Waterbird Monitoring of the Warden and Gore Wetlands in December 2011 and February 2012

Yellow-billed spoonbills at Lake Wheatfield (K. Quinlan)

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August 2012

Department of Environment and Conservation

Our environment, our future

EXECUTIVE SUMMARY

- Waterbirds were surveyed across the Warden and Gore-Quallilup wetland systems by air and from the ground in December 2011 and February 2012.

- **Waterbird richness**. Species richness for the Warden wetlands has been remarkably stable in recent years, varying between 42 and 47, with the exception of October 2006 when only 35 species were recorded during the more limited survey in that year. Fifty two species of waterbird were recorded using wetlands in the Warden system over spring/summer 2011/12. Forty seven were recorded in December 2011 and 44 in February 2012, with 39 present in both seasons. Richness on the Gore-Quallilup wetlands is more variable, with between 19 and 26 recorded during aerial surveys and 29 to 36 when both aerial and ground surveys have been completed. Thirty three species were recorded on the Gore-Quallilup wetlands in December 2011 and 36 in February 2012, with 44 species across the two surveys and 30 occurring in both surveys.

- **Notable records from the December 2011 and February 2012 surveys*:***

  - Five Australian spotted crakes were seen on the North Wheatfield wetlands in December 2011. Thirteen spotted crakes were then seen in February 2012, with nine on the largest of the Neridup wetlands and four on the Merivale wetlands. Spotted crakes were not seen during surveys between 2006 and Feb 2011. There is potential for greater numbers of crakes around the central Warden wetlands if water levels remain low and fringing sedges return, as they are starting to at Lake Wheatfield. Australian spotless crakes were seen near the golf course on Windabout Lake in February 2008 and February and November 2010 and at Lake Wheatfield in February 2008.
  - Three wood sandpipers were seen on the Wheatfield to Woody Channel (near Woody Lake) in February 2012. The only previous records since 2006 are two and three individuals on the Bukenerup wetland in February and November 2008 respectively.
  - The sighting of a terek sandpiper on Lake Warden in December 2011 was the first time this species has been seen during the current monitoring program. There were only two records of single individuals during the 1980s surveys (at Mullet Lake and Lake Warden).
  - Eighteen wood sandpipers and six red-kneed dotterels on the flow-through wetlands in February 2012 were the first records of these species using Gore-Quallilup wetlands since the current monitoring program began in 2006. Jaensch *et al.* (1988) did not record these species on Lake Gore during the 1980s..
  - The fairy tern seen over Windabout and Warden lakes (possibly the same individual) in December 2011 is the second record since 2006; the other being one flying over Windabout Lake in the previous February.

- **Warden wetlands**. About 8300 and 13300 waterbirds were present on Warden wetlands in December 2011 and February 2012 respectively. The December 2011 count was close to the average (8667) for other spring surveys at Warden wetlands since 2006. The February 2012 count was much higher than the two previous summer counts of 6649 in February 2010 and 7256 in February 2011, but 15% lower than for the February 2008 count of 15764. If banded stilts are excluded (because they are nomadic and accounted for nearly a quarter of birds counted in February 2008), then the 2012 count of 12719 birds is about the same as the February 2008 count (12244).

  In both seasons, the numbers of most waterbird species were within ranges recorded since 2006.

There was a notable absence of darters and fewer great cormorants, pied cormorants and great-crested grebes in December 2011. By contrast, the 502 little black cormorant was more than has been seen on the Warden wetlands during most recent surveys (average 296).

The number of coots (19) using the Warden wetlands in February 2012 was very low compared to the average for previous February and spring ground counts (410 and 258 respectively), with previous low counts being February 2011 (49) and December 2011 (122), suggesting a decline in coot abundance over the last couple of years.

The 245 straw-necked ibis perched on dead trees around the Bukenerup wetland in December 2011 is higher than previously recorded for the Warden wetlands. Previous counts since 2006 have averaged ~ 100.

The numbers of silver gulls counted on the Warden wetlands has also been higher in the two most recent surveys (A214/G414 and A375/G363) than for other surveys since 2006 (A0 to198/G1 to 186).

In February 2012, the Warden wetlands had the highest abundance of ducks since the current monitoring program began. A best estimate is around 9000 ducks, but counts are imprecise because of the large number of ducks repeatedly taking flight during the aerial survey and movement between wetlands during the ground survey. There was about 2300 shelduck, over 3000 grey teal and over 2000 Pacific black duck, the latter two counts being relatively high compared to other recent surveys.

Sixteen species of shorebirds were present on the Warden wetlands in December 2011. This is the second highest number of shorebird species since 2006, with the highest being February 2010 (17 species). A total of 1289 shorebirds were seen in December 2011, including 481 banded stilt. While fewer species of shorebirds (14) were recorded in February 2012, abundance of shorebirds was high (2040 including 511 banded stilt). The count of shorebirds other than banded stilt (1529) was higher than the three previous summer counts of 1133 to 1335.

February 2012 counts of several shorebird species are records for the current monitoring program. These are red-necked stints (919), sharp-tailed sandpipers (152), red-capped plovers (117), hooded plovers (81) and masked lapwings (44) on the Warden wetlands. The 59 hooded plovers and 135 sharp-tailed sandpipers on the Warden wetlands in December 2011 were also relatively high counts (the former exceeded only by the 81 recorded two months later). Most of these shorebirds were counted on Lake Warden and/or Windabout Lake, their numbers most likely reflecting reduced water depths.

The pattern identified by Pinder *et al.* (2012) of Warden system waterbird communities in February being different from those in October to December has not changed with the addition of two surveys. Similarly, the tendency of communities in more recent spring surveys (2009-2011) to be intermediate in composition between the earlier spring surveys (2006 to 2008) and all late summer surveys (2008 to 2012) is confirmed.

- **Gore-Quallilup wetlands**. The total waterbird count of about 9000 birds in December 2011 was within the range for other recent surveys conducted in spring, as were counts of most individual species. By contrast, the count of about 4200 waterbirds in February 2012 was particularly low, with 2008, 2010 and 2011 February counts being two to three times higher. The count of shelduck was particularly low in February 2012 (<500, whereas counts are normally in the 1000s, with >5000 present in December), suggesting that the exodus of moulted shelduck was greater (or earlier) than for previous years. The numbers of black swans counted in December and February (262 and 182 respectively) was also lower than for other recent years. The number of hoary-headed grebes has been low during the last four surveys (February 2011 to February 2012) compared to the three surveys before those (November 2009 to November 2010). Counts of great egrets and white-faced herons were also relatively low in December (5 of each) compared to recent surveys (usually 20 to 100 of each) but the usual numbers (19 and 45 respectively) were counted in February. Some of these changes may be related to declining water levels in the Gore-Quallilup wetlands, especially on the Kubitch to Quallilup flow-through which had greatly reduced depth area of inundation during the last two surveys. Depths at Lake Gore should still be high enough (> 1 m) to support large numbers of waterbirds but continued decline is likely to result in further changes to waterbird composition.

The total number of shorebirds using the Gore-Quallilup wetlands in December 2011 (139) was the lowest count for the 2006 to 2012 period, although richness (9 species) was not much lower than usual. This low abundance is surprising considering the greatly expanded areas of shorebird habitat on the flow-through system. In February, the 14 species of shorebirds was the highest richness for recent surveys and numbers had increased to 1218 (which is still modest for February shorebird counts on these wetlands).

- **Lake Warden**. There have been dramatic changes in waterbird community composition between the 1980s (as documented in Jaensch *et al.* 1988) and the last six years. In the 2000s, communities at Lake Warden were, on average, more diverse (both in terms of total species richness and number of waterbird groups represented) than recorded during the 1980s. In the 1980s, when depths were normally < 1m, shorebirds tended to contribute most to richness, with only one or two duck species normally present and rarely any herons, cormorants, pelicans and grebes. In the 2000s, depth was mostly above 2 metres, there are many more duck species present and herons, cormorants, grebes and pelicans were usually or always present. Abundance was highly variable on Lake Warden during the 1980s, but with regular counts > 2000. Abundance during the 2000s was consistently lower, with all ground and aerial counts < 1000.

  In surveys since mid-2009, depth has declined again and waterbird communities have returned to a composition similar to that recorded in the 1980s. In particular, there has been a return to higher shorebird richness and a decline in richness of other groups, with the February 2012 community having only five non-shorebird species. Abundance has increased, with most ground and aerial counts being > 1500 and some > 2000. Most shorebirds present at Lake Warden during the 1980s have returned in the last couple of years, but knots, and a few other less common small shorebirds (long toed stints, pectoral sandpipers, broad-billed sandpiper) that were also occasionally recorded in the 1980s, have not returned.

- **Central suite wetlands**. In wetlands of the central Warden suite (Lake Wheatfield, Woody Lake and Windabout Lake and associated satellite wetlands) there have been a few changes in waterbird composition between 2006 and 2012. Eurasian coot have become less abundant over the last few surveys, with 100 to 800 (average 312) present between 2006 and 2010 versus 19 to 49 for the last three surveys. Straw-necked ibis have not been seen for the last three surveys whereas they were always present in surveys between 2006 and 2011 and nankeen night heron, glossy ibis and little egrets have occurred less frequently in the last few surveys. Ducks are normally the most abundant waterbirds in these wetlands, but composition is variable. In February 2008 and 2012 the number of ducks present was higher than in the previous spring, whereas the 2009/10 and 2010/11 seasons have shown the opposite trend. Shorebird richness and abundance has increased over the last few years. Between October 2006 and November 2009 counts of shorebirds were 6 to 58 individuals of up to 4 species, but counts for the last five surveys have been 90 to 210 individuals of 6 to 11 species. This increase in diversity and abundance of shorebirds is presumably associated with greater shallow water and beach habitat resulting from operation of the gravity pipeline. Increased abundance is particularly notable for sharp-tailed sandpipers, common greenshank, black-fronted dotterels and masked lapwings. Hooded plovers were seen on the central suite wetlands for the first time (during the current monitoring program) in December 2011 and February 2012 (Windabout satellite wetland F).

  There have been considerable changes in waterbird abundance and composition in the three larger central suite wetlands between the 1980s and the last three years, especially at Wheatfield and Woody lakes. These changes have been very different (and contrary for some species) in each of the three main central suite wetlands but, in general, abundance has increased across the suite and richness has more than doubled. Richness of shorebirds during the last three surveys has been greater than during equivalently timed surveys of the 1980s, although differences in survey methods may partly account for some patterns. Another significant difference between these two periods is the loss of clamorous reed warblers (with loss of reeds).

- **Concluding remarks**. Surveys carried out over the last six years (2006 to 2012) have characterised spatial and temporal patterns in composition of waterbird communities of the Warden and Gore wetland systems. The overall picture in the Warden and Gore wetlands is of relatively stable richness and species composition. Total and species abundances are more variable, in part reflecting climate patterns and associated population dynamics and migration across the south-west and further afield. The decline in depth at Lake Warden and the central Warden wetlands, following installation of pipeline at Lake Wheatfield and a number of average to below average rainfall years, is likely to be associated with the observed altered community composition in those wetlands. These changes may be ongoing as new ecological regimes are established. For instance, recovery of the fringing trees and sedge communities is evident at both Lake Warden and the central suite wetlands and this can be expected to result in further change to waterbird communities. Declining depths in the Gore-Quallilup system as a result of low rainfall also appears to be associated with altered waterbird usage. We recommend continued monitoring of both of these systems to fully document the medium term responses of waterbird communities to changes in hydrology, whether managed or not. Monitoring need not be undertaken as frequently as at present, but reduced frequency exacerbates difficulties of interpreting waterbird data in variable climates. Ground and aerial surveys are complementary and both are recommended. However, where budgets do not allow both, we suggest that ground counts are preferred (to give detailed counts that include small and cryptic species) provided they are undertaken over the shortest possible duration (presently 1 day on the Gore-Quallilup system and two days on the Warden system).

  There is scope for further detailed wetland and species-specific analyses of existing data to determine the relative importance of particular wetlands and habitats within the Warden and Gore systems. Further analyses of relationships between waterbirds and habitat descriptors should also be undertaken with the aim of producing more general conceptual and/or quantitative models (e.g. Halse et al. (1993)) that can be used elsewhere, perhaps incorporating other monitoring data such as that being collected in the Muir-Unicup Recovery Catchment. However, annual reporting at the level of detail provided in these reports is excessive and expensive. We recommend that annual reports be much briefer and that a more analytical report be undertaken after a further three year period.

  Extension of waterbird monitoring to other major wetland systems along the south-coast or even the broader south-west would place data on waterbird population and wetland usage in a regional context. At the least, coordination of the various wetland survey and monitoring programs that are being undertaken in the south-west should be continued and enhanced. A more regional survey could be undertaken less frequently than is currently undertaken for the Warden/Gore wetlands, or be undertaken as a once off but multi-year program such as that undertaken by RAOU/Birds Australia in the 1980s and published by Jaensch *et al.* (1988).

INTRODUCTION

This report presents results of the 2011/12 waterbird monitoring of the Warden and Gore-Quallilup wetland systems near Esperance. This program is designed to provide information about waterbird diversity and abundance in relation to environmental conditions to assist with management of the wetlands. The program also provides data to address the need to regularly assess ecological character of the Warden and Gore Ramsar sites. A particular focus is the response of waterbird communities to reduced water levels in the Lake Wheatfield to Windabout Lake wetlands (the central suite of the Warden system) and Lake Warden, following installation of a gravity pipeline in March 2009 to reduce depths in these wetlands. The Warden and Gore-Quallilup wetlands were monitored for three consecutive years (October 2006 to November 2008) by Stuart Halse (either through DEC or Bennelongia Pty Ltd), who recommended that the program be repeated for three years after any significant management intervention (such as the gravity pipeline). The last six surveys (November 2009 to February 2012) have been carried out by DEC. Previous reports are Halse (2007), Bennelongia (2008a; Bennelongia Pty Ltd 2008b; Bennelongia Pty Ltd 2009), Pinder *et al.* (2010) and Pinder et al (2012).

This report presents results from the most recent two surveys (December 2011 and February 2012), summarises patterns of waterbird occurrence over the last six years and presents some comparisons with surveys undertaken in the 1980s.

Wetland suites

The Warden wetland system consists of about 90 wetlands occurring in an arc north of the town of Esperance. Formally named wetlands are (from east to west) Ewans Lake, Mullet Lake, Station Lake, Lake Wheatfield, Woody Lake, Windabout Lake, Lake Warden and Pink Lake, but there are many smaller un-named wetlands. Most of these wetlands have been surveyed for waterbirds during the current monitoring program. The above named wetlands, plus one other ("Racecourse Lake" or "North Windabout" also included in the current monitoring program) were also surveyed on numerous occasions during the 1980s (Jaensch *et al.* 1986). For summarising waterbird data the wetlands have been divided into 15 suites, detailed below, indicated in Figure 1 and listed in Appendices 1 and 2.

Neridup Creek (Suite 1) and Bandy Creek (Suite 2): Ten small wetlands south of Merivale Road and fed by flows from Bandy Creek and Neridup Creek. The two suites are divided by the dirt track almost opposite Hicks Road rather than by a Neridup/Bandy Creek drainage divide, which doesn't exist. Site 1A is clearly fed directly by Neridup Creek and site 2B is on the main channel of Bandy Creek. Some of the other wetlands would receive water from either or both sources. These have all had water during at least some of the spring surveys but most dry in summer. Sites 1A and 2B (which are part of the main Neridup and Bandy Creek drainage lines respectively) have usually had water in February. All of these wetlands are surveyed on foot.

Ewans Lake (Suite 3): This suite consist of Ewans Lake (both the larger southern basin and the smaller northern basin), the wetland areas where Bandy Creek enters the lake from the east, and the small pans north-east of the lake. All wetlands are surveyed on foot.

Mullet Lake (Suite 4): Main body of Mullet Lake. For surveys between November 2009 and February 2011, data for the Merivale Road wetlands (Suite 5B) were included with counts for Mullet Lake. Surveyed on foot, usually by walking the entire western and eastern shores and using a spotting scope for the southern shore.

Station Lake (Suite 5). This suite includes the main body of Station Lake and all peripheral area with water. Usually this is just the flats to the south-east partially separated from the main lake by a spit and the wetland to the south associated with where Bandy Creek starts again. These areas are always surveyed on foot, often from about half of the shore using spotting scopes.

Merivale Road wetlands (Suite 5B). Consisting of the chain of wetlands north and north-west of Mullet Lake, most of which form part of Bandy Creek. All surveyed on foot.

Gun Club wetlands (Suite 6). A small open water wetland within the Esperance Gun Club and a larger *Melaleuca* fringed wetland immediately north of it. Both surveyed on foot from the western shores.

Lake Wheatfield (Suite7). Lake Wheatfield, including parts of the Coramup Creek system south of Lakes Road, including the channel just upstream of the lake and the two circular wetlands that form part of the Coramup system north-west of the lake. The main lake and Wheatfield to Woody channel are surveyed by boat, walking up Coramup channel. The two wetlands associated with Coramup Creek are surveyed by walking in from Lakes Road. From October 2006 to February 2008, only the main wetland was surveyed from the ground.

North Wheatfield wetlands (Suite 8): Two wetlands north of Lakes Road and north of Lake Wheatfield. Both wetlands surveyed on foot.

Woody Lake (Suite 9). Woody Lake, plus the hour-glass-shaped wetland to its north, the channel through to Windabout Lake, the elongate wetland south of the channel, the small wetland near boat launching site and the wetland north of the intersection of Windabout Way and Tranquil Drive. From October 2006 to February 2008, only the main wetland was surveyed from the ground.

Windabout Lake (Suite 10). All basins of Windabout Lake, plus the triangular lake near the end of Windabout Way, the large basin east of the north-east bay of Windabout Lake, the small wetland just west of the Windabout Way boat launch site and the wetlands between the south-west and north-west bays. From October 2006 to February 2008, only the main wetland was surveyed from the ground.

North Windabout (Suite 11). A series of basins partially separated by parabolic dunes north of Windabout Lake. These are surveyed on foot.

Six Mile Hill wetlands (Suite 12). Five wetlands north of Lakes Road just above North Windabout Suite. All surveyed on foot.

Lake Warden (Suite 13). Lake Warden, plus the wetland associated with Burkenup Creek between Lake Warden and the railway line, three wetlands just west of the boat launching site and another small wetland over the dune on the south-west shore.

Burkenup wetlands (Suite 14). Burkenup Creek forms a series of shallow wetlands as it approaches Lake Warden from the west. The area surveyed is the area east of the rail-line including the eastern part of the hour-glass shaped wetland to the south of the main basin.

Pink Lake (Suite 15). Usually surveyed from the look out on the south-west corner of the lake, several vantage points on the southern shore and by walking around the eastern end of the lake from the salt works to point on the north-east shore.

Wetlands surveyed in the Gore-Quallilup system have also been divided into suites for convenience. From 2006 to 2008 only aerial surveys were undertaken. Since 2009 these wetlands have been surveyed from the air and from the ground.

Dalyup wetlands (Suite 16). The Dalyup River upstream from lake Gore to a basin connected to it on the south side of the channel. Usually surveyed on foot but if water deep enough then boat taken up the channel from Lake Gore. From 2009 this suite and Lake Gore (Suite 18) have usually been scored together.

Carbul wetlands (Suite 17). This suite consists of Lake Carbul, Lake Kubitch and Lake Gideon. These are surveyed on foot to the extent that it is required to count and identify shorebirds with a spotting scope. Lake Gideon has only been surveyed on the ground since November 2010 but was surveyed from the air since 2006.

Lake Gore (Suite 18). Main body of Lake Gore plus the peripheral wetlands that fringe its eastern side. Surveyed from a boat if deep enough, with surveys of the peripheral wetlands done on foot. If Lake Gore is too shallow, then the suite is surveyed using a spotting scope from about 100 metres north of the Dalyup River, walking and spotting from the river to the southern shore west of the end of the southern peripheral wetland, spotting from the western shore near Kubitch Lake and from the northern edge of the lake near the depth gauge.

Quallilup Lake (Suite 19). Consisting of Lake Quallilup and a satellite wetland to its north-east associated with the Kubitch-Quallilup flow-through.

Kubitch to Quallilup flowthrough (Suite 20). A series of interconnected basins and channels that carries water overflowing from Lake Gore to Lake Quallilup. When depth is sufficiently high it is possible to navigate the

entire system by boat, otherwise the surveys have been done by boat as far as possible from Lake Quallilup, then surveying the rest of the system by walking through to Lake Kubitch.

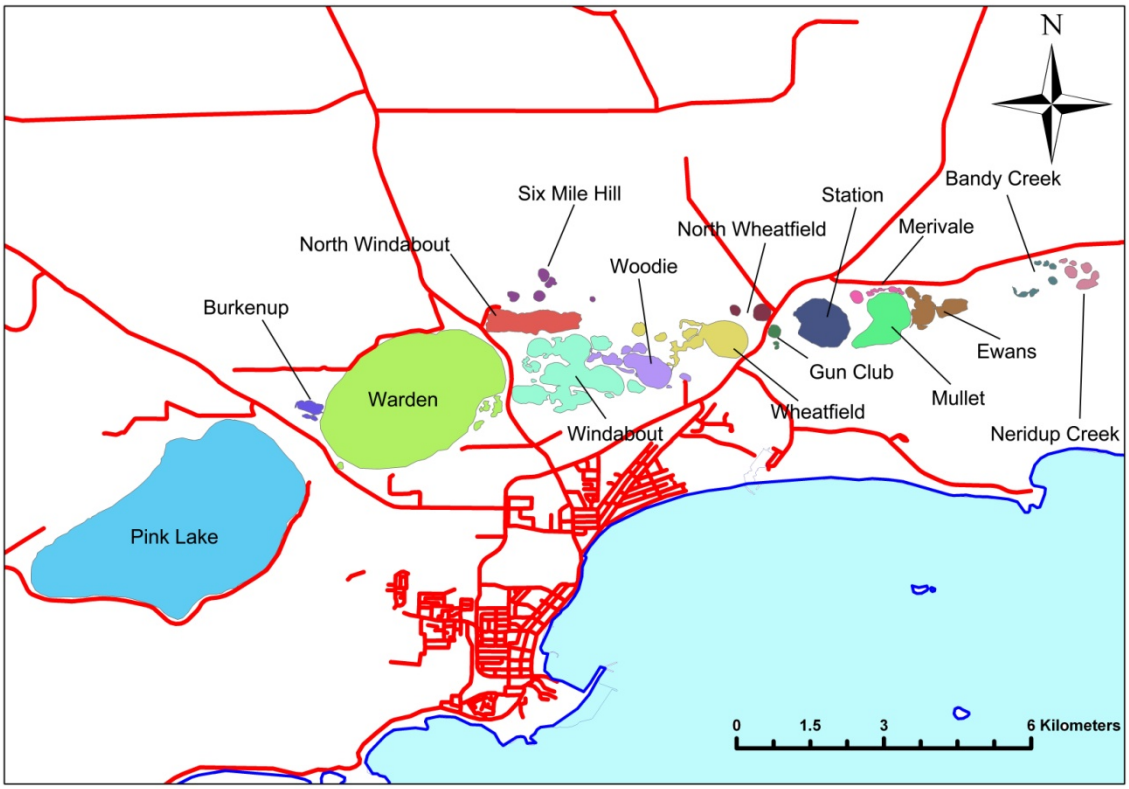

Figure 1. Wetland suites surveyed for waterbirds in the Warden system.

2011/12 weather

Table 1 and

Table 2 show monthly rainfall totals for two weather stations near the Warden wetlands (Esperance and Lake Warden Farm). These stations had similar rainfall patterns in 2011/12 and similar averages. In 2011/12, monthly rainfall was below average for the early southern wet season (April to June), about average for July and August, average during early spring (September and October), well above average for November and December and average to below average in late summer (January and February).

Figure 2 and Figure 3 show rainfall (as deciles) for the southern 2011 wet-season (April to November) and the northern 2011/12 wet season (October to February) respectively (note that there is a time overlap).

Table 1. Rainfall (mm) for the period Mar 2011 to February 2012 for Esperance (Bureau of Meteorology station number 9789). Source www.bom.gov.au 07-04-2011. Average values calculated from the period 1970 to 2012.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total
2011/12	34.2	35	47.8	39.8	110.8	79.2	72.4	46.6	67.4	62.2	29.6	14.8	639.8
Average	27	46.5	71.7	80.3	97	81.7	61.5	46.7	34.1	18	27.7	24.1	622.7

Table 2. Rainfall (mm) for the period Mar 2011 to February 2012 for Lake Warden Farm (Bureau of Meteorology station number 9800). Source www.bom.gov.au 23 Mar 2012. Average values calculated from the years 1970 to 1979, 1984 and 1989 to 2011 (some months missing in some years, including August 2011.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total
2011/12	26.6	27.7	58.2	23.8	104.1	-	72.1	45.9	70.8	60.4	30.2	10.8	-
Average	20	43.1	67.4	81.4	102.2	83.6	70.2	47.5	30.8	19.2	26.8	23.5	609.3

Weather 2006 to 2012

Since 2006, winter/spring rainfall in south-western Australia has mostly been average to below average (well below average in 2006). By contrast, rainfall in inland and northern Australia has been much more variable, ranging from an average to below average 2007 to an average to well above average 2010. Summer rainfall has mostly been average (i.e. low) to below average across the south-west, except that the eastern south coast (but not necessarily Esperance) had some well above average years (2006/7, 2008/9 and 2011/12). In the inland and north, there has generally been some areas with above average to well above average rainfall each summer but this has varied from the Pilbara and inland (2006/7, 2008/9 and 2011/12) to the Mid-west (2007/8), to across all of the north and inland (2010/11). In the summer of 2011/12 most of the north had above average rainfall but much of the Western Australian inland and the south-west had very much above average rains. These rainfall patterns have undoubtedly influenced the type and number of waterbirds using Esperance wetlands during the last ten surveys, though such influences are not always obvious and consistent, especially because they act simultaneously across a range of spatial scales and there is usually little corroborating waterbird data from elsewhere.

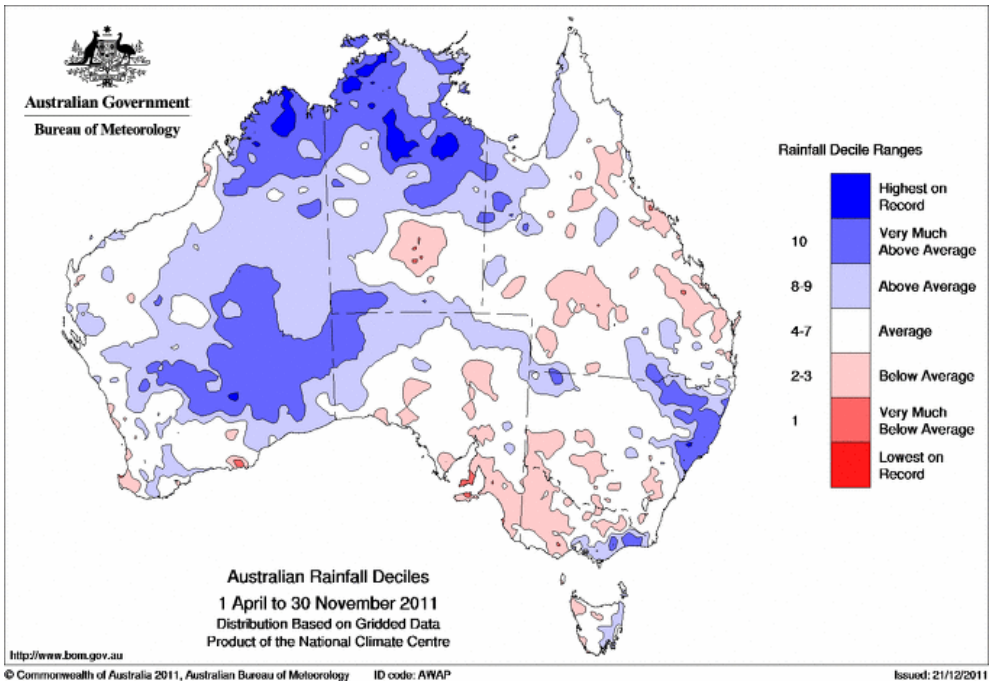

Figure 2. Rainfall deciles for Australia during the 2011 southern wet season. Sourced from the Australian Bureau of Meteorology 31 March 2011.

(http://www.bom.gov.au/jsp/awap/rain/index.jsp?colour=colour&time=latest&step=0&map=decile&period=cnws&area).

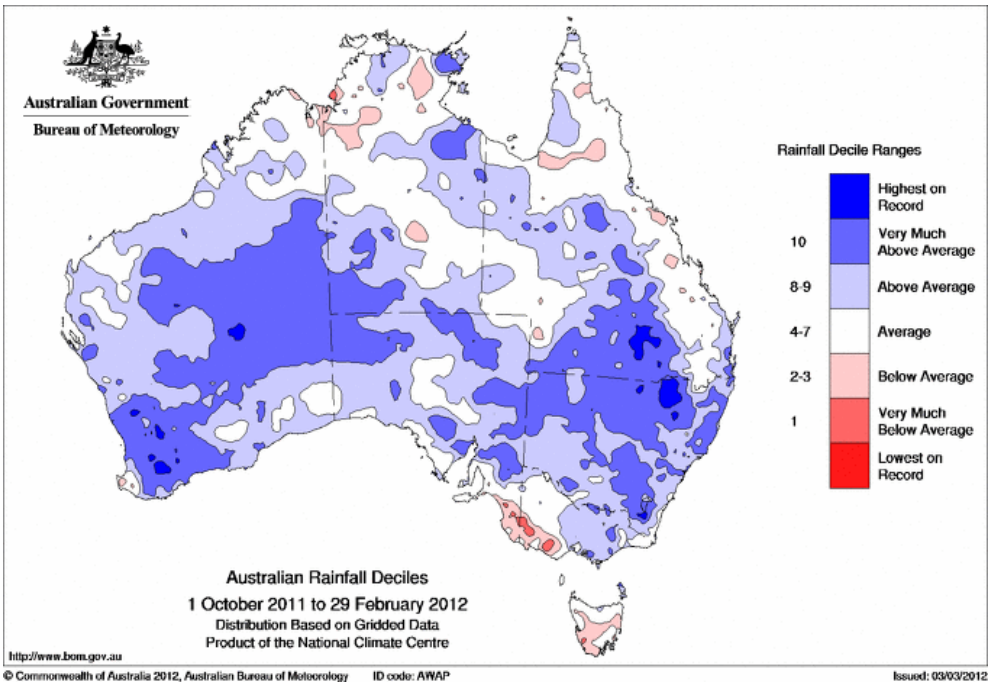

Figure 3. Rainfall deciles for Australia during the 2010/11 northern wet season. Sourced from the Australian Bureau of Meteorology 31 March 2011

(http://www.bom.gov.au/jsp/awap/rain/index.jsp?colour=colour&time=latest&step=0&map=decile&period=cnws&area).

Figure 4 shows the percent deviation from average seasonal rainfall at the Esperance weather station (station 9789) for the years 2006 to 2012. Winter rainfall was below average in all years, though mostly by less than 20%: the exception being 2006 which was 41% below average at 153 mm. Autumn rainfall was also mostly below average (driest in 2008 with 100mm [31% below average] wettest in 2007 with 183 mm). Spring rainfall has been more variable, but summer rainfall has tended to be higher than average. In 2006/7 summer rainfall was 198% higher than average at 208 mm, due to tropical cyclone Isobel which moved south and resulted in 153 mm of rain in 24 hours (5th February). In 2008/9 spring and summer were very wet, with rainfall 66% (237 mm) and 91% (133 mm) higher than average respectively: the latter associated with moisture from tropical cyclone Dominic (Bureau of Meteorology 2009). These summer rainfall events both caused extensive flooding of the Warden wetlands and that lake levels were thus abnormally high for many weeks. Spring and summer rainfall was 31% (183 mm) and 53% (107 mm) higher than average in 20011/12 as a result of storms in November and December, with December being the wettest on record for the south-west land division (BoM Dec 2011).

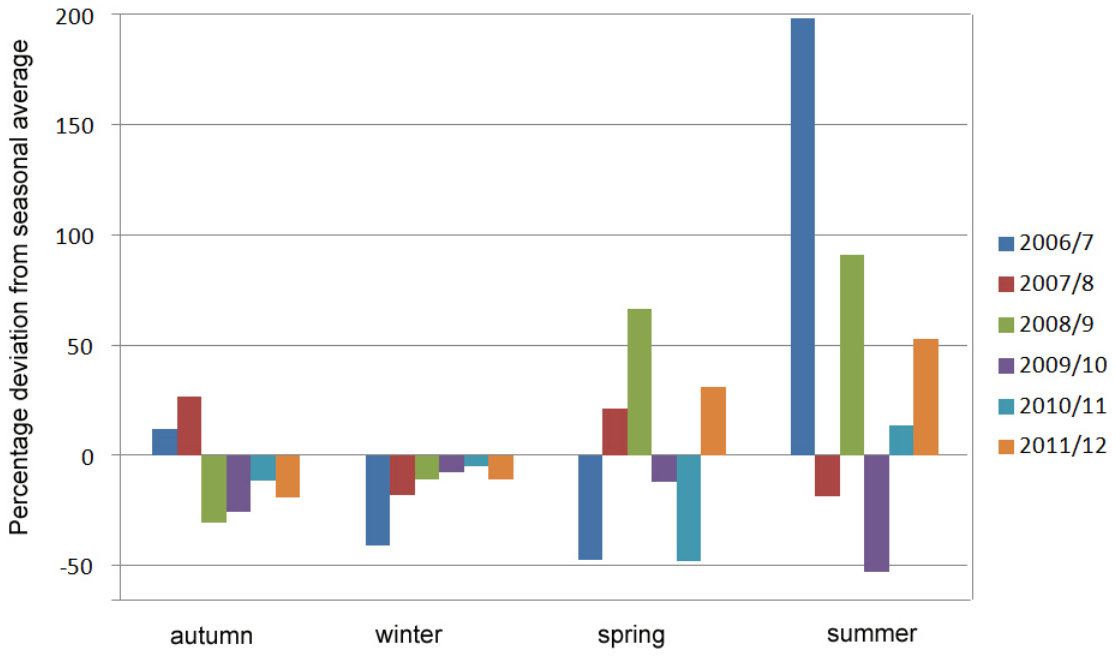

Figure 4. Deviations from average seasonal rainfall at Esperance (weather station XXXX) from 2006 to 2012.

Lake Depths

Depth, salinity, pH and nutrients have been measured in most of the larger Warden system wetlands in recent years by DEC Esperance staff (Department of Environment and Conservation 2012). Figure 5 shows depths in the eastern Warden suite (Mullet to Station), the central Warden suite (Lake Wheatfield to Windabout) and in Lake Warden from 2002 or 2003 until January 2012. Even though three 1:100 year flood events within the last decade, the average lake depth trend of the eastern suite has declined by approximately 150mm since 2007. This trend has been matched in residual rainfall in the Bandy Creek Catchment and may be as a result of climatic variability associated with the El Nino effect. In the central suite, depths were relatively constant until early 2009, except for lower depth at Lake Wheatfield in 2002/3 than in the next six years. Minimum and maximum depths have declined at all three central suite wetlands since the gravity pipeline began operating in autumn 2009. Depth at Lake Warden was also lower in summer 2002/3 than in subsequent years and, following 3 years of decline from 2009, in late summer 2011/12 was at its shallowest in the last 14 years.

Error! Reference source not found. puts the depth of Lake Warden into the context of a longer time series (November 1979 to May 2012). Depths from 1979 to 1985 are 5 to 6 measurements a year, reducing to just September and November measurements from 1986 to 2001, then approximately fortnightly from 2002. This graph shows that in the early 1980s depth was generally less than 1 m and usually well under 0.5 m (occasionally drying) over spring and summer. There was a sharp increase in depth in late 1984 without a subsequent return to shallow depth in subsequent years. Spring depths from that year onwards were then rarely <0.5 m. Spring depths during the 1990s were highly variable and frequently above 1.5 m in the early 1990s. From about 2000 to 2009 depth rarely fell below 1.5 metres and after 2006 was mostly above 2 m. Since 2009 depth has declined dramatically, so that during the December 2011 and February 2012 waterbird surveys depth was about 0.9 m and 0.7 m respectively.

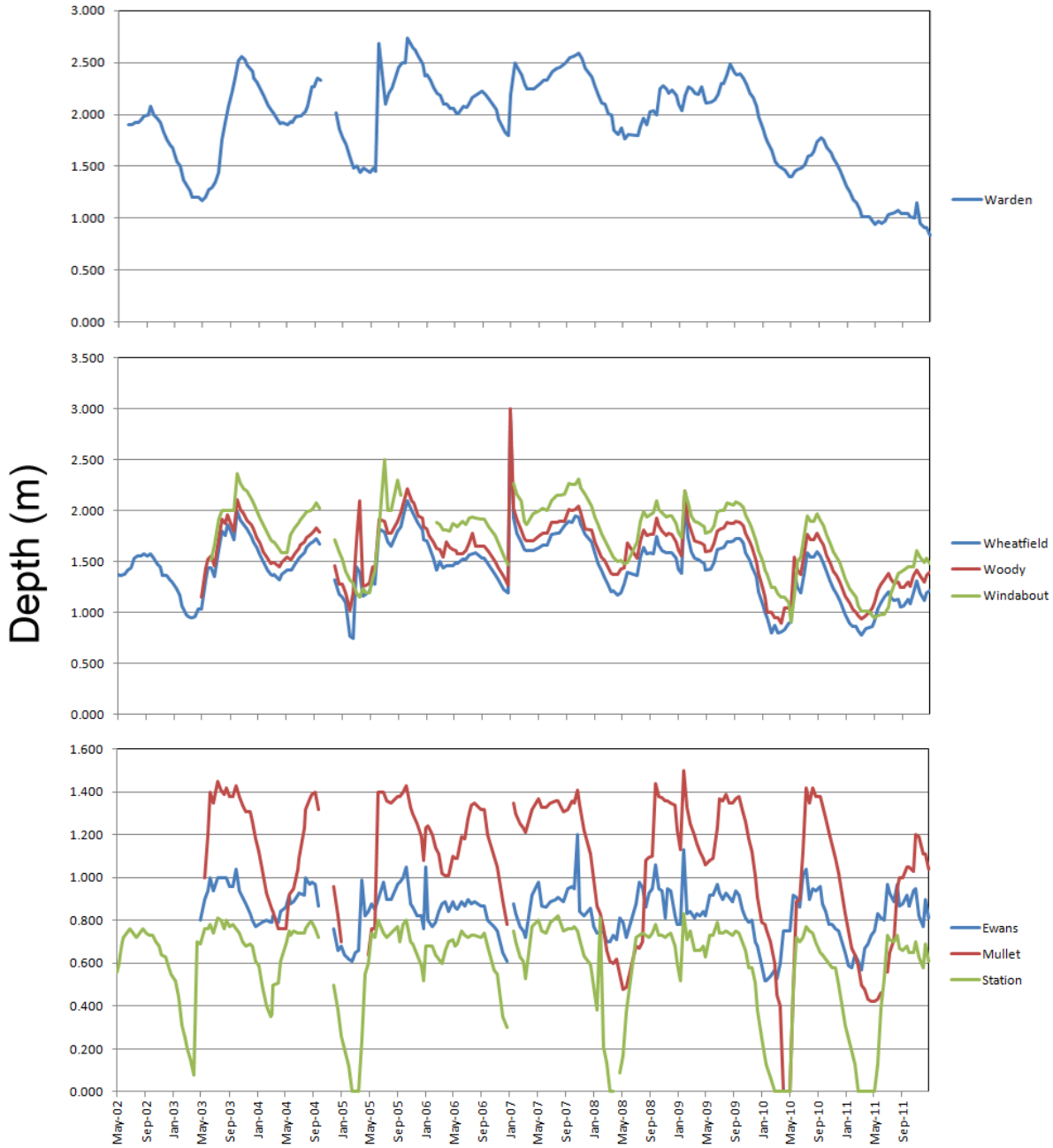

Figure 5. Depths in Warden Recovery catchment wetlands May 2002 to Jan 2012. Data from Department of Environment and Conservation (2012)

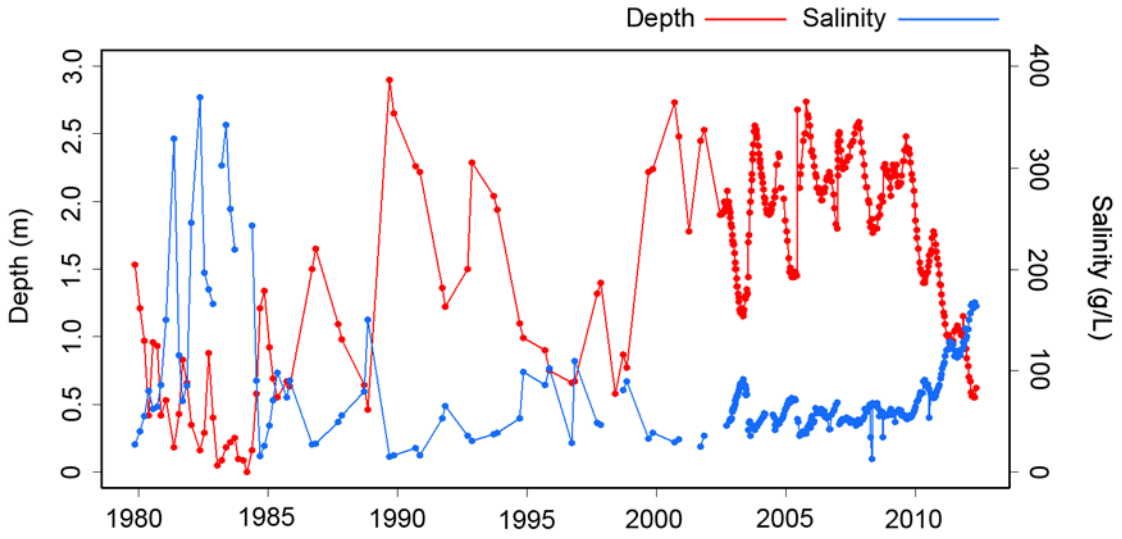

Figure 6. Depth and salinity of Lake Warden November 1979 to May 2012. Data from 1979 to 2002 from DEC's SWWMP project (Lane *et al.* 2011) and data from 2002 from Department of Environment and Conservation (2012).

METHODS

Count methods

Ground counts (on foot or by boat) were made at 56 separate wetland areas in December 2011 and February 2012 respectively, within 19 wetland suites. A count was planned for November 2011 to better match timing of the spring surveys since 2006, but predicted poor weather and then unavailability of staff led to a postponement until December.

Aerial counts were made at the same wetlands during the same week in both seasons. In February, 22 wetlands were dry but all were visited to check for shorebirds such as hooded plovers and red-capped plovers. Most of the satellite wetlands around Lake Gore (and included in the count for Lake Gore in December) were dry in February.

All counts were undertaken by David Cale (DC), Kirsty Quinlan (KQ) and Adrian Pinder (AP), assisted by John Lizamore (JL) and Sarah Davies (SD). Where there were multiple observers they contributed to single counts.

December 2011 ground counts

Ground counts were undertaken as per Table 3. The GPS track of the boat and walking survey of Quallilup Lake and the flow-through system is shown in Figure 7.

Table 3. Details of ground counts undertaken in December 2011.

Wetland Suite Name	Observers	Date	Comments
Neridup Suite	AP, DC	12/12/2011	
Bandy Creek Suite	AP, DC	12/12/2011	
Ewens Lake	DC	12/12/2011	
Mullet Lake and Merivale Suite	AP	12/12/2011	
Station Lake	DC	12/12/2011	
Gun Club wetlands	AP, DC	12/12/2011	

Wheatfield Suite	DC, JL	13/12/2011	By boat and on foot for satellites
North Wheatfield Suite	AP	13/12/2011	
Woody Suite	DC, JL	13/12/2011	By boat and on foot for satellites
Windabout Suite	DC, JL	13/12/2011	By boat and on foot for satellites
North Windabout Suite	AP	13/12/2011	
Six Mile Hill Suite	AP	13/12/2011	
Lake Warden Suite	DC, JL	14/12/2011	By boat and on foot for satellites
Burkenup Suite	DC, JL	14/12/2011	
Pink Lake	AP	14/12/2011	Walked around eastern ¼ of lake
Lake Gore Suite including Dalyup channel and wetland to south of channel	DC, SD	15/12/2011	Main lake by boat, Dalyup and peripheral wetlands on foor
Carbul Lakes	AP, DC, SD	15/12/2011	
Quallilup Lake	AP, JL	15/12/2011	By boat
Kubitch to Quallilup flow-through	AP, JL	15/12/2011	By boat in southern extent, then walked most of the length of flow-through due to low water level

Figure 7. GPS track recorded during the boat and walking survey of Lake Quallilup and the Kubich to Quallilup flow-through system in December 2011.

December 2011 aerial counts

An aerial survey of all Warden and Gore system wetlands was undertaken on 12 December 2011. This involved two observers, one in the rear of the plane (DC) looking to the left and one in the front (AP) looking to the right.

Lake Gore was surveyed (after a high level flight to see where birds were concentrated) by an anticlockwise circuit and a clockwise circuit and the average of these counts was used. This was followed by 10 transects across the lake at intervals of about 250 metres. The tear-shaped peripheral wetlands east of Lake Gore were surveyed by one transect, as was the Dalyup channel and the ovoid wetland to its south. Two transects were flown over the Carbul wetlands and these were scored separately. A single circuit was flown counter-clockwise over Quallilup Lake, then the flow-through system was flown twice with several transects each time.

February 2012 ground counts

Ground counts were undertaken as per Table 4.

For the February 2012 ground counts we changed the order in which the Warden wetlands were surveyed, so that, for the first time, all of the Warden wetlands were surveyed over two days (with the exception of the Neridup wetlands) rather than three, with all of the larger wetlands (except Lake Warden) surveyed on one day. So, on the 14th February, the Bandy Creek, North Wheatfield, Six Mile, North Windabout, Warden and Bukenerup suites (which were mostly dry) were surveyed. On the 15th, the Ewans, Mullet, Merivale, Station, Gun Club, Wheatfield, Woody, Windabout and Pink Lake suites were surveyed. This meant that we made a single count of most of the major wetlands in the system (except Lake Warden) while accounting for bird movements between wetlands. North Wheatfield had about 900 ducks on the 14th, so to check whether there had been significant overnight movements these wetlands were briefly checked on the 15th. There appeared to have been no significant overnight movement of ducks off North Wheatfield.

Table 4. Details of ground counts undertaken in February 2012

Wetland Suite Name	Observers	Date	Comments
Neridup Suite	AP, DC and KQ	13/02/2012	Most wetlands dry, wetland A with water
Bandy Creek Suite	KQ	14/02/2012	Most wetlands dry, wetlands A and B with water
Ewens Lake	DC	15/02/2012	
Mullet Lake	DC	15/02/2012	Excluding Merivale wetlands (those between Mullet Lake and Merivale Road)
Station Lake	DC	15/02/2012	
Merivale Suite	DC	15/02/2012	
Gun Club wetlands	DC	DRY 15/02/2012	Dry
Wheatfield Suite	AP, KQ, JL	15/02/2012	By boat and on foot for satellites and Coramup Channel
North Wheatfield Suite	AP	14/02/2012	
Woody Suite	AP, KQ, JL	15/02/2012	By boat and on foot for satellites
Windabout Suite	AP, KQ, JL	15/02/2012	By boat and on foot for satellites
North Windabout Suite	AP, DC and KQ	DRY 14/02/2012	Dry
Six Mile Hill Suite	AP, KQ	DRY 14/02/2012	All dry

Lake Warden Suite	AP, KQ, DC	14/02/2012	Walked entire circumference of lake. Satellite wetlands B and D not surveyed but seen to be dry from air
Burkenup Suite	AP	14/02/2012	Almost dry
Pink Lake	DC	15/02/2012	Spotted from salt works
Lake Gore Suite including Dalyup channel and wetland to south of channel	AP, SD	16/02/2012	Spotted from north and south of Dalyup Channel, then walked from Dalyup channel to southern shore, then spotted from western and northern shores.
Carbul Lakes	AP, SD	DRY 16/02/2012	Carbul dry, Kubitch and Gideon with water
Quallilup Lake	DC, KQ	16/02/2012	By boat
Kubitch to Quallilup flow-through	DC, KQ	16/02/2012	By boat in southern extent, then walked most of the length of flow-through due to low water level

February 2012 aerial counts

An aerial survey of all Warden and Gore system wetlands was undertaken on 14 February 2012. This involved two observers, one in the rear of the plane looking to the left (DC) and one in the front (AP) looking to the right. Figure 8 show the GPS track recorded during the aerial survey of the Warden wetlands.

The shore and near-shore areas of Lake Gore were surveyed by one anti-clockwise circuit and one clockwise circuit about 50 metres in from the edge, followed by eight transects across the middle of the lake The transects allowed complete coverage of the middle of the lake with each observer surveying about 150 metres either side of the plane (i.e. 300 metre transects). The data suggests we were not recounting birds on consecutive transects. Birds near the edges of the lake were ignored during these transects. The Dalyup channel near Lake Gore and the wetland to its south were surveyed by three transects and a single run was made over the mostly dry peripheral wetlands on the eastern side of Lake Gore. The three Carbul lakes were also surveyed by one to three transects per wetland. Quallilup Lake was surveyed by a single anti-clockwise circuit. The Quallilup-Kubitch flow-through was surveyed by four east-west transects plus a flight up the channel.

Pink Lake was surveyed by a single anti-clockwise circuit following the water-line. Lake Warden was surveyed by one near shore anti-clockwise circuit and an anti-clockwide circuit. It was obvious that there were no birds in the middle of the lake so transects were not flown. The Windabout, Woody and Wheatfield Suites were each counted by several transects. Station, Mullet and Ewans lakes were surveyed separately with 3 to 4 transects per lake, followed by a couple of flights over the mostly dry Neridup and Bandy Creek wetlands.

Figure 8. GPS track (red lines) recorded during the aerial survey of the Warden system wetlands in February 2012.

Data analysis

Consensus abundance estimates

Neither aerial surveys nor ground counts provide complete and accurate waterbird abundance data, especially where multiple wetlands are being surveyed. Aerial counts of many wetlands can be undertaken within a few hours, largely eliminating problems of waterbird movement between wetlands. However, aerial surveys can miss some species and/or provide only rough counts of others. More accurate counts can be made at a single wetland on the ground, but counts of multiple wetlands over a period of days can result in inaccuracies due to bird movements between wetlands.

In an attempt to reconcile aerial and ground counts to give a single best estimate of abundance, a 'consensus' estimate of the numbers of each species present across the Warden and Gore suites was calculated for each species on each survey using the following guidelines. These consensus figures were used only for total counts at the major group level: ducks, shorebirds etc.

The rules used to calculate consensus figures are presented in Pinder *et al.* (2012).

Multivariate analyses

Ordinations are a way of graphically showing how similar the overall composition of waterbird communities was between surveys (across or within wetlands). These analyses reduce presence/absence or abundance data of multiple species down to a single value that represents the overall similarity between two surveys. An ordination graph attempts shows each survey as a symbol and attempts to place them so that the distance between two surveys on the graph is proportional to their similarity. The extent to which an ordination achieves this is indicated by the stress value (more stress = less success, with stress values under 0.2 desirable). Two and three dimensional non-hybrid multidimensional scaling (nMDS) ordinations were performed using Primer v6 (Primer-E Ltd 2008) on either presence/absence data or abundance data (the latter either raw or square root transformed). Ordination graphs do not have meaningful axis scales as it is only the relative distances between samples (=surveys) that is important. These ordinations used similarity matrices calculated using Sorenson (for presence/absence) or Bray-Curtis (for abundance) dissimilarity indices. Square root transformation of counts reduces the influence of high abundance species on the similarity between surveys. Permanova+ (an add-on to Primer) was used to examine whether groups of surveys were statistically dissimilar to one another (e.g. spring

versus summer surveys). SIMPER analyses (in Primer) were used to identify which species best discriminate two groups of surveys. BVSTEP analyses (also in Primer) are used to identify which species are most highly correlated with similarities in overall waterbird community composition between surveys.

Comparisons between surveys undertaken in the 1980s with the current survey program

A number of comparisons between surveys since 2006 and surveys undertaken in the 1980s by Birds Australia/DEC (then RAOU/CALM), reported in Jaensch *et al.* (1988) have been made in this report. It should be kept in mind that the 1980s surveys may not have been as thorough as those undertaken in recent years. For most wetlands, the 1980s surveys were done from multiple vantage points on the edge of the wetlands, rather than by traversing the whole wetland on foot or by using a boat (although Windabout Lake was often surveyed by boat). Subtle differences between these two periods should probably therefore be viewed with caution, but some analyses revealed major differences in composition and abundance that are very unlikely to be due to differences in survey methods. Small differences in diversity and numbers of shorebirds, in particular, should be viewed with caution.

RESULTS AND DISCUSSION

In this report, aerial counts are often demoted by an 'A' and ground counts by a 'G', e.g. A109/G110 for chestnut teals at Lake Warden in November 2010.

Waterbird data for each wetland suite for surveys between October 2006 and February 2012 are provided in Appendix 3 and data for individual wetlands for surveys between November 2009 and February 2012 are provided in Appendix 4.

Warden wetlands

Richness and composition

Fifty two species of waterbird were recorded using wetlands in the Warden system over spring/summer 2011/12. Forty seven were recorded in December 2011 and 44 in February 2012, with 39 present in both seasons. Richness for each of these surveys and the combined spring/summer richness are about average for recent years.

Figure 9 shows the number of species within each major group of waterbirds recorded in Warden wetlands since October 2006. Species richness has been remarkably stable in recent years, varying between 42 and 47, with the exception of October 2006 when only 35 species were recorded, probably due to the more limited survey in that year. The number of species within each major group of waterbirds has also remained fairly stable. The number of shorebird species has been most variable with counts between 9 and 17 since 2006.

Notable records and counts for the December 2011 and February 2012 surveys are as follows:

- A higher than average number (245) of straw-necked ibis, all counted on the dead trees around the Bukenerup wetland in December 2011. Previous counts of this species on the Warden wetlands since 2006 have averaged about 100.
- Five Australian spotted crakes on the North Wheatfield wetlands in December 2011. Thirteen spotted crakes were then seen in February 2012, with nine on the largest of the Neridup wetlands and four on the Merivale wetlands north of Mullet Lake. Another small hen was seen in February 2012 on the eastern wetland of the North Wheatfield suite. Spotted crakes were not seen during surveys between 2006 and Feb 2011. There is potential for greater numbers of crakes around the central Warden wetlands if water levels remain low and fringing sedges return, as they are starting to at Lake Wheatfield. Australian spotless crakes were seen near the golf course on Windabout Lake in February 2008 and February and November 2010 and at Lake Wheatfield in February 2008.

- Higher numbers of shorebirds other than banded stilt (1529) were counted in February 2012 than during all other counts since 2006. Almost as many (1436) were counted in February 2008, whereas previous February counts have been under 1200. Spring shorebird counts (excluding banded stilt) have always been ≤ 600.
- February 2012 counts of several shorebird species are records for surveys undertaken since 2006. These are red-necked stints (919), sharp-tailed sandpipers (152), red-capped plovers (117), hooded plovers (81) and masked lapwings (44). The 59 hooded plovers and 135 sharp-tailed sandpipers in December 2011 were also relatively high counts. Most of these birds were counted on lake Warden and/or Windabout Lake, their numbers most likely reflecting reduced water depths.
- Three wood sandpipers were seen on the Wheatfield to Woody Channel (near Woody Lake) in February 2012. The only previous records since 2006 are 2 and 3 individuals on the Bukenerup wetland in February and November 2008 respectively.
- The sighting of a terek sandpiper on Lake Warden in December 2011 is the first time this species has been seen during the current monitoring program. There were only two records of single individuals during the 1980s surveys (at Mullet Lake and Lake Warden).
- The number of coots (19) was very low in February 2012 compared to the average for previous February and spring ground counts (410 and 258 respectively), with previous low counts being February 2011 (49) and December 2011 (122), suggesting a decline in coot abundance on Warden wetlands in the last couple of years. While this could be associated with declining lake depths on the central wetlands (where they were most abundant), depths have not declined to such an extent that it should have greatly affected coots.
- The fairy tern seen over Windabout and Warden lakes (possibly the same individual) in December 2011 is the second record since 2006; the other being one flying over Windabout Lake in the previous February.

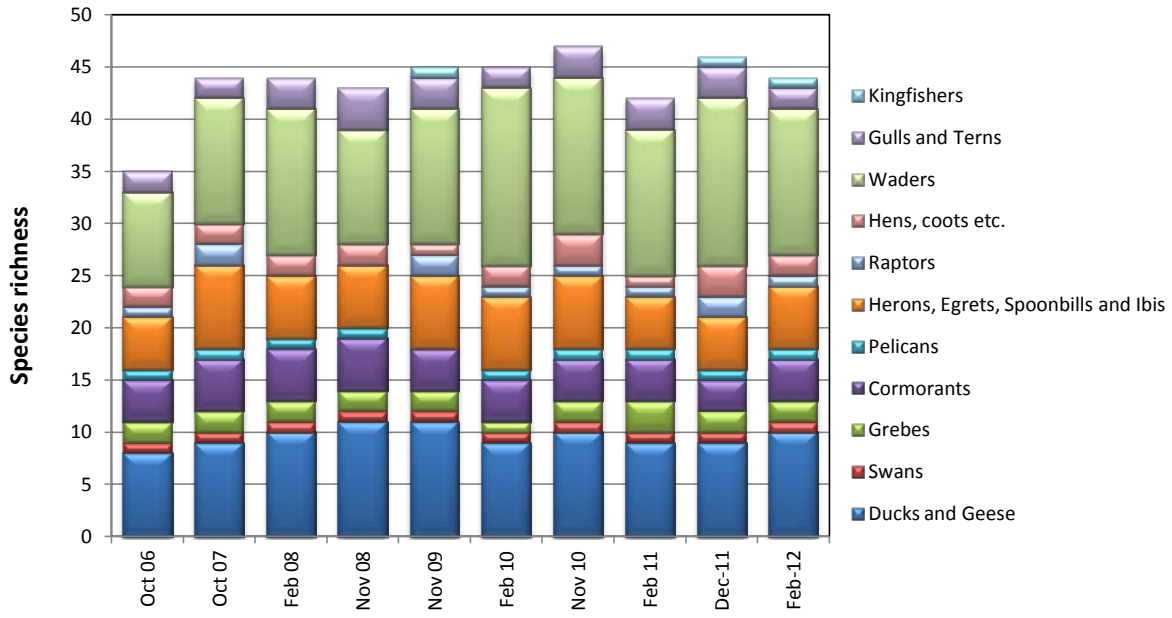

Figure 9. Richness of waterbirds in the Warden system wetlands from October 2006 to February 2012, combined from aerial and ground counts.

Abundance

Waterbird abundances from the aerial and ground counts in December 2011 and February 2012 are presented n Table 5. They are also provided along with all of the other October 2006 to February 2012 ground and aerial counts by wetland suite as a separate electronic appendix. Figure 10 shows waterbird abundance (calculated by combining aerial and ground counts, as detailed in the Methods section and in Pinder *et al.* (2012)) by major taxonomic group across the Warden wetlands for the period October 2006 to February 2012.

Total consensus abundance estimate for December 2011 (8373) was about average for spring counts of waterbirds on Warden wetlands since 2006 (8667). The number of shorebirds (1289) was also about average, except when banded stilt are ignored, then the December 2011 shorebird count of 871 was higher than the spring average of 640.

The total consensus waterbird count for February 2012 (13230) was much higher than the two previous summer counts of 6649 in February 2010 and 7256 in February 2011, but 15% lower than for the February 2008 count of 15764. If banded stilts are excluded (because they accounted for nearly a quarter of birds counted in February 2008), then the 2012 count of 12719 birds is about the same as the February 2008 count (12244). The number of ducks in February 2012 was particularly high (8840) but see below for discussion of problems reconciling duck numbers for the aerial and ground counts.

Table 5. Total abundances of waterbirds across the Warden wetland system from aerial and ground counts in December 2011 and February 2012.

Species	December 2011 aerial counts	December 2011 ground counts	February 2012 aerial counts	February 2012 ground counts
Blue-billed Duck	0	0	0	1
Musk Duck	74	188	98	293
Freckled Duck	0	0	0	0
Cape Barren Goose	0	6	42	6
Australian Shelduck	2234	2515	2362	2350
Australian Wood Duck	0	0	0	0
Pacific Black Duck	335	736	516	2676
Australasian Shoveler	15	33	0	55
Grey Teal	935	1136	2588	4054
Chestnut Teal	0	148	25	377
Pink-eared Duck	30	0	0	6
Hardhead	250	165	0	2
Unidentified duck	340	0	1925	0
Black Swan	808	1014	1253	1253
Hoary-headed Grebe	52	321	0	104
Australasian Grebe	0	0	0	0
Great Crested Grebe	0	3	0	11
Darter	0	0	0	6
Little Pied Cormorant	7	10	2	4
Pied Cormorant	0	0	0	0
Little Black Cormorant	502	732	105	268
Great Cormorant	0	2	1	0
Unidentified Cormorant	0	0	0	0
Australian Pelican	29	32	89	123
White-faced Heron	32	49	20	62
Great Egret	12	18	42	47
Nankeen Night Heron	0	0	0	1

Little Egret	0	0	0	0
Glossy Ibis	0	0	0	0
Australian White Ibis	4	10	0	23
Straw-necked Ibis	3	245	0	5
Yellow-billed Spoonbill	63	32	56	62
White-bellied Sea-eagle	0	1	0	0
Swamp Harrier	1	1	0	1
Australian Spotted Crake	0	5	0	13
Spotless Crake	0	0	0	0
Black-tailed Native Hen	0	2	0	0
Eurasian Coot	0	122	8	19
Unidentified hens (not crakes or coots)	0	0	0	0
Bar-tailed Godwit	0	1	0	1
Marsh Sandpiper	0	0	0	1
Common Greenshank	61	115	24	121
Wood Sandpiper	0	0	0	3
Common Sandpiper	0	14	0	11
Ruddy Turnstone	0	0	0	0
Red-necked Stint	0	38	0	919
Pectoral Sandpiper	0	0	0	0
Sharp-tailed Sandpiper	0	135	0	152
Curlew Sandpiper	0	31	0	0
Terek Sandpiper	0	1	0	0
Black-winged Stilt	70	37	25	42
Banded Stilt	560	418	574	511
Red-necked Avocet	144	334	14	14
Grey Plover	0	1	0	0
Great Knot	0	0	0	0
Red-capped Plover	0	47	0	117
Greater Sand Plover	0	0	0	0
Lesser Sand Plover	0	1	0	0
Black-fronted Dotterel	0	7	0	23
Hooded Plover	0	59	0	81
Red-kneed Dotterel	0	0	0	0
Banded Lapwing	0	0	0	0
Masked Lapwing (southern)	6	17	0	44
Unidentified wader	32	0	319	0
Silver Gull	214	414	375	363
Gull-billed Tern	0	0	0	0
Fairy Tern	0	2	0	0
Caspian Tern	0	2	0	16
Crested Tern	0	0	0	0
Whiskered Tern	0	0	0	0
Pacific Gull	0	0	0	0
Unidentified terns	0	1	0	0
Sacred Kingfisher	0	1	0	1

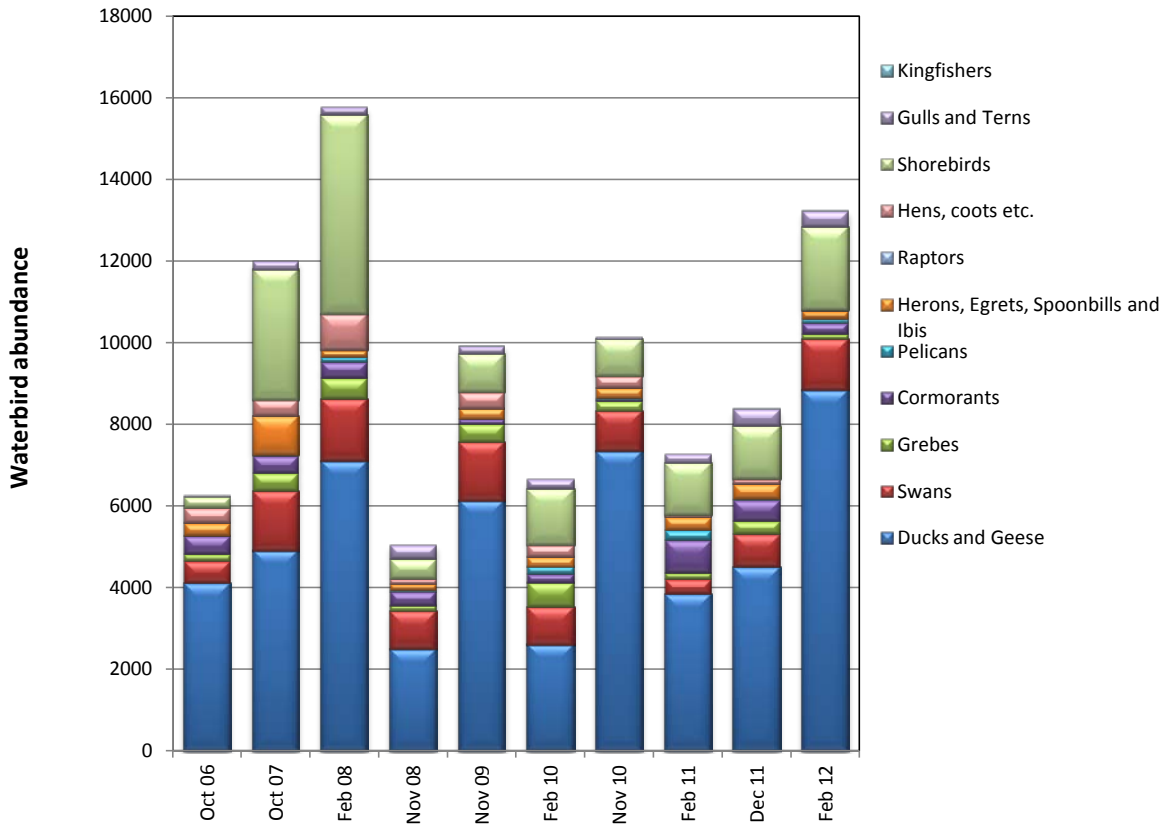

Figure 10. Consensus abundance of waterbirds in Warden system wetlands October 2006 to February 2012.

December 2011

Total aerial and ground counts for the Warden wetlands in December 2011 were 6813 and 9202 respectively (Table 5). Almost all waterbird groups had higher ground counts than aerial counts, with the largest discrepancies being for ducks (A4213/G4927) and shorebirds (A873/G1256). A consensus estimate for total waterbird abundance is 8373 (Figure 10), using aerial counts for 15 species (including most ducks, herons and cormorants) and ground counts for 32 (including all shorebirds except for black-winged stilts which were more abundant on Lake Warden during the aerial survey).

As for previous surveys, shelduck (A2234/G2515) were the most abundant duck, mostly occurring on Lake Warden (A1356/G1697) and the larger eastern wetlands (A468/G577). Grey teal (A935/G1136) and Pacific black duck (A335/G736) made up most of the rest. Comparisons of aerial and ground counts suggest the black ducks and grey teal were moving between wetlands. Thus, during the aerial survey no black ducks were seen on Mullet or Station and only 19 grey teals were seen, whereas on the ground 127 black duck and 271 grey teal were counted on these wetlands. Otherwise, both of these species were spread across most of the larger wetlands other than Lake Warden. Chestnut teal were not identified from the air (some of the aerial counts of grey teal would be this species) but on the ground 148 were spread across most of the large wetlands. Australasian shovelers (A15/G33) were almost all on the eastern wetlands, other than 2 on Lake Wheatfield during the ground survey. Thirty pink-eared ducks were seen on the Lake Wheatfield suite from the air but were not seen from the ground. Counts of hardheads were also higher from the air (250) than on the ground (165), with most occurring on Wheatfield, Woodie and the North Wheatfield wetlands. Six Cape Barren geese were on the golf course south of Windabout Lake.

The number of swans appears to have been underestimated from the air on the large eastern wetlands (A630/G841) whereas the surveys matched for Windabout (A129/G125). A few were also seen on the Neridup and Bandy Creek wetlands (A40/G29).

Hoary-headed grebes (A52/G321) were mostly on Windabout (A50/G226), with smaller numbers on North Wheatfield, Mullet, Ewans, Station and one of the Bandy Creek wetlands. The single great-crested grebe on Mullet Lake and another two on Lake Wheatfield represent a relatively low count for this species on Warden wetlands.

While darters are not normally present in large numbers on the Warden wetlands, their absence in December 2011 was unusual. The numbers of little pied cormorant (A7/G10, mostly on Windabout Lake) and great cormorant (A0/G2 on Lake Wheatfield and Woody Lake) were also low but these are also never very abundant on the Warden wetlands (average 29 and 11 respectively for previous 2006+ surveys). By contrast, the 502 little black cormorant is more than has been seen on the Warden wetlands during most recent surveys (average 296). Most of these were on the three larger central wetlands (Wheatfield, Woody and Windabout) and the higher ground count (Table 5) was a result of double counting a flock moving between Woody and Windabout.

Twenty nine pelicans were counted from the air (almost all on Windabout Lake).

Most of the white-faced heron (A32/G49) were on the Neridup and Bandy Creek wetlands, with the extra ground counts almost certainly due to overnight movement of 17 herons between these two suites. Great egrets (A12/G18) were almost all using the central wetland suites. The count of Australian white ibis was taken to be 7 (the number seen together at Woody Lake) rather than the aerial/ground totals of 4 and 10. Only three straw-necked ibis were seen from the air (on Lake Warden and Pink Lake) whereas 245 were perched in dead trees on the Burkenup wetland during the ground count. Sixty one yellow-billed spoonbills were seen on the western wetland of the North Wheatfield Suite from the air and another two were counted on Woody and Wheatfield lakes. On the ground, only 32 were counted in total and most of these were on Wheatfield and Woody lakes.

One swamp harrier was hunting over the Neridup and Bandy Creek wetlands.

Five Australian spotted crake were observed at close range moving in and out of sedges on the western shore of the western North Wheatfield wetland. These were the first records of this species in the current monitoring program, though some were also seen in February 2012 (see below). Spotless crakes have been seen on Windabout and Wheatfield in recent years and both species were occasionally present on Warden wetlands during the 1980s (Jaensch *et al.* 1986). Two black-tailed native hens were seen; one on one of the gun club wetlands and one on the western North Wheatfield wetland.

There have been fewer Eurasian coots on Warden wetlands in the last couple of years than there were from 2006 to 2010. In December 2011, 122 were counted on the ground (none seen from the air), with 37 on Ewans Lake and 85 on Lake Wheatfield.

Sixteen shorebirds were present on the Warden wetlands in December 2011. This is the second highest number of shorebird species since 2006, with the highest being February 2010. The most abundant species were red-necked avocet (A144/G334), banded stilt (A560/G418), common greenshank (A61/G115), sharp-tailed sandpiper (A0/G135). All of the red-necked avocets and banded stilt were on Lake Warden. Almost all of the sharp-tailed sandpipers were on Station Lake (125) but 10 were present on one of the Windabout Lake satellite wetlands (WRP010C). As is usual, common greenshank were more dispersed, although there was a concentration on the Bandy Creek wetlands (A40/G0) and Ewans Lake (A4/G64) and Windabout wetlands (A14/G13). The count of 59 hooded plovers (almost all on Lake Warden) is a record for the Warden wetlands in recent years, though exceeded by the February 2012 count of 81 (mostly on Mullet lake and Lake Warden).

February 2012

Total aerial and ground counts for the Warden wetlands in February 2012 were 10463 and 14242 respectively, which is the largest discrepancy between aerial and ground counts since the current monitoring program began in 2006. A third of this discrepancy is accounted for by the 1352 small shorebirds missed from the air. Most of the remaining discrepancy of 2427 birds is associated with the very large number of ducks present on the Warden wetlands. There were many thousands of ducks present on the central wetlands (Windabout, Woody

and Wheatfield lakes) and during the aerial survey these were repeatedly taking to the air, swirling around and landing in different combinations and on different parts of the wetlands, making counting and identification difficult. The aerial and ground counts of Australian shelduck, which were not as flighty, were remarkably close (A2362/G2350), as were the counts of black swans (A1253/G1253). However, ground counts of teals and black ducks totalled 7107 whereas only 5054 (including unidentified ducks) were counted from the air. While there is some uncertainty in numbers, the impression of the counters was that there were many more ducks present on these wetlands than has been recorded since 2009 (when the current team of observers took over the counts). For this survey, we generally consider the ground counts to be more reliable. However, for the consensus counts of teals and black ducks we have used their proportional representation in the ground counts multiplied by the average of the combined aerial and ground counts for teals, black ducks and unidentified ducks. This gives a value for total waterbird abundance of 13320.

The largest differences between ground and aerial counts were for Pacific black ducks (A516/G2676), grey teal (A2588/G4054) and chestnut teal (A25/G377). These differences are partially offset by 1925 unidentified ducks, almost all of which would have been these species. Ducks with low abundance (such as pink-eared ducks and hardheads) are extremely difficult to spot amongst large mobile flocks of teals and black ducks from the air.

Wetlands with largest numbers of ducks were Ewans (A1035/G1365), Wheatfield (A1018/G1803), North Wheatfield (A877/G902), Woody (A1322/G550), Windabout (A1334/G2755) and Warden (A524/G876). Grey teals, Pacific black ducks and Australian shelducks were by far the dominant species on all these wetlands. Musk ducks (A98/G293) were mostly on Mullet Lake (G225), Wheatfield (G40) and Windabout (G16). The only hardheads (A0/G2) and blue-billed ducks (A0/G1) were on Wheatfield. Australasian shovelers (A0/G55) were distributed across several of the larger wetlands.

Black swans were most abundant on Ewans (A350/G335), Mullet (A172/G303), Station (A342/G274) and Windabout (A374/G338).

Most of the 104 hoary-headed grebes (seen only from the ground) were on Windabout (62) or Station Lake (18), with a few on Ewans, Mullet, North Wheatfield and Wheatfield. Great-crested grebes were also present on three of these wetlands: Wheatfield (4), Mullet Lake (2) and Windabout (5).

There were only six darters seen on the Warden wetlands, all on Wheatfield and only four little pied cormorants (two each on Ewans and Woody Lake). Little black cormorants (A105/G268) were mostly on the North Wheatfield wetlands (A100/G0), Windabout (A5/G218) and Wheatfield (A0/G46), with four also seen on Woody during the ground survey. A great cormorant was counted from the air over Wheatfield but none were seen from the ground.

Australian pelicans (A89/G123) were present on several wetlands, but most were on Windabout (A49/G66), Wheatfield (A20/G33) and Ewans (A10/G13).

Most of the white-faced herons (A20/G62) were on the Merivale wetlands (A0/G14) and Windabout Lake (A1/G27) and almost all of the great egrets (A42/G47) were on Windabout (A37/G36). One nankeen night heron was seen at Windabout. The Australian white ibis (A0/G23) were spread over Wheatfield, Woody, Windabout and the western North Wheatfield wetland whereas all of the straw-necked ibis were using the eastern North Wheatfield wetland (A0/G5). Almost all of the yellow-billed spoonbills were also on Wheatfield (A24/G33) and the western North Wheatfield wetland (A30/G29).

One swamp harrier was seen flying over the western North Wheatfield wetland.

Australian spotted crakes were observed on one of the Neridup wetlands (A0/G9) for the first time since these surveys began in 2006. These were moving in and out of sedges and along the exposed mudflat on the south-eastern shore of wetland Neridup wetland A. Four more were seen around the Merivale wetlands. These are probably always present in the Warden system but are secretive and have only been observed once before (in November 2011 on the western North Wheatfield wetland). There are also three recent records of spotless crakes at Windabout (February 2008, February 2010 and November 2010) and at Wheatfield (February 2008). Eurasian coots (A/8/G19) were unusually low in abundance in February 2012: 18 on Wheatfield and 1 on

Windabout. Other surveys since 2006 have usually recorded more than 200 across the Warden system (average ground counts of 280), mostly on the larger of the central wetlands.

Fourteen species of shorebirds were counted in February 2012. Significant records were a marsh sandpiper on Neridup wetland A, a wood sandpiper on Lake Wheatfield and a bar-tailed godwit on Lake Warden. Total abundance of shorebirds (G2040) was the third highest since 2006 and the number of shorebirds other than banded stilt (G1529) was the highest since 2006. The abundances of red-necked stints, hooded plovers, sharp-tailed sandpipers, red-capped plovers, and masked lapwings were also the highest on record during this current monitoring program. The most abundant species were banded stilt (G574), red-necked stint (G919), common greenshank (G121), sharp-tailed sandpiper (G152) and red-capped plover (G117). Most of the red-necked stint were on Lake Warden (768) and Station Lake (118) with a few also on Neridup wetland A (12) and the Merivale wetlands (21). All but one of the 511 banded stilt were also on Lake Warden. Common greenshank (G121) were present on most suites but with highest numbers on Ewans Lake (G29), the eastern North Wheatfield wetland (G26) and the main body of Windabout Lake (G22). Hooded plovers (G81) were mostly present on Lake Warden (G36) and Mullet Lake (G38), with single individuals on some of the Neridup and Bandy Creek wetlands and six on one of the Windabout satellite lakes (Windabout wetland F). Sharp-tailed sandpipers were split between Ewans Lake (G79) and wetland C in the Windabout Suite (G72), except for a single individual at Woodie Lake. The increase in the number and diversity of shorebirds using Warden wetlands in recent years is most likely due to the increase beach and wading habitat (especially at Lake Warden) created by declining lake depths, which is at least partly a result of the pipeline installed at Lake Wheatfield.

The count of silver gulls was the second highest since 2006 (A375/G363), with most of these on Windabout Lake (A284/G224). The only other seabirds on the Warden wetlands were 16 Caspian terns, mostly on Windabout Lake (G12).

A kingfisher was seen on wetland E of the Windabout suite.

Community composition in Warden wetlands 2006 to 2012

Figure 11 is an nMDS ordination based on square root transformed consensus abundance data for species recorded during more than two of the ten surveys between October 2006 and February 2012. The pattern identified by Pinder *et al*. (2012) of waterbird communities in February being different from those in October to December has not changed with the addition of two surveys. Similarly, the tendency of communities in more recent spring surveys (2009-2011) to be intermediate in composition between the earlier spring surveys (2006 to 2008) and all late summer surveys (2008 to 2012) is confirmed. A cluster analysis produced a dendrogram (Figure 12) that separated the three earliest spring surveys (in 2006, 2007 and 2008) from all other surveys, but no other divisions were significant.

A second ordination of just the spring surveys was performed to identify which species are associated with altered spring community composition between the 2006-2008 and 2009-2012 periods. A BVStep analysis revealed that the patterns of occurrence of five species produced a between survey resemblance matrix that was highly correlated ($r^2 = 0.95$) with the resemblance matrix based on all species. These species were grey plover, red-necked stint, Caspian tern, red-necked avocet and masked plover.

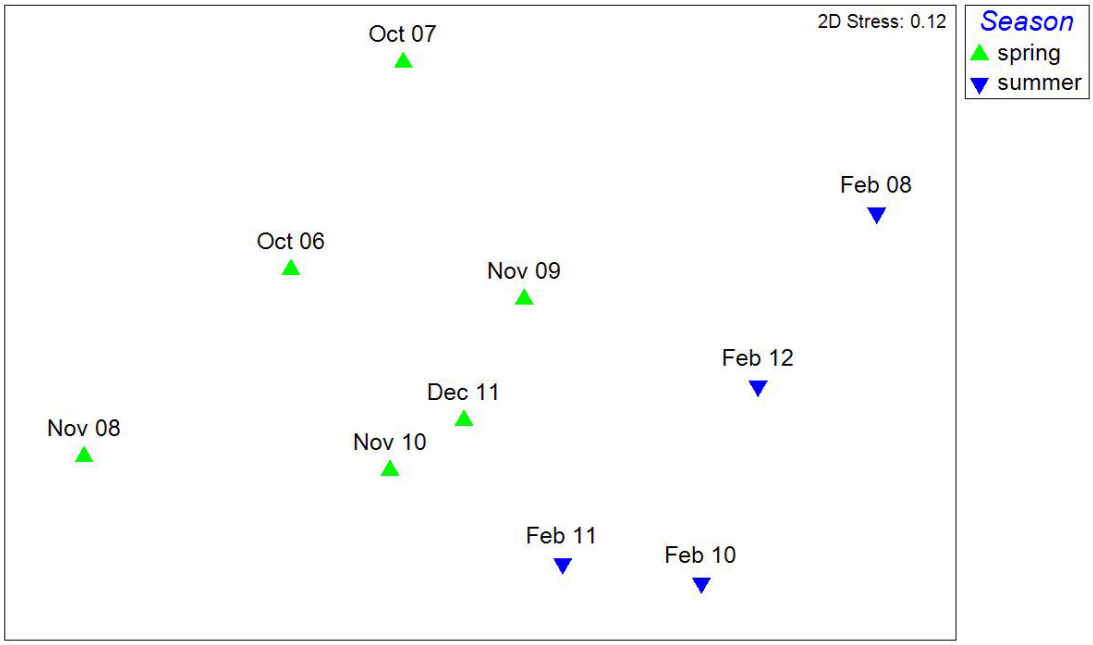

Figure 11. Two-dimensional nMDS ordination of waterbird surveys of the Warden wetlands based on square root transformed consensus abundance of species recorded more than twice.

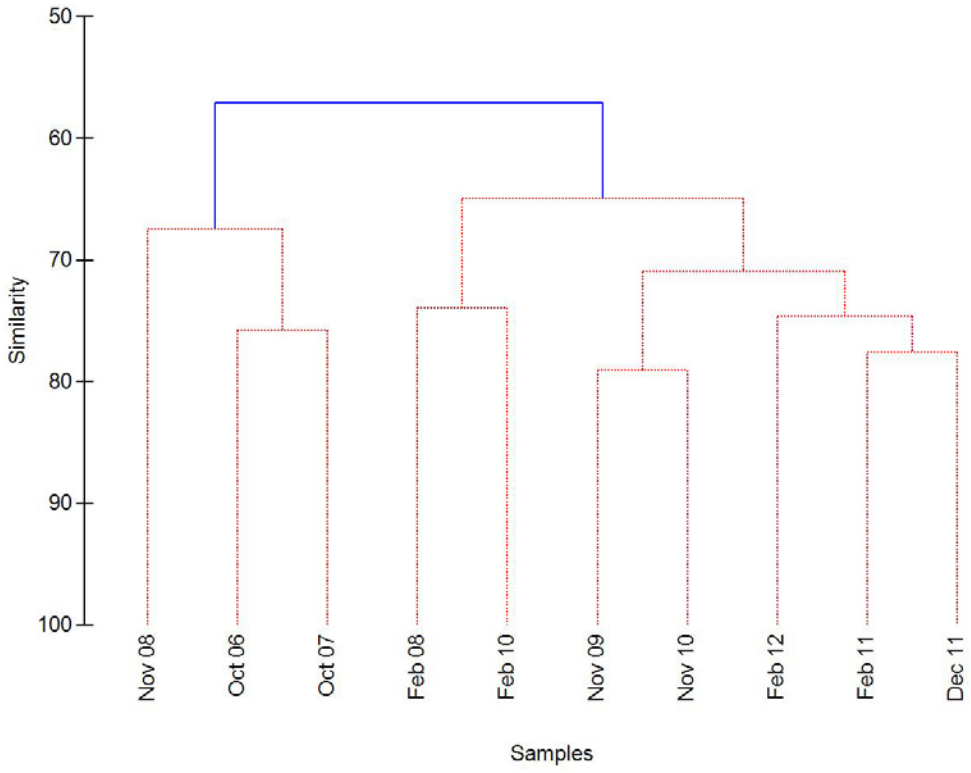

Figure 12. Cluster analysis of surveys based on square root transformed consensus abundance of species that occurred in more than one survey. Blue line connects groups of surveys with significantly different composition. Red lines connect surveys that were not significantly different in composition.

Analyses of selected wetlands of the Warden system

Since much of the management focus within the Warden Recovery Catchment is on water levels in Lake Warden and the central wetland suite, more detailed analyses of these lakes are presented below.

Lake Warden

Figure 13 shows changes in depth and salinity between November 1979 and May 2012, with timing of waterbird surveys indicated on the depth plot (red symbols). In general, Lake Warden was shallower but more variable in the 1980s (average November depth 0.92 ± 0.25 m) and salinity was higher and more variable (average 74.8 ± 20 g/L) compared to the 2000s (average November depth 2.3 ± 0.08 m and salinity 46 ± 3.3 g/L). Depth has declined dramatically since 2009 (to 0.67 m in February 2012) and by November 2011 salinity had risen to its highest measured concentration (145 g/L) since 1988.

Depth during the spring and summer surveys of the 1980s was always below 1 m (where known), except for November 1984 when depth was 1.34 m. Depths during surveys between 2006 and 2009 were all ≥ 2 m whereas the subsequent four surveys have been made while depth was declining from 1.65 m in February 2010 to 0.67 m in February 2012.

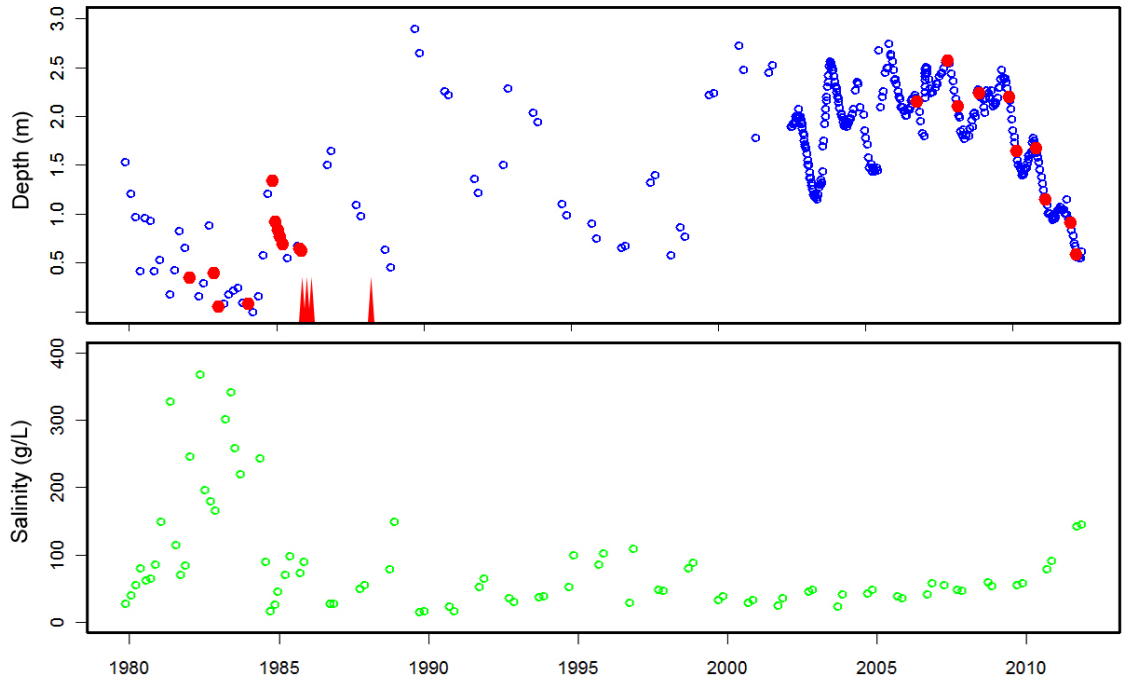

Figure 13. Depth and salinity of Lake Warden November 1979 to May 2012. Depth data from (Lane, Clarke *et al.* 2011) (Nov 1979 to Nov 2001) and from the Warden Natural Diversity Recovery Catchment monitoring program (Department of Environment and Conservation 2012). Salinity data all from Lane *et al.* (2011). Red dots on the depth graph show timing of waterbird surveys from 2006 to 2012 in relation to depth, where depth was recorded on or about the same time or could be confidently interpolated. Red marks on the X-axis of the depth plot indicate timing of four other surveys where depth was unknown and cannot be interpolated from existing depth data.

Fifty seven species of waterbird have been observed using Lake Warden during surveys in the 1980s and/or since 2006. Of these species, 45 have been recorded since 2006, of which 14 were not recorded in the 1980s.

Figure 14 and Figure 15 shows species richness and abundance during all spring and summer ground counts for the 1980s surveys (Jaensch, Vervest *et al.* 1988) and for the recent (2006+) surveys. It should be noted that survey methods have not been consistent through this period. During the 1980s, surveys were made from vantage points around the lake and it was acknowledged (Jaensch, Vervest *et al.* 1988) that surveys may not

have been complete. Surveys between October 2006 and November 2008 were also carried out using a spotting scope from vantage points around the lake, whereas a boat was used to survey the whole wetland between November 2009 and December 2011. Depth was too shallow to use the boat in February 2012 so the entire perimeter of the lake was walked. That the boat survey in 2009 did not find more species or numbers of birds than the vantage point surveys for the previous two spring counts suggests that the change in method was not a significant issue.

Richness during the 1980s was highly variable, but shorebirds were always the richest group with 1 to 10 species (5 on average). There was usually only one or two species from other waterbird groups on each date. Swans were usually present during the 1980s (often in numbers > 500) but grebes were rarely present. Spring and early summer of 1984/5 differed from other years by the presence of up to four species of duck and three species of seabird, but with no decline in shorebird richness. Depth in early November 1984 was 1.34 m and declined to only 0.7 m by the end of summer whereas November depths during other 1980s survey years were 0.1 to 0.7 m (Figure 13).

The main difference in species composition between the early 1980s and the mid to late 2000s is a virtual lack of shorebirds during the latter period: just 44 red-necked avocet in February 2008 and one common greenshank in November 2009. Total richness of other waterbird groups was occasionally as high as was recorded during much of the 1980s and ducks and grebes were occasionally richer in the mid 2000s than during the 1980s.

From February 2010 there was a sharp increase in the number of shorebird species using Lake Warden (to between 7 and 13 species) and over the last two years this has been accompanied by a decline in the richness of other waterbird groups. This increase in shorebird richness coincides with sharply declining lake depth and increasing shorebird habitat. Swans and grebes have been absent during the last two surveys whereas they were usually present between 2006 and 2008 and the number of duck species has declined. Species composition in the last few years is now more like that observed in the 1980s than during the 2000s. Increased salinity has allowed colonisation of the lake by *Artemia* brine shrimp. Previous records of brine shrimp from Lake Warden (and from Pink Lake) (1970s and 1980s) are of the endemic *Parartemia longicaudata*, so the origin of the *Artemia* is unknown. It was most likely brought in as cysts by waterbirds. Brine shrimp are a significant food source for banded stilt and may have contributed to the return of these species to the lake (albeit still in modest numbers of a few 100) in the last year. Hooded plovers are known to eat *Coxiella* snails amongst other invertebrates and seeds (Weston and Elgar 2000) and these too have been seen in abundance at Warden. *Coxiella* snails inhabit highly saline lakes and were not present (as live specimens) when sampled by Pinder *et al.* (2010) but live specimens were collected by Cook *et al.* (2007) and Cook and Farrell (2008).

During the 1980s there were usually more than 2000 birds present during surveys (average 3630), although there were three surveys with under 1000. The very high count in November 1982 (16919) was one of three counts at this wetland over 10000 for the Jaensch *et al.* (1988) project. The other two such counts (13500 two months earlier and 10700 in May 1985) are not shown because they are at times of the year not surveyed in the current (2006+) program. All other total counts not shown on Figure 15 for the same reason were <5500.

Communities were numerically dominated by ducks during the 1980s, with an average of 1840 per survey, shelduck consistently being the most abundant species and grey teal the only other duck to be present in numbers > 100 (and then only rarely). Swans were also frequently quite abundant, with ≥ 500 present on a third of the survey dates. While shorebirds were always the richest group during the 1980s they were usually less abundant than the ducks or swans. The highest abundance of shorebirds was in November 1982 when 7000 banded stilt were present. Other relatively high counts of shorebirds (January to March 1985 and March 1988) were also largely due to high numbers of banded stilt. Most other shorebirds were only present in low numbers, but red-capped plovers, red-necked stints, hooded plovers, curlew sandpipers and sharp-tailed sandpipers were occasionally present in numbers ≥100. Of these, the first three had average abundances of more than 50.

Total abundance of waterbirds was extremely low for surveys between 2006 and 2009 and composition was highly variable, dominated variously by musk duck, grey teal, hoary-headed grebes, whiskered terns or silver gulls. Highest abundance during this period was in February 2008 when 721 birds were counted from the ground, with the most numerous being musk duck, hoary-headed grebes and silver gulls. Total abundance was generally higher from February 2010, though still never exceeding the average for the 1980s (3630). The three

most recent surveys have recorded > 2000 birds, with dominant species being different in each year (including little black cormorants, shelduck, chestnut teal, silver gulls, banded stilt, red-necked avocets and red-necked stints). Shorebirds have become an increasing proportion of total waterbird abundance since February 2010, constituting 61% of total abundance in February 2012.

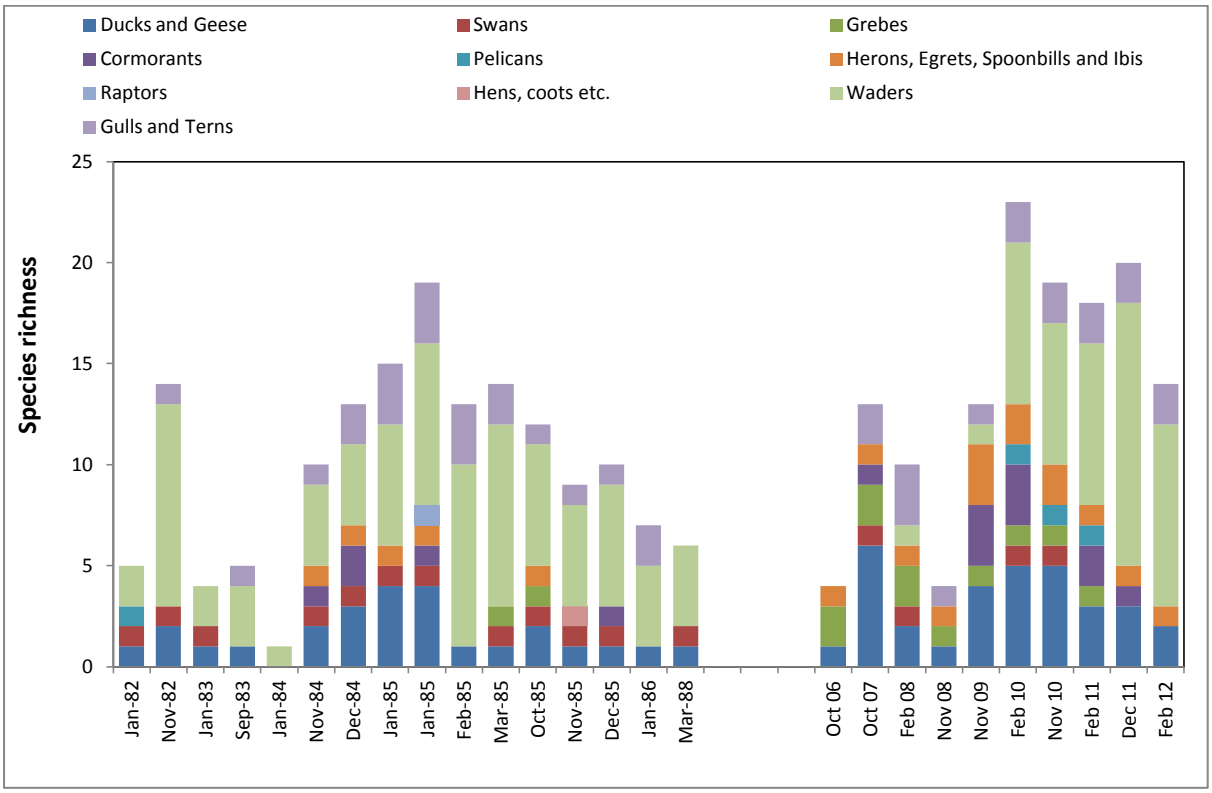

Figure 14. Richness of waterbirds on Lake Warden during the 1980s and since 2006.

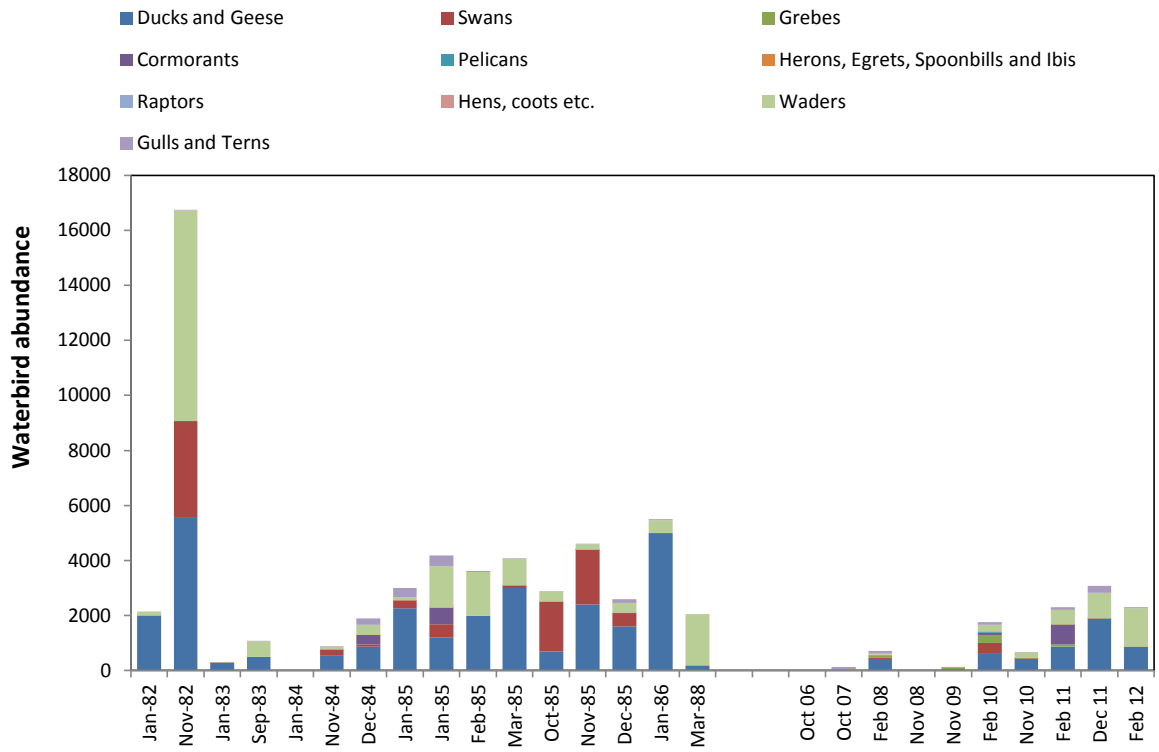

Figure 15. Abundance of waterbirds on Lake Warden during the 1980s and from 2006. All data from ground counts (some aerial counts were higher). Legend as per Figure 14.

Notable changes in the occurrence of particular waterbirds include:[1]

- Australian shelduck were always abundant during the 1980s, with most surveys recording more than 1000 and counts over 2000 to 3000 common. Surveys between 2006 and 2009 recorded between 0 and 28 shelduck, but the numbers have increased again in recent years (1697 in December 2011 and 869 in February 2012). Lower shelduck numbers in the 2000s may be related to reduced shallow water/edge loafing area compared to the 1980s and this habitat has again expanded in recent years.
- Musk duck were absent during the 1980s but present during almost all of the surveys since 2006, with more than 300 present in February 2008 and February 2010. Counts of this diving species during the last two February surveys (2011 and 2012) have been much lower at 27 and 7, perhaps reflecting the much lower depths and higher salinities in the last couple of years.
- Counts of black swans regularly exceeded 300 in the 1980s: with highest counts being 3500 in November 1982 (depth 0.4 m) and 2000 in November 1985 (depth 0.63 m). Since 2006 there has only been one count above 50 (371 in February 2010), despite depth and salinity returning to similar levels. During the mid 2000s depth may have been too high for large numbers of swans (that need to reach macrophytes on the bottom) and growth of macrophytes in the lake is probably not sufficient to attract large numbers now depth has declined.
- Hoary headed grebes were rarely present in any numbers during the 1980s (2 of 15 surveys and then only <20), whereas they were always been present in the 2000s (maximum 510 in February 2010), perhaps again reflecting greater depth (more diving habitat) and lower salinity. With declining depth

[1] Note that some abundance figures for these species quoted below are different to those cited in the same section in Pinder *et al.* (2012). This is because the earlier report used only one date from each season in each year of the 1980s dataset. In this report we have used all relevant dates (i.e. sometimes 2 dates per season).

they have been absent again for the last two surveys. Similarly, great-crested grebes were absent in the 1980s and only present between 2006 and February 2008 in the recent survey program.

- Many small shorebirds were much more abundant at Lake Warden in the 1980s than during the 2000s. Examples are 100 great knots in October 2005, several records of >100 hooded plover (maximum 240), up to 95 red knot, regularly more than 50 red-capped plover, more than 200 red-necked stint (maximum 700 in March 2008), up to 220 curlew sandpiper and 120 sharp-tailed sandpiper. Most of these species have returned over the last couple of years, including red-capped plovers (57 in February 2012), red-necked stints (768 in February 2012), hooded plovers (53 in December 2011 and 34 February 2012) and curlew sandpiper (29 in December 2011). Knots, and a few other less common small shorebirds (long toed stints, pectoral sandpipers, broad-billed sandpiper) that were also occasionally recorded in the 1980s, have not been since 2006.
- Of the larger shorebirds, red-necked avocets were often present during late spring/summer counts in the 1980s, but rarely in great numbers (maximum 77) and black-winged stilts were never present (although rarely present in other seasons). During the 2000s these species were mostly absent (just 44 red-necked avocets in February 2008) but since February 2010 red-necked avocets have been present during all surveys (average abundance 180) and black-winged stilts have been present during four of the five surveys (average 28). Banded stilt were occasionally recorded at numbers at or above 1000 (7000 in November 1982 and records of 9000 and 10000 in May 1985 and September 1982), whereas they were absent during all of the 2006 to 2010 surveys. Their numbers have increased during the three most recent surveys so that by February 2012 there were 510 present. This species can move around southern and inland Australia in large flocks in response to rainfall events and habitat availability so numbers present at any one wetland are strongly dependant on whether large numbers are in the region. This means that the numbers seen in the 1980s may not be expected again in the short to medium term. One or two bar-tailed godwits were occasionally present in the 1980s and, while they were not seen at all during the 2000s, one individual was seen during each of the last two surveys (December 2011 and February 2012). The occurrence of common greenshanks hasn't changed much: they were only present in the summer of 1984/5 in the 1980s and have only been present since 2010 during the recent surveys.
- White-faced herons are much more frequently recorded now than in the 1980s, but are not much more abundant when present.

Figure 16 is an ordination (based on square root transformed abundance data) summarising the above changes in waterbird community composition over three decades. January 1984 is excluded because only one individual was recorded and this was placed as an outlier in an earlier ordination. The graph shows that waterbird communities differed in composition between the 1980s (green diamonds) and the 2000s (blue triangles) – i.e. the symbols representing surveys in these two periods clearly form separate groups. More recently, surveys between 2010 and 2012 (light blue squares) have revealed communities gradually returning to within the range of compositions seen during the 1980s.

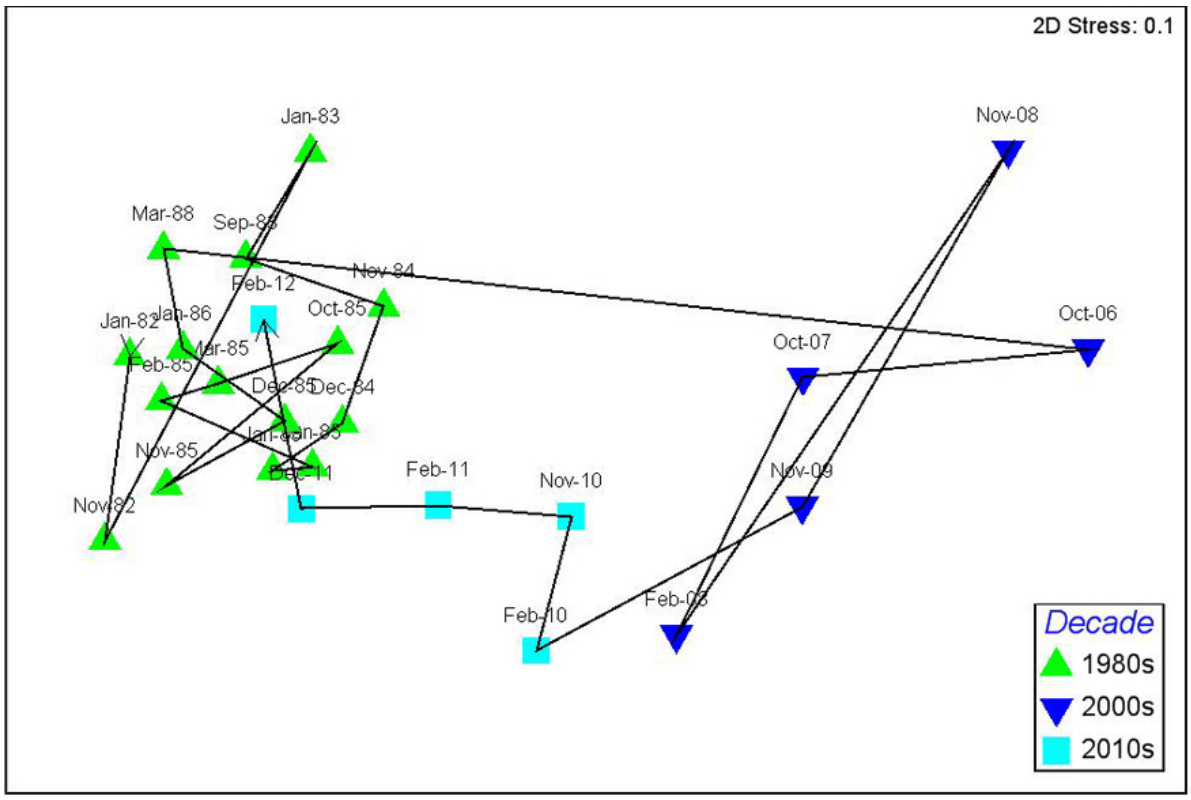

Figure 16. Two-dimensional nMDS ordination of square root transformed waterbird abundance for surveys of waterbirds conducted at Lake Warden during spring and summer between 1982 and 1988 (Jaensch et al. 1988) and between 2006 and 2012. Singleton species excluded.

The central suites (Wheatfield to Windabout)

In this section we have analysed waterbird data (ground counts only) for the three main central wetland suites: Wheatfield, Woody and Windabout and associated wetlands. Not all dates could be compared for these wetlands due to extent of wetlands surveyed on different dates. In the 1980s only the main lakes (Wheatfield, Woody and Windabout) were surveyed. From 2006 onwards the satellite wetlands near these larger lakes were also surveyed but for the first four surveys (October 2006 to November 2008) counts of the main wetland and satellite wetlands were combined. From November 2009 counts of waterbirds on the satellite wetlands were scored separately so counts from just the main lake could be compared with those from the 1980s.

Only surveys from the 1980s undertaken between October and March were used for these analyses.

A total of 64 species have been recorded from these wetlands (main lakes and satellites) during the 1980s and/or surveys conducted since 2006. Of these, 58 have been recorded since 2006, 40 were recorded in the 1980s and 30 have been recorded in both periods.

Figure 17 shows total combined ground counts for all three of the central suites, including the satellite wetlands, between 2006 and 2012. There has been substantial variability over this period, but little directional change. Ducks have always dominated abundance, although composition of these has been variable. In most years grey teal and Pacific black duck have been the most common species (average 722 and 580 respectively), but in October 2007 hardheads were the most abundant (1588 compared to an average of 91 in other years) and in November 2008 Australian shelduck were dominant (1459 compared to an average of 442 in other years). There is no temporal trend in the abundance of any of the duck species. Between 100 and 800 (average 312) Eurasian coots were usually present between 2006 and 2010 but these have been much less common (19 to 49) for the last three surveys. White-faced herons may have become more abundant, with an average of 9 per survey

between 2006 and Nov 2009 versus 20 between Feb 2010 and Feb 2012. Common greenshank has certainly become more abundant, with an average of 8 per survey between 2006 and 2009 compared to 48 between 2010 and 2012. There have been similar increases in the abundance of some other shorebirds between these two periods, including sharp-tailed sandpipers (averages of 0 and 32), common greenshank, black-winged stilt (0 versus 9), black-fronted dotterel (3.6 versus 22) and masked lapwings (0 versus 18). Sightings of hooded plover Windabout satellite wetland F in December 2011 and February 2012 are the first for the current monitoring program.

Figure 18 shows species richness for the three central wetland suites by major waterbird group between 2006 and 2012. There has been no consistent temporal trend in total richness over this time, although there have been more shorebird species since Feb 2010 and 1 or 2 fewer large wading species (herons etc.) in the last three surveys. Straw-necked ibis have not been seen for the last three surveys whereas they were always present in surveys between October 2006 and November 2011 and nankeen night heron, glossy ibis and little egrets have occurred less frequently. The reason for the decline in these large wading birds is unknown, but could be associated with the fringing trees (used as perching sites) no longer being in the water as frequently and/or changes in food resources. Spotless crakes and black-tailed native hens (with one or the other always seen prior to February 2010) have also been absent in the last three surveys.

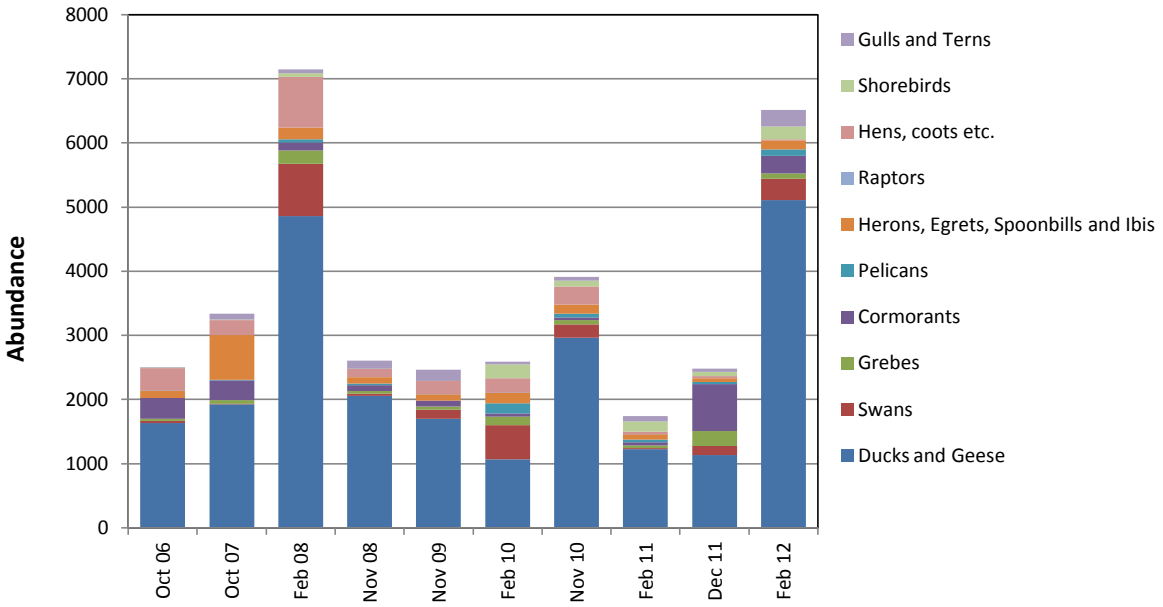

Figure 17 Abundance of waterbirds on the wetlands in the Wheatfiekd, Woody and Windabout wetland suites from 2006 to 2012.

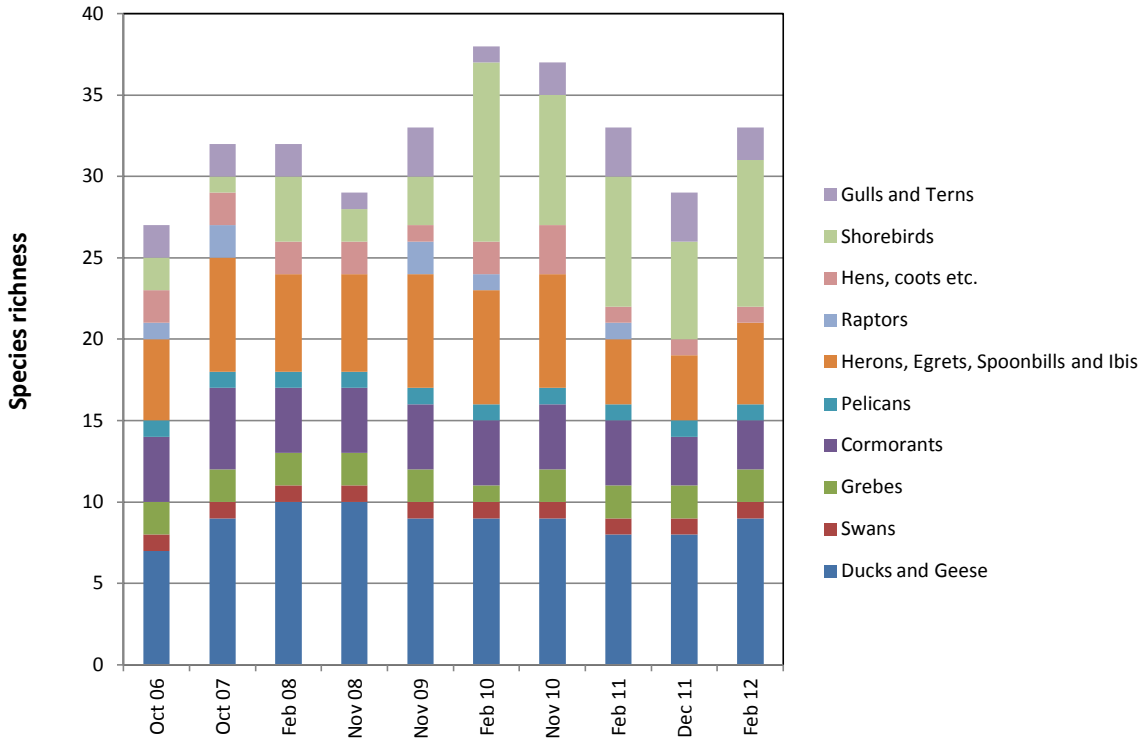

Figure 18. Richness of waterbird communities on the Wheatfield, Woody and Windabout wetlands suites from 2006 to 2012.

Figure 19 is an ordination based on waterbird community composition (square root transformed abundance) for all wetlands in the Wheatfield, Woody and Windabout suites from 2006 to 2012, with surveys coded according to whether they were undertaken in summer (circles) or spring (triangles) and prior to (red) or after (blue) installation of the Wheatfield pipeline. This ordination indicates a difference in waterbird community composition between surveys undertaken in summer compared to those undertaken in spring. There is also a suggestion of a shift in composition after installation of the pipeline, with post-pipeline surveys placed more towards the left than surveys from the same season pre-pipeline. However, ignoring season, a Permanova analysis suggested no significant difference in waterbird composition between pre-pipeline and post-pipeline surveys ($p=0.07$). There have not been enough surveys to undertake such an analysis within a season.

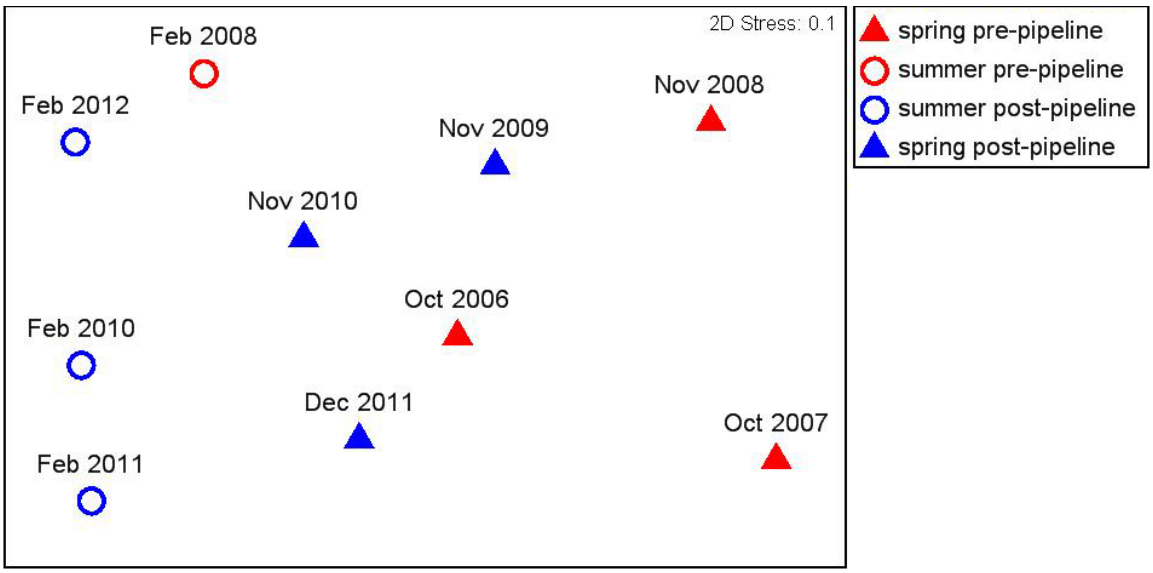

Figure 19. Two-dimensional nMDS ordination of wetland surveys of the central wetland suites (Wheatfield, Woody and Windabout including satellite wetlands) based on square root transformed abundance data from ground counts. Symbols coded according to whether the gravity-fed pipeline in autumn 2009. See Methods section for explanation of this type of graph.

Figure 20, Figure 21 and Figure 22 shows waterbird abundances from surveys carried out in the 1980s and between 2009 and 2012 at Lake Wheatfield, Woody Lake and Lake Windabout (excluding satellites). Data for 2006 to 2008 are not shown because counts for these wetlands included birds from satellite wetlands, whereas from 2009 the satellites were counted separately so could be excluded. Figure 23 shows ordinations based on square root transformed abundance data for the same wetlands and surveys.

Lake Wheatfield

An ordination (Figure 23) indicates that the composition of waterbird communities using Lake Wheatfield has changed since the 1980s. Surveys in the 1980s recorded an average of 13 species whereas surveys since 2009 have recorded an average of 25. There have been far more ducks recorded since 2009 than in the 1980s (average 835 ± 245 versus 186 ± 62). Grey teal, Pacific black duck and musk duck were consistently amongst the most abundant species in both the 1980s and since 2009, but Australian shelduck, hardhead and chestnut teal have been more common since 2009. There may have been fewer hoary-headed grebes since 2009 but abundance of this species was variable in the 1980s. Between 18 and 43 yellow-billed spoonbills have been present during all six surveys between 2009 and 2012 whereas these were never present in the 1980s. Similarly, Australian white ibis have always been present since 2009 and straw-necked ibis have sometimes been present, but neither of these species were present in the 1980s (having moved through the south-west during the 1980s and 1990s). Eurasian coots have been present during almost all surveys in both periods, but appear to be less abundant since 2009 (average 58 ± 18) compared to the 1980s (average 233 ± 56).

A higher number of shorebird species and higher abundance of shorebirds have been recorded since 2009 (average 6 species per survey) compared to the 1980s (average 2), although the more thorough surveys since 2009 may have contributed to this observation. In both periods, the most abundant and frequently observed species were black-fronted dotterel, common greenshank and common sandpiper. Several species have been recorded once or twice since 2009 but were not recorded in the larger number of surveys in the 1980s (black-winged stilt, great knots, grey plover, red-capped plover and red-necked avocets). Another five species were recorded once during the 1980s but not at all since 2009 (hooded plover, wood sandpiper, banded stilt, broad-billed sandpiper and red-kneed dotterels).

Finally, clamorous reed warblers were recorded on three occasions in the 1980s but have not been recorded on the central suite wetlands at all since 2006.

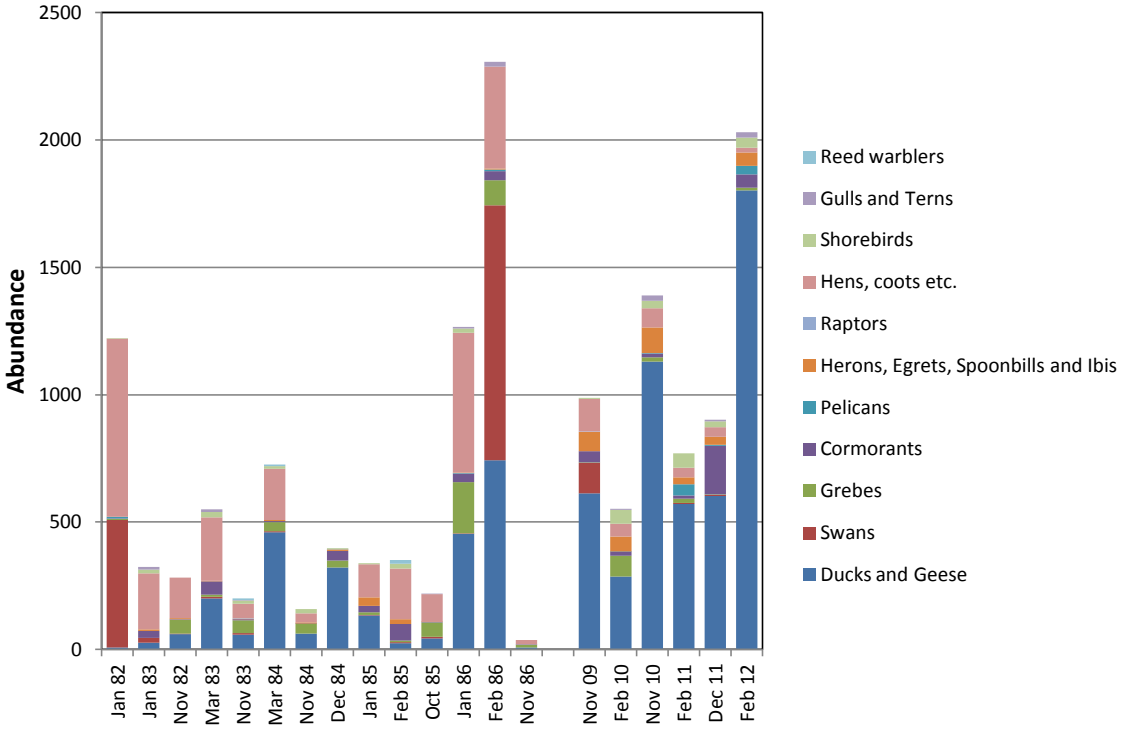

Figure 20. Waterbird abundance on Lake Wheatfield during the 1980s and between 2009 and 2012.

Windabout Lake

As for Lake Wheatfield, the ordination (Figure 23) indicates that there has been a change in community composition between the 1980s and the last six surveys. This wetland was sometimes surveyed by boat in the 1980s so results should be reasonably comparable to those obtained for the more recent survey series. Total waterbird abundance on these wetlands has generally been much higher since 2006 (average 1698 ± 513) than in the 1980s (343 ± 97). Most species of duck were either more frequently recorded (i.e. in a greater proportion of surveys) and/or were more abundant when recorded since 2009. Species with large increases in abundance were grey teal, Australian shelduck, Pacific black duck and chestnut teal. Musk duck were always seen in the 2009+ surveys but very rarely so in the 1980s. Pink-eared duck, hardhead, blue-billed duck and freckled duck have all been recorded occasionally since 2006 but were not recorded at all during the 1980s. Swans are more commonly seen now but are not necessarily more abundant when present. Hoary-headed grebes are certainly more commonly seen (all 2006+ surveys versus only 2 from the 1980s) and more abundant when present.

Little black cormorants were usually present during the 1980s but not in the numbers (>200) seen during the two most recent surveys. Darters were not seen at all during the 1980s but have been present for most of the more recent surveys. Pelicans are also now quite abundant (average 71, often on the sandspit where the Woody channel enters Windabout) whereas in the 1980s only 1 individual was seen (in 1982). Depths may have been too shallow to support many cormorants and pelicans in the 1980s but there may also have been an increase in fish abundance. White-faced heron were almost always present in the 1980s and always present since 2009, in low numbers for both periods. By contrast, great egrets were hardly ever seen in the 1980s but have always been present since 2009 (2 to 36 per survey). As for Lake Wheatfield, yellow-billed spoonbills have been present in all 2009+ surveys but were absent in the 1980s, probably also associated with more dead trees suitable for perching sites. Unlike at Wheatfield, Eurasian coots have not been more abundant since 2009 than in the 1980s. Crakes have been seen twice since 2009 but these are secretive birds and are likely to have been present (probably in larger numbers than at present) in the 1980s even though not observed.

Shorebird diversity has been higher since 2009 (average four species and as many as seven in the most recent surveys) than in the 1980s (average one species with a maximum of three). Species now regularly present but that were rare or absent in the 1980s are common greenshank, masked lapwings (since 2010) and sharp-tailed sandpipers. It may be that shorebirds were undercounted in the 1980s.

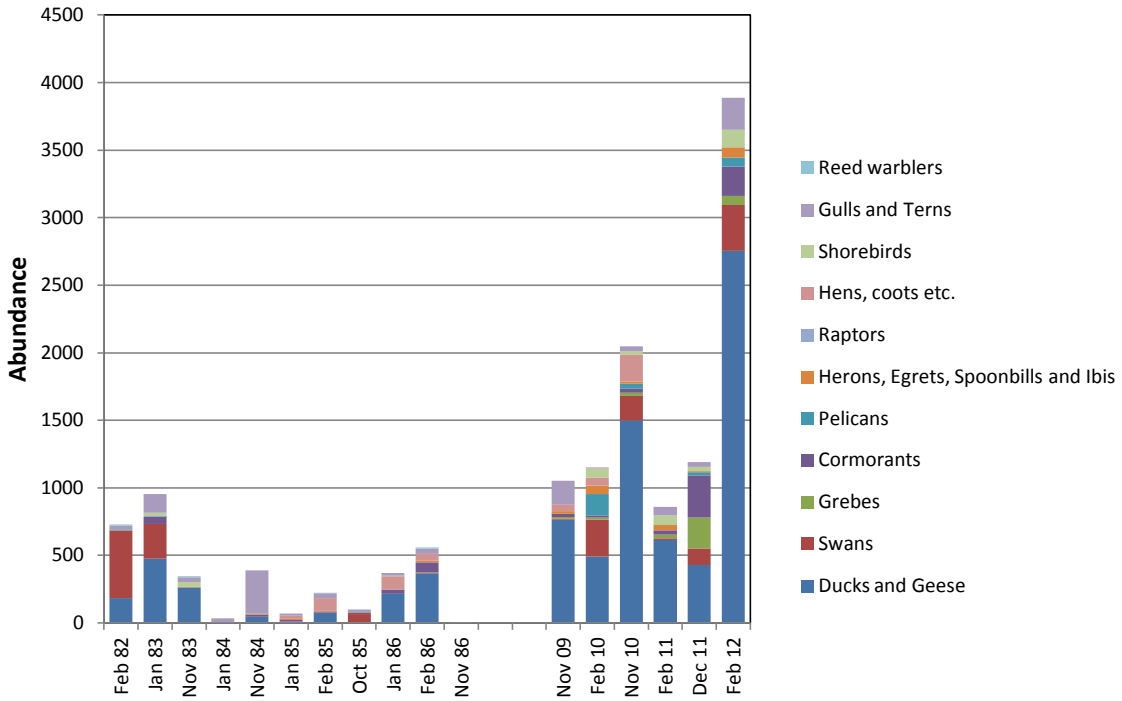

Figure 21. Waterbird abundance on Windabout Lake during the 1980s and between 2009 and 2012.

Woody Lake

The ordination analysis (Figure 23) suggested less of a change in waterbird community composition between the 1980s and the 2009 to 2012 period than is the case at Wheatfield and Woody. This is also seen from Figure 22 which shows that waterbird communities have been highly variable in both composition and abundance during both periods. Dominant species in the 1980s included swans (up to 500), Pacific black duck (200), shelduck (950), grey teal (120), little pied cormorants (120) and Eurasian coot (200), but with different combinations of these being dominant for different surveys. The swans (up to 74), grey teal (313) and pacific black duck (193) were also amongst the most numerous species in the 2009 to 2012 surveys (again not always at the same time), but shelduck and little pied cormorants were only present in very low numbers and Eurasian coots have been absent. Little black cormorants were the most numerous species in December 2011 (225). In both seasons grey teal, Pacific black duck, little pied cormorants, little black cormorants and white-faced herons have been amongst the most frequently recorded. In the 1980s, musk duck and hoary headed grebes were also almost always present but these have been rarely seen since 2009 (though they were present on some satellite wetlands). Conversely, pelicans and great egrets have usually been present during surveys conducted since 2009 but were usually absent in the 1980s.

Shorebirds haven't been particularly abundant or diverse at Woody Lake during surveys in either period. Only three species were present in the 1980s (banded stilt, common sandpiper and common greenshank) and only three of the 13 surveys recorded any shorebirds. Maximum abundance was 13 individuals (representing all 3 species) in March 1984. Shorebirds were seen in four of the six surveys since 2009, with a total of six species

across this period. Common Sandpipers, common greenshank, black-fronted dotterels and sharp-tailed sandpipers and each been recorded during three of the 2009-2012 surveys while there has only been single records of greater sand plovers and red-necked avocets.

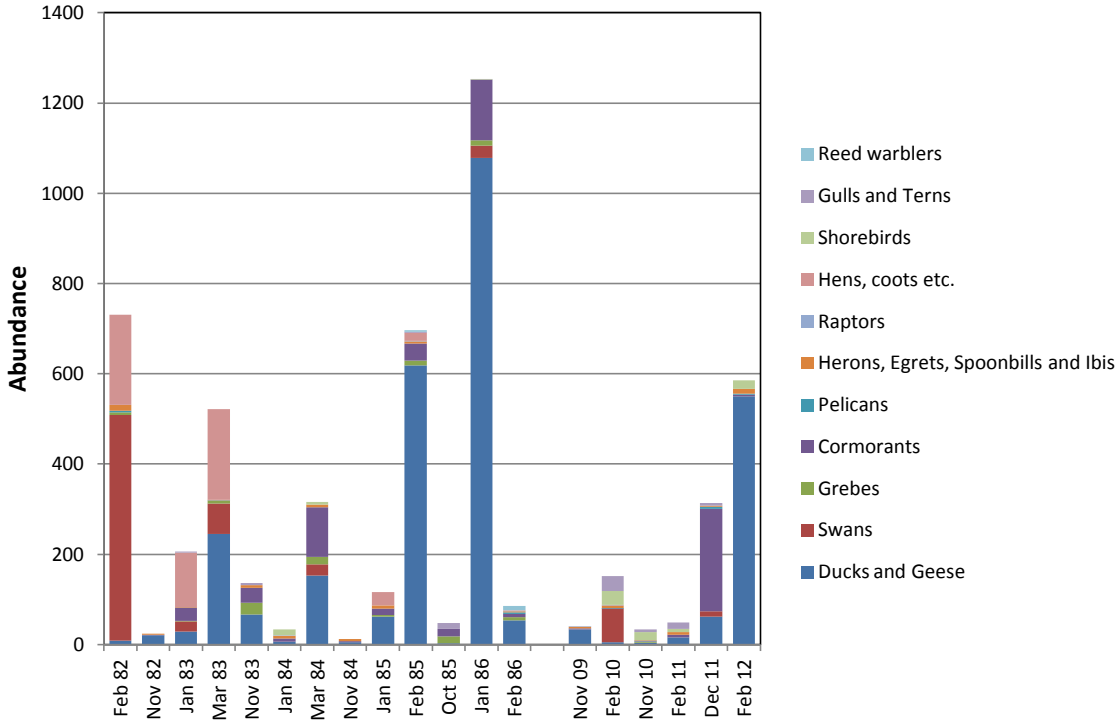

Figure 22. Waterbird abundance on Woody Lake during the 1980s and between 2009 and 2012.

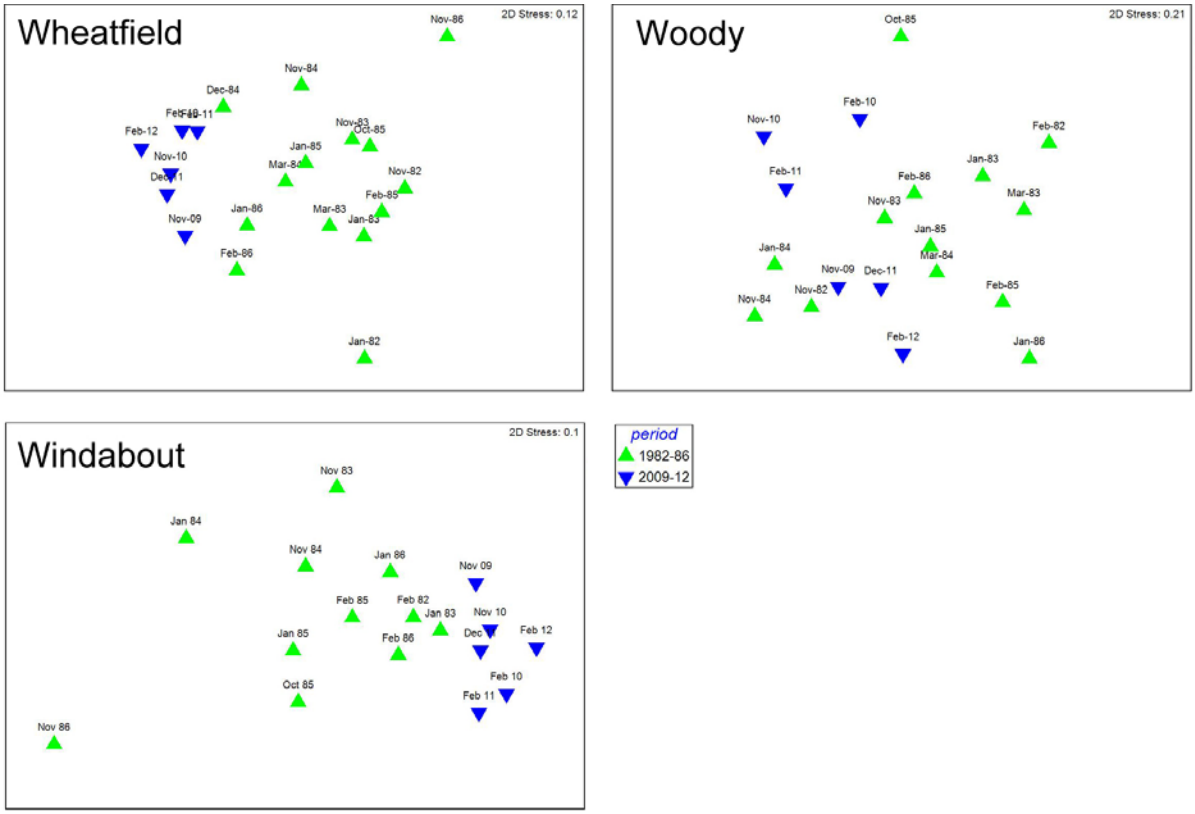

Figure 23. Two dimensional ordinations based on square-root transformed abundance data for Wheatfield Lake, Woody Lake and Lake Windabout during surveys undertaken between 1982 and 1986 and between 2009 and 2012.

Gore-Quallilup wetlands

Richness and composition

Figure 24 shows waterbird richness across the Gore-Quallilup wetlands from October 2006 to February 2012, with richness shown separately for aerial surveys only (except for November 2009), ground surveys only (November 2009 to February 2012) and combined aerial/ground surveys (February 2010 to February 2012). Over this period there has been little change in the total number of waterbird species (or number of species within major taxonomic groups) using the Gore-Quallilup wetlands. A total of 52 species have been recorded using the Gore-Quallilup wetlands since 2006, with five species recorded only in December 2011 and/or February 2012: little egret (an uncertain aerial identification), wood sandpiper, red-kneed dotterel, fairy tern and sacred kingfisher.

Forty four species of waterbird were recorded using wetlands in the Gore-Quallilup wetlands over spring/summer 2011/12. Thirty three were recorded in December 2011 and 36 in February 2012, with 30 present in both seasons. Richness in December 2011 was about average for recent surveys but the February 2012 count was the highest (by one species) since ground counts began in November 2009. In February, all species recorded were seen from the ground whereas only 19 species were seen from the air – the difference mostly being the far greater number of shorebirds identified from the ground. The December 2011 aerial and ground counts were more similar (23 and 28 respectively).

Significant records for the 2011/12 surveys, other than those five species mentioned above, are as follows:

- The number of sharp-tailed sandpipers in February 2012 (124) was 50% higher than the previous recent record of 85 in November 2010. These were all on the Quallilup to Kubitch flow-through wetlands whereas those seen in November 2010 were on Quallilup Lake, the flow-through and Lake Gore.
- Numbers of red-capped plovers were also higher (124, mostly on Carbul Lake and the flow-through) compared to previous surveys (maximum 68).
- The 184 hooded plovers, mostly on the dry Carbul Lake with a few on Kubitch, is the second highest count of this species. The highest count of 213 was in November 2009 (mostly on Kubitch Lake).
- Eighteen wood sandpipers and six red-kneed dotterels on the flow-through wetlands in February 2012 are the first records of these species using Gore-Quallilup wetlands since the current monitoring program began in 2006. Jaensch *et al.* (1988) did not record these species on Lake Gore during the 1980s.

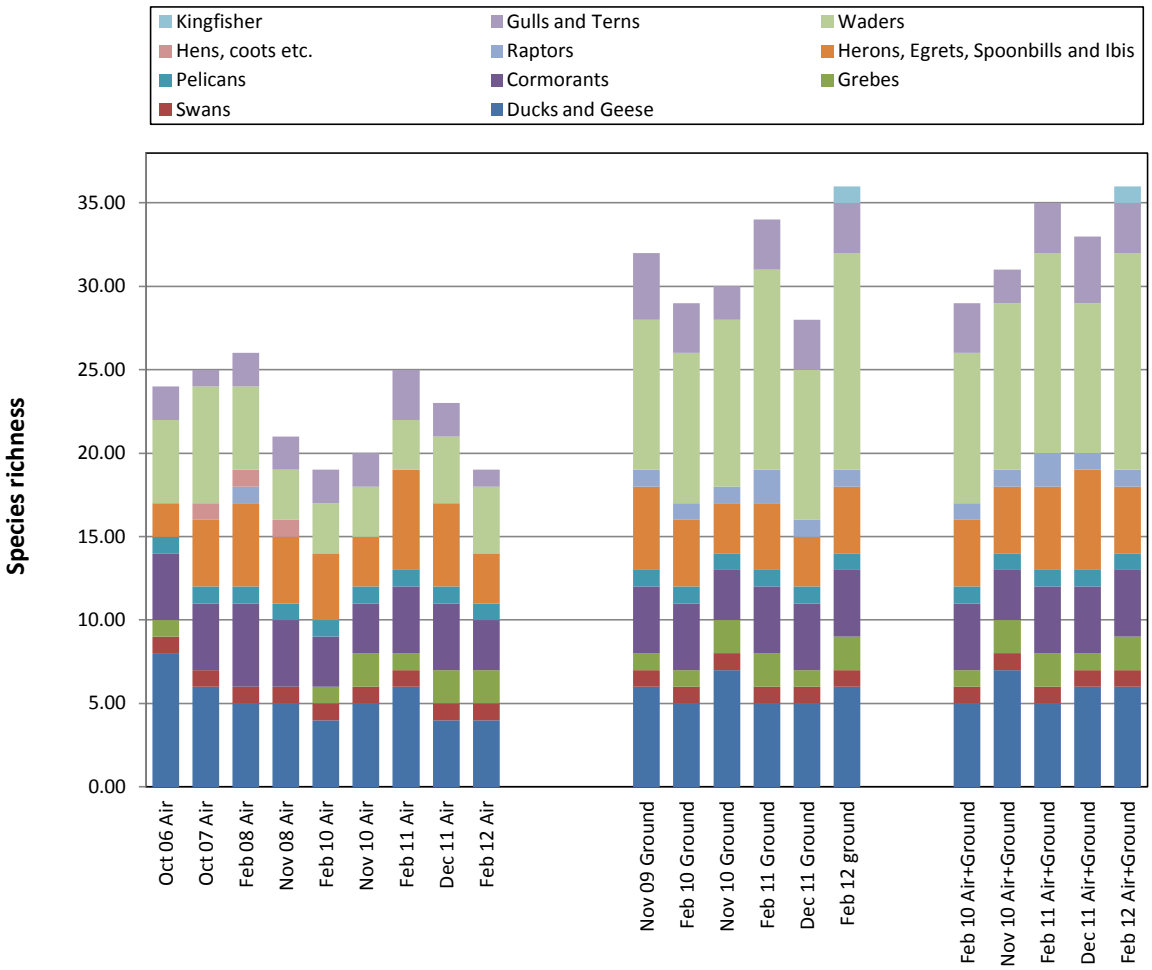

Figure 24. Richness of waterbirds in Lake Gore-Quallilup wetlands from October 2006 to February 2012 from aerial surveys or ground surveys or combined from ground/aerial surveys.

Table 6. Total abundances of waterbirds across the Gore-Quallilup wetland system from aerial and ground counts in November 2011 and February 2012.

Species	December 2011 aerial counts	December 2011 ground counts	February 2012 aerial counts	February 2012 ground counts
musk duck	88	408	228	396
Australian shelduck	7163.5	6417	475	256
Pacific black duck	2	20	5	20
Australasian shoveler	0	0	0	1
grey teal	14	54	107	479
chestnut teal	3	69	0	97
pink-eared duck	1	0	0	0
unidentified duck	26	0	0	0
black swan	164	262	182	144
hoary-headed grebe	106	219	115	341
great crested grebe	0	0	1	7
darter	3	17	2	8
little pied cormorant	6	8	0	5
little black cormorant	440	112	280	438
great cormorant	2	19	2	3
Australian pelican	33	51	85	180
white-faced heron	5	6	45	20
great egret	6	11	19	6
nankeen night heron	1	0	0	0
little egret	1	0	0	0
Australian white ibis	3	0	0	17
yellow-billed spoonbill	10	7	12	11
white-bellied sea-eagle	0	4	0	1
common greenshank	42	14	5	51
wood sandpiper	0	0	0	18
common sandpiper	0	1	0	4
red-necked stint	0	17	0	123
sharp-tailed sandpiper	0	2	0	124
curlew sandpiper	0	0	0	1
black-winged stilt	0	0	5	28
banded stilt	10	13	27	16
red-necked avocet	35	2	290	499
red-capped plover	0	14	0	124
black-fronted dotterel	0	7	0	22
hooded plover	0	0	0	184
red-kneed dotterel	0	0	0	6
masked lapwing (southern)	0	8	0	7
unidentified wader	25	0	232	0
silver gull	65	83	188	307
fairy tern	0	8	0	0
Caspian tern	2	1	0	6

whiskered tern	1	0	0	0
Pacific gull	0	0	0	2
unidentified terns	2	0	1	0
sacred kingfisher	0	0	0	1

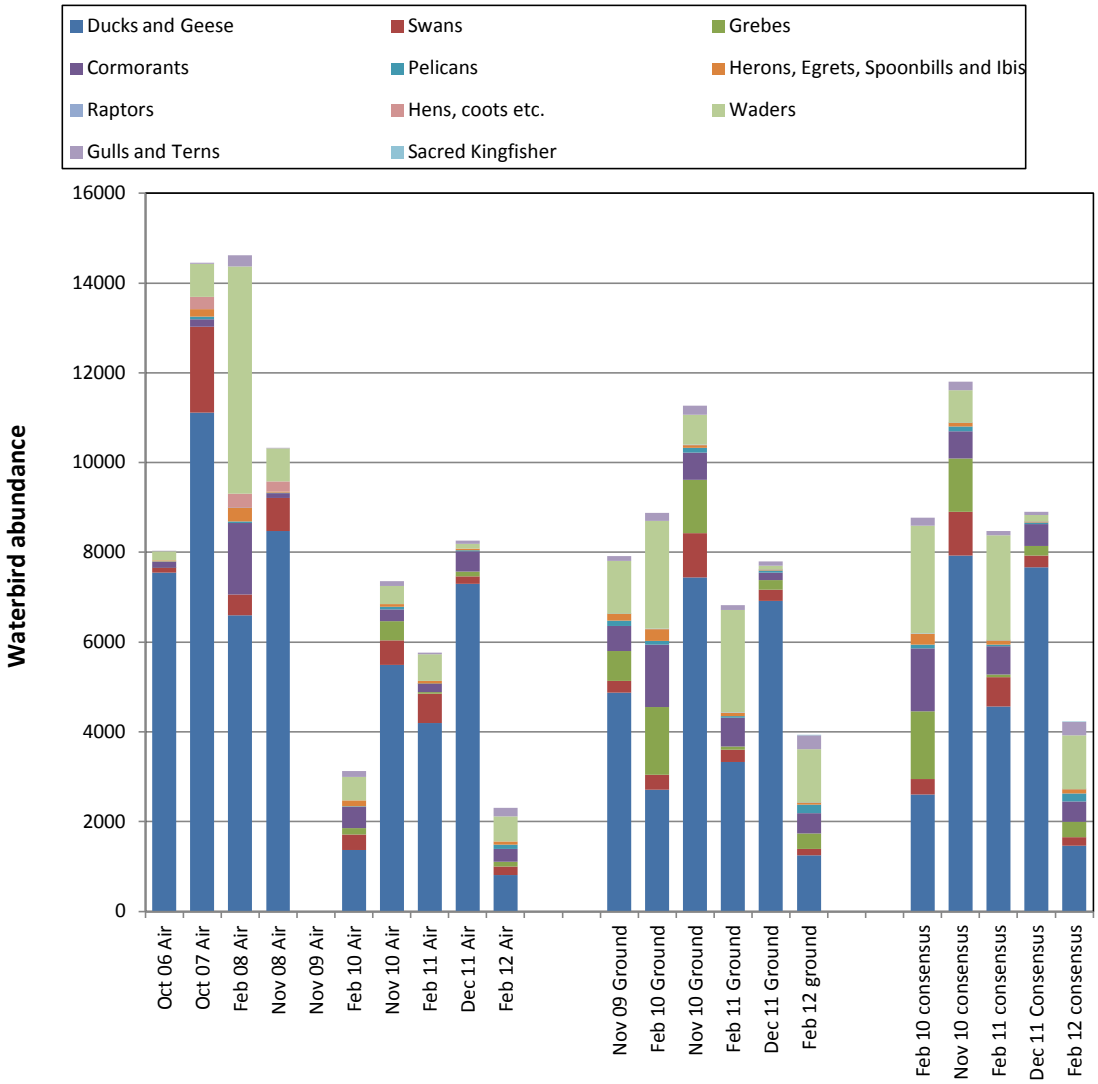

Figure 25. Consensus abundance of waterbirds in Gore-Quallilup wetlands October 2006 to February 2012, by survey method (aerial, ground and consensus).

Abundance

Waterbird abundance data from aerial and ground counts in December 2011 and February 2012 are presented in Table 6. They are also provided along with all of the other 2009 to 2012 ground count data by wetland in Appendix 4 and with October 2006 to February 2011 ground and aerial counts by wetland suite in Appendix 3. Figure 25 is a graph of waterbird abundance (aerial and ground surveys and consensus) by major taxonomic group across the Gore-Quallilup wetlands for the period October 2006 to February 2012. The latest two surveys highlight the inter-seasonal and inter-annual variability in abundance of waterbirds on these wetlands. For instance, numbers of ducks have varied from a high of about 11000 in October 2007 to less than 2000 in February 2012 and numbers within most other groups have been as variable. February counts have tended to be

lower than those made in spring, largely due to reduced numbers of shelduck as moulted birds leave, partly countered by greater numbers of shorebirds in February. Total abundance in February 2012 was the lowest in recent years, with only 2306 seen from the air, 3919 from the ground and a consensus estimate of 4227.

December 2011

In December 2011, 8260 birds were counted from the air and 7854 were counted from the ground on Gore-Quallilup wetlands. The consensus estimate is 8957. The main absolute discrepancies between aerial and ground counts were for shelduck (A7164/G6417), little black cormorant (A440/G112), musk duck (A88/G408), black swan (A164/G262) and hoary-headed grebe (A106/G219).

Almost all of the ducks were shelduck, mostly occurring on Lake Gore (A5919/G4191) but with hundreds on each of the flow-through (A521/G655), the Dalyup wetland (A485/G673), Carbul Lake (A0/G296) and Lake Gideon (A173/G527), these numbers suggesting movement of shelduck from Lake Gore to adjacent wetlands between the aerial and ground counts. Some of the shelduck counted from the air on Lake Gore may have been diving musk ducks (A88/G373). The only other ducks present were grey teal (A14/G54, mostly on the flow-through), chestnut teal (A3/G69, mostly on Quallilup Lake and the flow-through) and Pacific black duck (A2/G20, spread across the system).

Black swan (A164/G262) were mostly on Lake Gore and Lake Gideon during both the aerial and ground surveys.

Most of the hoary-headed grebes were on Lake Gore (A85/G96) but others were seen on the Dalyup wetland (A21/G26), Lake Gideon (A0/G65) and the flow-through (A0/G32). The number of hoary-headed grebes has been low in the last three surveys compared to the three surveys before those, reflecting lower water depth at Lake Gore. Great-crested grebes were absent, as they have been during some other spring surveys.

Almost all of the cormorants were little black cormorants (A440/G112). It is unusual for aerial counts of this species to be higher than ground counts for the Gore-Quallilup system because this species normally remains on tree roosts and nests on the flow-through and therefore difficult to see during aerial surveys. During the aerial survey, half of the little black cormorants were on Lake Gore (242) and most of the rest (181) were on the Dalyup channel and associated wetlands. On the ground a few days later, only 17 were seen on the same wetlands, but with another 95 on the flow-through. Water depth on the flow-through was lower than has been the case in recent year, so cormorants were not nesting in this system as they frequently do when water depth is higher. Since little black cormorants regularly move between the Warden and Gore-Quallilup systems during the day, a total count across both systems can sometimes provide the best count. In December 2011, the number of cormorants counted across both systems from the air (942) is close to the ground count (844). This total count will not always make aerial and ground counts match as the ground counts for the two systems are done on different days (e.g. see results for February 2012 below). A few little pied cormorants were present on the flow-through (A6/G7) and Lake Quallilup (A0/G1). Two great cormorants were seen from the air on the flow-through whereas 17 were seen on the ground and another 2 were present on Lake Quallilup. It is likely that some of the 95 little black cormorants counted from the air on the flow-through were actually great cormorants. There were also 17 darters on Lake Quallilup and the flow-through, but only 3 were seen from the air.

All of the pelicans were on the flow-through system (A33/G51).

A few white-faced herons (A5/G6) were spread across the Gore-Quallilup wetlands. Almost all of the great egrets were on either Lake Gore (A2/G5) or on the flow-through (A4/G6), with one also on Lake Gideon, and all of the yellow-billed spoonbills were on the flow-though (A10/G7). The number of white-faced herons and great egrets were lower than for other recent surveys (normally more than 20 to 30 and up to ~100 of each). A single nankeen night heron was seen over Lake Gore during the aerial survey. Two white-bellied sea eagles seen over the Dalyup wetlands were probably the same two seen over the flow-through on the same day.

Nine species of shorebirds were observed on the Gore-Quallilup wetlands, but none were particularly numerous. Total shorebird abundance was 139 (A112/78). The most abundant were common greenshank (A42/G14), red-necked avocet (A35/G2), banded stilt (A10/G13) and red-necked stint (A0/G17, with some of the 25

unidentified waders counted from the air presumably this species). Forty of the greenshank counted from the air were on the flow-through, as were all of the red-necked stint and most (12) of the red-capped plovers (A0/G14). The banded stilt were all on Lake Gore, as were most (A33/G2) of the red-necked avocets. Seven black-fronted dotterels were present: one on Lake Quallilup and 6 more on the flow-through. Remaining shorebirds were a common sandpiper and five masked lapwing on Lake Gore, 3 other masked lapwings on the Dalup wetland and two sharp-tailed sandpipers at Quallilup Lake. The latter is a low count for the Gore-Quallilup system, with the average for other recent ground counts being 62 ± 20. The total number of shorebirds using the Gore-Quallilup wetlands in December 2011 (A112/78) is the lowest count for the 2006 to 2012 surveys. This is surprising considering the expanded areas of shorebird habitat on the relatively dry flow-through system. Numbers of shorebirds were higher again in February 2012.

Most of the seabirds were silver gulls and these were mostly on Lake Gore (A60/G74) with a few over the flow-through (A2/G3) and Lake Quallilup (A3/G6). There were also a few fairy terns (A0/G8) on Lake Gore, Lake Kubitch and the flow-through and one Caspian Tern over the flow-through. These are the first records of fairy tern using Gore-Quallilup wetlands since 2006. Jaensch *et al*. (1988) recorded fairy terns only once in these wetlands in the 1980s: 4 terns at Lake Gore.

February 2012

Abundance of waterbirds on the Gore-Quallilup wetlands in February 2012 (A2306/G3953, consensus 4260) was lower than for previous February surveys. February aerial counts in 2008, 2010 and 2011 were 14622, 3126 and 5768 respectively while ground counts in February 2010 and 2011 were 8878 (2010) and 6818 (2011). Counts were particularly low for shelduck, with fewer than 500 present whereas counts are normally in the 1000s, with >7000 present two months earlier (see above). Lake Gore is a significant moulting site for shelduck, which then disperse over summer after they have moulted, so this summer the exodus from Gore was greater than in recent years, with perhaps more than usual moving to the Warden system. Aerial counts were lower than ground counts for many species, but particularly musk duck (A228/G396), grey teal (A107/G479), hoary headed grebes (A115/G340), little black cormorants (A280/G438), Australian pelicans (A85/G180) and numerous shorebird species. Aerial counts were higher for Australian shelduck (A475/G256), black swan (A182/G144) and white-faced herons (A45/G19).

Australian shelduck, musk duck and grey teal dominated the February 2012 Gore-Quallilup duck count. The number of musk duck counted from the ground (396) on Lake Gore was about twice that counted from the air (228) but that is not surprising for a diving species. Musk ducks were otherwise rare, with two on Lake Gideon and one on the flow-through. In contrast to musk duck, the number of shelduck counted on Lake Gore from the air (266) was higher than for the ground count (125) and the same was true for the flow-through (A192/G79) but not Lake Gideon (A15/G50). Most of the grey teals were on the flow-through where they were grossly underestimated during the aerial count (61 versus 479 from the ground). During the ground survey, the teals on the flow-through were all loafing under dead trees and not inclined to move into the limited open water, so would not have been easily seen from the air. Otherwise there was grey teal on Lake Gore (A44/G13), Lake Gideon (A0/G45) and Lake Quallilup (A2/G14). The problem of grey teal staying under dead trees was repeated for chestnut teal where there was 77 seen on the ground but none from the air (except that some of the 'grey' teal counted from the air may have been chestnut teal). A few other chestnut teal were counted on the ground on Lake Gore, Lake Gideon and Quallilup Lake. Other ducks were a single Australasian shoveler on Lake Gideon and small numbers of Pacific black duck on Quallilup Lake (A0/G2) and the flow-through (A0/G18).

Hoary headed grebes were mostly on Lake Gore (A115/G340), with a few on the Dalyup wetland, Lake Gideon, Quallilup Lake and the flow-through. The few great-crested grebes were all on Lake Gore (A1/G7).

The number of little black cormorants seen on Lake Gore from the air (251) was similar to the number seen from the ground (215). For both counts, most of these were on the water rather than perched in trees. About the same number (221) was seen on the flow-through from the ground survey but only 29 were seen from the air. The numbers of this species on Lake Gore and the flow-through are suspiciously similar, but the two counts were made at about the same time with no evidence of movement. Undercounting little black cormorants from

the air, even with deliberate effort to detect them, is a recurrent problem in the highly wooded flow-through system, where this species tends to remain perched on trees during the aerial survey. Combining counts for the Warden and Gore-Quallilup systems (to account for movement between them) does not help to match up aerial and ground counts as it did in December 2011. Darters, little pied cormorants and great cormorants were also present in low abundance on Gore-Quallilup wetlands.

Most of the Australian pelicans were on the flow-through system (A85/G165), with a few on Lake Gideon (A0/G14) and Quallilup Lake (A0/G1).

A majority of the large wading birds were on the flow-through, including White-faced herons (A39/G12), great egrets (A18/G4), Australian white ibis (A0/G13) and yellow-billed spoonbills (A12/G9), but smaller numbers of these were scattered across other parts of the Gore-Quallilup system.

A single white-bellied sea-eagle was seen flying over the flow-through.

Fourteen species of shorebird were seen on the Gore-Quallilup system: a record for recent (2006+) surveys, with the previous maximum being 12 in February 2011. Most of these had highest abundance on the flow-through system, which had much larger areas of shallow and exposed shorebird habitat than has been the case in recent years. The 18 wood sandpipers and six red-kneed dotterels (both entirely on the flow-through) are first records of those species using the Gore-Quallilup wetlands for the present monitoring program and neither were recorded on Lake Gore by Jaensch *et al.* (1988). The most abundant of the remaining species were red-necked avocets (A290/G499), hooded plover (A0/G184), sharp-tailed sandpiper (A0/G124), red-necked stint (A0/G123) and red-capped plover (A0/G124). Almost all of the avocet (A290/G499) were on the flow-through system: ground counts of 478 in a single group on the flow-through plus 21 on Lake Gore. Most of the hooded plover (A0/184) were sheltering from the wind in small hollows (footprints) on the dry bed of Lake Carbul, but a few were on the edge of Kubitch Lake. The sharp-tailed sandpiper were all on the flow-through in groups of 1 to 13 birds. Red-capped plovers were more distributed, with 70 on Lake Carbul, 34 on the flow-through, 10 on Lake Gore, 9 on the Dalyup wetland and one on Kubitch Lake. Red-necked stints were mostly on the flow-through (66) but with some on Lake Carbul (34), Lake Gore (15) and the Dalyup wetland (8). The seven masked lapwings, 22 black-fronted dotterels, 28 black-winged stilt and 4 common sandpipers were all on the flow-through, as were 43 of the 51 common greenshank. A single curlew sandpiper was present on the Dalyup wetland. Fifteen of the 16 banded stilt were on Lake Gore, with one present on the flow-through.

Silver gulls were mostly on Lake Gore (A144/G181) but with some on the Dalyup wetland (A0/G13), the flow-through (A43/G86), Lake Gideon (A1/G0) and Lake Quallilup (A0/G6). Other seabirds were three Caspian terns and two Pacific gulls on Lake Quallilup Lake and three more Caspian tern on the flow-through, or the latter might have been the same ones as seen on the lake.

A sacred kingfisher seen in the flow-through is the first record of this species in the Gore-Quallilup system for the current monitoring program, though we have only been doing ground counts for three years.

Species of interest

Hooded Plover

Hooded plovers have been observed during most of the last 10 surveys of the Warden wetlands (Table 7). The number of sightings and counts has increased over the last few surveys, with the maximum count being in February 2012 (a total of 81 across six wetlands). Warden wetlands at which hooded plovers are most frequently sighted are Lake Warden, Pink Lake, North Windabout and the Merivale wetlands. Breeding has been observed only at Lake Warden during these surveys. Figure 26 shows average abundance of hooded plover across the Warden wetlands between 2006 and 2012.

Assuming there are around 2500 western hooded plovers (*Thinornis rubricollis tregellasi*) (Garnet *et al.* 2010) then the numbers recorded recently in the Warden system represent up to 3% of the estimated total population for the subspecies. Counts representing > 1% of the estimated total population size were made during the last three surveys. Our data suggest a recent increase in usage of Warden wetlands. At Lake Warden this is likely to be associated with increased beach areas with declining depth, but this cannot be the reason for their apparently more frequent presence on the eastern wetlands during surveys since 2010.

Table 7. Records of hooded plovers on wetlands in the Warden wetland system 2006 to 2012.

Wetland	Suite code	Oct-06	Oct-07	Feb-08	Oct-08	Nov-09	Feb-10	Nov-10	Feb-11	Dec-11	Feb-12
Neridup wetland A	WRP001								2		1
Neridup wetland E	WRP001										1
Bandy Creek wetland E	WRP002							2			
Bandy Creek wetland A	WRP002										1
Mullet Lake	WRP004								14		38
Station Lake	WRP005						11	1		1	
Merivale wetlands	WRP005-2	3				1		11	9		
Windabout (wetland F)	WRP010									2	6
North Windabout	WRP011	2				4		2		2	
Lake Warden	WRP013						4	3	5	53	34
Pink Lake	WRP015		6		4	1		1	1	2	

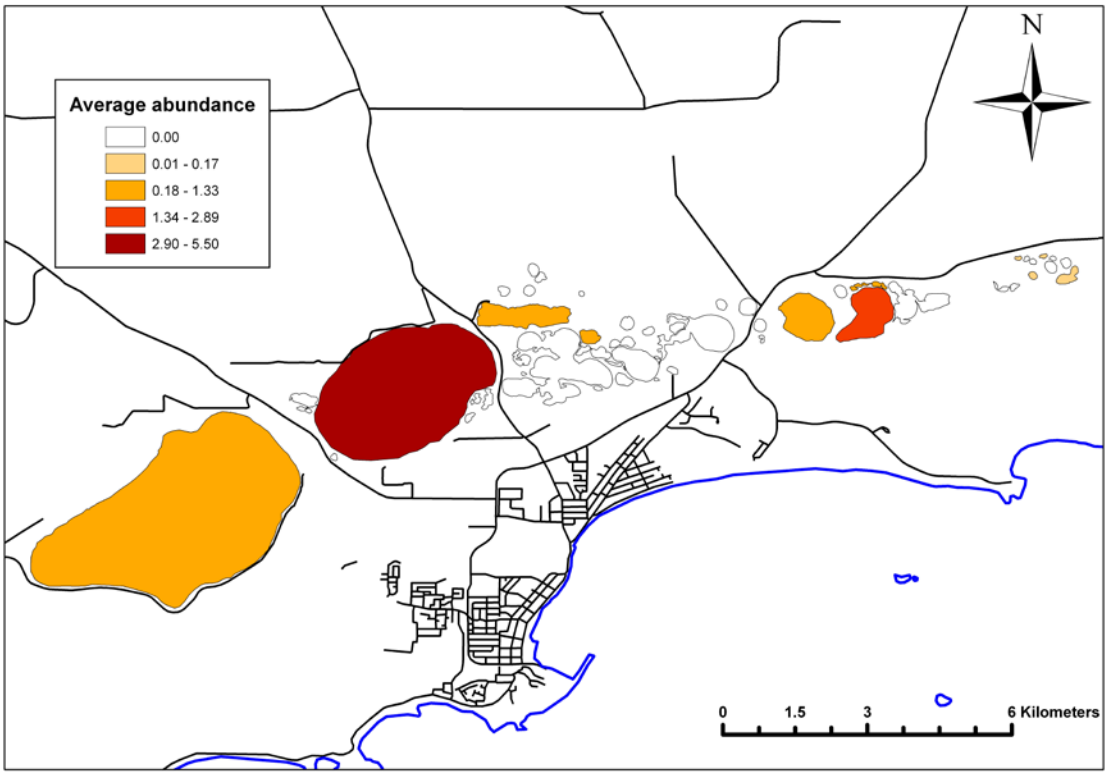

Figure 26. Average abundance of hooded plover across the Warden wetlands based on surveys from 2006 to 2012.

In the Gore-Quallilup system two of the four hooded plover records have been on Carbul Lake (64 in February 2011 and 169 in February 2012), one was at Kubitch Lake (15 in February 2012) and one was on the flow-through (213 in November 2009).

Chestnut Teal

Chestnut teal have been present on the Warden wetlands during all ten surveys since 2006. Ground counts have ranged from 121 to 873. Lake Windabout is particularly important for chestnut teal, with an average of 189 individuals counted from this suite (mostly on the main lake), with Lake Wheatfield, Lake Warden and Ewans Lake also important with an average of 29 to 77 individuals per wetland per survey (Figure 27). Chestnut teal counts on Warden wetlands have been higher much in February (average ground counts 859) than in spring (286), suggesting immigration over summer. Of the above four wetlands, numbers of chestnut teal are most variable on Lake Warden, with none seen during four of the ten surveys.

In spring 2008 a National Waterbird Survey counted waterbirds at over 4000 wetlands across Australia (including most of the wetlands considered to be important waterbird habitats) and another 837 were surveyed at the same time for other projects[2]. This survey counted almost 11000 chestnut teals, although this is certainly an underestimate of the continental populations, with south-west WA populations alone estimated at 5000 to 40000 in the 1988/9 to 1991/2 annual waterfowl counts, e.g. Halse *et al.* (1990) and Halse *et al.* (1995). In any case counts in both the Warden and Gore wetlands occasionally represent at least 1% of the State, if not the Australian, populations.

Table 8. Records of chestnut teal on wetlands in the Warden wetland system 2006 to 2012.

Wetland/Suite	SiteCode	Oct-06	Oct-07	Feb-08	Nov-08	Nov-09	Feb-10	Nov-10	Feb-11	Dec-11	Feb-12
Neridup wetland A	WRP001					12		4			
Bandy Creek wetland B	WRP002									6	
Ewens Lake	WRP003		14	27		46		12	116	18	59
Mullet Lake	WRP004					33			100	6	
Mullet Lake	WRP004	40									
Station Lake Suite	WRP005	30			9	29		2		4	9
Merrivale wetlands	WRP005-2	20	20		2						
Gun Club Suite wetland A	WRP006	18		12	2	36				3	
Lake Wheatfield Suite	WRP007	45	24	59	18	9	28	46	43	16	46
North Wheatfield Suite	WRP008			3		4			12	6	48
Woodie Lake Suite	WRP009		2	159	2	7	18	8		2	35
Windabout Suite	WRP010	225	78	607	62	10	186	140	375	25	180
North Windabout Suite	WRP011					23		4			
Six Mile Hill Suite	WRP012		6		2						
Lake Warden Suite	WRP013		4			13	70	160	468	62	

[2] http://www.wetrivers.unsw.edu.au/docs/rp_nws_home.html

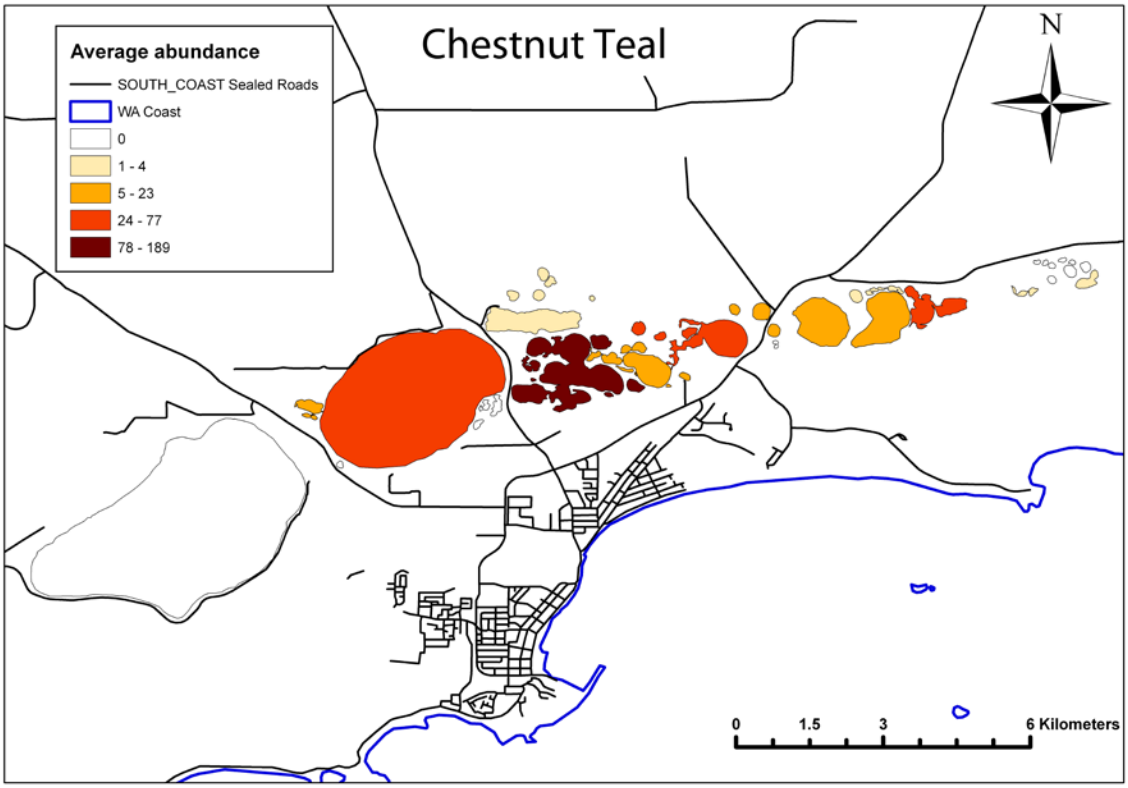

Figure 27. Average abundance of chestnut teal across the Warden wetlands based on surveys from 2006 to 2012. For some early surveys numbers were not recorded for individual wetlands within a suite, so for most suites the whole suite is given the same colour, though usually highest numbers were on the main lake rather than a satellite.

ACKNOWLEDGEMENTS

Field work was funded by DEC's Lake Warden Recovery Catchment Program and South Coast Natural Resources Management. Data analysis and reporting was funded as in-kind support by DEC's Science Division. Thanks to John Lizamore for arranging the field work and assisting with the surveys, providing advice about the Warden and Gore-Quallilup wetlands, providing water depth and chemistry data and for reviewing an earlier version of this report. Sarah Davies also assisted with field work. Thanks also to Ken Read from the Esperance Bird Observers Group for discussions and data on Esperance shorebirds.

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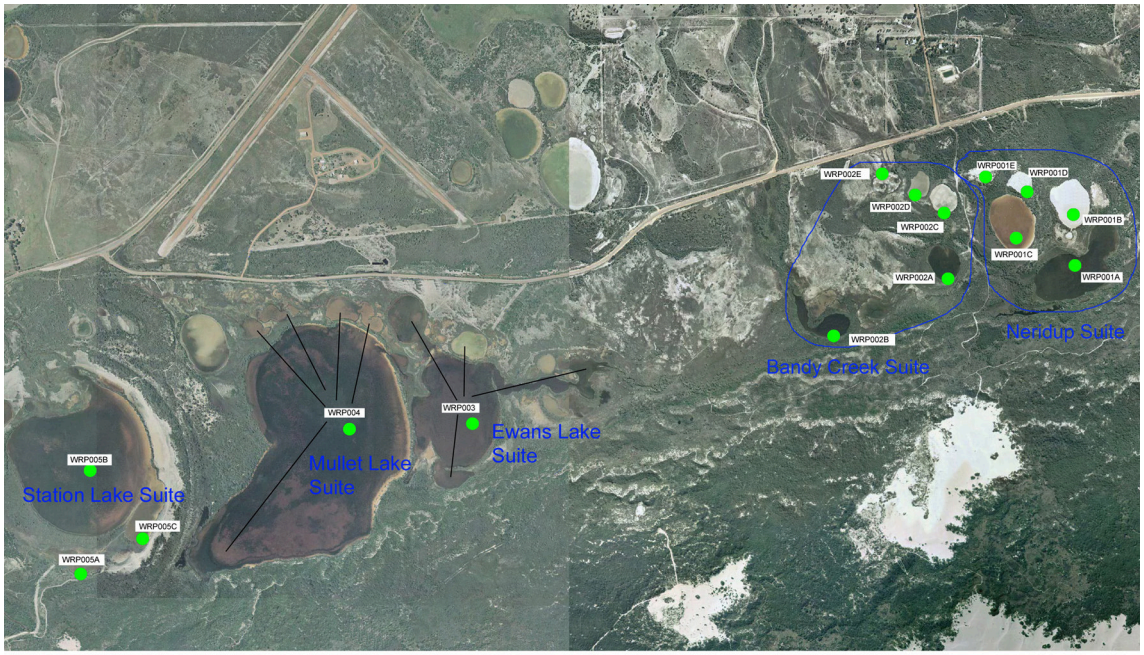
Appendix 1: Wetlands surveyed for waterbirds in the Warden and Gore systems 2006 to 2012

Wetland Suite Code	Wetland Suite Name	Wetland	Location	Nov-09	Feb-10	Nov-10	Feb-11	Dec-11	Feb-12
WRP001	Neridup Suite	A	large southern lake with two basins	19/11/2009	DRY 22/02/2010	15/11/2010	14/02/2011	12/12/2011	13/02/2012
		B	medium sized central eastern lake	19/11/2009	DRY 22/02/2010	15/11/2010	DRY 14/02/2011	12/12/2011	DRY 13/02/2012
		C	medium sized central western lake	19/11/2009	DRY 22/02/2010	15/11/2010	DRY 14/02/2011	12/12/2011	DRY 13/02/2012
		D	small lake just above WRP001C	19/11/2009	DRY 22/02/2010	15/11/2010	DRY 14/02/2011	DRY 12/12/2011	DRY 13/02/2012
		E	small northern-most lake	19/11/2009	DRY 22/02/2010	DRY 15/11/2010	DRY 14/02/2011	DRY 12/12/2011	DRY 13/02/2012
WRP002	Bandy Creek Suite	A	south-eastern lake	19/11/2009	DRY 22/02/2010	15/11/2010	DRY 14/02/2011	12/12/2011	14/02/2012
		B	south-western lakes and adjacent areas	19/11/2009	22/02/2010	15/11/2010	14/02/2011	12/12/2011	14/02/2012
		C	eastern lake closest to track	19/11/2009	DRY 22/02/2010	DRY 15/11/2010	DRY 14/02/2011	12/12/2011	DRY 14/02/2012
		D	lake between C and D	19/11/2009	DRY 22/02/2010	DRY 15/11/2010	DRY 14/02/2011	DRY 12/12/2011	DRY 14/02/2012
		E	north-western most lake close to Merivale Road	19/11/2009	DRY 22/02/2010	DRY 15/11/2010	DRY 14/02/2011	DRY 12/12/2011	DRY 14/02/2012
WRP003	Ewens Lake	A	includes large wetland areas to north and north-west of Ewans that are connected to Ewans, but didn't get into the southern-most eye-shaped section in 2009	19/11/2009	22/02/2010 and 23/02/2010	15/11/2010	14/02/2011	12/12/2011	15/02/2012
WRP004	Mullet Lake	A	includes pans to north of main lake	19/11/2009	23/02/2010	15/11/2010	14/02/2011	12/12/2011	15/02/2012
WRP005	Station Lake	A	flats to south of main lake	20/22/2009	DRY 23/02/2010	15/11/2010	DRY 14/02/2011	12/12/2011	15/02/2012
		B	main lake	20/22/2009	DRY 23/02/2010	15/11/2010	14/02/2011	12/12/2011	15/02/2012
		C	overflow areas to east of main lake	20/22/2009	DRY 23/02/2010	15/11/2010	14/02/2011	12/12/2011	15/02/2012
WRP005B	Merivale Suite	A		not surveyed	not surveyed	not surveyed	not surveyed	12/12/2011	15/02/2012
WRP006	Gun Club wetlands	A	main lake opposite Lake Road (north of Gun Club)		DRY 22/02/2010	16/11/2010	DRY 14/02/2011	12/12/2011	DRY 15/02/2012
		B	hour-glass shaped on eastern edge of Gun Club	19/11/2009	DRY 22/02/2010	16/11/2010	DRY 14/02/2011	12/12/2011	DRY 15/02/2012
WRP007	Wheatfield Suite	A	Wheatfield Lake plus channel to Woodie Lake	20/11/2009	23/02/2010	17/11/2010	15/02/2011	13/12/2011	15/02/2012
		B/C	areas between the larger eastern section of the Wheatfield to Woodie channel and the Coweramup Inflow channel	20/11/2009	DRY 23/02/2010	17/11/2010	DRY (except for channel) 15/02/2011	13/12/2011	DRY 15/02/2012

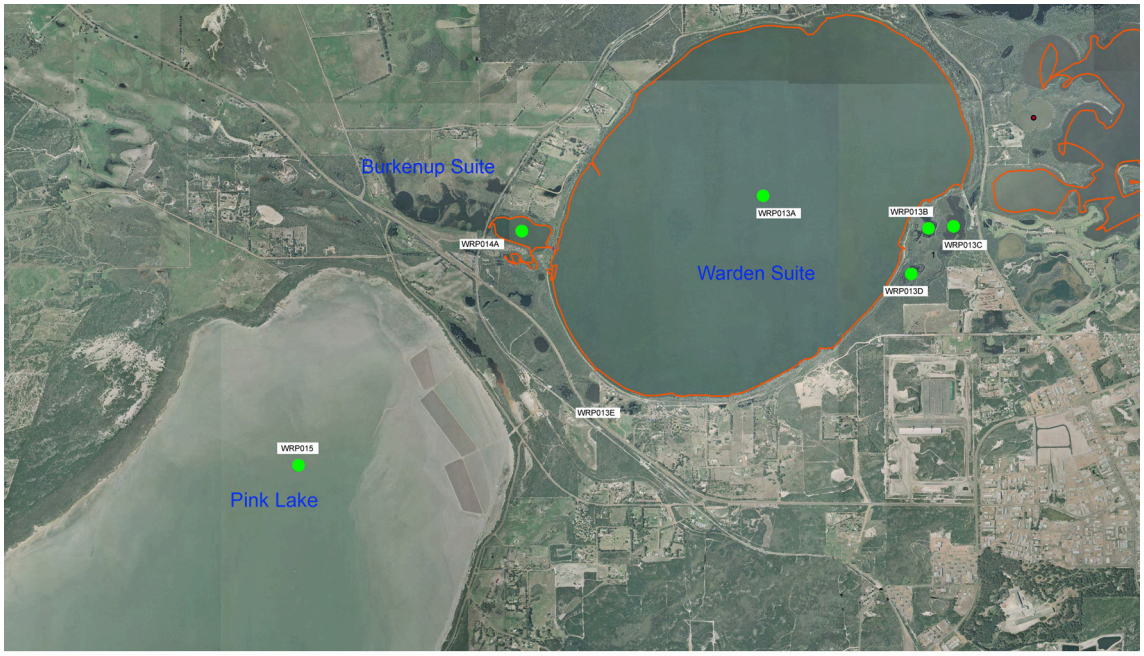
Wetland Suite Code	Wetland Suite Name	Wetland	Location	Nov-09	Feb-10	Nov-10	Feb-11	Dec-11	Feb-12
		D	satellite wetland north-west of main channel	20/11/2009	23/02/2010	17/11/2010	DRY 15/02/2011	13/12/2011	14/02/2012
		E	satellite wetland north-west of 007D near Lake Road	20/11/2009	DRY 23/02/2010	17/11/2010	DRY 15/02/2011	13/12/2011	14/02/2012
WRP008	North Wheatfield Suite	A	western	20/11/2009	DRY 24/02/2010	16/11/2010	14/02/2011	13/12/2011	14/02/2012
		B	central	20/11/2009	DRY 24/02/2010	not surveyed	not surveyed	13/12/2011	14/02/2012
		C	eastern	20/11/2009	DRY 24/02/2010	16/11/2010	14/02/2011	13/12/2011	14/02/2012
WRP009	Woodie Suite	A	main lake	20/11/2009	23/02/2010	17/11/2010	15/02/2011	13/12/2011	15/02/2012
		B	very small wetland just near western edge of main lake	20/11/2009	DRY 23/02/2010	17/11/2010	DRY 15/02/2011	13/12/2011	DRY 15/02/2012
		C	spectacle' lake north of Woodie	20/11/2009	DRY 23/02/2010	17/11/2010	DRY 15/02/2011	13/12/2011	15/02/2012
		D	Woodie to Windabout channel	20/11/2009	23/02/2010	17/11/2010	15/02/2011	13/12/2011	15/02/2012
		E	small wetland opposite boat lauch area	20/11/2009	23/02/2010	17/11/2010	DRY 15/02/2011	13/12/2011	DRY 15/02/2012
		F	long wetland between Woodie and Windabout	20/11/2009	23/02/2010	17/11/2010	15/02/2011	13/12/2011	DRY 15/02/2012
		G	wetland at end of Windabout Way	20/11/2009	23/02/2010	17/11/2010	DRY 15/02/2011	13/12/2011	DRY 15/02/2012
WRP010	Windabout Suite	A	main lake	20/11/2009	23/02/2010	17/11/2010	15/02/2011	13/12/2011	15/02/2012
		B	triangular lake south-east of main body	20/11/2009	23/02/2010	17/11/2010	15/02/2011	13/12/2011	15/02/2012
		C	small wetland south of south-east bay	20/11/2009	23/02/2010	17/11/2010	15/02/2011	13/12/2011	15/02/2012
		D	small wetland north of south-west bay	20/11/2009	DRY 23/02/2010	17/11/2010	15/02/2011	13/12/2011	DRY 15/02/2012
		E	large wetland south of north-west bay	20/11/2009	23/02/2010	17/11/2010	15/02/2011	13/12/2011	15/02/2012
		F	large wetland east of north-east bay	20/11/2009	23/02/2010	17/11/2010	15/02/2011	13/12/2011	15/02/2012
WRP011	North Windabout Suite	A	series of interconnected wetlands between Lake Road and Windabout	20/11/2009	24/02/2010	17/11/2010	DRY 15/02/2011	13/12/2011	DRY 14/02/2012
WRP012	Six Mile Hill Suite	A	south-east	21/11/2009	DRY Aerial only	16/11/2010	DRY 15/02/2011	13/12/2011	DRY 14/02/2012
		B	south-west	21/11/2009	DRY Aerial only	16/11/2010	DRY 15/02/2011	13/12/2011	DRY 14/02/2012
		C	south-central	21/11/2009	DRY Aerial only	16/11/2010	DRY 15/02/2011	13/12/2011	DRY 14/02/2012
		D	southern wetland of central pair	21/11/2009	DRY Aerial only	16/11/2010	DRY 15/02/2011	13/12/2011	DRY 14/02/2012
		E	northern wetland of central pair	21/11/2009	DRY Aerial only	16/11/2010	DRY 15/02/2011	13/12/2011	DRY 14/02/2012
		F	northern wetland	not surveyed	DRY Aerial only	not surveyed	not surveyed	not surveyed	not surveyed

Wetland Suite Code	Wetland Suite Name	Wetland	Location	Nov-09	Feb-10	Nov-10	Feb-11	Dec-11	Feb-12
WRP13	Lake Warden Suite	A	main lake	21/11/2009	24/02/2010	18/11/2010	16/02/2011	14/12/2011	14/02/2012
		B	middle of three satellite wetlands on south-eastern edge	21/11/2009	24/02/2010	18/11/2010	16/02/2011	not surveyed	not surveyed
		C	long wetland immediately west of boat ramp track	21/11/2009	24/02/2010	18/11/2010	15/02/2011	14/12/2011	14/02/2012
		D	western-most of three stallite wetlands on south-eastern edge	21/11/2009	24/02/2010	not surveyed	not surveyed	14/12/2011	14/02/2012
		E	small satellite wetland on southern edge of lake	not surveyed	24/02/2010	18/11/2010	16/02/2011	not surveyed	not surveyed
WRP014	Burkenup Suite	A	west of rail-line only, including sattelite wetlands to south of main area	21/11/2009	24/02/2010	18/11/2010	16/02/2011	14/12/2011	14/02/2012
WRP015	Pink Lake	A	main lake	21/11/2009	DRY Aerial only	18/11/2010	16/02/2011	14/12/2011	15/02/2012
WRP016+18	Lake Gore Suite including Dalyup channel and wetland to south of channel	A	main lake plus elongate flats behind dunes on eastern side of lake and small basins on western shore.	22/11/2009	25/02/2010	19/11/2010	17/02/2011	15/12/2011	16/02/2012
WRP017	Carbul Lakes	A	Carbul Lake	22/11/2009	DRY 25/02/2010	19/11/2010	16/02/2011	15/12/2011	DRY 16/02/2012
		B	Kubitch Lake	22/11/2009	DRY 25/02/2010	19/11/2010	16/02/2011	15/12/2011	16/02/2012
		C	Gidong Lake	Aerial only	DRY Aerial only	Aerial only	16/02/2011	15/12/2011	16/02/2012
WRP019	Quallilup Lake	A	main lake	22/11/2009	25/02/2010	19/11/2010	17/02/2011	15/12/2011	16/02/2012
		B	satellite wetland on north-eastern edge	not surveyed	25/02/2010	19/11/2010	17/02/2011	15/12/2011	16/02/2012
WRP020	Kubitch to Quallilup flow-through	A	From Quallilup north through wetland complex as far as water depth allows boat access	22/11/2009	25/02/2010	19/11/2010	17/02/2011	15/12/2011	16/02/2012

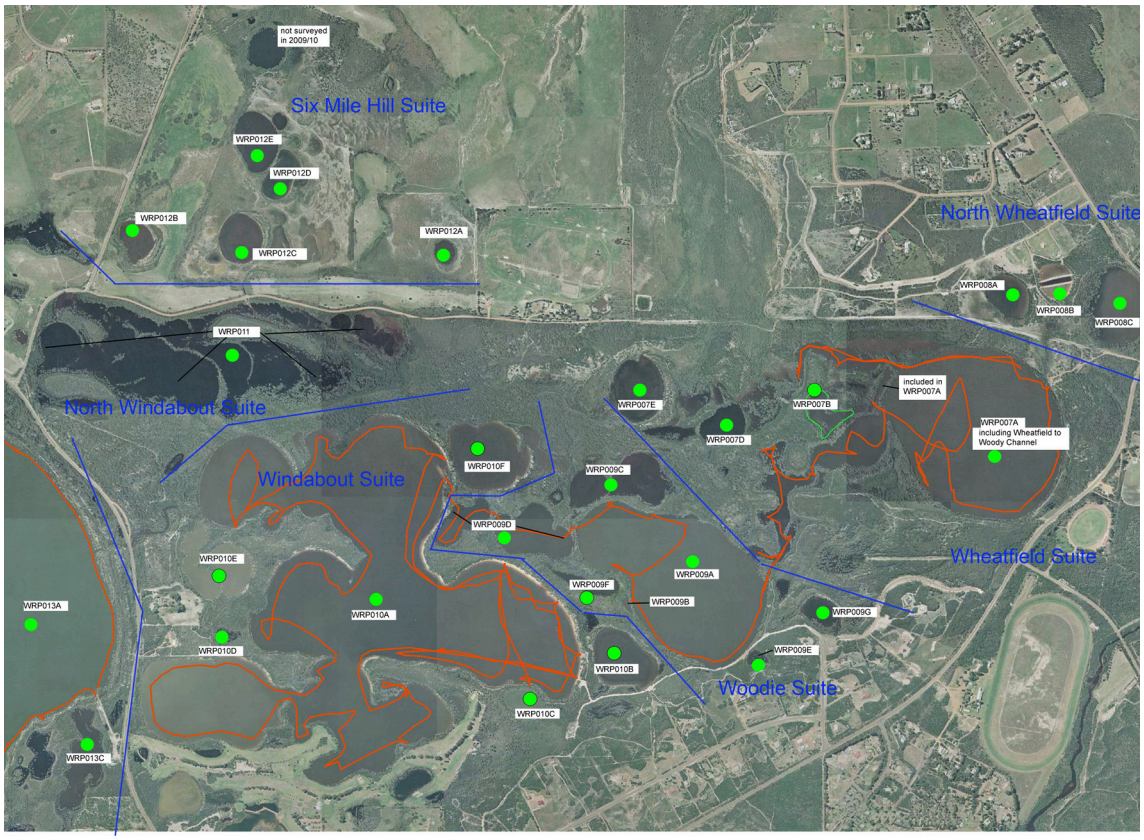
Appendix 2 (cont.). Lake Gore wetlands



Appendix 2. Wetland suites and individual wetlands. Station Lake to Neridup Suites



Appendix 2 (cont). Warden Lake to Pink Lake suites and wetlands. The orange line is the route taken during the November 2009 boat survey (excluding on-foot visits to satellite wetlands).



Appendix 2 (cont.). Windabout to North Wheatfield suites and wetlands. Purple lines delineate suites. The orange line is the route taken during the November 2009 boat survey (excluding on-foot visits to satellite wetlands.