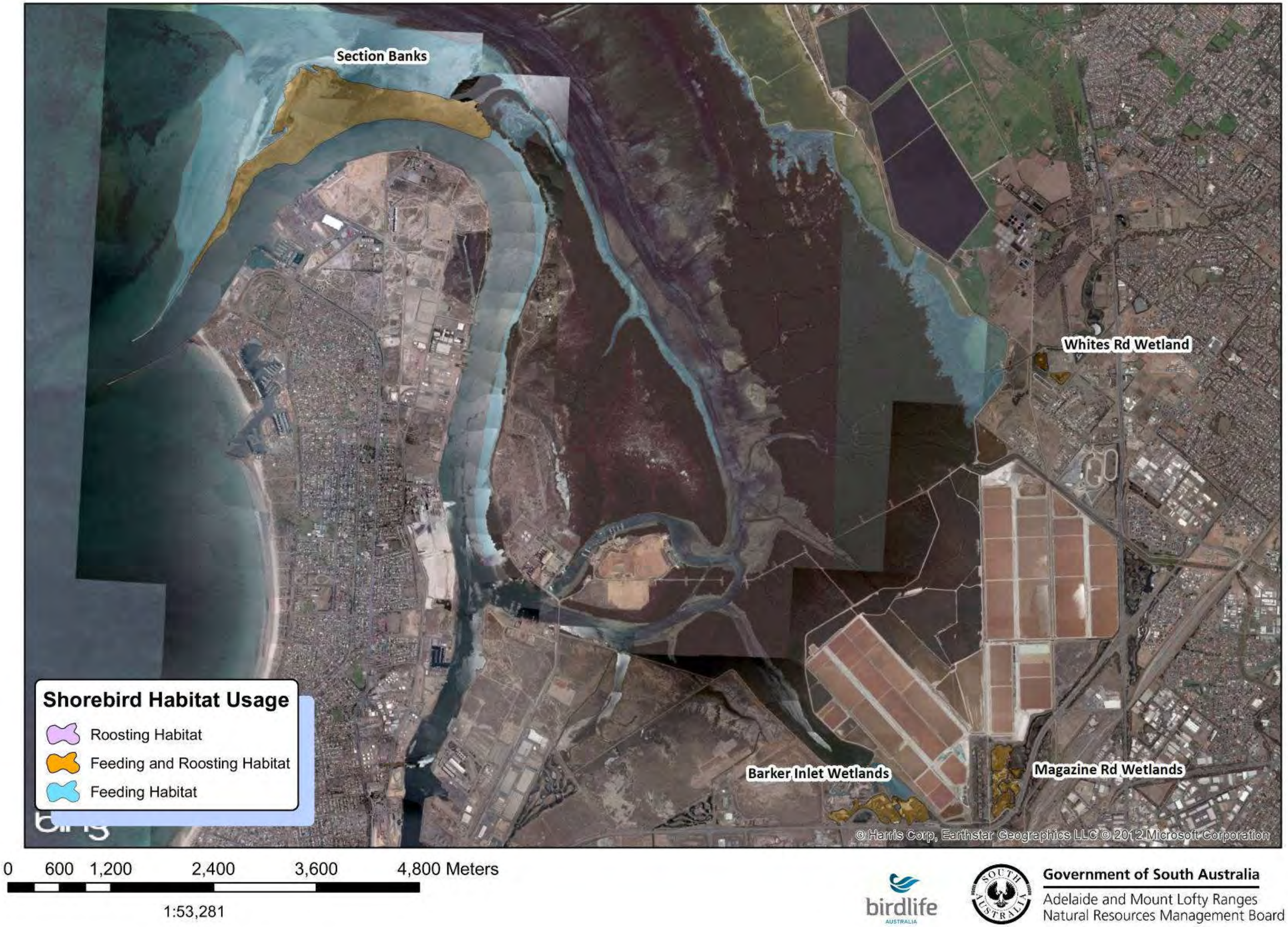
Map 7. Intertidal zone between Light Beach and Middle Beach.



Map 8. Middle Beach, Salt Creek Spit, Pt Gawler Intertidal zone, Buckland Park Lake and Dry Creek saltfields.

Shorebird habitat in Gulf St Vincent

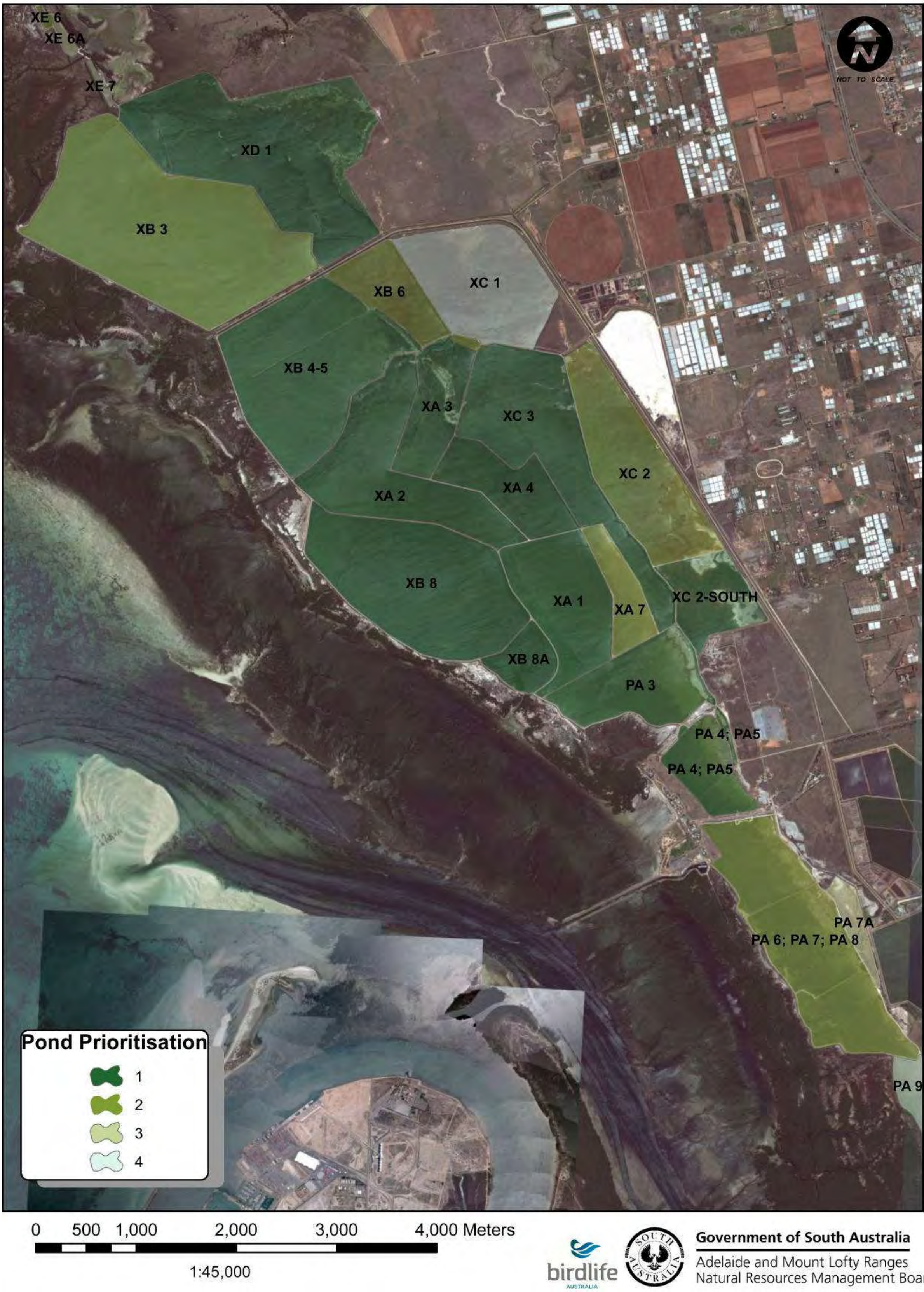
Map 9. Bolivar Waste Water Treatment outlet, Dry Creek saltfields and XB 8 sand spit.



Map 10. Dry Creek saltfields, Section Banks, Barker Inlet Wetlands Magazine Rd Wetlands and Whites Rd Wetlands

APPENDIX C: *Priority shorebird habitats within the Dry Creek* Saltfields

Shorebird Habitat in Gulf St Vincent



Government of South Australia
Adelaide and Mount Lofty Ranges Natural Resources Management Board

Shorebird Habitat in Gulf St Vincent

0 405 810 1,620 2,430 3,240 Meters

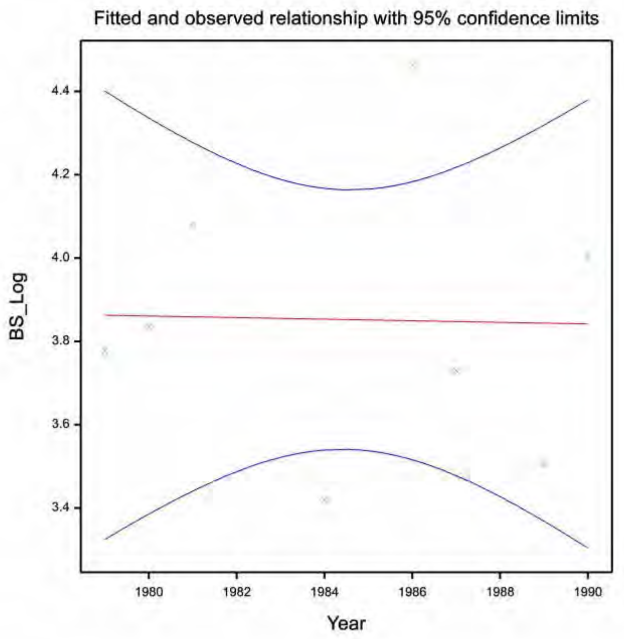
1:35,000

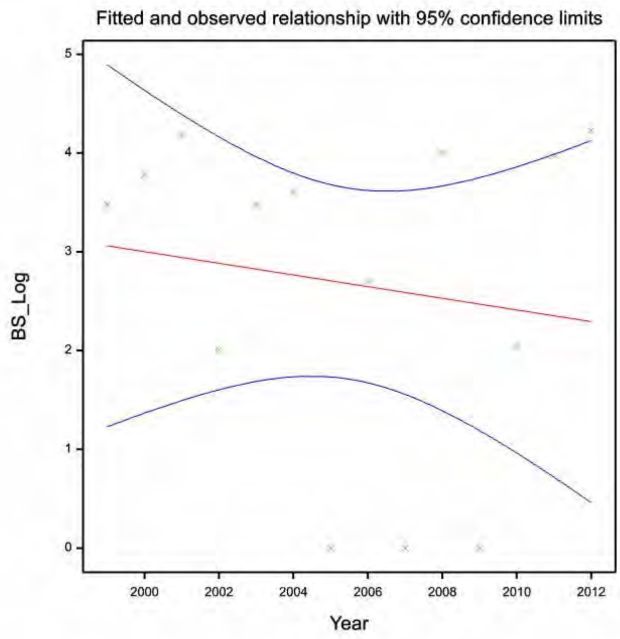
birdlife AUSTRALIA

Government of South Australia
Adelaide and Mount Lofty Ranges Natural Resources Management Board

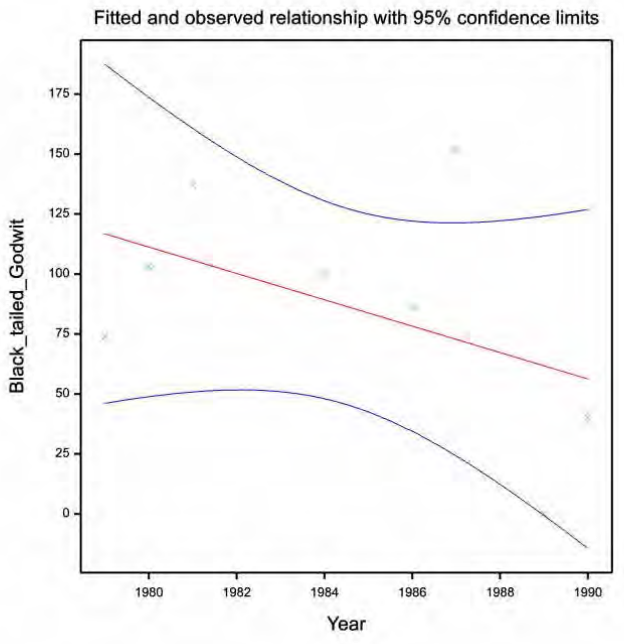
Appendix D: Trend analysis

Banded Stilt





Black-tailed Godwit



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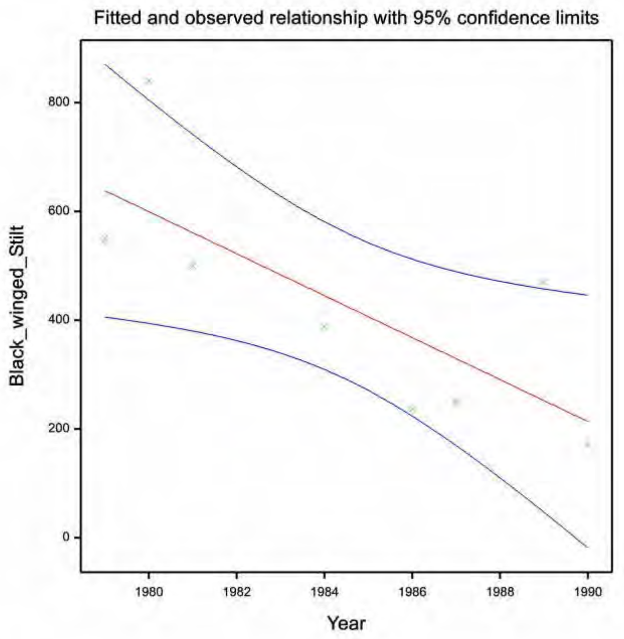

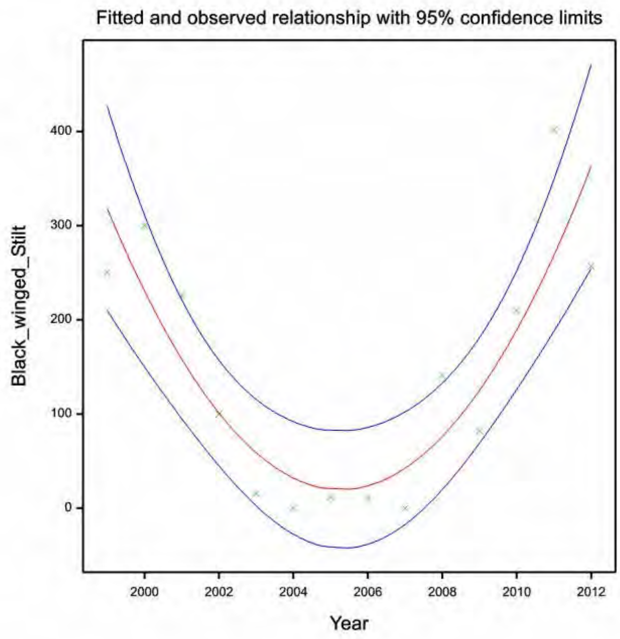

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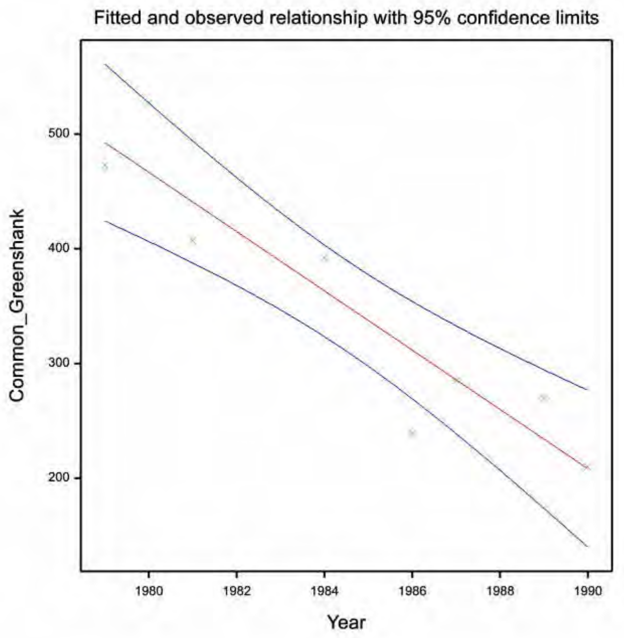
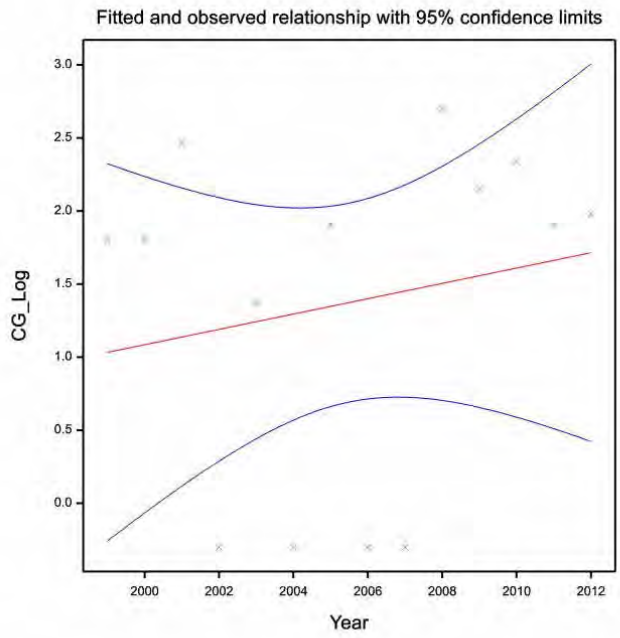
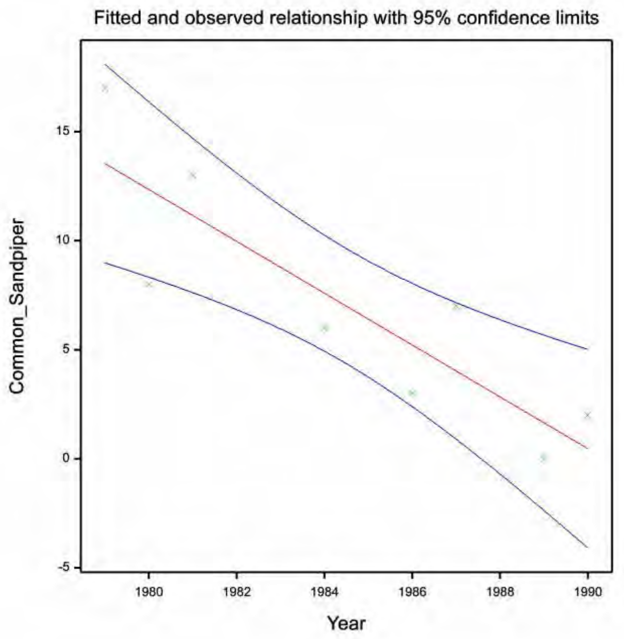
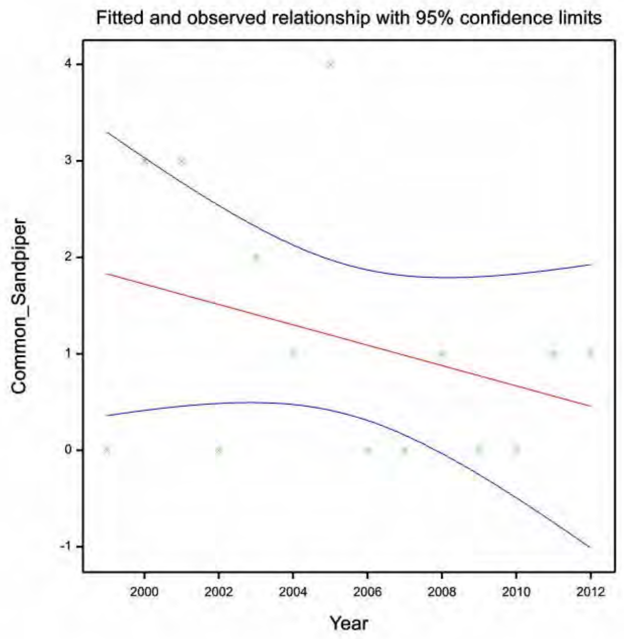


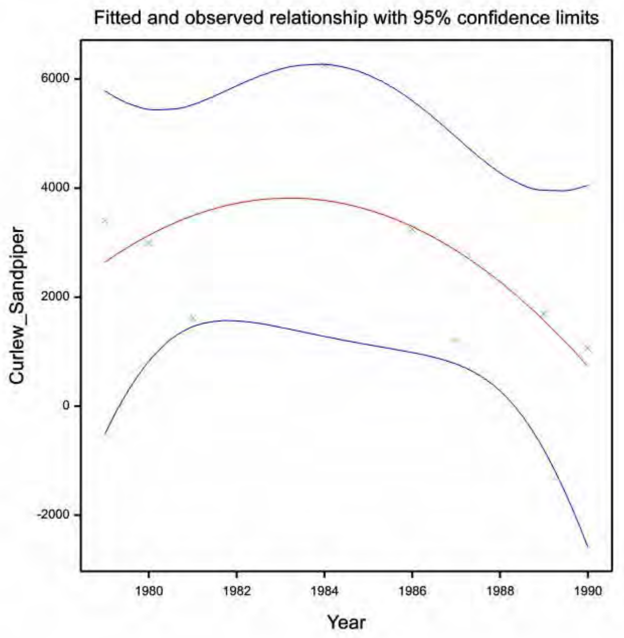


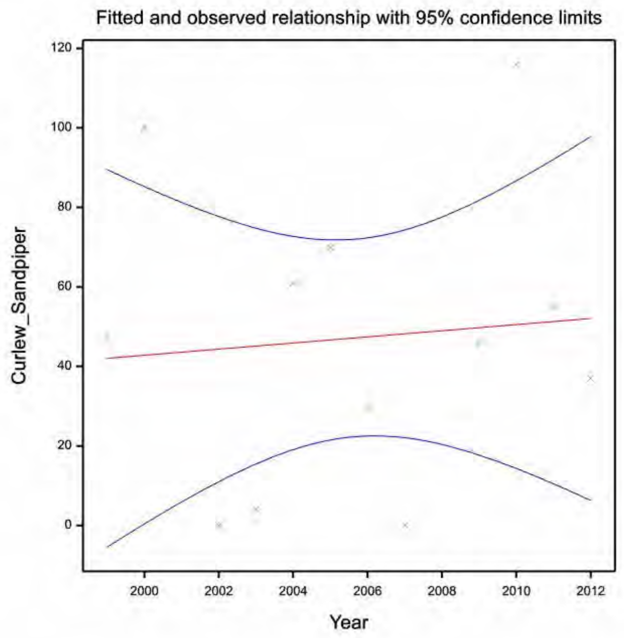
Common Sandpiper



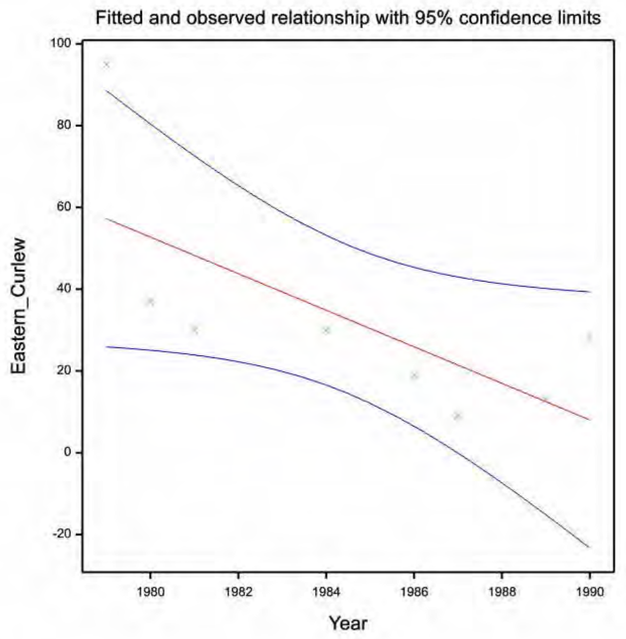


Curlew Sandpiper

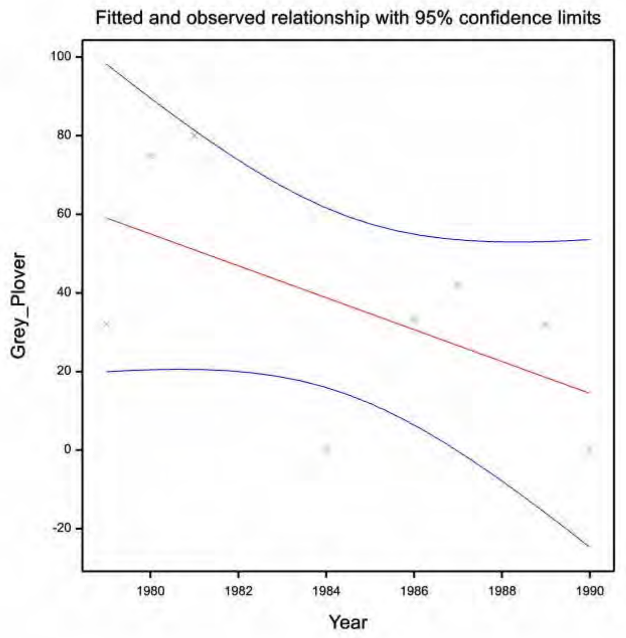


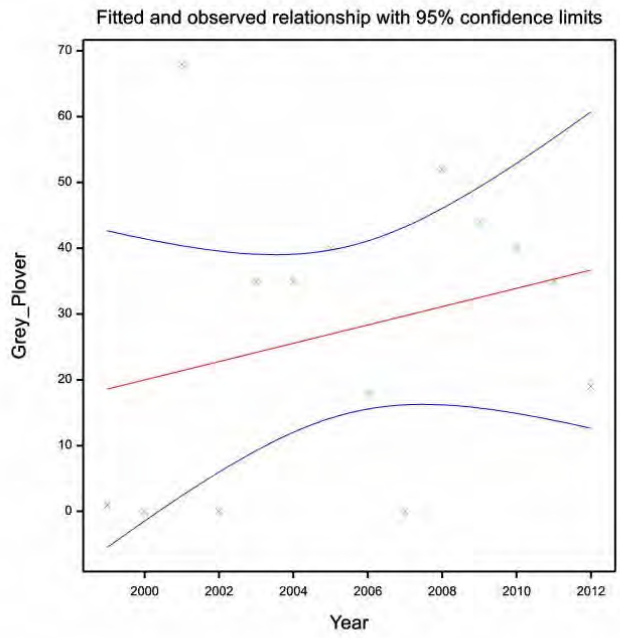


Eastern Curlew

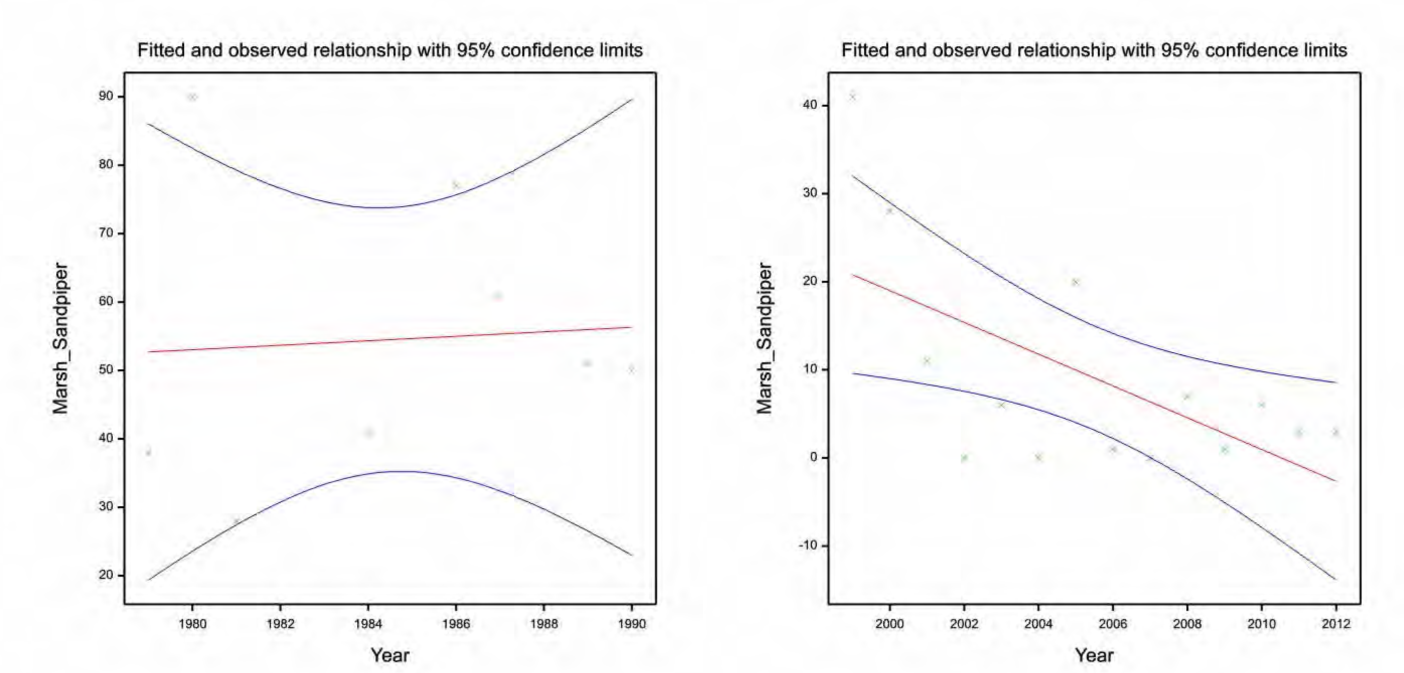


Grey Plover

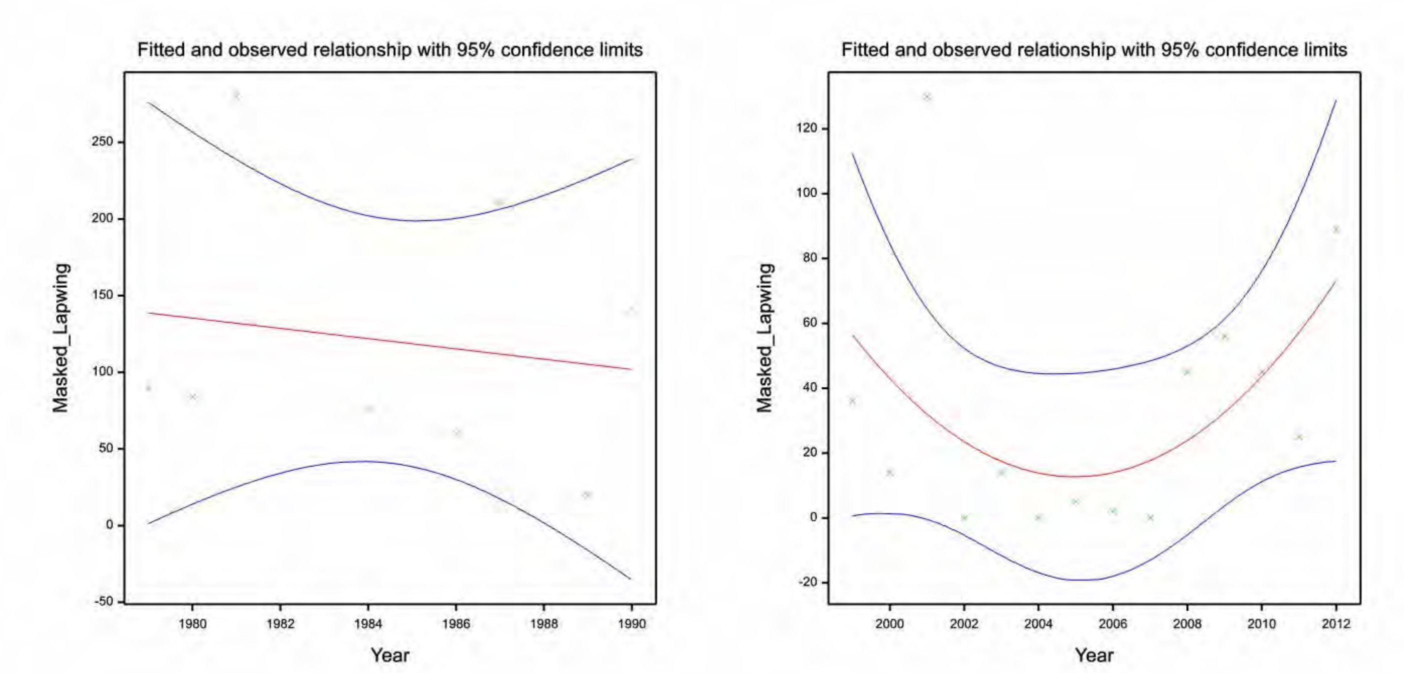




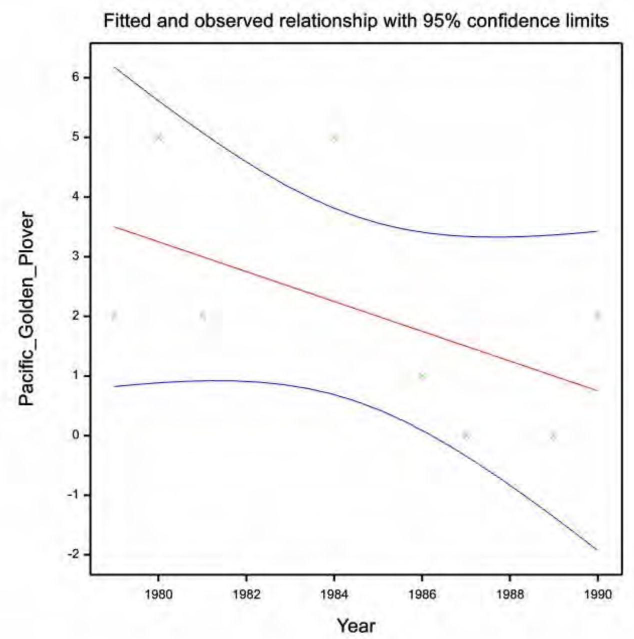
Marsh Sandpiper

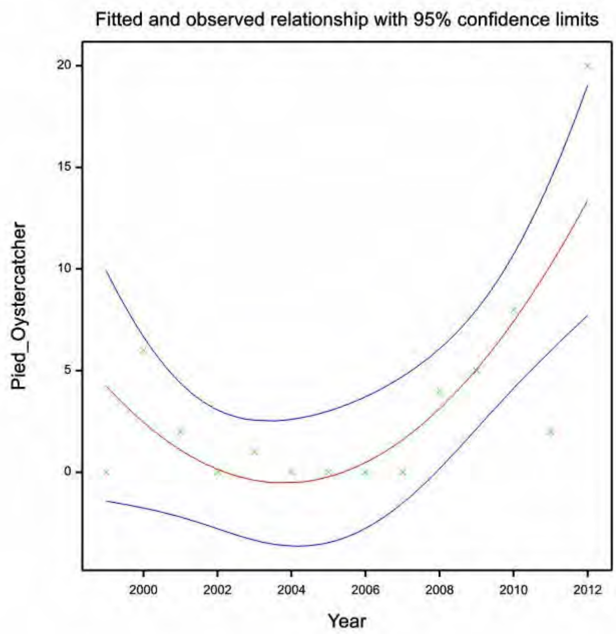


Masked Lapwing

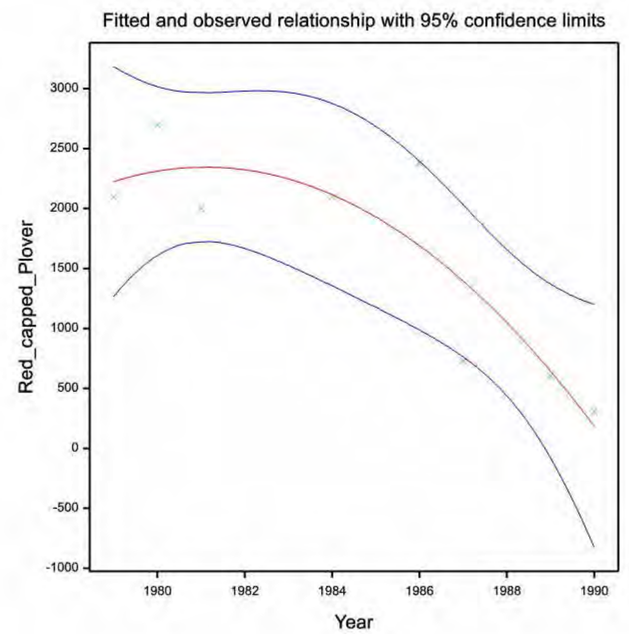


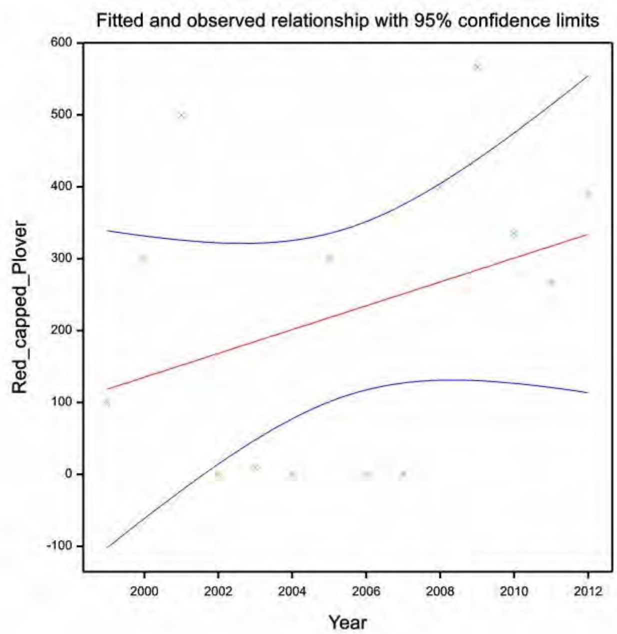
Pacific Golden Plover



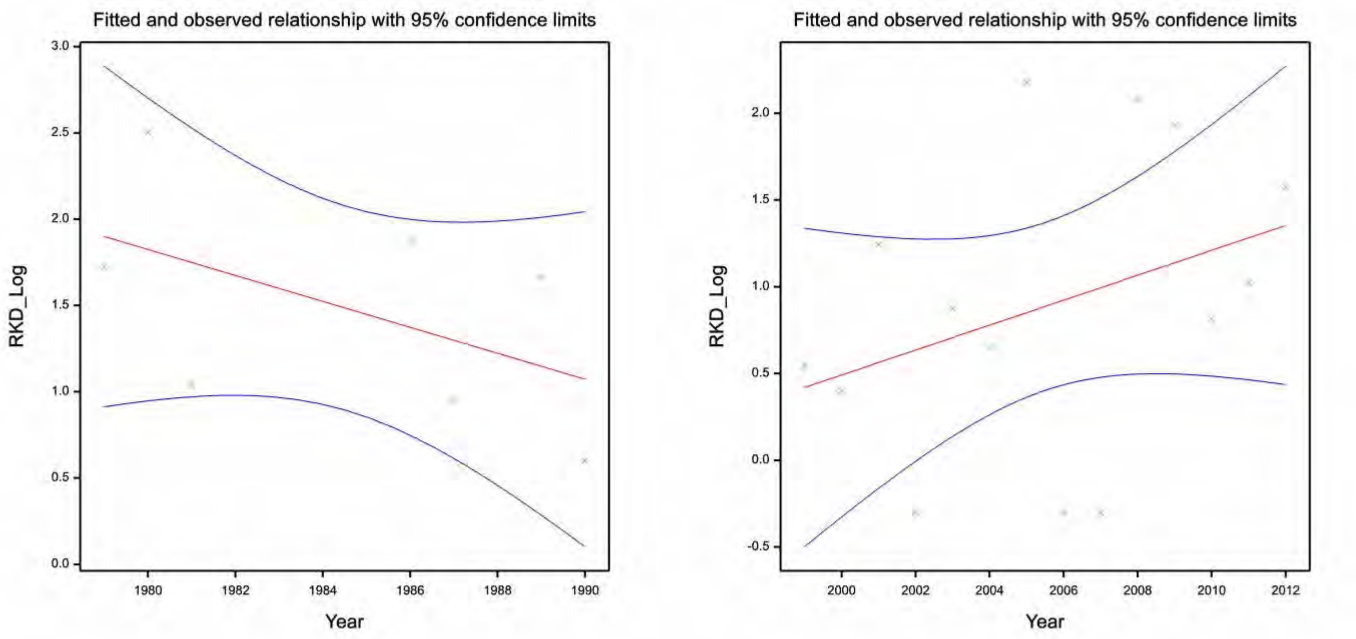


Red-capped Plover

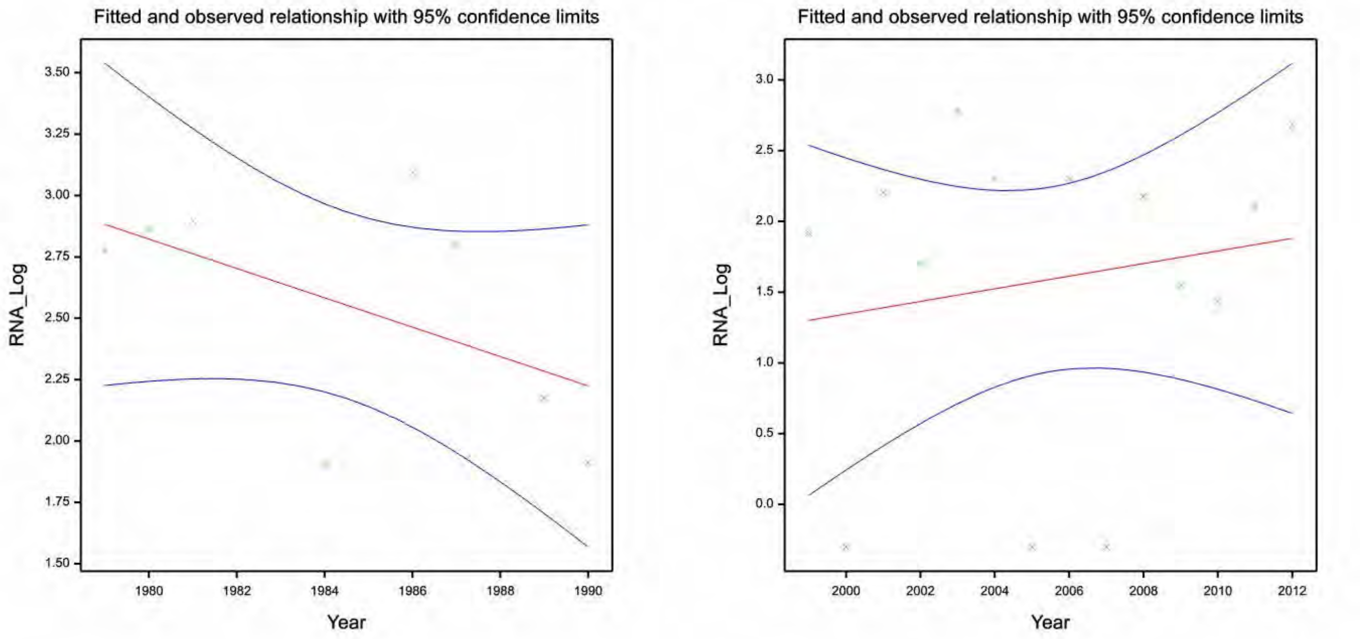




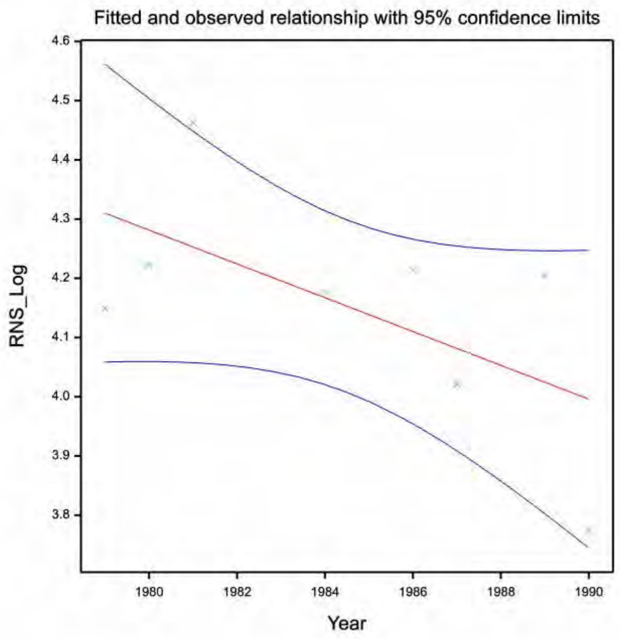
Red-kneed Dotterel

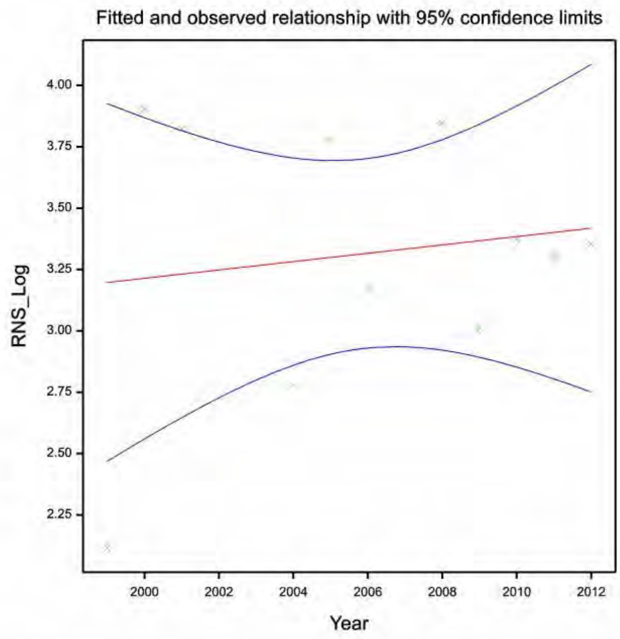


Red-necked Avocet

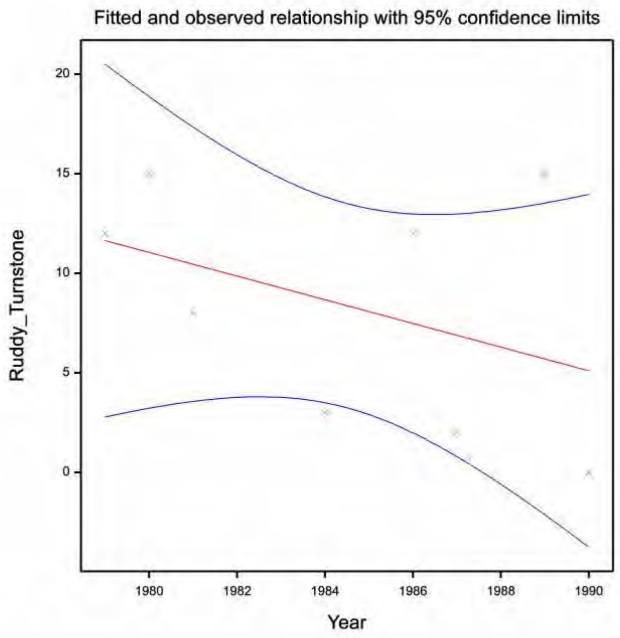


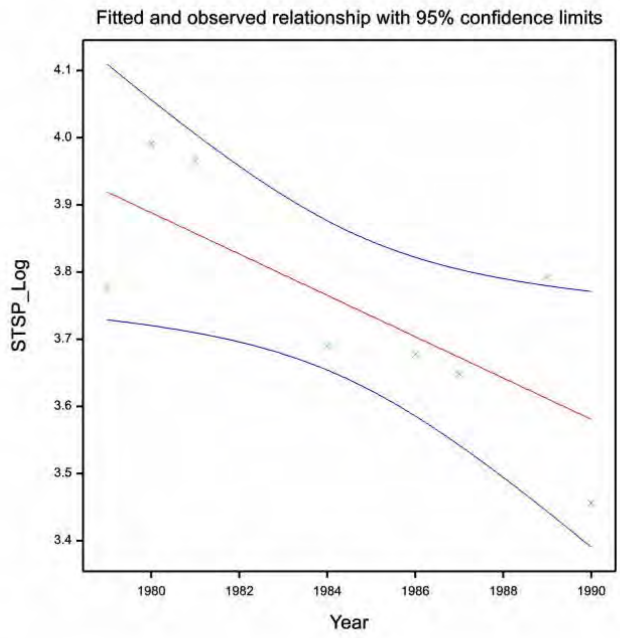
Red-necked Stint



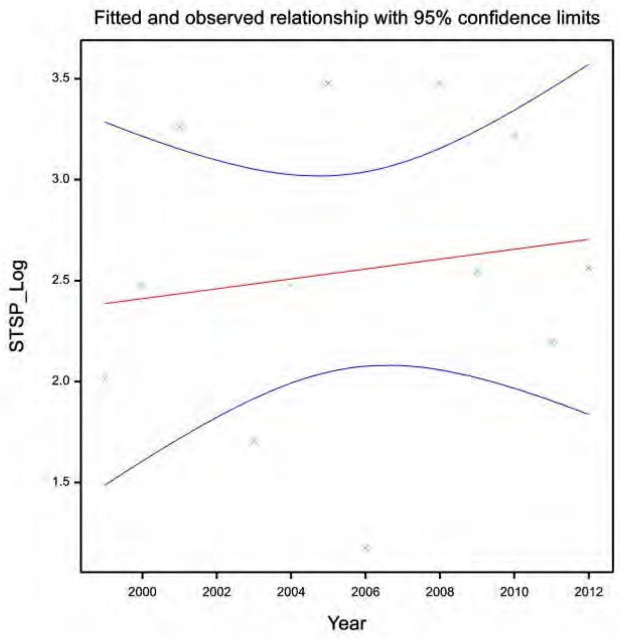


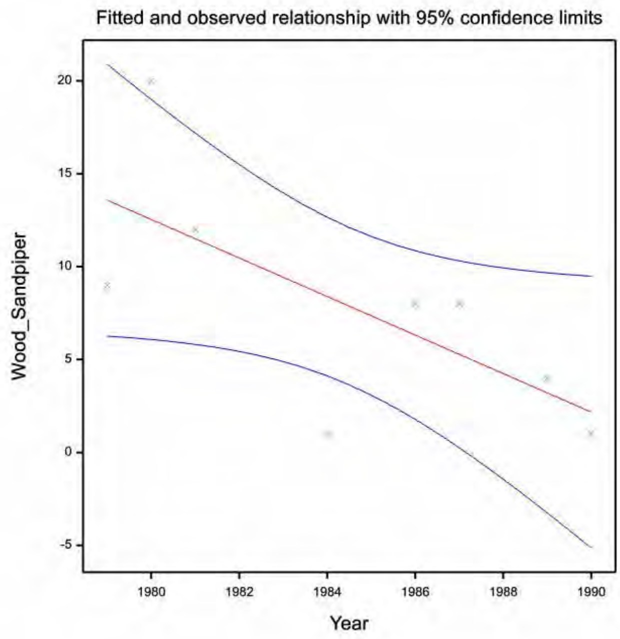
Ruddy Turnstone





Sharptailed Sandpiper





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