The decline in Holarctic shorebirds using Dry Creek Saltfields, South Australia, from 1985-86 to 2015-16

COLIN ROGERS AND JOHN COX

Abstract

Dry Creek Saltfields was one of the primary roost sites for migratory Holarctic shorebirds in Gulf St Vincent, South Australia, until their numbers sharply declined between 1992 and 2000. This decline is linked to an Australia-wide drop in shorebird numbers arriving from Asia but was especially noticeable in south-east coastal areas during the Millennium Drought of 1997-2009 when it is probable many birds avoided the arid interior and became diverted to the south-west. A numerical examination of ten species that had regularly used Dry Creek Saltfields since 1985 revealed all were locally declining, with no indication of a recovery after the drought, and their numbers had collapsed by 2016. This collapse was primarily caused by changes to the saltfields environment which are an additional factor to the general drop in shorebird numbers arriving from Asia. Saltfields production ceased in 2013, after which important roosting areas for shorebirds were allowed to dry out and water regimes changed, causing a loss and degradation of habitat suitable for shorebirds. Adjacent freshwater wetlands, which were important attractions for some shorebirds that usually moved into the saltfields later during the summer, have also become severely degraded through changes in water usage, developments and other disturbances detrimental to shorebirds.

INTRODUCTION

Many shorebirds that breed during the northern summer in Asia and Alaska migrate southwards to spend the southern summer in Australia (Battley and Rogers 2007). They travel down the East-Asian Australasian Flyway (EAAF) and stop at many locations on the way (Conklin *et al.* 2014). After arrival in Australia, most generally follow east or west coastal routes before arriving at destinations in southern Australia, but many also move south across the continent on a broad front making short hops using ephemeral wetlands when conditions are suitable (Lane 1987: 31-32, Figure 2.1).

The most notable species which regularly, but not exclusively, use the trans-continental route are Pacific Golden Plover, *Pluvialis fulva*, Black-tailed Godwit, *Limosa limosa melanuroides*, Sharp-tailed Sandpiper, *Calidris acuminata*, Curlew Sandpiper, *Calidris ferruginea*, Red-necked Stint, *Calidris ruficollis*, Common Greenshank, *Tringa nebularia*, and Marsh Sandpiper, *Tringa stagnatilis* (Badman and May 1983; Lane 1987: 32, Table 4), whereas more maritime feeders such as Grey Plover, *Pluvialis squatarola*, Whimbrel, *Numenius phaeopus*, Eastern Curlew, *Numenius madagascariensis*, Bar-tailed Godwit, *Limosa lapponica baueri*, Ruddy Turnstone, *Arenaria interpres*, Great Knot, *Calidris tenuirostris*, and Red Knot, *Calidris canutus*, generally follow the coastal routes (Lane 1987).

As part of a population monitoring program (PMP), counts of shorebirds were undertaken over the years at many but not all coastal sites in Australia, with some understandable bias towards human population centres (Gosbell and Clemens 2006). In particular, there were no PMP sites in the Gulf of Carpentaria, which was identified as one of the three primary shorebird sites in Australia (Lane 1987: 2-3), and the interior of the continent was largely unmonitored. The only PMP sites shown for South Australia (SA) were West Eyre Peninsula, Gulf St Vincent, The Coorong and the South-East Coast.

Gulf St Vincent, SA, was recognised to be an important feeding ground for shorebirds (Lane 1987) and along its eastern shores the Dry Creek Saltfields (DCS) at St Kilda (34° 42′ S, 138° 30′ E) are located just north of Adelaide (Figure 1). They were constructed in 1940, mostly east of the existing mangrove belt and over the landward samphire-fringed tidal pools and saltbush plains that were previous roosting sites for the shorebirds that primarily feed at low tide on the extensive mudflats to the west. Since then, the DCS have acted as an alternative high-tide roost and were listed by Lane (1987) as one of the primary roost sites for Holarctic shorebirds in the Gulf. They are part of a much larger eco-system of mudflats and mangroves that extends along the coast north to Clinton Conservation Park and then south down the east coast of Yorke Peninsula to Price. Historically, shorebird monitoring has referred to this area as Gulf St Vincent (Close and McCrie, 1986).

The numbers of Holarctic shorebirds occurring in Australia have significantly declined since the early 1990s (Wilson 2000, Table 7) and possible reasons for their decline in central coastal districts of SA are discussed below, but the principal focus of this paper is on the decline of migratory shorebirds using DCS. These saltfields ceased production in 2013 when water regimes changed along with a degradation and loss of habitat for shorebirds.

METHODS

Counts

Counts of shorebirds were usually made by two methods. Method A: regular and comprehensive counts conducted by teams of people at high tides as part of the PMP; and Method B: irregular and incomplete counts conducted by individuals at high tides (Close and McCrie 1986: 146). Both systems have their advantages and disadvantages.

Counts using Method A were usually undertaken annually at high tide on a designated date by several observers of varying experience. To be useful these formal counts should have been made consistently. However, it appears that the regularity and frequency of counts using Method A was not maintained in SA for much of the period. Harris (1994) had no counts for Gulf St Vincent for the seasons 1990-91 to 1992-93, but had results for 1994-95 (Harris 1995), while Skewes (2004) noted that Gulf St Vincent was not counted in 2001-02.

In addition, depending on the time of year, such counts using Method A often missed species that had several roosts which were not necessarily visible on the date and time of a formal count. Eastern Curlew and Black-tailed Godwit are prime examples of species that formed independent roosting flocks at the DCS throughout the season but moved between several roosts as tide heights varied during the day and, depending on local conditions, used different sites over the season. Such species were easily missed or under-counted on the particular day. Counts using Method B alleviated this problem by monitoring these species at irregular but continuous intervals over the season and often captured higher numbers of some that flocked in the austral autumn shortly before northward migration, whereas counts using Method A were usually conducted nearer mid-Summer and consequently recorded lower numbers of the same species (see results below).

In the early part of the sample period, the most notable problems with counts using Method B were the very large numbers of Red-necked Stint, Sharp-tailed Sandpiper, Curlew Sandpiper and Common Greenshank that were impossible for one person to accurately count during one high-tide period and they were sometimes noted only to be present in large numbers. Regular counts of these species are therefore only available from 1999-00, when it became apparent that Holarctic shorebird numbers were falling (Wilson 2000), until 2015-16.

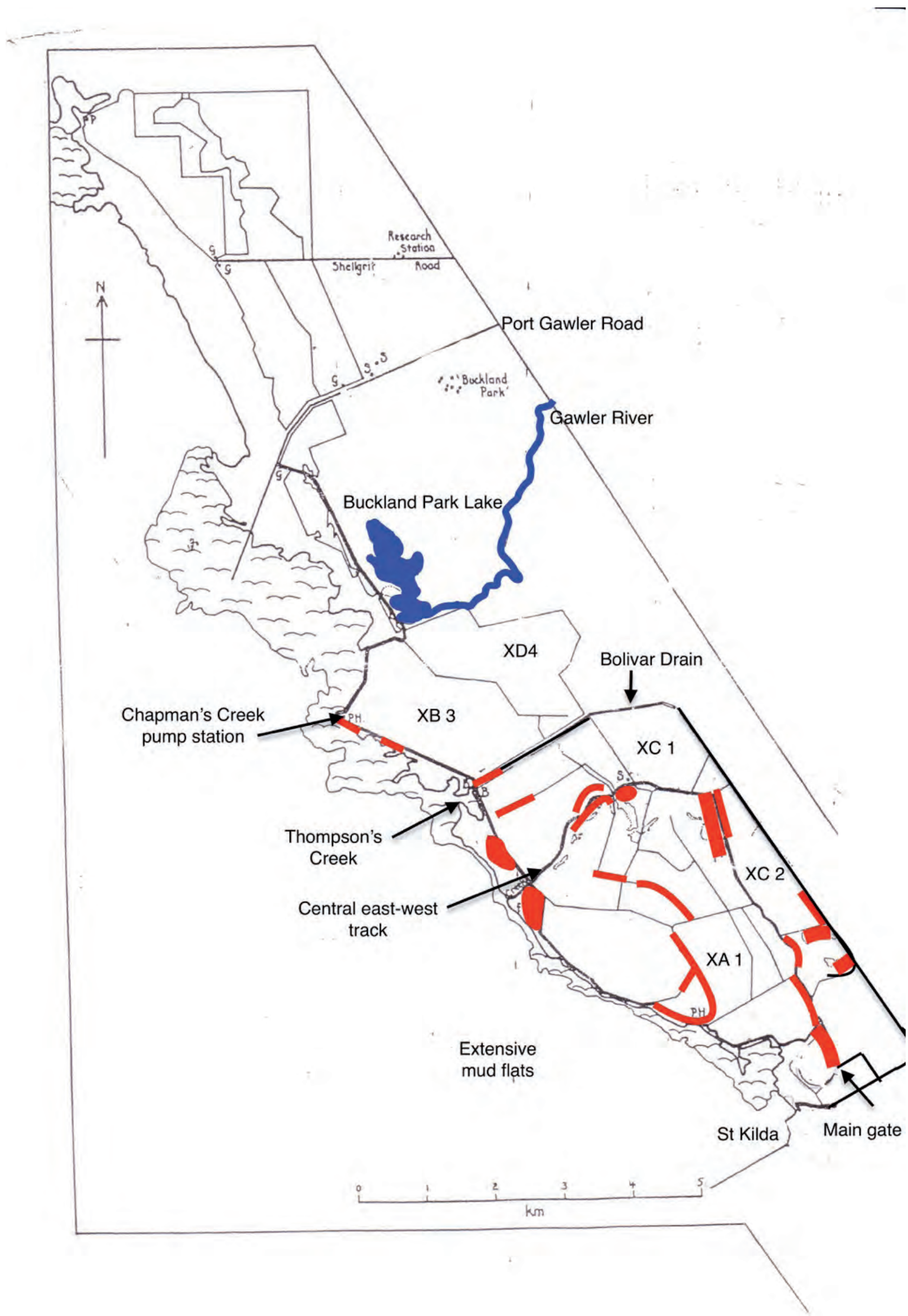

Figure 1. Map of the Dry Creek Saltfields. The main roost areas for Holarctic shorebirds from 1985-86 to 2015-16 are shaded red, freshwater blue.

In an attempt to overcome the disadvantages of both methods, a database was compiled by the authors that combines the published reports reliant on Method A with their personal records of shorebirds, and those of John Hatch, gathered during hundreds of visits to the DCS that effectively span the period 1985-86 to 2015-16 using Method B.

Most Holarctic shorebirds arrive in SA about August-September and depart by mid-April to mid-May of the following calendar year. Therefore, for convenience, the period used in this study applies to the season beginning on 1 September and ending on 30 April.

The Method B counts were conducted in the area shown in Figure 1 and also in the DCS from St Kilda seven kilometres southwards to Globe Derby Park. However, it should be noted that PMP counts were concerned with counting all shorebirds in Gulf St Vincent, rather than just the DCS, and there is some variation in the area covered. For example, Wilson (2000, Table 5) did not include Buckland Park Lake in Gulf St Vincent counts but included Greenfields Wetlands Stage 3 which abuts the southern edge of DCS at Dry Creek, perhaps because Buckland Park Lake has often remained dry for whole seasons since the 1990s. Nevertheless, when water-levels were suitable many shorebirds could be easily counted on the lake from adjacent DCS tracks, although early in the season when the lake was full they would usually be absent from any counts using Method A, but would be picked up by later counts or Method B as shorebirds moved into the DCS when the lake normally dried out by late January or February.

Species

While 36 species of migrant Holarctic shorebirds (Appendix I) were recorded in DCS over the period 1985-86 to 2015-16 the ten species examined below were selected on the basis that reasonable numbers consistently used the DCS as a roosting and feeding area for most of this period. It is interesting that several species commonly recorded roosting further north in Gulf St Vincent at Port Prime, Thompson Beach, Clinton Conservation Park and Price Saltfields did not use DCS as a primary roost site during those years and occurred mainly as transient visitors, sometimes in small temporary roosting flocks. They include Bar-tailed Godwit, Whimbrel, Great Knot and Red Knot and, as noted above, they follow an almost exclusively coastal route to Gulf St Vincent. In comparison, seven of the ten species that consistently used the DCS generally followed the trans-continental route.

RESULTS

From 1985 to 2016 the major roost and feeding sites for Holarctic shorebirds at DCS were found between the Chapman Creek Pump Station and St Kilda Road. Within this area large numbers of smaller sandpipers roosted near the main gate and along the eastern pans (Figure 1). Species such as Sharp-tailed Sandpiper, Curlew Sandpiper and Red-necked Stint also actively fed at these sites and all three were regularly encountered throughout DCS, including feeding or roosting on tracks. In contrast, larger shorebirds such as Eastern Curlew, Black-tailed Godwit, Grey Plover and Pacific Golden Plover were usually restricted to roosting at a selection of one or two sites on mangrove ponds, islands near the central east–west track or lightly used tracks south of the drain and Thompson Creek.

The numbers used in Charts 1-10 represent the highest count per species available for the seasons 1985-86 to 2015-16 from Methods A or B. Using the highest count for each year eliminates the seasonal pattern that exists in migrant shorebird numbers in Australia noted by Close and McCrie (1986) and Alcorn, Alcorn and Fleming (1994) and allows identification of longer-term trends in the number of shorebirds using DCS. This produces an almost continuous series for six species that occurred in smaller numbers, but a truncated series for the four species that initially occurred in larger numbers.

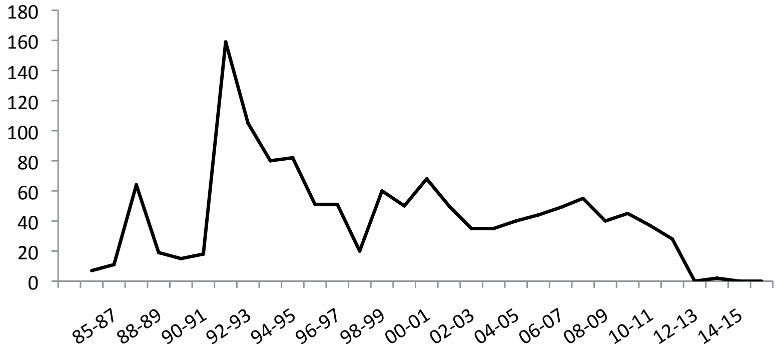

Chart 1. Grey Plover. Counted using Methods A and B.

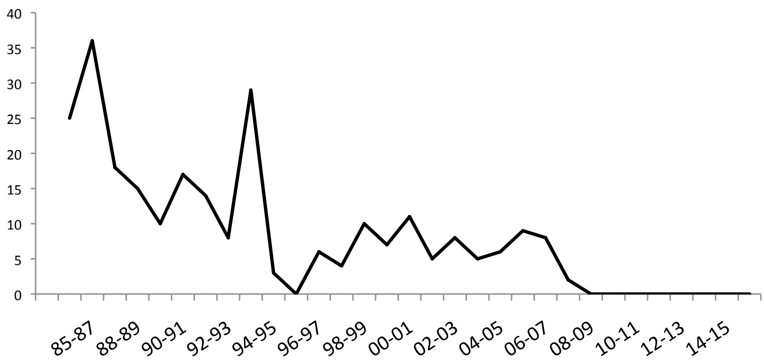

Chart 2. Pacific Golden Plover. Counted using Methods A and B but often missed by Method A.

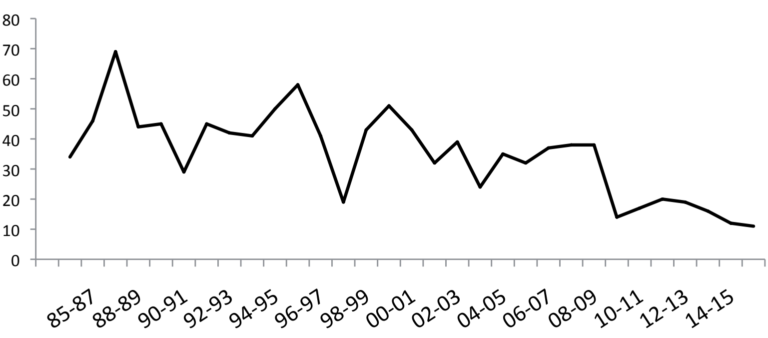

Chart 3. Eastern Curlew. Only reliably counted using Method B.

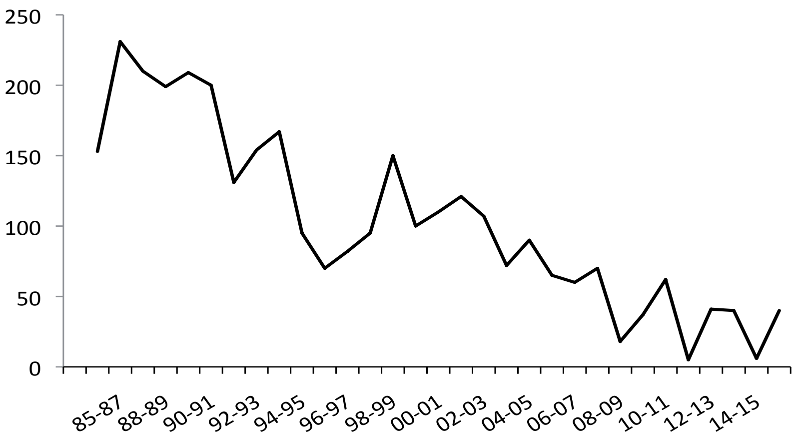

Chart 4. Black-tailed Godwit. The series for the Black-tailed Godwit is probably the most accurate as they are easily counted using Method B but often missed by Method A. For example, see Close (2008). Although Black-tailed Godwits were seen in 1996-97 and 2000-01, no proper counts were undertaken during those seasons.

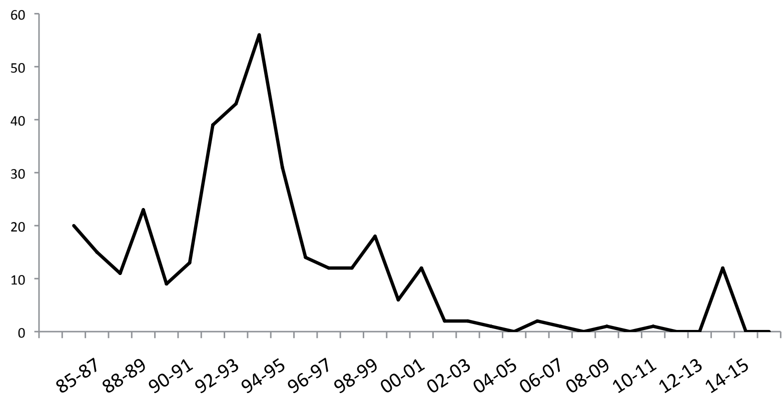

Chart 5. Ruddy Turnstone. Counted using Methods A and B and like Grey Plover showed a surge in numbers using the DCS in the 1991-92 to 1994-95 seasons before falling to very low numbers by 2002-03. The numbers for 2013-14 represent a small transient flock.

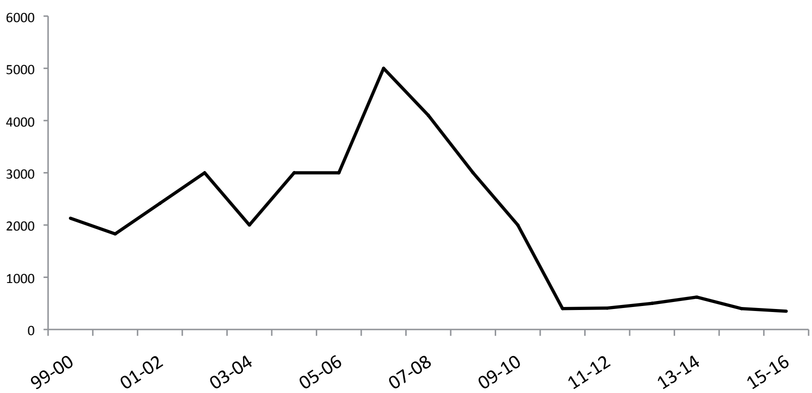

Chart 6. Sharp-tailed Sandpiper. Counted using Methods A and B.

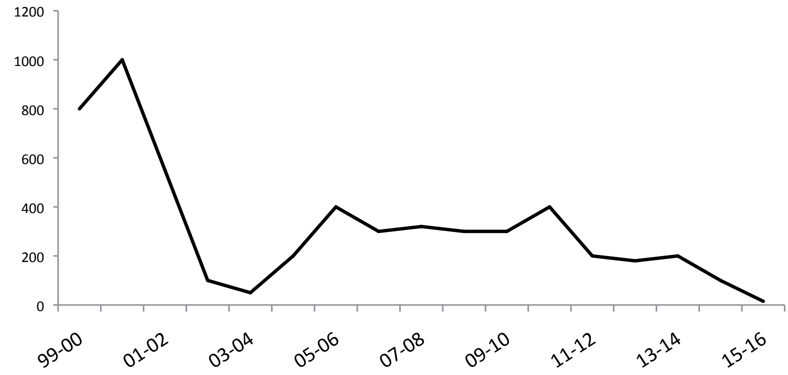

Chart 7. Curlew Sandpiper. Counted using Methods A and B. The sharp decline between 2001-02 and 2002-03 was due to factors on the Asian leg of the EAAF flyway.

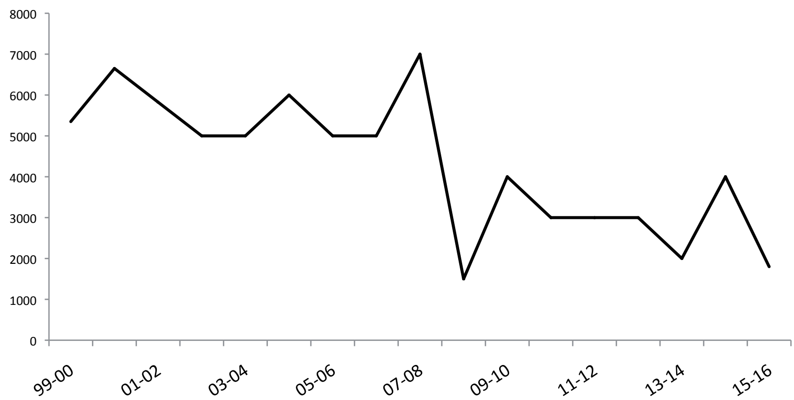

Chart 8. Red-necked Stint. Counted using Methods A and B but subject to count error when in large flocks.

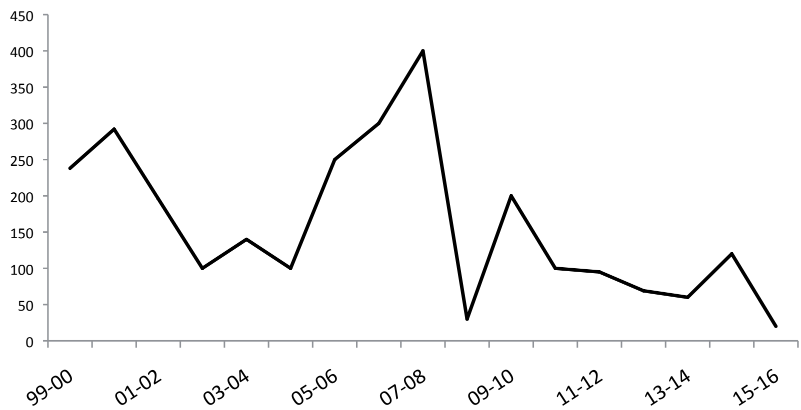

Chart 9. Common Greenshank. Counted using Method B.

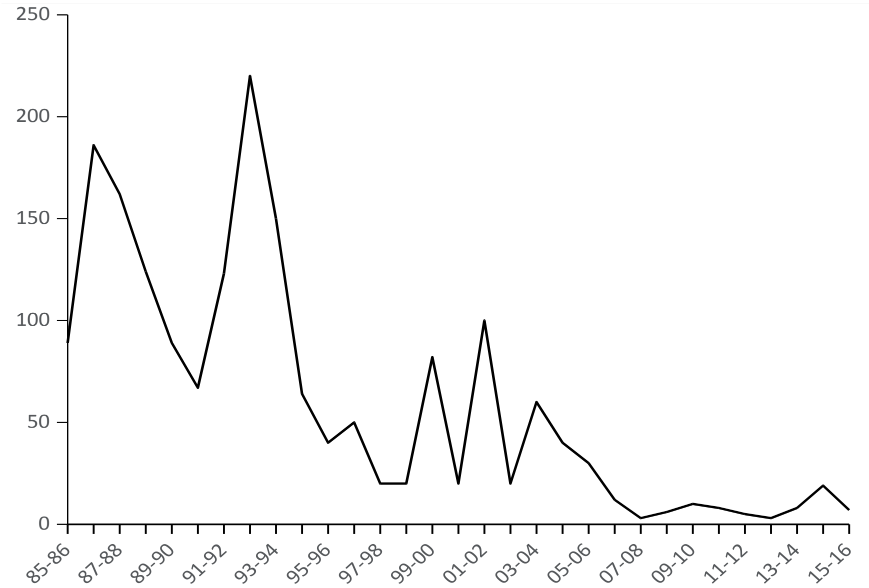

Chart 10. Marsh Sandpiper. Counted using Method B but often difficult to locate and prone to dispersive local movements.

The results illustrated in Charts 1-10 indicate that some species have continuously declined in number in DCS since the 1980s, but at an increased rate prior to 1995-96. Others sharply declined before 2000. These declines then led to a collapse in the numbers of Holarctic shorebirds using DCS by 2016.

For unknown reasons, the numbers of Grey Plover roosting in DCS dramatically increased in the early 1990s, but by the end of the decade had stabilized to within the range of 20 to 70 individuals until 2012-13 when they effectively abandoned the site. Close (2008, Table 1) noted a 52% decline in their numbers in Gulf St Vincent between the periods of 1979-85 and 2000-08.

Pacific Golden Plover numbers varied between 10 and 36 individuals during the late 1980s, prior to a dramatic decline in 1995-96. During the period 1997-1998 to 2007-2008 numbers varied between 5 and 12 but were often difficult to locate. For example, Wilson (2000, Table 7) had a zero PMP count for this species in Gulf St Vincent in 2000 whereas Chart 2 reveals there were seven or eight present in DCS located using Method B. Numbers fell to zero after the 2007-08 season but the reason for the departure of this species from DCS is unknown.

Counts of Eastern Curlew illustrated in Chart 3 do not show the volatility of other species but exhibited a slow decline from numbers fluctuating around 45 until 2001-02. Over the period 2001-02 to 2008-09 numbers in the range 30 to 40 were recorded but in 2009-10 they dropped to below 20 and have not recovered.

The steadily declining trend in the number of Black-tailed Godwits roosting in DCS (Chart 4) obscures a seasonal pattern that can be discerned only by counts using Method B and is applicable to other shorebird species that travelled overland and south to the central coast of SA. These counts revealed a trend of lower numbers early in the season, which gradually increased to peak numbers later in the season shortly before northward migration. Cox (1990) recorded that in September 1986 the Black-tailed Godwit flock consisted of 56 birds, by October there were 86, November 102, with the flock steadily increasing to 155 by February 1987 until reaching the peak number of 231 in April. The following season was similar, with 48 in September 1987 and gradually

Figure 2. Black-tailed Godwit coming into roost at DCS, 27 March 2016. Image Colin Rogers

increasing to 210 by April 1988. This seasonal trend was still apparent until 2015-16 even though Black-tailed Godwit numbers had also severely declined in DCS, from a peak of over 200 in the late 1980s to less than 50 by 2011.

Counts of Ruddy Turnstone peaked at over 50 in the mid-1990s but then declined steadily until 2004-05 and have since seldom been recorded. The reason for the peak in the mid-1990s is unknown (Chart 5), but it coincides with that of Grey Plover: Close (2008, Table 1) showed there was a significant increase in Ruddy Turnstone numbers in Gulf St Vincent from 1979-85 to 2000-08.

Sharp-tailed Sandpiper numbers peaked at DCS in 2006-07, but then declined steadily until 2010-11 and thereafter stabilized at around 500 (Chart 6). The earlier lower numbers could reflect some diversion of this species into Greenfields Wetlands Stage 3 where 2000 were counted, with 2000 also in DCS (Wilson 2000, Table 7)! A rise to 5000 in 2006-07 represented a recovery to only 50% of the numbers counted in the 1980s (Close and McCrie 1986, Table 1) and a significant decline in numbers therefore occurred prior to the 1999-00 season. The numbers for the 2015-16 season suggest that this species is no longer a common bird in DCS.

After 2000-01 Curlew Sandpipers suffered a significant decline on the Asian leg of the EAAF that was reflected in their numbers at DCS which fell from 1000 in 2000-01 to less than 100 in 2002-03. By 2005-06 numbers had recovered to 400 and they fluctuated between 300-400 before falling to 200 in 2011-12 and then falling below 100 in 2015-16 (Chart 7). Nevertheless, the significant decline in Curlew Sandpiper numbers occurred before 1999-00 because 2700 were counted in DCS from February 1979 to May 1981 (Close and McCrie 1986).

From 1999-00 to 2007-08 Red-necked Stint numbers varied from 5000 to 7000, but in 2008-09 they fell below 2000. Numbers then stabilized to around 3000 until 2015-16 when they fell back to 1800. However, the major decline in numbers occurred before 1999-00 because 23 000 were counted at DCS in 1979-81 (Close and McCrie 1986).

Common Greenshank numbers in DCS have also significantly declined, from the low hundreds in 2007-08 to less than 50 in 2015-16. A significant increase from about 100 to 400 occurred during 2004-05 to 2007-08, followed by a dramatic decline in 2008-09. Numbers then stabilized again in the region of 100 but dropped below 50 in the 2015-16 season. For comparison, a maximum of

450 was counted between February 1979 and May 1981 (Close and McCrie 1986, Table 1).

Over 200 Marsh Sandpipers were counted at DCS in the early 1990s, after which their numbers varied on a declining trend until 1996-97, with some stabilization in the lower range until 2003-04. Since 2005-06 numbers have remained at less than 20 (Chart 10). In contrast to these numbers from DCS, it is the only species of Holarctic shorebird which has reportedly increased in Gulf St Vincent between 1981 and 2000 (Wilson 2000, Table 7), which may reflect on the mobility of this species between sites and/or a consequence of undercounting using Method A in previous years because only 58 were located in Gulf St Vincent in 1981. However, a significant proportion of the initial decline in DCS reflected a redistribution from DCS to other sites in Gulf St Vincent. In particular, 45 Marsh Sandpiper were counted in Greenfields Wetlands with only 82 in the DCS in February 2000 (Wilson 2000). Close (2008, Table 1) similarly showed Marsh Sandpipers increased by 22% in Gulf St Vincent over the period 1979-85 to 2000-08 but the numbers used may also reflect a redistribution within the Gulf and some earlier undercounting using Method A.

The above counts of Holarctic shorebirds stand in sharp contrast to the statement by Purnell, Peter and Clemens (2013: 4) that DCS supports the "..greatest abundance of 'migrant' shorebirds in the region [Gulf St Vincent] (15, 000 on average)". Holarctic shorebirds have not been recorded in such numbers at the DCS since the 1980s. The reason for this difference is that Purnell, Peter and Clemens (2013) combined Australian nomadic breeding species with the Holarctic shorebirds and thereby significantly inflated the numbers of 'migrant' shorebirds because many thousands of Banded Stilt, *Cladorhynchus leucocephalus*, and many Red-necked Avocets, *Recurvirostra novaehollandiae*, also frequented these saltfields in 2013. Wilson (2000, Table 7) clearly restricted the term 'migrant' to Holarctic shorebirds.

DISCUSSION

A feature of trends in the numbers of Holarctic shorebirds visiting the DCS, visible in some charts that cover the whole period and evident in comparisons with Close and McCrie's (1986) and Wilson's (2000) data, is the sudden decline in numbers that occurred between 1992 and 2000. Similar patterns were observed at Corner Inlet in Victoria where Minton *et al.* (2012) concluded; "... most of these declining species show strong evidence of a step-wise sudden decrease in numbers rather than a gradual decline. The timing of these decreases has varied between species, with most of the major changes occurring between the 1992 and 2000 period."

Possible factors contributing to the decline of Holarctic shorebirds visiting DCS

The results illustrated in Charts 1 to 10 indicate that a complex interaction between local and external factors influenced the numbers of Holarctic shorebirds using DCS from 1985-86 to 2015-16. Close (2008) noted there were few obvious causes for the decline in Holarctic shorebird numbers in Gulf St Vincent at that time, so the cause(s) must lie on the Australian and/or Asian legs of the flyway. An interpretation of the declining trends should therefore consider factors on all sectors of the EAAF.

(i) Asian leg of the flyway

Piersma *et al.* (2016) provided a depressing assessment of the health of the EAAF and Clemens *et al.* (2016) suggested there had been a significant decline in shorebird numbers reaching Australia from the Asian leg of the flyway but there are some puzzling aspects about their data.

The lack of PMP sites in the Gulf of Carpentaria showed Australia-wide data to be incomplete and Clemens *et al.* (2016) had no information on migratory shorebirds from that region (supplementary materials Figures S1 to S4). In addition, they sourced their data from Bamford *et al.* (2008), who Schuckard (2008) criticised for failing to consider the relevant literature. Bamford *et al.* made no reference to Close and McCrie (1986) and significantly underestimated the numbers of Red-necked Stint and other migrant shorebirds recorded for DCS in the 1980s.

In view of the incomplete data it is therefore not possible to clarify the extent to which any continental decline in migrant shorebird numbers affected the decline at sites in SA. Nevertheless, the significant decline of coastal species such as Eastern Curlew, Bar-tailed Godwit and Grey Plover in Gulf St Vincent was noted by Wilson (2000: 19) who wondered if such declines indicated a deterioration in the Gulf as habitat for shorebirds. Furthermore, although continental data for most species are incomplete, the Eastern Curlew has decreased in number at almost all Australian PMP sites (Clemens *et al.* 2016: 126, Figure 1), which indicates a causal factor in Asia or on the Asian leg of the flyway.

(ii) Australian leg of the flyway

There are no PMP sites in central Australia and monitoring of shorebirds across the continent is almost non-existent with only intermittent and opportunistic records available. Even so, many ephemeral wetlands of inland SA, such as those at Coongie Lakes or Lake Harry near Maree, have attracted thousands of migrant shorebirds for many weeks in spring and early summer (Badman and May 1983; pers. obs.). Most would have arrived from the north during a southwards migration across the continent and only stopped to feed until the wetlands dried or otherwise became unsustainable with the advancement of summer.

It is during summer that numbers of the same species steadily increase at sites in southern coastal regions, such as DCS, until autumn when they depart (see above Results: Black-tailed Godwit). By then, many of the inland wetlands are normally dry and shorebirds on their return northwards migration must at least make longer flights or fly directly over the continent. Some may only partially migrate because 12 000 small shorebirds, the majority stints and probably first year birds, were noted on Lake Eyre in the winter of 1984 (Lane 1987: 35).

By comparison, the coastal elements are well-covered, even if not completely. Clemens *et al.* (2016: 126-128 and supplementary material) used PMP data and concluded that population trends of Holarctic shorebirds were not uniform across Australia. For example, the numbers of Red-necked Stint and Sharp-tailed Sandpiper increased in the north of Australia and decreased in the south (below 28^{o}S), while at PMP sites in SA their numbers increased at Streaky Bay, Baird Bay, Sceale Bay, and Eyre Island after 1996, but declined significantly in Gulf St Vincent, Kangaroo Island and the Coorong. Therefore, in the mid-1990s, the numerical decline of migratory shorebirds using DCS was, at least in part, due to a State or continent-wide process that diverted birds away from their traditional sites in the south-central coastal regions of SA.

A proximate and plausible explanation on a scale large enough to have caused such a diversion of shorebirds away from their regular sites in SA is the Millennium Drought (MD) of 1997-2009 (Bureau of Meteorology 2015) and this drought may have affected species that used the trans-continental sector of the Australian flyway. Lane (1987, pp. 34-35) outlined the impact of drought or changes in rainfall patterns on the food supply that drives Holarctic shorebird movements across central Australia. Many species showed site fidelity but responded to changes in food availability induced by rainfall.

The rainfall patterns of 1997-2009 (Figure 3) indicate that many shorebirds then arriving in northern Australia, particularly in the north-west and east to Gulf of Carpentaria where well above average precipitation occurred, would most likely have stayed to feed at northern ephemeral wetlands, as indicated by the increase in Sharp-tailed Sandpiper and Red-necked Stint numbers north of 28^{o}S (Clemens *et al.* 2016). Any migrant shorebirds from the north that attempted the

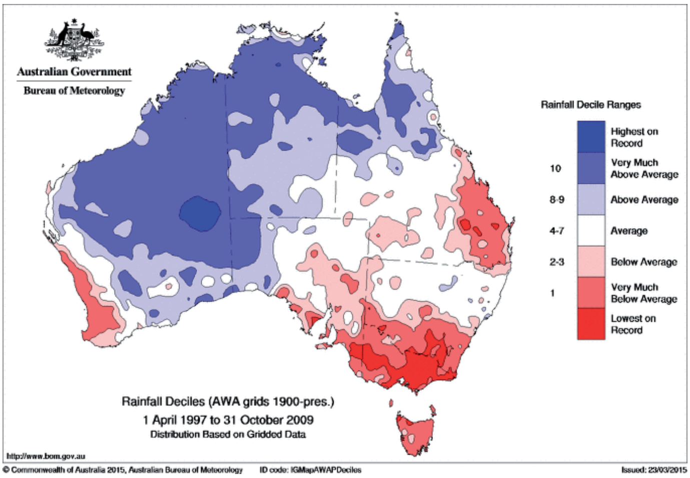

Figure 3. Rainfall across Australia during the Millennium Drought 1997-2009.
Source: Bureau of Meteorology (2015)

trans-continental route would have avoided the drought conditions in central and southern Australia and exhibited a bias towards the south-west. In SA, such conditions would have tended to increase shorebird numbers on western Eyre Peninsula, as noted by Clemens *et al.* (2016), and reduce the numbers further east at traditional sites in south-central coastal regions.

The long period of drought between 1997 and 2009 significantly impaired the trans-Australian route as reduced rainfall across the northern areas of SA and southern Queensland left many of ephemeral wetlands dry. The lack of convenient stop-over locations in northern SA meant that many migrant shorebirds either remained at key sites in northern Australia or diverted to other sites in SA and Australia.

(iii) Local factors

The most noticeable change in DCS occurred in 2013 when salt production ceased and some of the eastern pans were allowed to dry out (Figures 4 to 6). This action significantly reduced the roosting and feeding areas for species like Sharp-tailed Sandpiper, Curlew Sandpiper and Red-necked Stint in pans XC 2 and XC 2 south. In addition, the water pumped through the remaining pans was of lower salinity in areas near the St Kilda Road and maintained at higher levels throughout, causing increased erosion of banks and tracks and the inundation of some roost sites previously used by shorebirds.

While the numbers of Sharp-tailed Sandpiper, Red-necked Stint and Curlew Sandpiper have sharply declined, Pacific Golden Plover has not been recorded in DCS since 2007-08 and Grey Plover most likely stopped roosting there when water-levels rose after salt production ceased in 2013. It is possible that both species have re-located to other sites in Gulf St Vincent. Since 2013, the remaining Eastern Curlews and Black-tailed Godwits have roosted on eroded tracks rather than the mud-spits or islands previously preferred. Other shorebirds that occurred annually in small numbers are now no longer seen in the DCS. For example, the Terek Sandpiper, *Xenus cinereus*, has not been recorded since 2013. Pectoral Sandpiper, *Calidris melanotos*, Long-toed Stint, *Calidris subminuta*, and Wood Sandpiper, *Tringa glareola*, are now seldom seen although numbers have been regularly recorded in nearby freshwater wetlands. Therefore, along with numbers, species diversity in DCS has also decreased.

Areas adjacent to DCS have also changed. Buckland Park Lake abuts the saltfields (Figure 1) and frequently filled with water from the Gawler River until the late 1980s, but that frequency declined before and during the MD with

Figure 4. Aerial view of main shorebird roosting areas in DCS with the dry pans, XC 1 and XC 2 visible down the eastern boundary. They are no longer suitable for shorebirds, as indicated in Figure 6. Source: Google maps, satellite

Figure 5. Part of a massed flock of Sharp-tailed Sandpipers with some Red-necked Stints and Curlew Sandpipers roosting in pan XC 2 south on 28 January 2008. Image Colin Rogers

water flow into the lake sometimes restricted by increased upstream retention. Moreover, associated earthworks have caused severe levels of silt to accumulate in southern parts of the lake. Hence, throughout the period of the MD Buckland Park Lake seldom held water and was generally unusable for shorebirds such as Sharp-tailed and Marsh Sandpipers, that were normally attracted to the lake early in the season, but during the MD they would not have been present, to later move into DCS.

Some increase in habitat suitable for Holarctic shorebirds was initially gained in the 1990s with

Figure 6. Pan XC 2 south, the location of the roost shown in Figure 5, as it appeared in the 2015-16 season. **Image Colin Rogers**

the construction of a few smaller freshwater wetlands near DCS. The original intention was to create stormwater retention and filtration basins with associated wildlife habitat. Nevertheless, these sites are also dependent on rainfall and most now have steep-sided heavily vegetated banks that attract only a few shorebirds when water-levels are low.

Two exceptions are Greenfields Wetlands Stage 3 (Magazine Road) and the northern half of Barker Inlet Wetlands which have extensive areas of shallow water and mudflats that attracted large numbers of Holarctic shorebirds, particularly those with a preference for freshwater. However, these sites are also under threat: at Greenfields Stage 1 the operating emphasis is now placed on water-recycling and water pumped from there and into underground aquifers has drastically reduced the flow into Greenfields Stage 3, with the consequence that areas crucial for shorebirds now remain dry for most of the summer; while in Barker Inlet Wetlands a six-lane highway is currently being constructed through the shorebird habitat of the northern half.

CONCLUSIONS

Holarctic shorebirds numbers had dramatically fallen in Gulf St Vincent by the 1990s and as this decline involved species which used the coastal and trans-continental legs of the Australian flyway the causal problems are most likely to be in Asia or on the Asian leg of the EAAF. In Australia the MD of 1997-2009 probably diverted those species using the trans-continental route to the south-west and away from the south and south-east coasts, but after the drought ended and a more regular rainfall pattern resumed there was no indication of a recovery in shorebird numbers at DCS up to 2015-16. This aspect indicates that local factors were also a contributory cause of the decline.

These factors include the effective loss of Greenfields Stage 3, together with a reduced area of saltpans in DCS, where the loss of roosting sites and changes to the water regime have rendered these saltfields unattractive to Holarctic shorebirds. Nevertheless, the importance of Buckland Park Lake, and other nearby freshwater wetlands, for the attraction of some species to Gulf St Vincent is apparent. Despite the decline in the importance of DCS, seven species of shorebirds that use the trans-continental route will be attracted to the area if freshwater habitat at Buckland Park Lake and other nearby sites is maintained and managed with some degree of protection. The rehabilitation of some roosting and feeding areas in a reduced DCS, by way of managing water-levels correctly, and reviving the ponds adjacent to Bolivar would also benefit migratory shorebirds.

In DCS many Australian native shorebirds still occur in good numbers, including Banded Stilt, Red-necked Avocet, White-headed Stilt, *Himantopus leucocephalus*, Red-capped Plover, *Charadrius ruficapillus*, and Red-kneed Dotterel, *Erythrogonys cinctus*. Areas of deeper water remain attractive to numbers of other waterbirds. In particular, Blue-billed Duck, *Oxyura australis*, Musk Duck, *Biziura lobata*, Hoary-headed Grebe, *Poliocephalus poliocephalus*, and Great Crested Grebe, *Podiceps cristatus*, prefer ponds XB 3 and XD 4. Whiskered Terns, *Childonias hybrida*, and Crested Terns, *Thalasseus bergii*, also roost in large numbers in the evening on posts in pond XA 1. The DCS therefore remains an important refuge for waterbirds within Gulf St Vincent even if numbers of Holarctic shorebirds have declined significantly.

ACKNOWLEDGEMENTS

We are grateful to John Hatch for his records, Lucy Hatch for scanning the map, two anonymous reviewers and William Breed for suggestions that greatly improved an earlier draft of the paper.

REFERENCES

Alcorn, M., Alcorn, R. and Fleming, M. 1994. *Wader Movements in Australia.* Australasian Wader Studies Group, RAOU Report 94. Royal Australian Ornithologists Union, Melbourne.

Badman, F. J. and May, I. A. 1983. Waders in Northern South Australia. *South Australian Ornithologist* 29: 29-39.

Bamford, M. D., Watkins, D., Bancroft, W., Tischler, G., and Wahl, J. 2008. *Migratory Shorebirds of the east Asian-Australian flyway: population estimates and internationally important sites.* Wetlands International Oceania, Canberra.

Battley, P. F. and Rogers, D. I. 2007. Migration. In *Shorebirds of Australia.* A. Geering, L. Agnew and S. Harding (eds). CSIRO, Melbourne.

Bureau of Meteorology. 2015. http://www.bom.gov.au/climate/updates/articles/a010-southern-rainfall-decline.shtml

Conklin, J. R., Verkuil, Y. I. and Smith, B. R. 2014. *Prioritizing migratory shorebirds for conservation action on the East Asian–Australasian Flyway.* WWF-Hong Kong, Hong Kong.

Clemens, R. S., Rogers, D. I., Hansen, B. D., Gosbell, K., Minton, C. D. T., Straw, P., Bamford, M., Woehler, E. J., Milton, D. A., Weston, M, A., Venables, B., Weller D., Hassell, C., Rutherford, B., Onton, K., Herrod, A., Studds, C.E., Choi, C-Y., Dhanjal-Adams, K. L., Murray, N. J., Skilleter, G. A., and Fuller, R. A. 2016. Continental-scale decreases in shorebird populations in Australia. *Emu* 116: 119-135.

Close, D. H. 2008. Changes in wader numbers in the Gulf St Vincent, South Australia, 1979–2008. *The Stilt* 54: 24–27.

Close, D. H. and McCrie N. 1986. Seasonal fluctuation of waders in Gulf St Vincent, 1976-85. *Emu* 86: 143-154.

Cox, J. B. 1990. Observations of a Hudsonian Godwit in South Australia. *South Australian Ornithologist* 31: 48-50.

Gosbell, K. and Clemens, R. 2006. Population monitoring in Australia: some insights after 25 years and future directions. *The Stilt* 50: 162-175.

Harris, K. 1994. Population monitoring counts. *The Stilt* 25: 12-19.

Harris, K. 1995. Population monitoring counts. *The Stilt* 27: 27-29.

Lane, B. 1987. *Shorebirds in Australia*. Nelson, Melbourne.

Minton, C., Dann, P., Ewing, A., Taylor, S., Jessop, R., Anton, P. and Clemens R. S. 2012. Trends in shorebirds in Corner Inlet, Victoria, 1982-2011. *Stilt* 61: 3-18.

Piersma, T., Lok, T., Chen, Y., Hassell, C. J., Yang, H.-Y., Boyle, A., Slaymaker, M., Chan, Y-C., Melville, D. S., Zhang, Z.-W., and Ma, Z. 2016. Simultaneous declines in summer survival of three shorebird species signals a flyway at risk. *Journal of Applied Ecology* 53: 479-90.

Purnell, C., Peter, J. and Clemens, R. 2013. Shorebird Population Monitoring within Gulf St Vincent: July 2012 to June 2013. *Annual Report*. Birdlife Australia, Melbourne.

Schuckard, R. 2008. Review of 'Migratory Shorebirds of the east Asian-Australian flyway: population estimates and internationally important sites'. by Bamford, M.D. *et al.* (2008). *Notornis* 55: 226-228.

Skewes, J. 2004. Report on population monitoring counts. *The Stilt* 46: 86-92.

Wilson, J. R. 2000. *South Australian Wader Surveys: January and February 2000*. Australasian Wader Studies Group, Melbourne and South Australian Ornithological Association, Adelaide.

Colin Rogers
6 Flavel Avenue
Woodforde, South Australia 5072

John Cox
28 Devon Drive
Salisbury, South Australia 5108

Appendix I

Holarctic migratory shorebirds seen by one or both authors at Dry Creek Saltfields from 1985-86 to 2015-16.

Grey Plover, *Pluvialis squatarola*
Pacific Golden Plover, *Pluvialis fulva*
American Golden Plover, *Pluvialis dominica*
Little Ringed Plover, *Charadrius dubius*
Greater Sand Plover, *Charadrius leschenaultii*
Oriental Plover, *Charadrius veredus*
Whimbrel, *Numenius phaeopus*
Little Curlew, *Numenius minutus*
Eastern Curlew, *Numenius madagascariensis*
Bar-tailed Godwit, *Limosa lapponica*
Hudsonian Godwit, *Limosa haemastica*
Black-tailed Godwit, *Limosa limosa*
Ruddy Turnstone, *Arenaria interpres*
Great Knot, *Calidris tenuirostris*
Red Knot, *Calidris canutus*
Sanderling, *Calidris alba*
Sharp-tailed Sandpiper, *Calidris acuminata*
Curlew Sandpiper, *Calidris ferruginea*
Pectoral Sandpiper, *Calidris melanotus*
Long-toed Stint, *Calidris subminuta*
Red-necked Stint, *Calidris ruficollis*
Little Stint, *Calidris minuta*
White-rumped Sandpiper, *Calidris fuscicollis*
Baird's Sandpiper, *Calidris bairdii*
Broad-billed Sandpiper, *Limicola falcinellus*
Buff-breasted Sandpiper, *Tryngites subruficollis*
Ruff, *Philomachus pugnax*
Latham's Snipe, *Gallinago hardwickii*
Terek Sandpiper, *Xenus cinereus*
Common Sandpiper, *Actitis hypoleucos*
Grey-tailed Tattler, *Tringa brevipes*
Lesser Yellowlegs, *Tringa flavipes*
Common Greenshank, *Tringa nebularia*
Wood Sandpiper, *Tringa glareola*
Marsh Sandpiper, *Tringa stagnatilis*
Red-necked Phalarope, *Phalaropus lobatus*

A Common Redshank, *Tringa totanus*, in 1983 is the only additional species seen at DCS.