Response of Waterbirds to Environmental Change in the Lower Lakes, Coorong and Murray Mouth Icon Site

DEWNR Technical report 2013/23

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Project Summary

This report presents findings from monthly monitoring of waterbirds in the Lower Lakes, Coorong, and Murray Mouth (LLCMM) Icon Site. This monitoring was undertaken through the Living Murray and the Murray Futures' ecological monitoring programs. Specifically, this report assesses progress towards achieving a specific target of the LLCMM Icon Site Condition Monitoring Plan: 'Maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth'. The results of this monitoring will also contribute to improving the understanding of the ecological character of the site.

The 2012-2013 monitoring period was characterised by high flows to the Lakes and Coorong subregions. Water levels in the Lakes have stabilised at 0.58-0.84 m AHD since the return of flows to the system in 2010. Coorong water levels were variable (depending partially on the volume of water released through the Barrages), but below 0 m AHD in the South Lagoon in summer 2012. These hydrological conditions, together with a combination of local and off-site food and habitat conditions influenced the pattern of waterbird reporting rate and relative abundance within LLCMM subregions.

- Patterns of reporting rate and relative abundance of selected species have shown some general patterns of waterbird recovery, however some species have continued to decline or persist in small numbers within the site or particular subregions.
- Species such as the Australian Pelican, Chestnut Teal, Red-necked Avocet and Banded Stilt have responded positively to the return of water flows, and are now detected at rates and relative abundances that are comparable to those observed in the early 2000s (pre-drought).
- Species within the same functional group (i.e. piscivore or shorebird) often responded differently to ecological changes at the site. For example, most shorebird species (Red-necked Stint, Sharp-tailed Sandpiper and Red-capped Plover) have shown ongoing signs of recovery since the return of water flows to the site in 2010. However, abundances of two migratory shorebird species, the Curlew Sandpiper and Common Greenshank, declined during the period of low flow, but show little or no signs of population recovery in recent reporting periods (2010-2013).
- Recovery of many waterbird species, such as the Black Swan and various waterfowl/shorebirds are likely to be affected by the distribution and abundance of *Ruppia tuberosa*. This aquatic macrophyte species is a key food resource in the Coorong and has specific hydrological requirements (such as consistent water levels over spring/summer), that require ongoing management.

In summary, recent environmental conditions have maintained or improved populations of many waterbird species in Lower Lakes, Coorong and Murray Mouth Icon Site (within the 2000-2013 monitoring period). Further research is required in order to understand the reasons for continued declines or comparatively low population sizes of some species. Such research should focus on local ecological requirements and/or broader landscape-scale habitat requirements of certain species.

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Introduction

Background

The Lower Lakes, Coorong and Murray Mouth (LLCMM) is recognised as both a Ramsar 'Wetland of International Importance' and as one of the six 'Icon Sites' under The Living Murray program (MDBC 2006; Phillips and Muller 2006). The LLCMM supports more waterbirds (annually) than any other South Australian wetland (Kingsford et al. 2012). Waterbirds respond to hydrological and resulting ecological conditions at the site (as well as off-site factors), with most species declining in abundance during periods of drought and/or low water flows (Paton and Rogers 2009a; Paton et al. 2011; Rogers 2012; Thiessen 2011; Wainwright and Christie 2008). Since 1985, changes in waterbird distribution and abundance have been monitored in various survey programs undertaken through the Coorong, Lower Lakes and Murray Mouth Program (Murray Futures), and The Living Murray Program (reviewed in O'Connor et al. 2012). Local population numbers and trends are used to report on targets and objectives of the Ramsar Convention and 'The Living Murray program' (O'Connor et al. 2012; Paton 2012; Paton et al. 2009; Rogers 2012; Thiessen 2011).

This project uses 13 years of point-count bird survey data to assess changes in waterbird abundance in relation to wetland water levels in the LLCMM. These data are used to determine progress against a specific target (B1) of the 'Lower Lakes, Coorong and Murray Mouth Icon Site Condition Monitoring Plan' (Maunsell Australia 2009), which relates to birds:

- *'Maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth' (*where 'Improved' is defined as an increase in population abundances over time (i.e. populations display a positive trajectory)).

Icon Site targets are used to "either directly or indirectly assess the success of The Living Murray water applications against higher ecological objectives" (Maunsell Australia 2009). Demonstrating a direct tangible link between application of Living Murray water and progress toward ecological targets (and waterbird targets in particular) is extremely challenging given the broader environment that these birds are operating in, and the diversity of drivers that they respond to at various spatial and temporal scales. However changes in the relative distribution and abundance of waterbirds provide a reasonable surrogate for changes in habitat availability through time.

Aims and Objectives

This study reports against LLCMM Icon Site target B1: '*Maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth'* using two main outputs:

1. Report on the population distribution of the 16 selected waterbird species within each sub-region of the icon site:
    - Lake Alexandrina
    - Lake Albert
    - Goolwa Channel
    - Murray Estuary
    - Coorong North Lagoon
    - Coorong South Lagoon
2. Report on population changes of the selected species from 2001-2013 at each subregion. Population trends will be discussed in relation to water level and barrage release data. Population changes will refer to changes in relative abundance (the data are not suitable for estimating absolute population size).
3. Report on waterbird abundances at the managed Narrung Wetland (2010-2013)

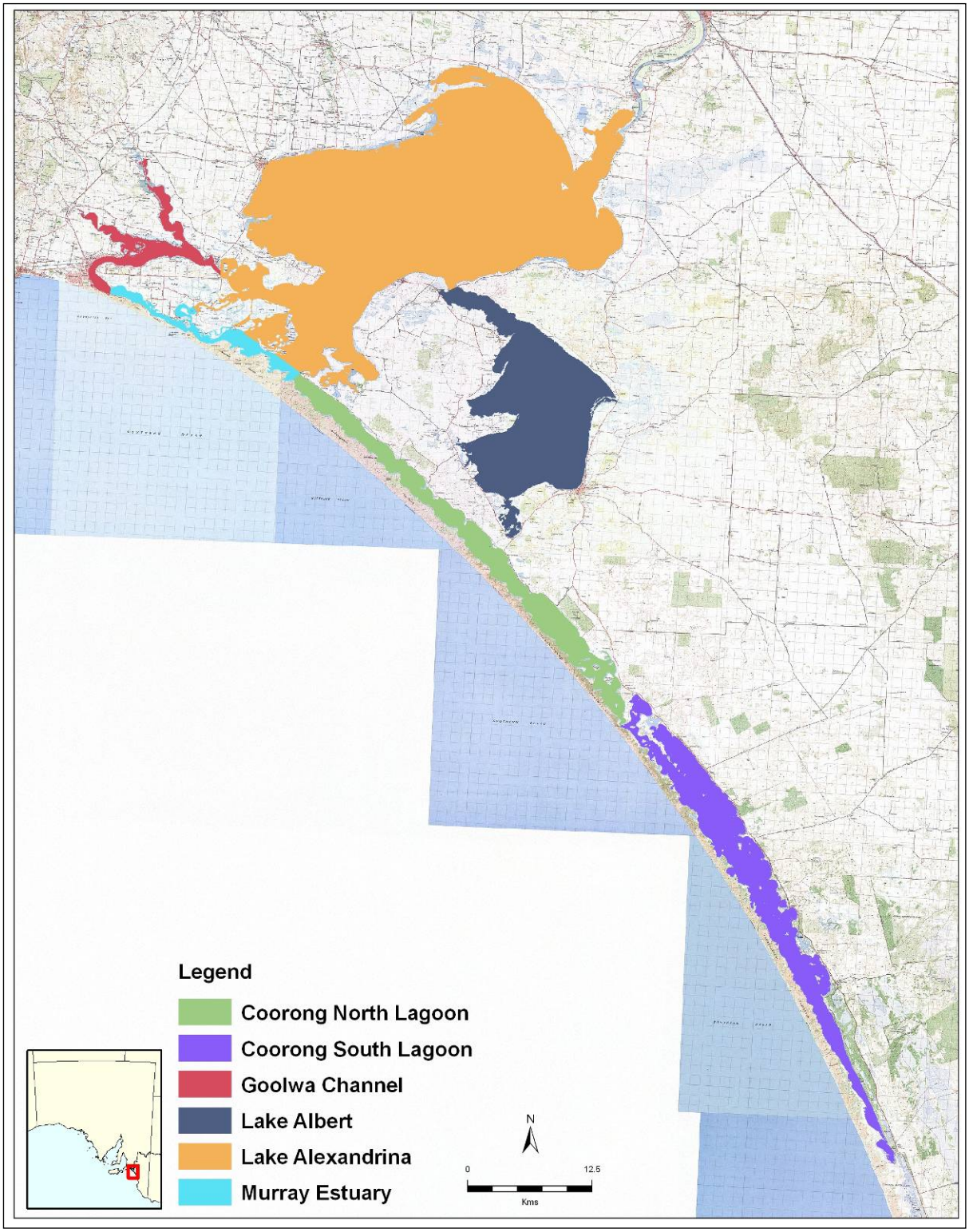

Figure 1. Map of the LLCMM Icon Site, with the different subregions colour-coded.

This report focuses on the distribution and abundance of 16 species selected in the Icon Site Monitoring Plan. These species have been selected based "on their presence contributing to the Ramsar status of the site and their importance to indigenous culture, and from a suite of different functional groups (e.g. waders, cryptic, piscivorous, herbivorous)" (Maunsell Australia 2009).

- Australasian Bittern *Botaurus poiciloptilus*
- Australian Pelican *Pelecanus conspicillatus*
- Australian Spotted Crake *Porzana tabuensis*
- Banded Stilt *Cladorhynchus leucoceohalus*
- Black Swan *Cygnus atratus*
- Chestnut Teal *Anas castanea*
- Common Greenshank *Tringa nebularia*
- Curlew Sandpiper *Calidris ferruginea*
- Fairy Tern *Sterna nereis*
- Latham's Snipe *Gallinago hardwickii*
- Australian Pied Oystercatcher *Haematopus longirostris*
- Red-capped Plover *Charadrius ruficapillus*
- Red-necked Avocet *Recurvirosta novaehollandiae*
- Red-necked Stint *Calidris ruficollis*
- Sanderling *Calidris alba*
- Sharp-tailed Sandpiper *Calidris acuminata*

Through much of this report, these species have been grouped according to common ecological requirements (e.g. shorebirds that utilise mudflats in the LLCMM, piscivores etc.). However, each species will have different requirements, and their responses will differ based on other aspects of their ecology other than those used to describe the groups. This intra-group variation is touched on in the following interpretation of the results, and should be kept in mind when interpreting results at this ecological group level.

The remaining outputs recommended by Maunsell Australia Pty Ltd (2009) that relate to quantifying total population sizes for the Icon Site, and relating these population estimates to flyway population estimates, will not be reported against here, as the data used in this report are not suitable to obtain total population size (which requires a census methodology). Total

population sizes for the LLCMM Icon Site are reported through the annual waterbird census for the site (Paton and Bailey 2012).

Methodology

Collection of Data

The waterbird survey data presented here have been collected by David and Margaret Dadd (Coorong Nature Tours) at approximately monthly intervals from 2002 to present (with a small number of sites, limited to the Coorong South Lagoon, surveyed in 2001). Over this time period, 78 sites have been surveyed, although the number of sites visited in any subregion in any year varies (Figure 2).

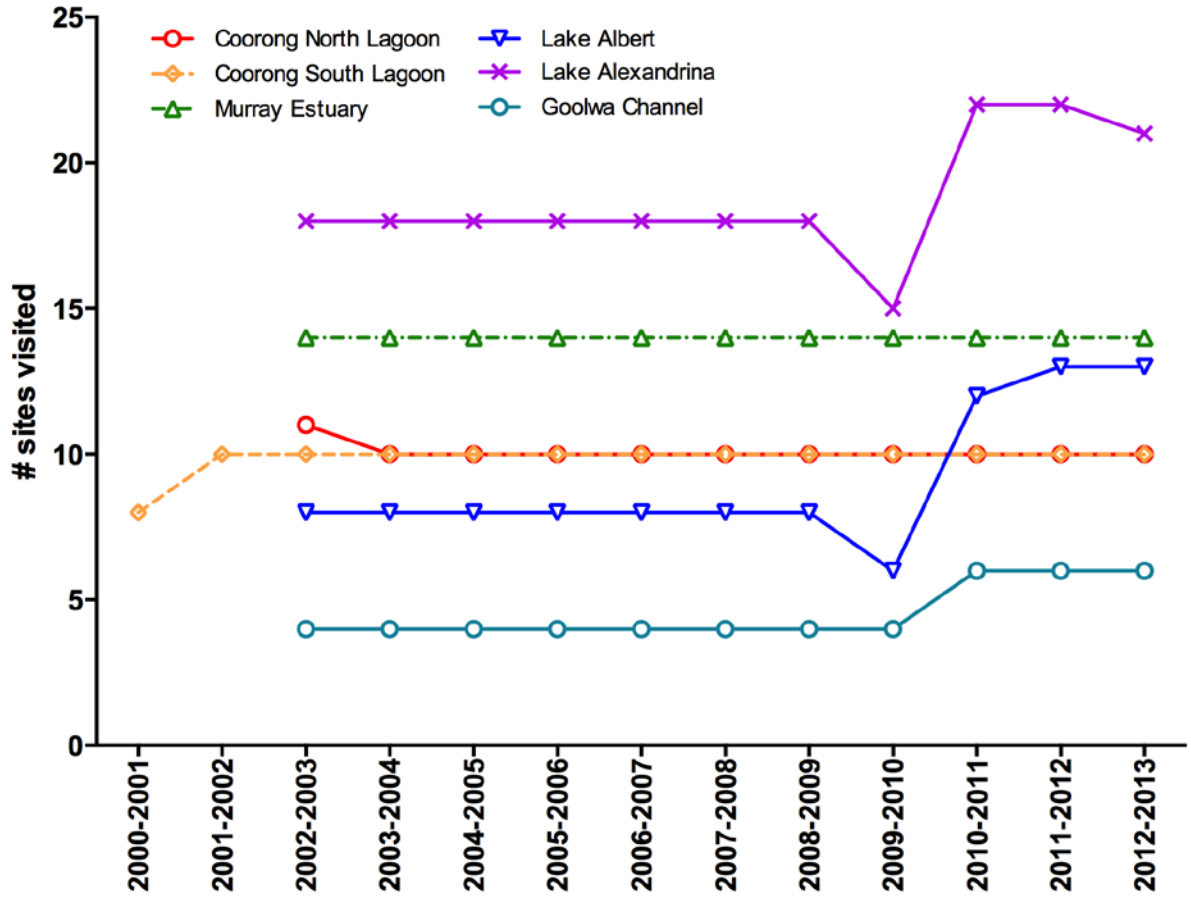

Figure 2. Total number of sites visited in each subregion of the LLCMM Icon Site in each reporting year.

For each site visit, a 1.5 km arc was scanned using either binoculars or spotting scope from a single observational point for a period of 30 minutes whereby all species observed were counted and recorded. Additional information regarding the behaviour of birds, and site information regarding weather, were also collected.

Data Analysis

The analyses presented in this report focus on changes in distribution and abundance, at the subregion level, with some additional consideration given to one managed wetland site (Narrung Wetland). The abundance of selected species is presented in two ways:

1. For long-term trends, data are presented as the proportion of site visits in which each species was recorded for each subregion in each financial year (July-June), independent of the number of birds species recorded in that site visit.
2. A second analysis looking particularly at recent changes (in response to the most recent drawdown and reinundation of the LLCMM, from 2006-2013) presents data at monthly (rather than annual) intervals, as the average number of individuals recorded per site visit per month per subregion.

The observed trends for each of these analyses are interpreted in the context of known environmental change during these periods, particularly with regard to the key drivers of water level and water quality (particularly salinity).

Water Level Data

Water level data were obtained from the DEWNR WaterConnect website: http://www.waterconnect.sa.gov.au/.

Mean water level values (per month) were calculated from 1-3 sites within each subregion (Table 1).

Table 1. Sites that were used to calculate mean monthly water level values within each LLCMM subregion.

Site name	SiteID	Subregion category
Parnka Point	A4260633	Coorong North Lagoon
Long Point	A4261135	Coorong North Lagoon
NW Snipe Island	A4261165	Coorong South Lagoon
Near Cattle Island	A4261209	Coorong South Lagoon
Goolwa Barrage US	A4261034	Goolwa Channel
DS Hindmarsh Island Bridge Beacon 23	A4261123	Goolwa Channel
Meningie Sailing Club Jetty	A4260630	Lake Albert
Near Waltowa Swamp	A4261153	Lake Albert
2 km N Warrengie Point	A4261155	Lake Albert
Milang Jetty	A4260524	Lake Alexandrina
Near Mulgundawa	A4260574	Lake Alexandrina
Poltalloch Plains	A4260575	Lake Alexandrina
Adjacent Barker Knoll	A4261039	Murray Estuary

Results

1. Inter-annual variation in the distribution of selected species

1.1 Piscivores

The reporting rate for the three selected piscivorous (fish-eating) species (Australian Pelican, Fairy Tern and Common Greenshank) show variable trends between species and subregions.

Australian Pelicans were reported in declining numbers from 2001 to 2009 during a period of drought and low flow conditions to the LLCMM. Following the return of water flows to the system in 2010 (Figure 9), pelicans have been reported in increasing and now stable numbers up to May 2013 (Figure 3). This trend is consistent across all subregions, with a slight increase in pelicans using the lakes in 2013 compared to the 2010-11 reporting period.

Fairy Terns have been reported in relatively stable numbers in the Murray Estuary and Coorong South Lagoon since 2010 (Figure 3). This species has shown a recent decline in use of the Coorong North Lagoon, as a result of shifting ecological conditions post-drought. For example, Fairy Tern distributions are known to follow that of fish prey species such as the Smallmouth Hardyhead, which was the only suitably-sized prey species available in significant numbers in the Coorong South Lagoon during the peak of the drought (2006-2009)(Noell et al. 2009). Even so, Smallmouth Hardyhead were in relatively low abundance in the Coorong South Lagoon during this time compared to other sampling periods (Livore et al. 2013; Rogers and Paton 2009; Ye et al. 2012). The return of Fairy Terns to the Coorong South Lagoon in recent years (2009-2013) also follows the recovery of Smallmouth Hardyhead populations to the same area (Paton and Bailey 2012; Ye et al. 2012). The relationship between Fairy Terns and Smallmouth Hardyhead populations is explained in further detail elsewhere (Paton and Bailey 2012; Paton and Rogers 2009b; Rogers and Paton 2009). Fairy Terns are also known to feed on other small-sized fish (which are sometimes juveniles of larger species) such as Mullet (Hitchcock 1937), Sandy Sprat and ocean fish species such as Garfish (Sutton 1927) and Anchovies (Sardinops sp.) (Paton and Rogers 2009b). This report focuses on changes in reporting rate only, hence these results should be considered in conjunction with recent Fairy Tern monitoring programs (Paton et al. in preparation), which may provide finer-scale patterns of population change across the LLCMM.

The reporting rate of Common Greenshank in the Coorong Lagoons and Murray Estuary has increased following the return of water flows (post-2009) (Figure 3), however overall abundance of this species remains very low compared to numbers observed in the early 2000s (Paton and Bailey 2012; Paton 2010; Rogers and Paton 2009). The species is infrequently reported in all three lakes subregions (Figure 3), although an increase in reporting rate was detected (in the Goolwa Channel in particular) during the height of the drought (2006-2009). This trend appears to have been influenced by low water levels in the Lakes during the same period (Figure 9), which resulted in the provision of alternative mudflat foraging habitats for shorebird species such as the Common Greenshank (Paton and Bailey 2010). This species is thought to feed predominantly on fish within the LLCMM, but is also known to feed on macroinvertebrate prey (Higgins and Davies 1996; O'Connor et al. 2013).

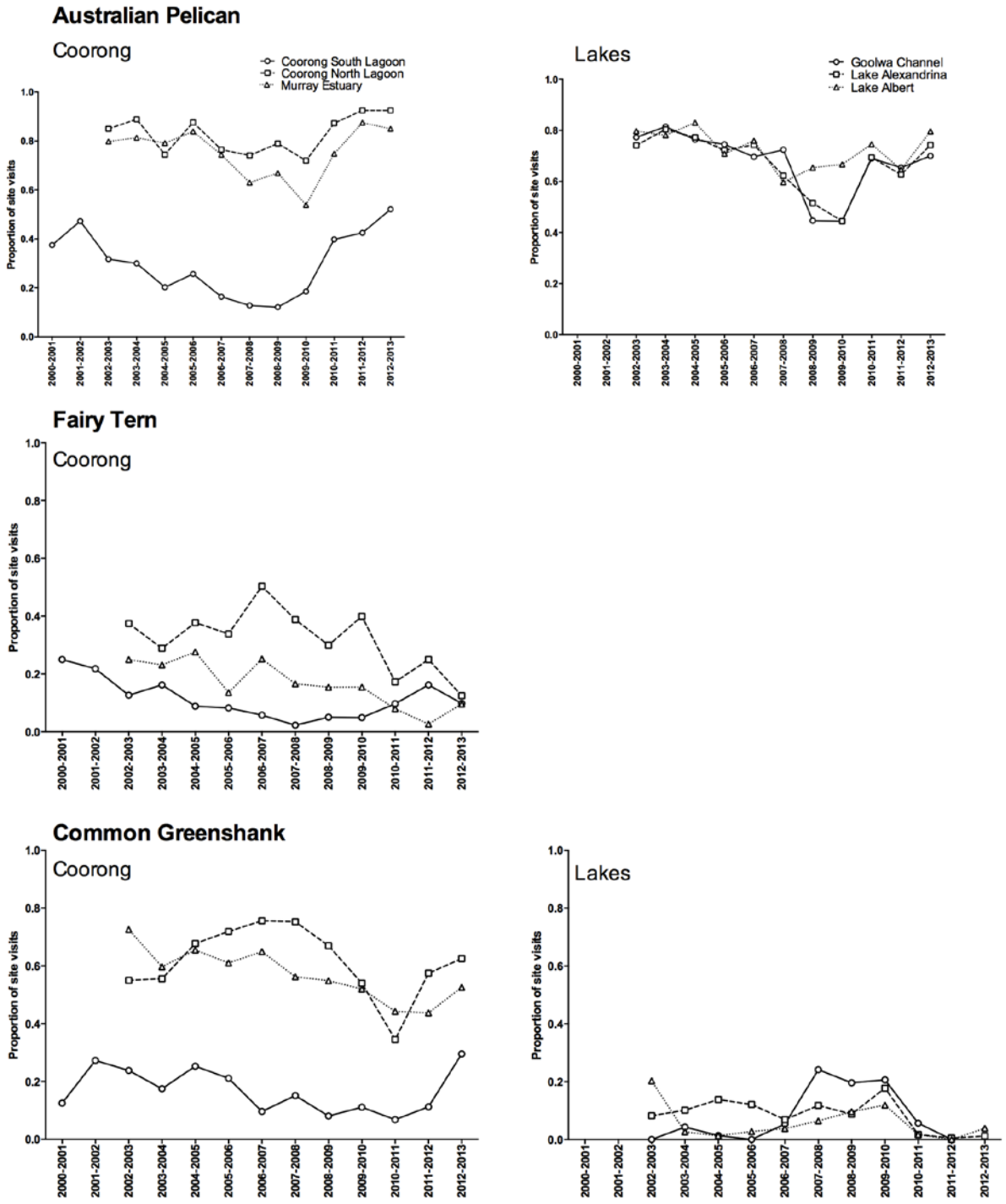

Figure 3. Changes in the reporting rate of three selected piscivorous waterbird species in the Coorong (left) and Lower Lakes (right) between 2000-2001 and 2012-2013. Reporting rate is given as the proportion of site visits within each subregion within each reporting year, in which at least one individual of the species was detected. Note that scale differs between species (but not between the two graphs for each species).

1.2 Waterfowl

Changes in reporting rate for Black Swan and Chestnut Teal varied between species and subregions.

In the Lakes and Coorong subregions, the reporting rate for Black Swans declined between 2001-2009 when the water levels were low (Figure 9). Since then, however population trends have differed between subregions. A recent positive trend in Black Swan reporting rate has been recorded in the Coorong South Lagoon (Figure 4). This trend is surprising given that key food resources such as the aquatic plant *Ruppia tuberosa* remain depleted in the Coorong South Lagoon (Paton and Bailey 2012; Paton and Bailey 2013). Paton and Bailey (2012) similarly found recent increases of Black Swans using the Coorong, however few individuals (10-20%) were using the area for foraging. In contrast, the reporting rate for Black Swans increased in the lakes subregions as well as the Murray Estuary and Coorong North Lagoon between 2010-2012 (following the return of water flow to the site) (Figure 9), but have shown a decline in the latest (2012-2013) reporting period. This pattern may follow that of aquatic macrophyte recovery in the lakes (Gehrig et al. 2012), although the most recent lakes vegetation monitoring data (2012-2013) were not available at the time of writing this report.

Chestnut Teal have been reported at relatively stable rates across the Coorong and Lakes subregions since 2001. This species is frequently reported from the Coorong North and South Lagoons, but infrequently reported from the Murray Estuary or Lakes subregions.

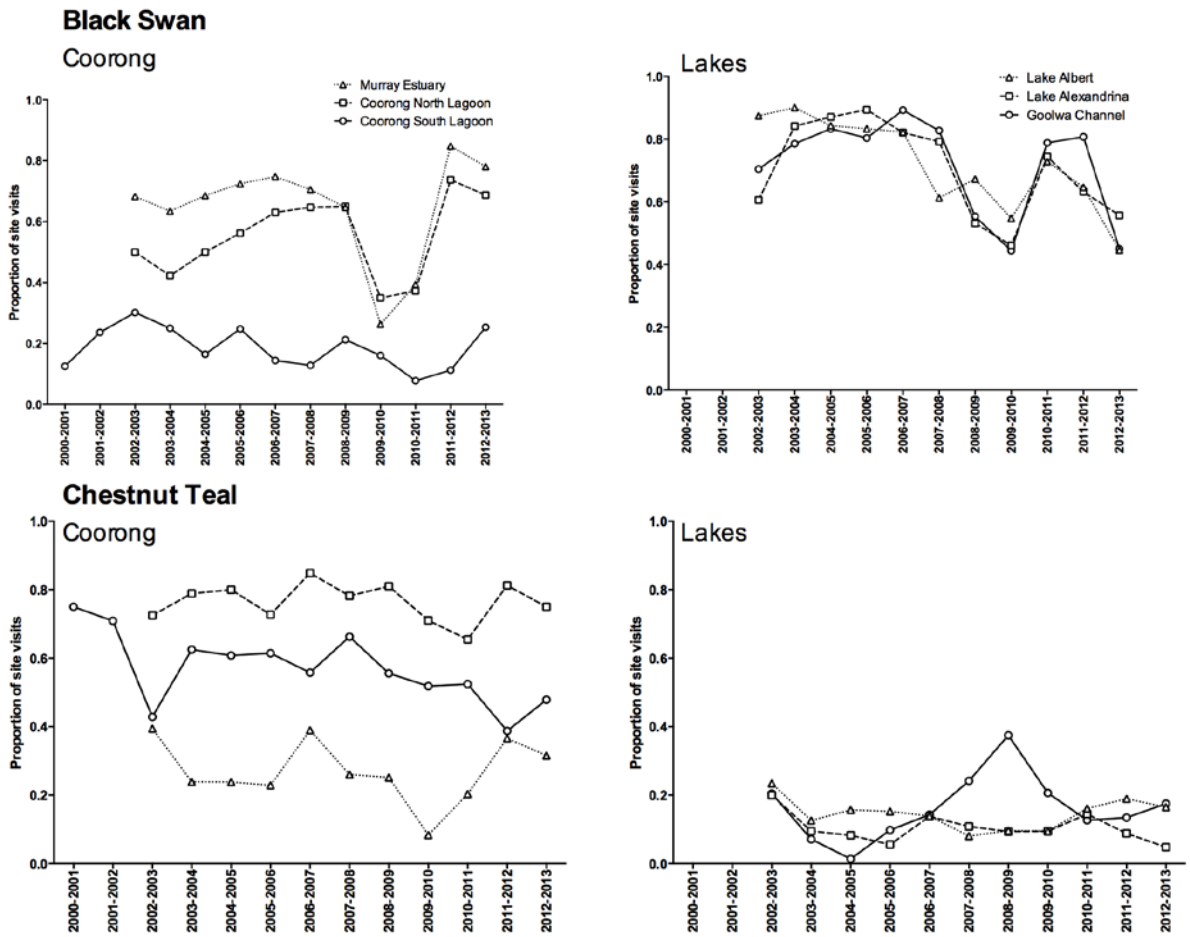

Figure 4. Changes in the reporting rate of three selected waterfowl (ducks, geese and swans) species in the Coorong (left) and Lower Lakes (right) between 2000-2001 and 2012-2013.
Reporting rate is given as the proportion of site visits within each subregion within each reporting year, in which at least one individual of the species was detected. Note that scale differs between species (but not between the two graphs for each species).

1.3 Shorebirds

Across the four most widespread shorebird species (Curlew Sandpiper, Red-necked Stint, Sharp-tailed Sandpiper and Red-capped Plover) selected for reporting here, some consistent patterns in reporting rate emerge across years and subregions. In the Coorong, the reporting rate of all four species showed a general decline from 2001-2009. Despite the return of water flows to the wetlands in late 2009, shorebird reporting rates did not begin to recover until 2011. All four species have shown consistent increases in reporting rate in the Coorong from 2011-2013 and now appear to be approaching pre-drought levels (e.g. early 2000s).

Consistent patterns in the reporting rate of these four shorebird species were also observed in the Lakes subregions. All four species were reported at higher rates in the lakes from 2007-2011, when water flows (and subsequently water levels) were higher (e.g. Figure 9). The observed increase in shorebirds using the lakes probably reflects the increased availability of mudflats for foraging during this period. Mudflat habitats are relatively scarce in the lakes under conditions of normal water levels. Following the return of significant water flows to the Lakes in late 2009, the reporting rate of shorebirds declined to pre-drought levels.

The fifth shorebird species selected for reporting, Sanderling, has only ever been recorded in the Murray Estuary subregion. This species is strongly associated with ocean beach habitats (Higgins and Davies 1996), such as that provided by the Murray Estuary rather than sheltered estuarine and other mudflat habitats (e.g. the Coorong). This species has always been recorded at very low rates in this study (1% to 3.8% of visits), but was not recorded at all between 2010-2012 (Figure 6).

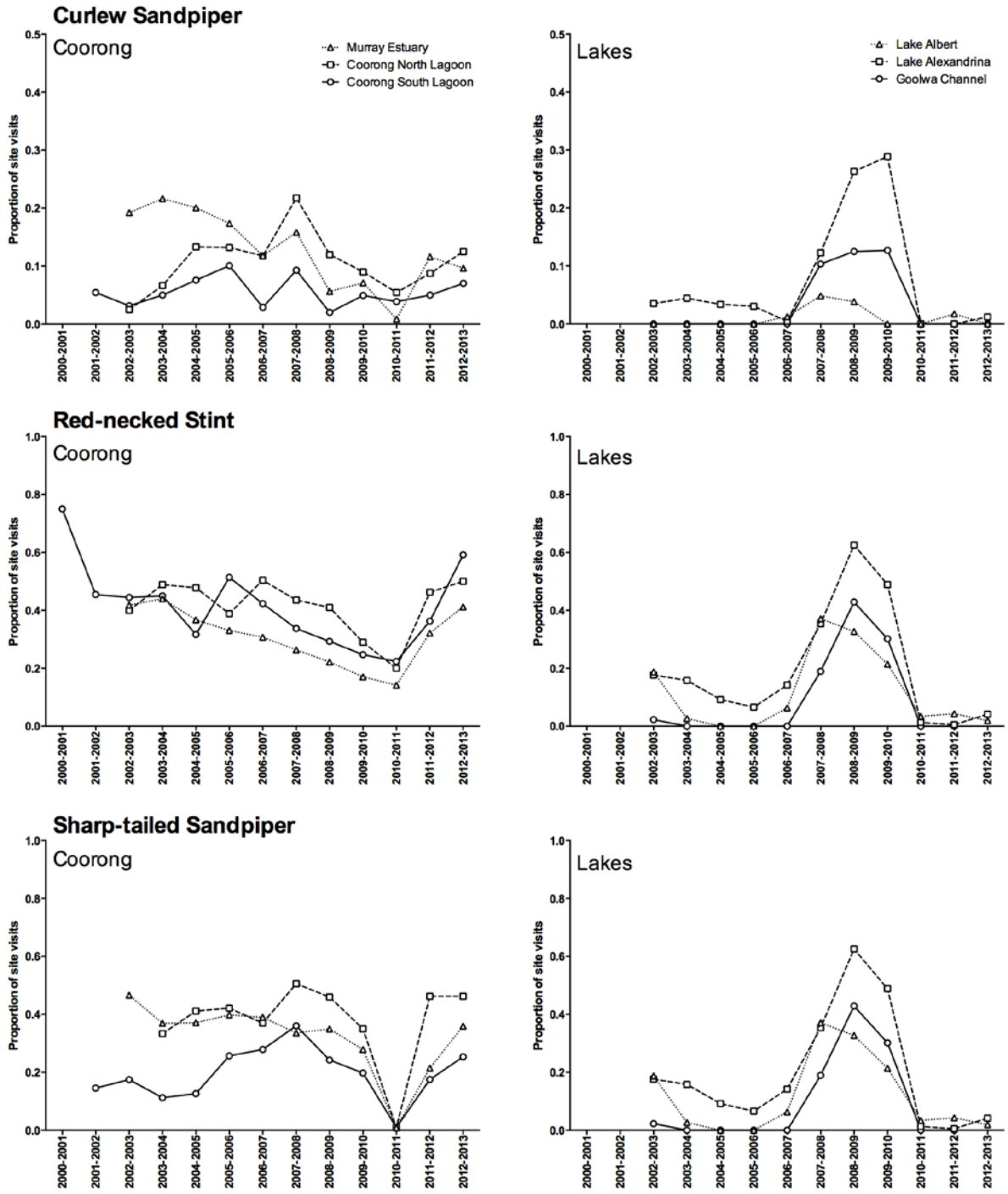

Figure 5. Changes in the reporting rate of selected shorebird species in the Coorong (left) and Lower Lakes (right) between 2000-2001 and 2012-2013. Reporting rate is given as the proportion of site visits within each subregion within each reporting year, in which at least one individual of the species was detected. Note that scale differs between species (but not between the two graphs for each species).

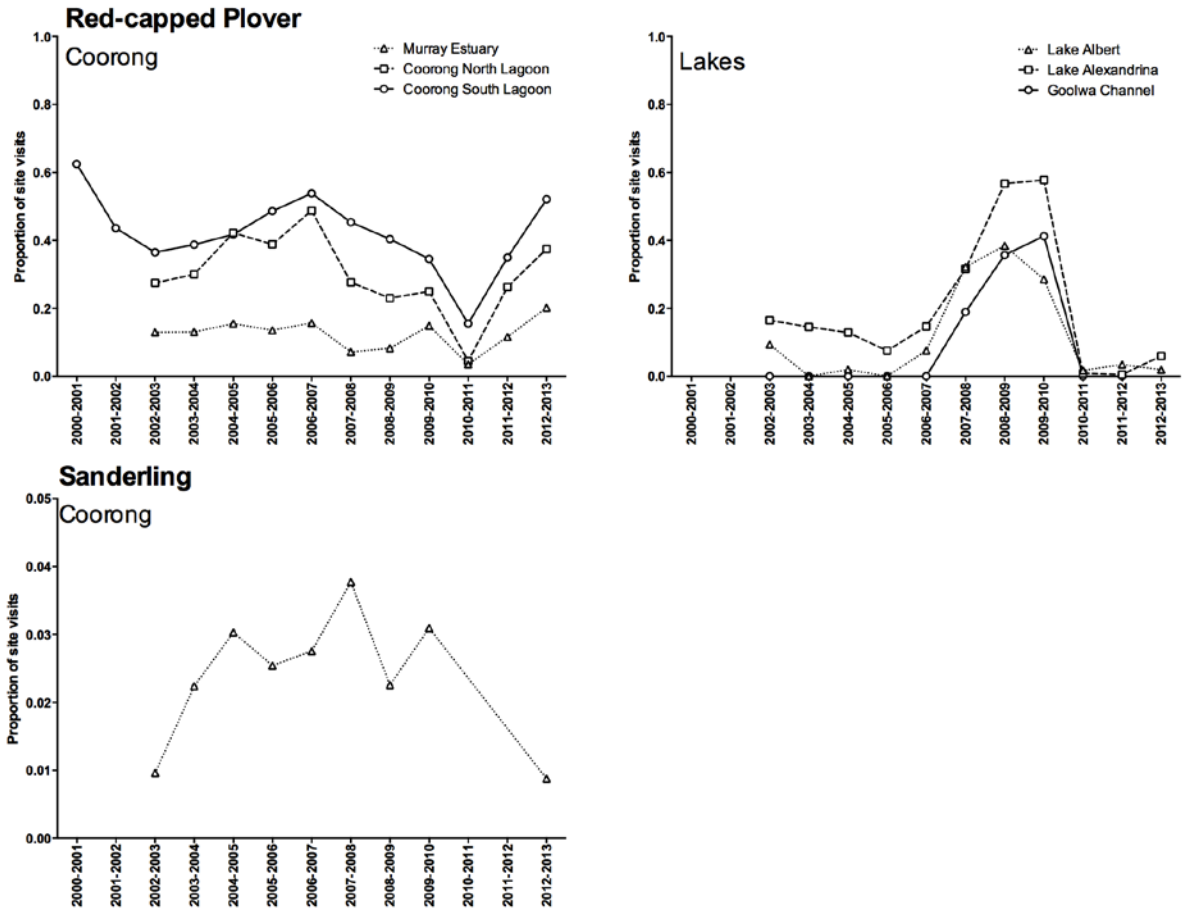

Figure 6. Changes in the reporting rate of selected shorebird species in the Coorong (left) and Lower Lakes (right) between 2000-2001 and 2012-2013. Reporting rate is given as the proportion of site visits within each subregion within each reporting year, in which at least one individual of the species was detected. Note that scale differs between species (but not between the two graphs for each species).

1.4 Large endemic waders

Two of the three species of large endemic wader (Red-necked Avocet and Banded Stilt) selected for reporting showed consistent patterns of interannual change in reporting rate. This is not surprising, considering that the species have very similar ecological requirements (Marchant and Higgins 1990). For example, both species prefer saline environments, and frequently occur on inland salt lakes (when inundated) for foraging and breeding (Marchant and Higgins 1990). Both species were infrequently recorded in the (usually freshwater) Lakes subregions from the commencement of monitoring in 2002 to the latest surveys in 2013. In the Coorong, both species were reported more frequently in the hypersaline South Lagoon. Banded Stilt were one of the only LLCMM waterbird species to be reported at higher rates during the peak of the drought (2006-2009); Red-necked Avocets declined during the same time period. This may reflect an increased tolerance of Banded Stilt to extreme hypersaline conditions; which most probably translates to a high physiological tolerance to food sources (e.g. brine shrimp) with high salt content (Marchant and Higgins 1990). Banded Stilt were observed in record numbers (>213,000) in 2009 (O'Connor et al. 2012; Paton and Bailey 2012; Wainwright and Christie 2008). Following the recovery of water flows to the wetlands, both species have been recorded at generally increasing rates in all subregions of the Coorong.

Caution must be taken when interpreting the local abundance or reporting rate of continentally or regionally nomadic species such as Banded Stilt, Red-necked Avocet, Australian Pelican, and Chestnut Teal (O'Connor et al. 2013). These species will respond to changes in habitat availability at a regional or national scale (e.g. flooding of inland salt lakes), hence declines at a LLCMM scale may be affected by 'ideal' conditions elsewhere rather than 'poor' conditions at a local scale

The Australian Pied Oystercatcher was reported in relatively stable rates across the entire period, with a sudden decline and recovery between 2010 and 2013. Oystercatchers forage in marine mudflat habitats, which may have become scarce following the return of significant flows to the wetlands. This species has not been reported in the lakes, where saline mudflat habitats (and presumable small bivalve prey) are very scarce.

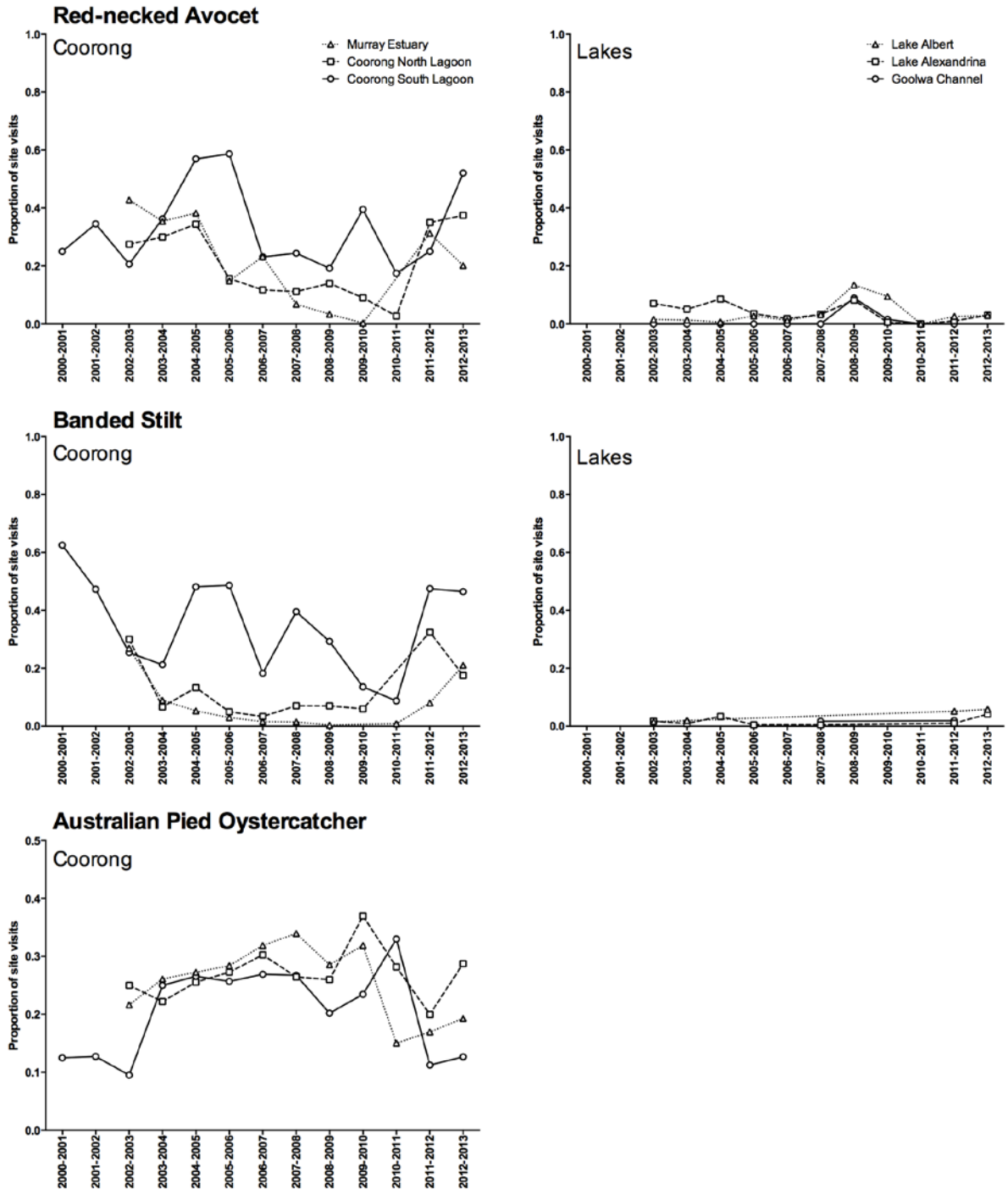

Figure 7. Changes in the reporting rate of selected large endemic wader species in the Coorong (left) and Lower Lakes (right) between 2000-2001 and 2012-2013. Reporting rate is given as the proportion of site visits within each subregion within each reporting year, in which at least one individual of the species was detected. Note that scale differs between species (but not between the two graphs for each species).

2. Seasonal changes in LLCMM environmental variables and relative abundance, 2006-2013

The period 2006-2013 represented some of the most dramatic hydrological and ecological changes that have occurred in the LLCMM Icon Site's recorded history (see Rogers 2012, pg 16, for a full discussion of hydrological and ecological changes at the site during 2006-2012). This report will primarily focus on whether species trends have changed in the past reporting period (2012-2013), compared to the years immediately following the return of significant flows to the system (2010-2012).

2.1 Impact of lakes water level management and barrage releases (2012/2013) on waterbirds

The five barrages (Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere) separate the Lakes from the River Murray Mouth and Coorong, and are used to control flows within the system (primarily to maintain freshwater conditions in the lakes). The timing and quantity of flows through barrages therefore impact hydrological and ecological conditions in the Coorong and Murray Mouth. For example, during severe drought conditions from 2006-2009, little to no water was released from the barrages, which effectively halted freshwater flows to the Coorong and Murray Mouth (Kingsford et al. 2011; Paton 2010). This resulted in extreme hypersaline conditions in the Coorong lagoons, and the need to dredge the Murray Mouth in order to keep it open to the sea.

Barrage outflows in winter-spring 2012 of up to 1529 GL/Month (Figure 8) were actually higher than those recorded in the 1980s or 1990s (average <900 GL/Month and <1200 GL/Month respectively) and are closer to the long-term average natural flows of 1300-1700 GL/Month during the same period (Aug-Dec) (Paton 2010, p 95). 2012 flows were considered to be exceptionally high (flooding) events, which highlights the shifting baseline of 'average' flow volumes. Salinities in the Coorong South Lagoon in particular, were lower during this period of recent high barrage flow release (Figure 8). However, very low barrage flows from Dec 2012 to May 2013 (Figure 8) resulted in sharp decreases in Coorong water levels (Figure 9), which negatively affected the reproductive success of naturally-occurring and recently translocated *Ruppia* in the Coorong (Paton and Bailey 2013). *Ruppia* is an aquatic macrophyte (submerged vegetation), and can die quickly after short periods of exposure (Paton and Bailey 2013). Since *Ruppia* is a key food resource for many waterbird species, including Black Swan, Sharp-tailed Sandpiper and Chestnut Teal (O'Connor et al. 2013; Paton 2010), decreases in its abundance and distribution are likely to have a negative impact on waterbird populations.

Recent salinity levels in the Coorong and Lower Lakes are within the normal ranges of natural variation for the site (Kingsford et al. 2011; Phillips and Muller 2006; Webster 2007), and the within the physiological tolerances of most key waterbird food resources (see O'Connor et al. 2013; Paton 2010).

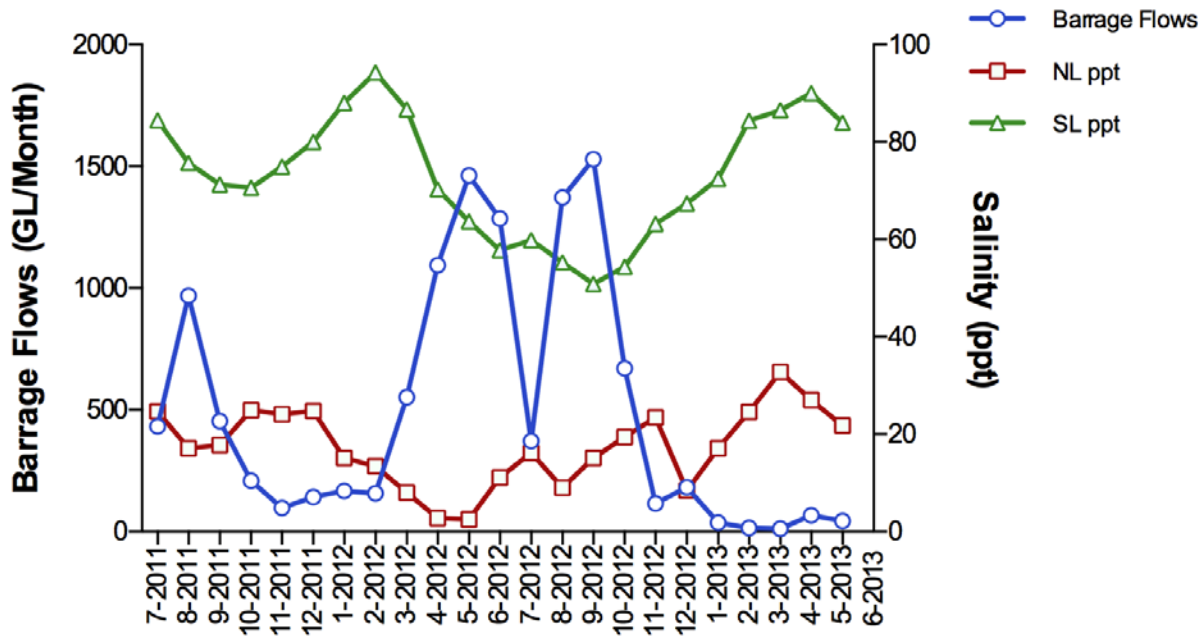

Figure 8. Barrage outflows and corresponding salinity levels in the Coorong (July 2011 to May 2013). Salinity data is presented as 'NL ppt' (North Lagoon), or 'SL ppt' (South Lagoon).

In the Lakes subregions, water levels have been stable at 0.58 to 0.84 m AHD since the return of water flows in 2010 (Figure 9).

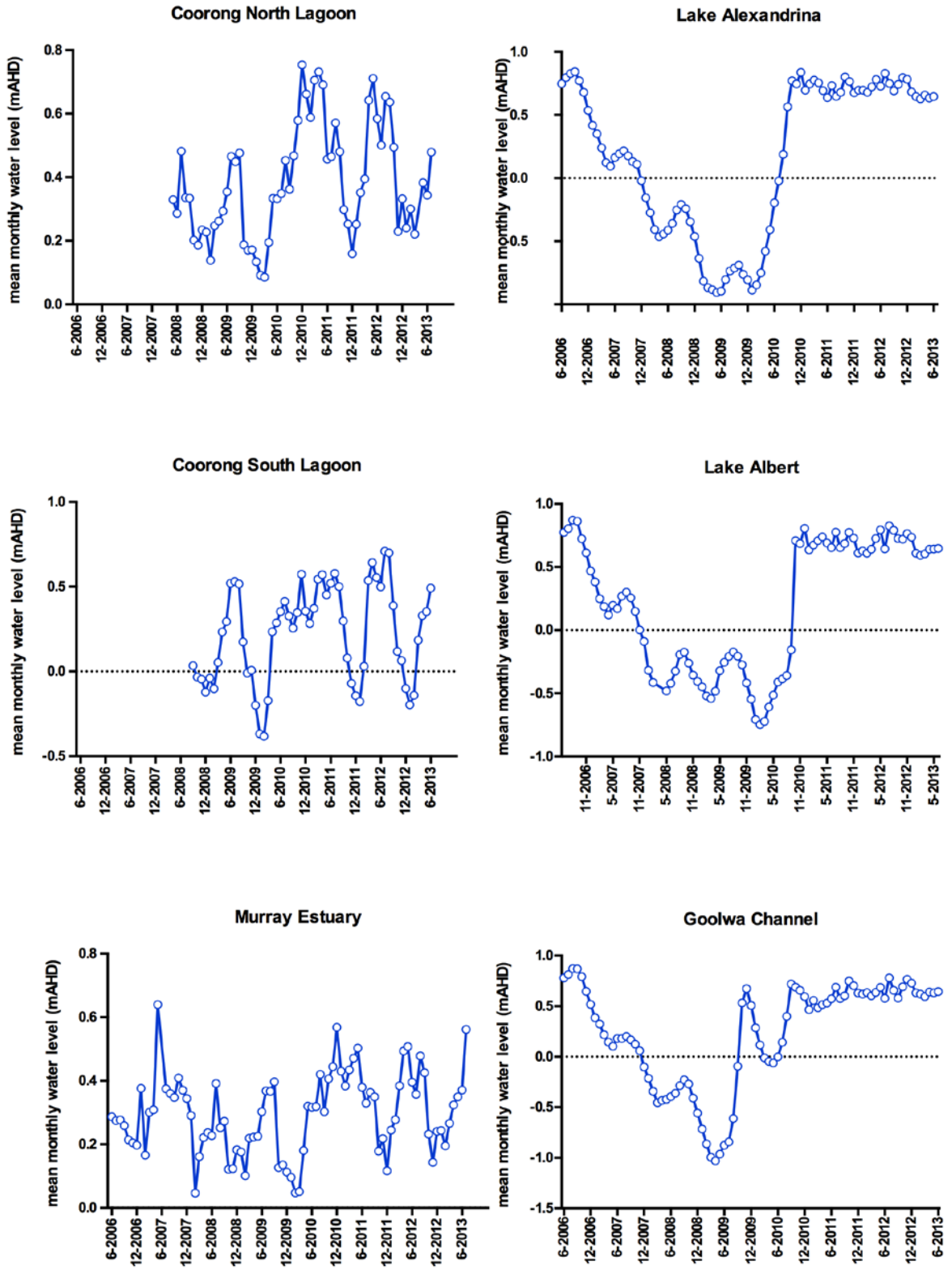

Figure 9. Changes in average water level (m AHD) for each of the six subregions of the LLCMM Icon Site, from 2006-2013. Average water level was calculated by averaging a number of monitoring stations within each subregion; the number of monitoring stations varied between subregions and through time.

2.2 Seasonal changes in the abundance of selected species

Seasonal changes in the relative abundance of waterbird species partly reflect changes in environmental conditions at a given site. As discussed in Section 1.4, migratory or nomadic species will also respond to off-site conditions, and hence their local abundance within the LLCMM will often be affected by the availability and condition of other wetland sites at a regional, national or international scale, as well as traditional movements (e.g. migration) on and off the site. For the purposes of this report, the relative abundance of selected species are discussed in relation to water levels and other ecological conditions within each subregion (at a local LLCMM scale), noting that these relationships may be difficult to establish given these off-site drivers of abundance.

The selected waterbird species appear to respond to ecological conditions at different scales within the six main subregions. For example, species such as the Fairy Tern (Figure 11), Chestnut Teal (Figure 14), and Banded Stilt (Figure 19) were generally detected at a higher frequency within the Coorong subregions compared to the lakes. These species are predicted to respond strongly to local conditions within the Coorong, as compared to Australian Pelican and Black Swan, which are commonly reported across all Coorong and Lakes subregions and respond to conditions at broader scales.

Few major changes in relative abundance have been observed since the 2011-2012 reporting period (see Rogers 2012). The Australian Pelican was observed at consistent relative abundances of 50-350 birds in each of the six subregions, but have recently increased in numbers in the Coorong South Lagoon and Murray Estuary. The large numbers of pelicans recorded in South Lagoon is not surprising considering that 2170 active pelican nests were observed on three South Lagoon islands in a separate study over the same time period (O'Connor 2013). Fairy Terns appeared to have responded positively to the return of flows in 2010, but have since declined in relative abundance in all Coorong subregions (Fairy Terns rarely use the lakes). This is surprising, considering the recent increased abundance of fish prey resources, such as the Smallmouth Hardyhead in the Coorong South lagoon (Livore et al. 2013; Ye et al. 2012). Recent Fairy Tern abundance, distribution and breeding success will be discussed in more detail in Paton et al. (In Preparation). Common Greenshank have been observed in relatively low numbers (<40 per visit) from 2006-2013 (Figure 12), and show no signs of recovery following the return of flows to the wetlands. This species was relatively abundant during pre-drought conditions, with >8000 birds counted in the Coorong in 2000. However that number had declined to just 50 birds using the whole system (Coorong and Lakes) in 2012 (O'Connor et al. 2012; Paton and Bailey 2012; Rogers and Paton 2009). The Black Swan has experienced a gradual but steady decline in the

Lakes, but has recently increased in relative abundance in the Coorong (Figure 13). As discussed earlier, increased abundance in the Coorong subregions does not reflect an increase in the species' key food resource: *Ruppia tuberosa* (although broad areas of germination in early spring may have provided a temporary food source (Paton and Bailey 2013), but may reflect increases in abundance across the broader region (e.g. through habitat improvements in the Lakes and other regional wetlands). Chestnut Teal predominantly use Coorong wetlands (relative to their use of the Lakes), where they appear to have experienced a slight decline in relative abundance over the past six years (Figure 14). Recent aerial surveys (October 2012) of the Coorong counted 3710 Chestnut Teal in the Coorong (P. Wainwright, DEWNR, unpublished data), which is lower than the regular 5000-15 000 birds counted in annual January surveys (D. Paton, Adelaide University). The relative abundance of Curlew Sandpiper in the Coorong remains very low (Figure 15), whereas other shorebird species: Red-necked Stint (Figure 16), Sharp-tailed sandpiper (Figure 17), and Red-capped Plover (Figure 18), have remained relatively stable. This may reflect the different ecological requirements of the Curlew Sandpiper to other migratory waders, or off-site impacts such as poor breeding or foraging conditions at other sites along the Curlew Sandpiper's migratory route (Gosbell and Clemens 2006; Minton et al. 2003). The Curlew Sandpiper is, in fact, declining at an international scale (Gosbell and Clemens 2006). However, on-site conditions such as foraging conditions and food availability may also be affecting local abundances. For example, The relative abundance of Banded Stilt has remained very low in the most recent reporting period (Figure 19), however this measure does not accurately reflect actual abundances, which are often between 10 000 and 50 000 birds in the Coorong , but peaked at 213 000 during the height of the drought (O'Connor et al. 2012; Paton and Bailey 2012; Paton and Bailey In Preparation). The recent recovery of Red-necked Avocet in the Coorong subregions, particularly the Murray Estuary (Figure 20) probably reflect improved foraging conditions (such as increased macroinvertebrate abundances) at the site (Dittmann et al. 2013).

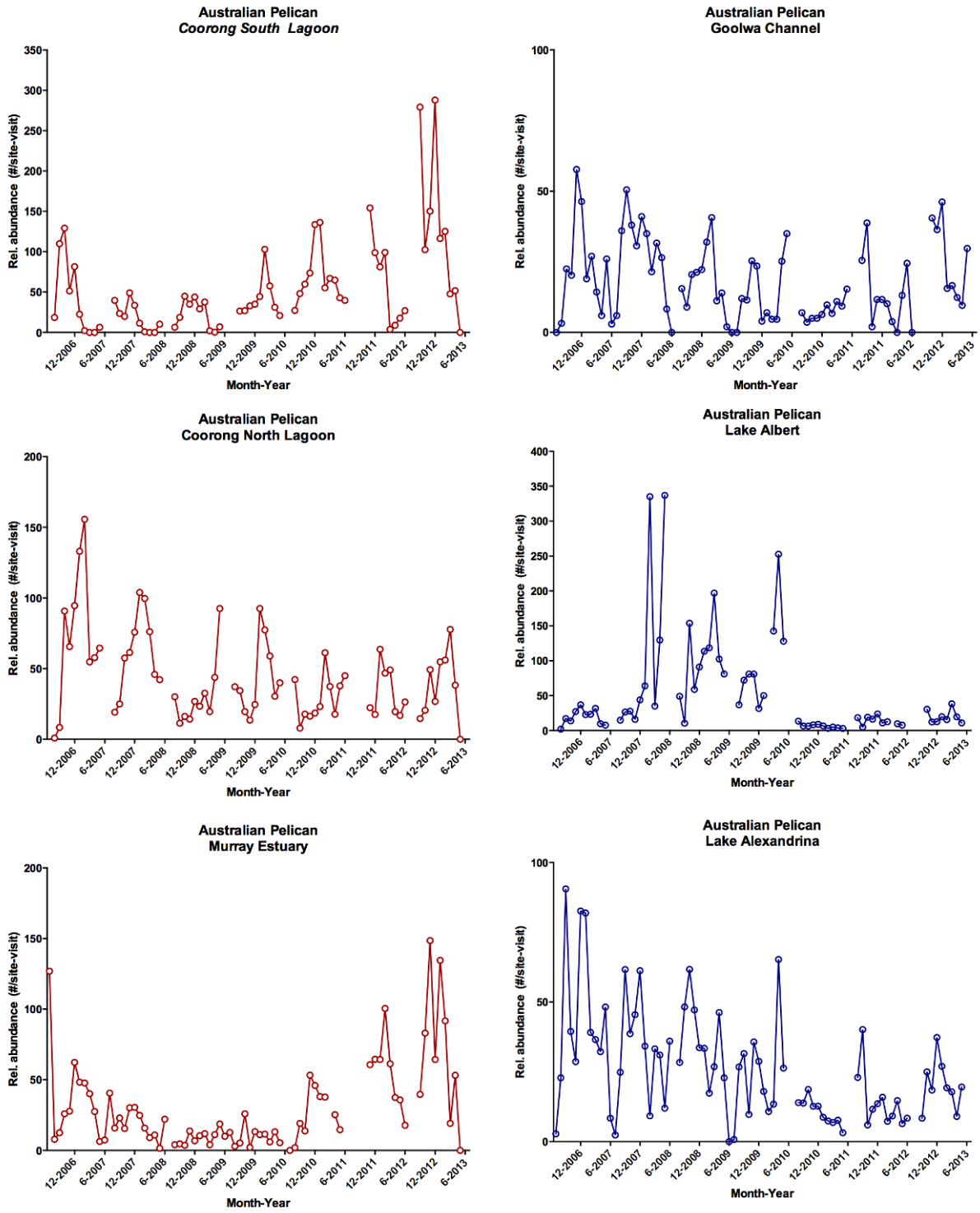

Figure 10. Monthly relative abundance (individuals/site.visit) of Australian Pelican between July 2006 and June 2013, for each of six subregions of the LLCMM Icon Site. Line breaks relate to periods where no surveys were conducted.

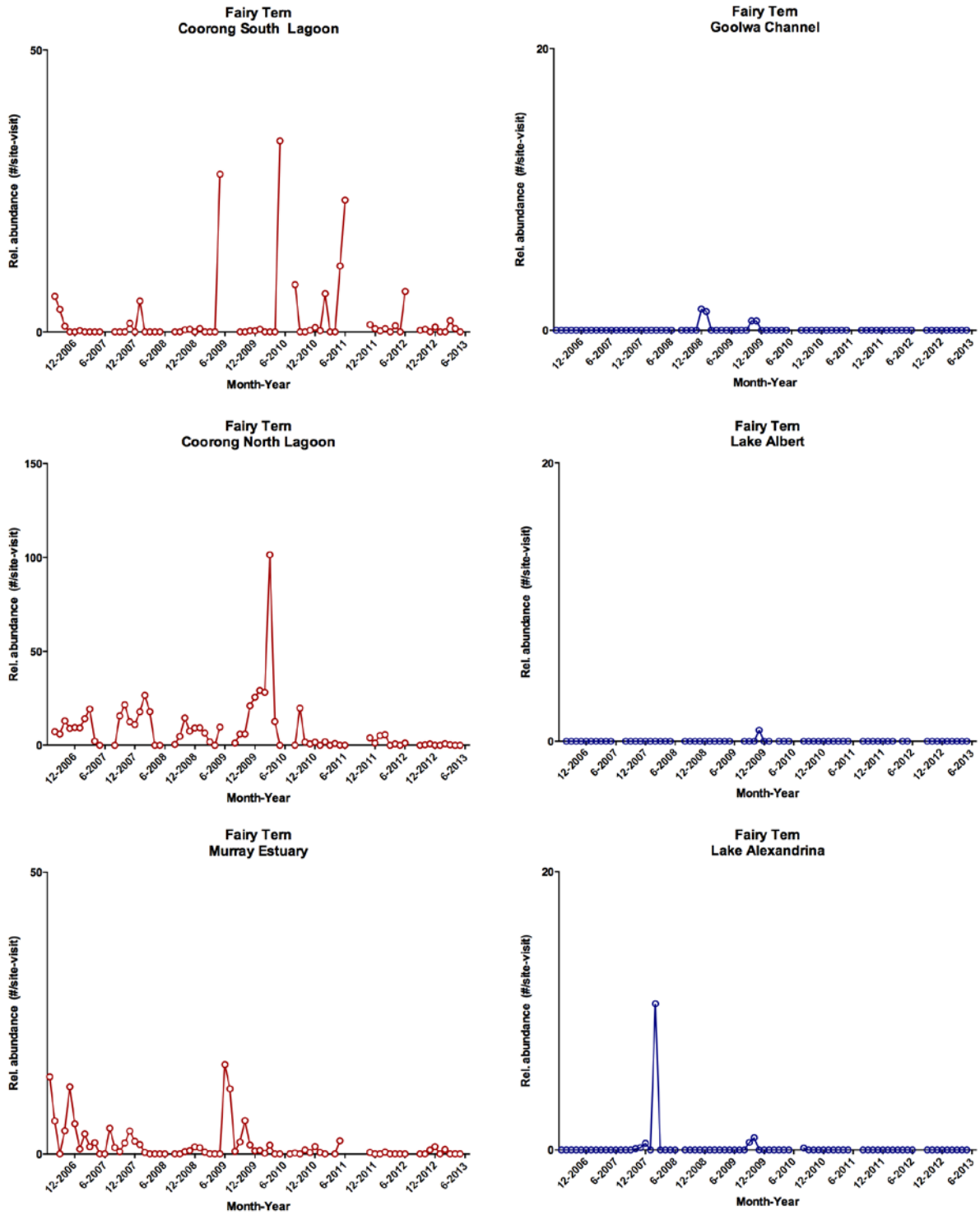

Figure 11. Monthly relative abundance (individuals/site.visit) of Fairy Tern between July 2006 and June 2013, for each of six subregions of the LLCMM Icon Site. Line breaks relate to periods where no surveys were conducted.

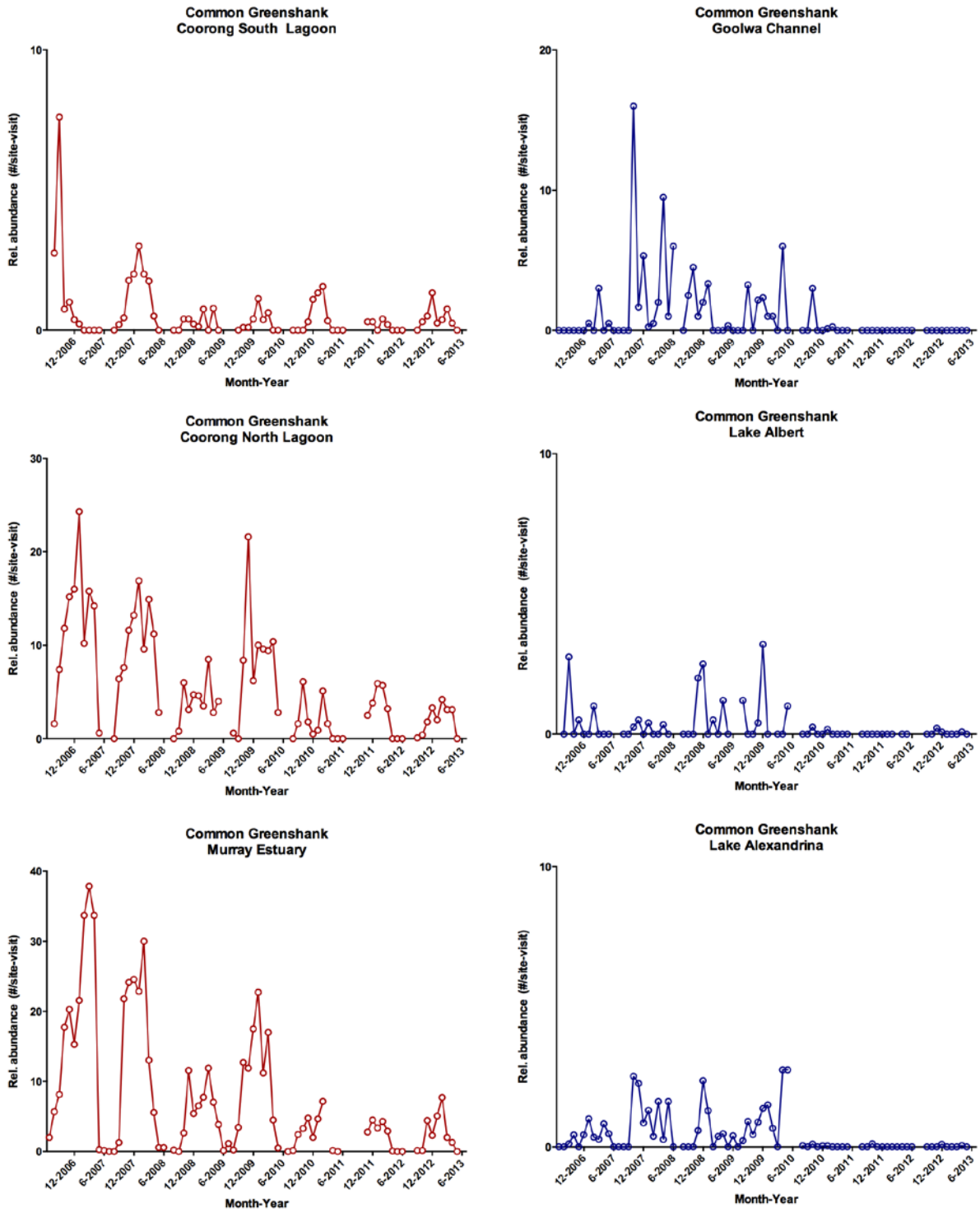

Figure 12. Monthly relative abundance (individuals/site.visit) of Common Greenshank between July 2006 and June 2013, for each of six subregions of the LLCMM Icon Site. Line breaks relate to periods where no surveys were conducted.

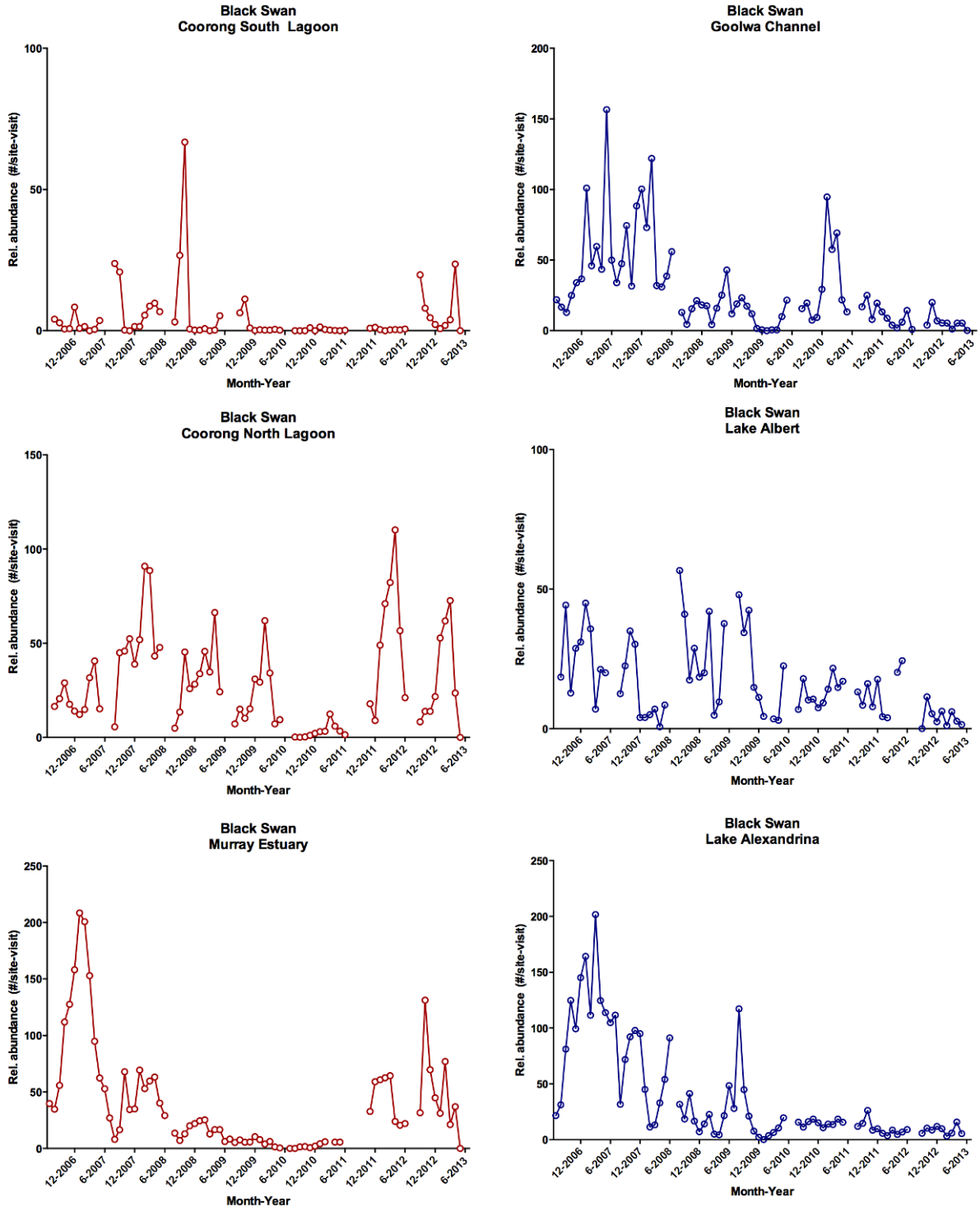

Figure 13. Monthly relative abundance (individuals/site.visit) of Black Swan between July 2006 and June 2013, for each of six subregions of the LLCMM Icon Site. Line breaks relate to periods where no surveys were conducted.

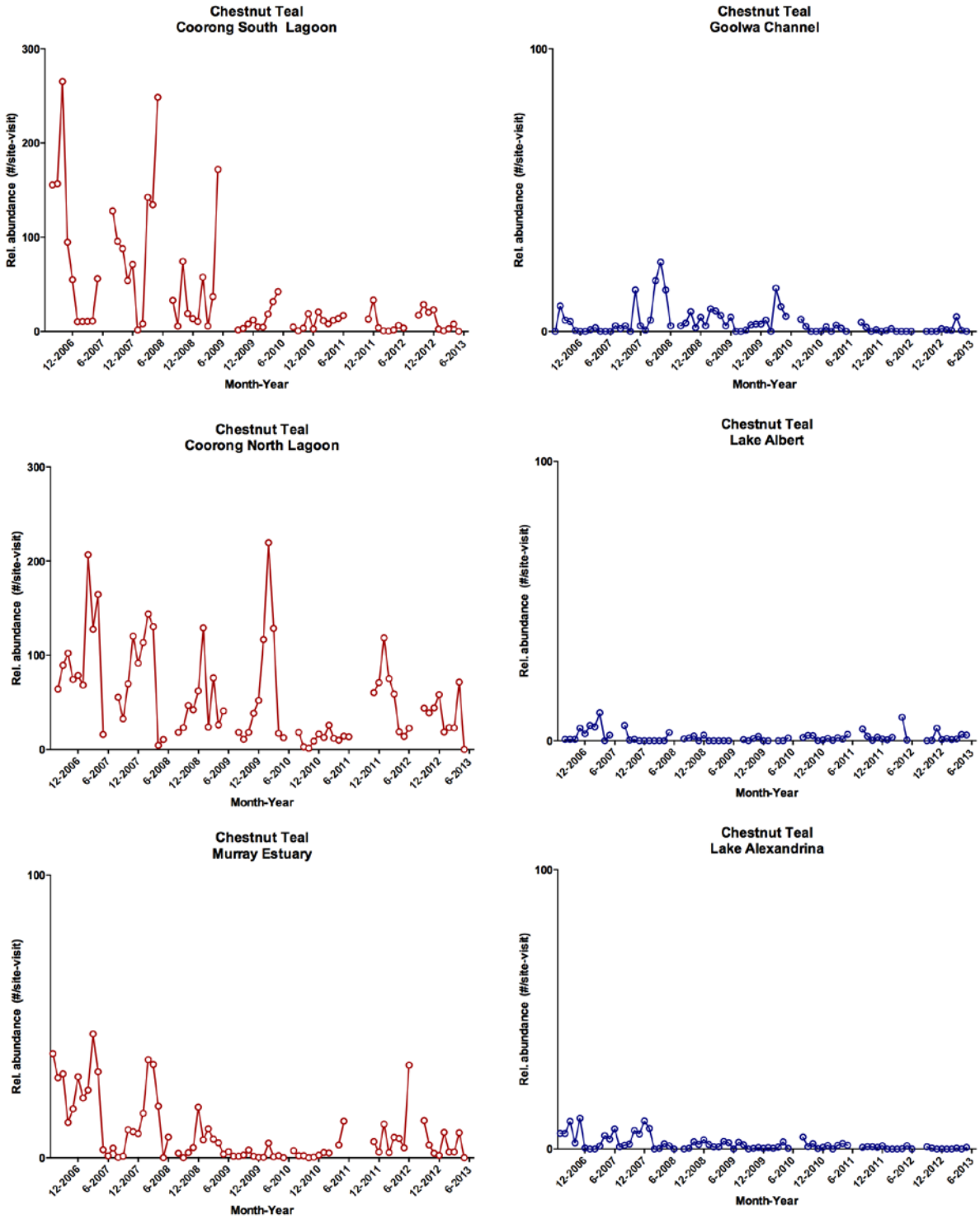

Figure 14. Monthly relative abundance (individuals/site.visit) of Chestnut Teal between July 2006 and June 2013, for each of six subregions of the LLCMM Icon Site. Line breaks relate to periods where no surveys were conducted.

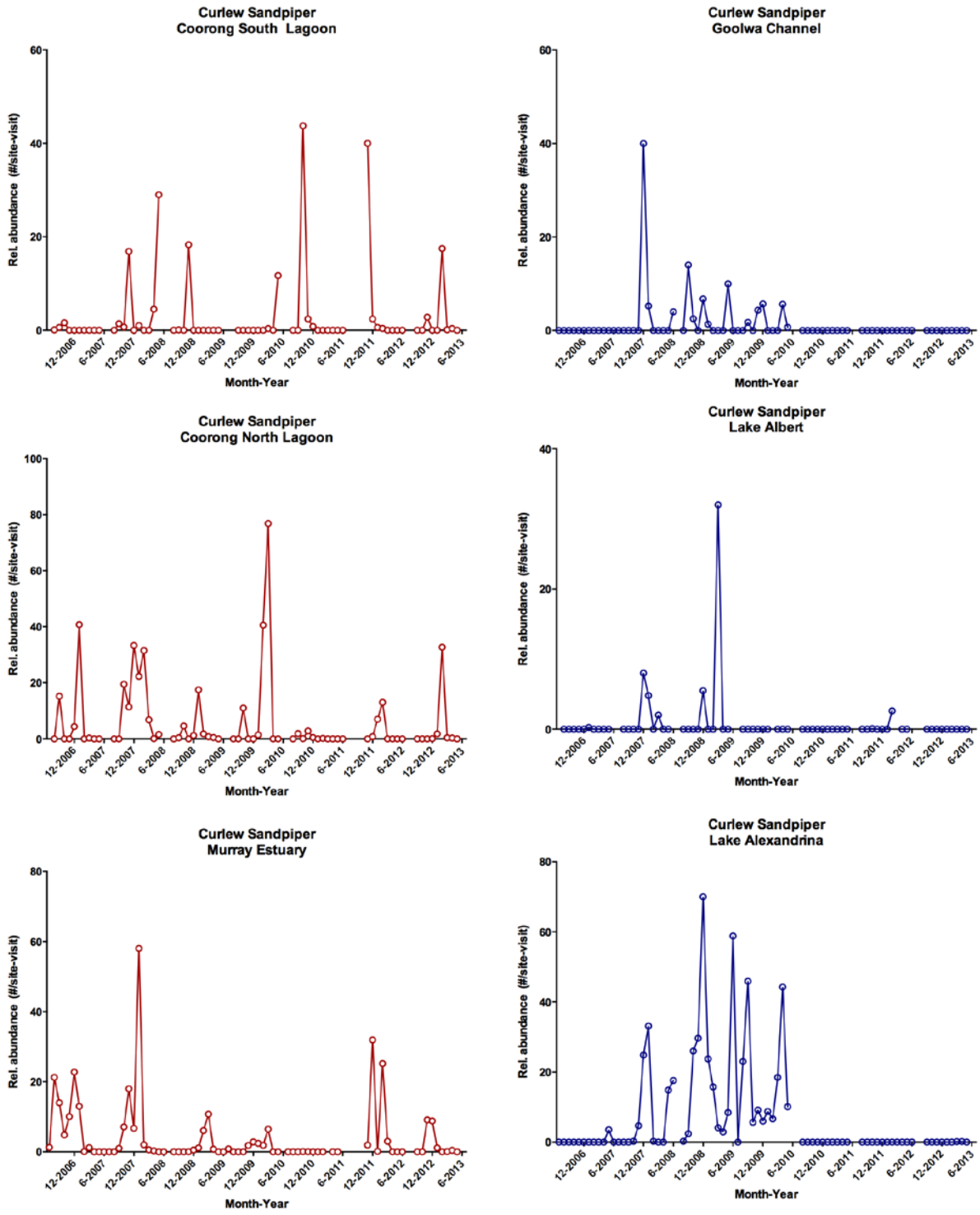

Figure 15. Monthly relative abundance (individuals/site.visit) of Curlew Sandpiper between July 2006 and June 2013, for each of six subregions of the LLCMM Icon Site. Line breaks relate to periods where no surveys were conducted.

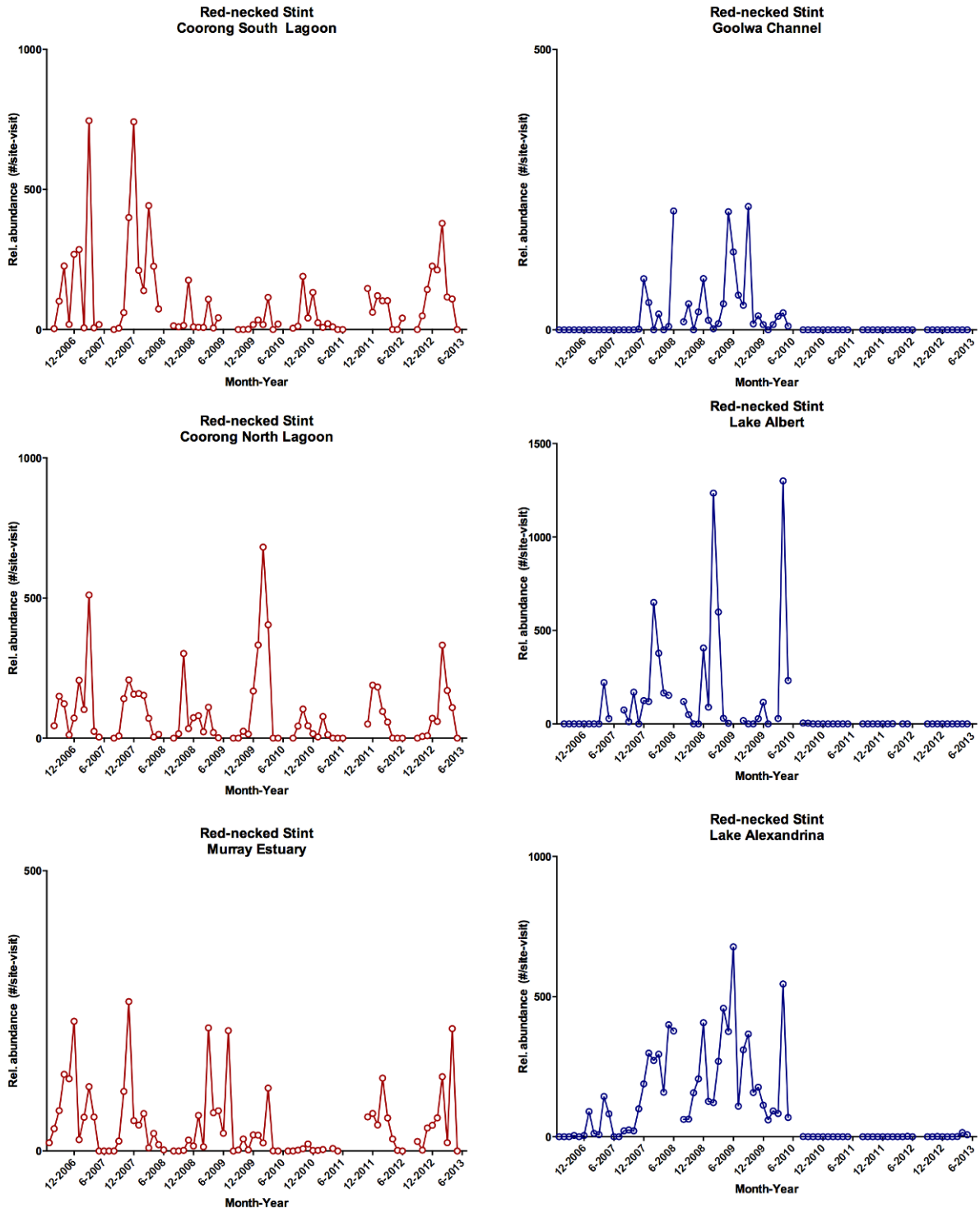

Figure 16. Monthly relative abundance (individuals/site.visit) of Red-necked Stint between July 2006 and June 2013, for each of six subregions of the LLCMM Icon Site. Line breaks relate to periods where no surveys were conducted.

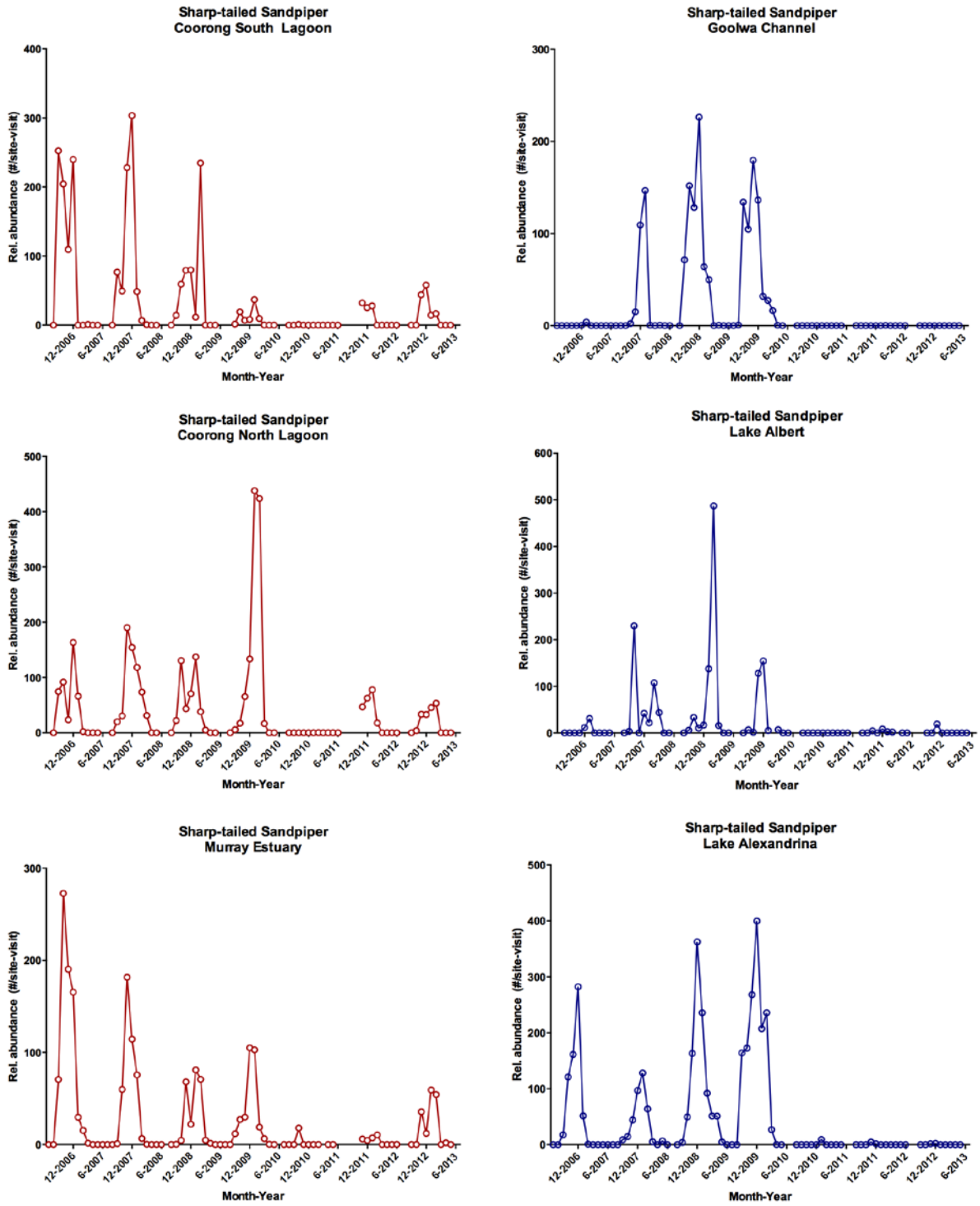

Figure 17. Monthly relative abundance (individuals/site.visit) of Sharp-tailed Sandpiper between July 2006 and June 2013, for each of six subregions of the LLCMM Icon Site. Line breaks relate to periods where no surveys were conducted.

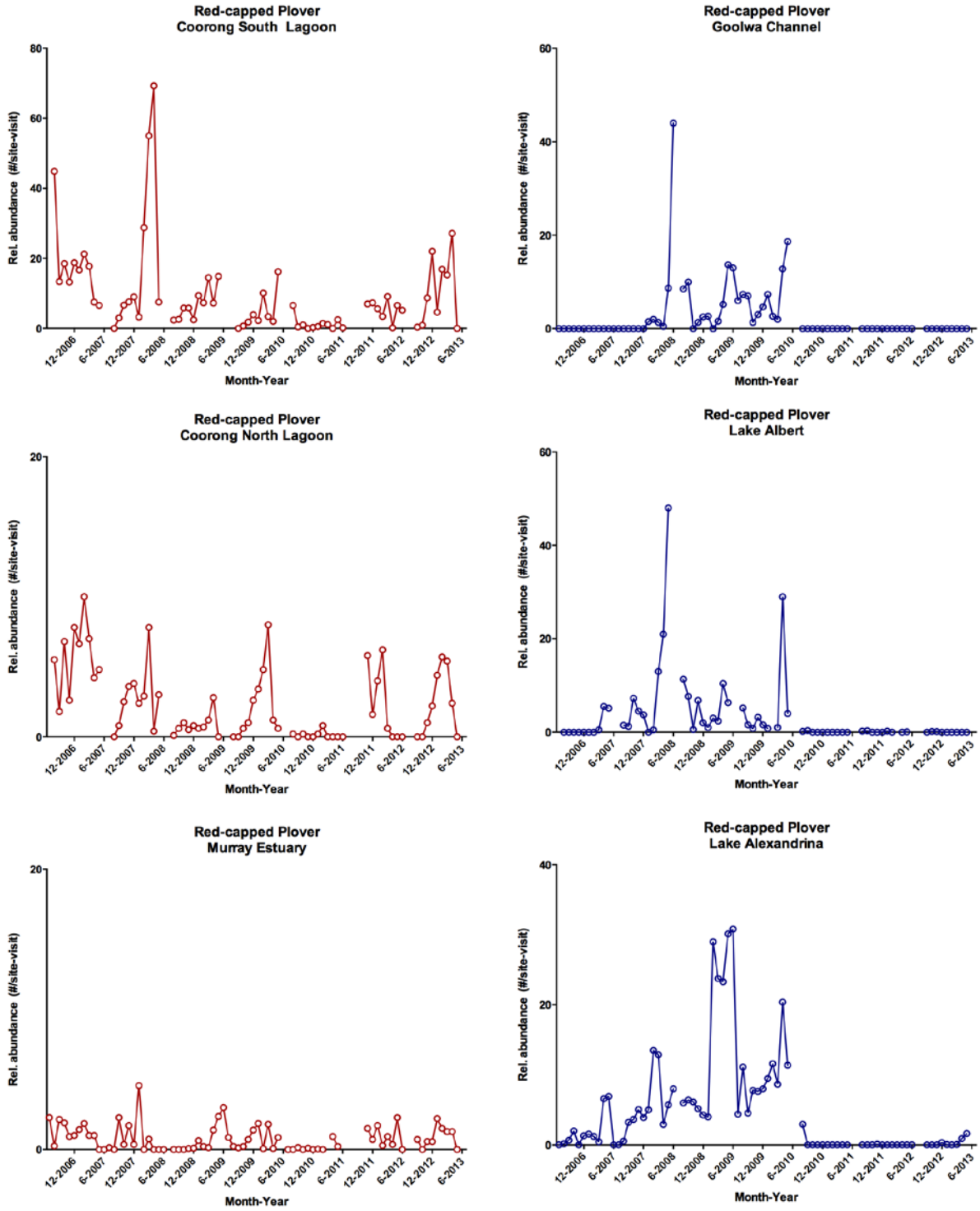

Figure 18. Monthly relative abundance (individuals/site.visit) of Red-capped Plover between July 2006 and June 2013, for each of six subregions of the LLCMM Icon Site. Line breaks relate to periods where no surveys were conducted.

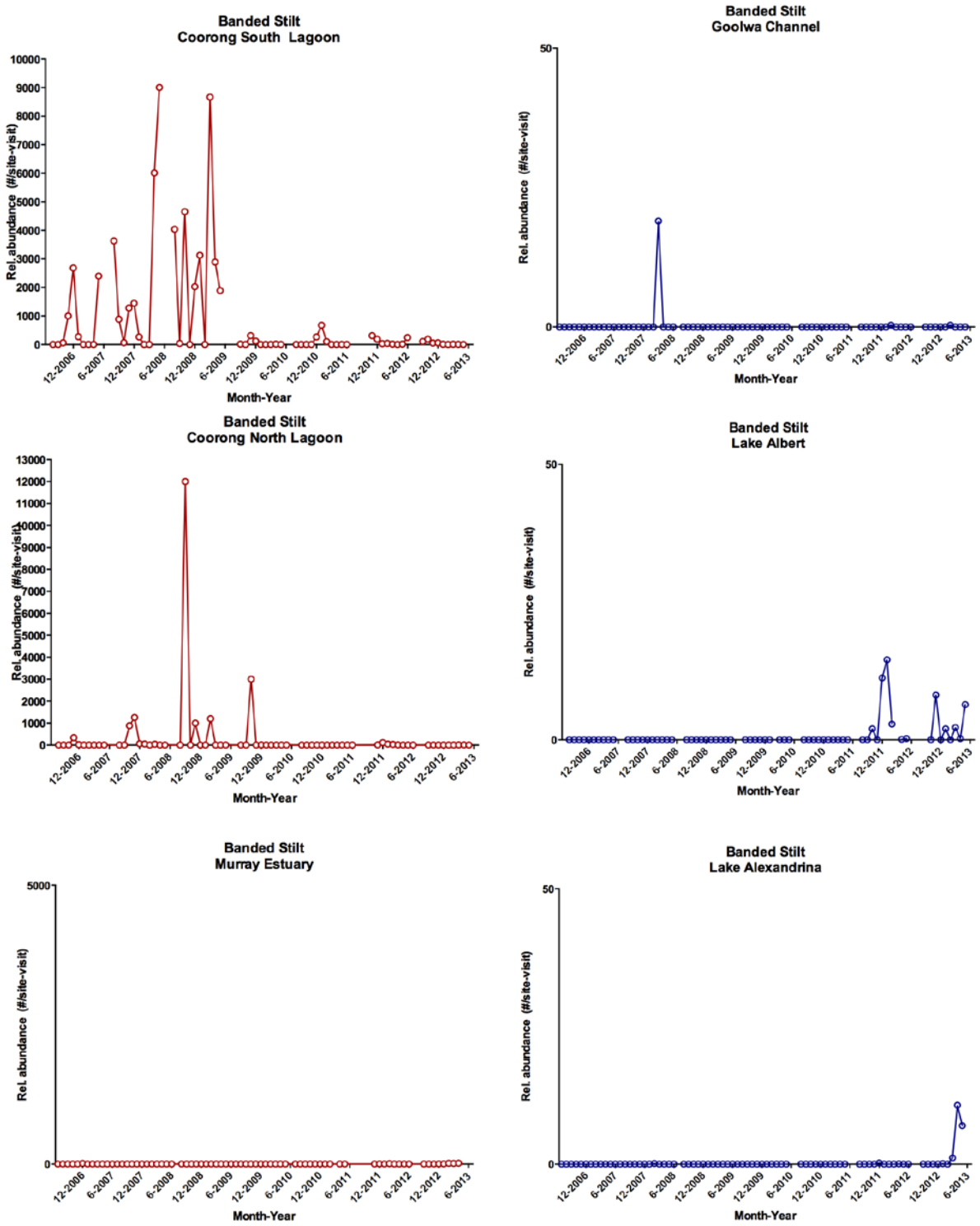

Figure 19. Monthly relative abundance (individuals/site.visit) of Banded Stilt between July 2006 and June 2013, for each of six subregions of the LLCMM Icon Site. Line breaks relate to periods where no surveys were conducted.

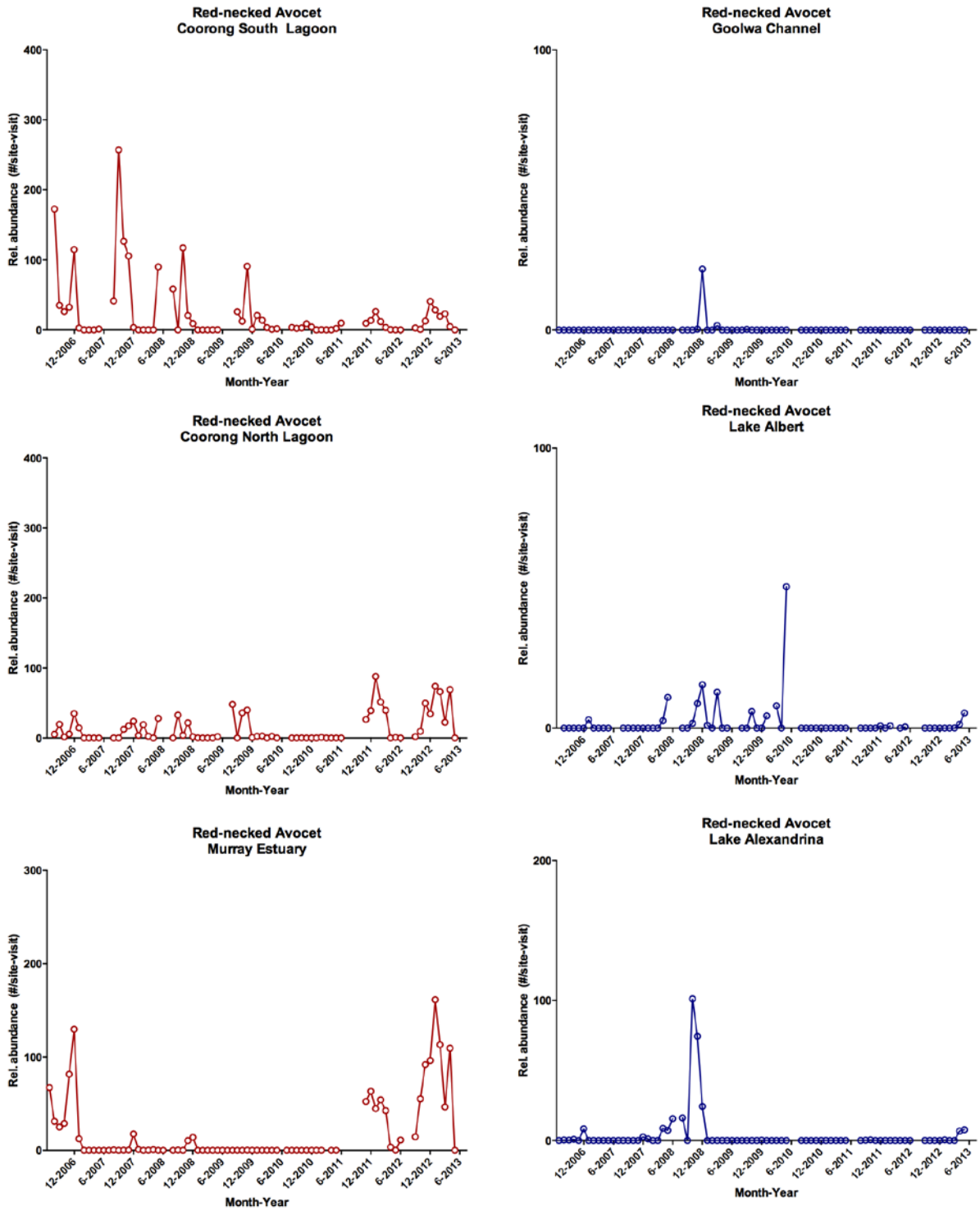

Figure 20. Monthly relative abundance (individuals/site.visit) of Red-necked Avocet between July 2006 and June 2013, for each of six subregions of the LLCMM Icon Site. Line breaks relate to periods where no surveys were conducted.

3. Managed Wetlands

Narrung wetland was first visited in November 2010, and was visited 19 times to May 2013. Bird surveys were intended to coincide with managed water release at the wetland. This report presents local abundance data for four selected species (Australian Pelican, Banded Stilt, Sharp-tailed Sandpiper and Black Swan), in relation to wetland water levels. Trends in species abundance at the Narrung Wetland followed some consistent patterns in relation to water levels, although the lack of consistent bird survey and water level data hinders a more complete interpretation of results. Peak abundances of all four species were generally observed between October 2011 and January 2012 when water levels were low (0.4 m AHD). Banded Stilt and Sharp-tailed Sandpiper abundances were particularly high during this drawdown period, probably in response to the increased availability of mudflats for foraging. Conversely, trends in the abundance of Australian Pelican and Black Swan did not follow a consistent pattern in relation to water levels at the site. Most Australian Pelican were observed to 'rest' or 'fly overhead' at the site, which indicates that they are probably not responding strongly to food resources within the wetland. Black Swan, however, are more likely to respond to the abundance of submerged vegetation at the wetland, which is partially driven by water level variation (Gehrig et al. 2012; Paton and Bailey 2013).

Consistent measurement of water levels at the site (on a monthly basis), would allow further comparison of water levels and waterbird abundance at the wetland (including an interpretation of 2013 patterns).

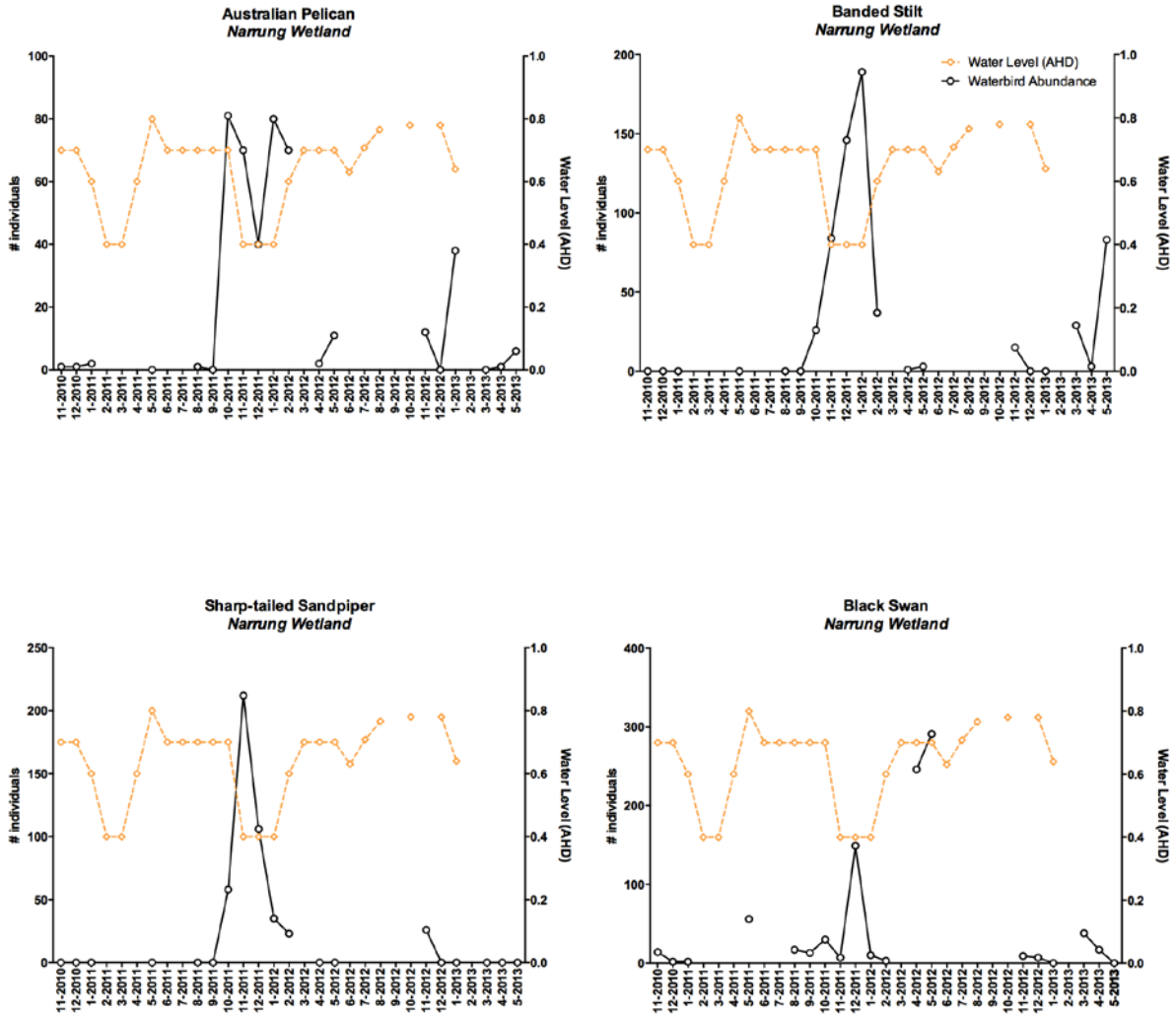

Figure 21. Abundance of four selected species at the Narrung wetland between October 2011 and November 2013. Line breaks relate to periods where no surveys were conducted.

Discussion

The results of this study show that waterbirds have responded to environmental change in the LLCMM. The majority of waterbird species responded negatively to low water flows under drought conditions (2006-2009). However, waterbird species showed different patterns of temporal and spatial response to the return of water flows in 2010.

This report presented data for 14 of the 16 species that were selected for reporting at the LLCMM icon site (Maunsell Australia 2009). Latham's Snipe and Australasian Bittern were detected in very low numbers in this monitoring program, hence their population trends are not discussed in this report (see O'Connor 2013 for recent, targeted surveys of these species).

The results presented in this report are used to assess the Icon site's waterbird target:

> *"Maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth"*

In summary, patterns of reporting rate and relative abundance of selected species have shown some general patterns of waterbird recovery; however some species have continued to decline or only persist in small numbers within particular subregions. Table 2 shows a summary of annual trends in species response to environmental change during pre-drought, drought and post-drought conditions.

Overall trends in the reporting rate of selected waterbird species have shown a continued increase or stabilisation since the return of water flows in 2010. This suggests a general 'maintenance' or 'improvement' of bird populations, at the Icon site, at least compared with the relative abundance of these species immediately prior to the period of extended low flow. This response of waterbirds to returned water flows is not surprising given that waterbirds are known to respond rapidly and positively to increased water availability in wetlands (Kingsford and Auld 2005; Murray et al. 2012; Stewart and Harper 2002). However, despite the ubiquitous need for water flows, different LLCMM waterbird species require different hydrological conditions in order to utilise the site for foraging, breeding or as a drought refuge (O'Connor et al. 2013; Paton and Bailey 2012; Paton 2010; Paton et al. 2011; Paton et al. 2009). For example, within the Coorong wetlands over summer, migratory shorebirds require tidal mudflats for foraging (low water levels and tidal movement) (Paton 2010; Paton et al. 2009) and piscivorous Fairy Terns and Australian Pelicans simultaneously require high lagoon water levels that can sustain fish prey resources, and isolate island breeding sites from terrestrial predators (DENR 2011; DENR 2012; O'Connor 2013; Paton In Preparation;

Paton and Rogers 2009b). Furthermore, the maintenance of aquatic plant food species, such as *Ruppia tuberosa* in the Coorong, ideally requires the maintenance of 30-60 cm deep water (Paton and Bailey 2013) between April and December. Hence to 'maintain or improve bird populations in the Lower Lakes, Coorong and Murray Mouth', managers must also endeavour to maintain minimum (but variable) water levels, that can sustain key waterbird food (e.g. *Ruppia*, fish, macroinvertebrate) and other habitat resources (breeding, foraging and drought refuge) within the wetland system. There is a wealth of monitoring and modelling data to support such management (e.g. Dittmann et al. 2013; Gehrig et al. 2012; Lester et al. 2011; Livore et al. 2013; O'Connor et al. 2013; Paton and Bailey 2012; Paton and Bailey 2013; Webster 2007).

In this report 'maintenance' of populations is considered within the 2000-2013 monitoring period (i.e. populations that have maintained or stabilised to rates that are comparable to the early 2000s). However, many species such as the Fairy Tern and Curlew Sandpiper had already experienced significant declines prior to this period (O'Connor et al. 2012; Paton 2010; Paton et al. 2009). The term 'maintenance' may therefore need further clarification within the context of Icon Site reporting.

The waterbird 'reporting rates' presented in this report, should also be interpreted with caution. These reporting rates represent the proportion of site visits at which a species was detected in each reporting year, and are not analogous to actual waterbird abundances, which are surveyed annually in January (Paton and Bailey 2011; Paton and Bailey 2012; Paton and Rogers 2009a; Paton et al. 2009).

Spatial and temporal trends in species abundance were also assessed using monthly relative abundance data (the number of individuals per site per visit) for each species in each subregion (2006-2013). These analyses show finer-scale differences that include a measure of abundance as opposed to reporting rate. Overall trends in the relative abundance of selected waterbird species have shown variable, and often species-specific patterns of response since the return of water flows in 2010. Notably, species within the same functional group of birds (e.g. piscivores, shorebirds, waterfowl, and large endemic waders) often showed species-specific patterns of spatial and temporal response to the return of water flows. For example, most shorebird species (Red-necked Stint, Sharp-tailed Sandpiper and Red-capped Plover), have shown ongoing patterns of recovery since 2010. However, abundances of two migratory shorebird species, the Curlew Sandpiper and Common Greenshank, declined during the period of low flow, but show no sign of recovery following the return of water flows to the system (O'Connor et al. 2012; Paton and Bailey 2012; Paton

et al. 2009). Further research into the specific ecological (including foraging) requirements of these species is recommended.

In conclusion, ecological conditions during the 2012-2013 monitoring period appear to have sustained stable populations of many waterbird species that are recovering from a period of severe drought (2006-2009). However some species have shown variable or no signs of recovery over the past three years of monitoring, indicating that local or off-site habitat conditions are not meeting the ecological requirements of these species. In this sense, the TLM target has not been fully met, because local populations of a few species are not being improved or maintained. In order to manage the site for the broad range of waterbirds that utilise different subregions of the wetland for different purposes, a better understanding of the ecological requirements of some bird species, and how they respond to changing hydrological, habitat and food resource conditions is required. Integrated monitoring programs, such as those that investigate links between different trophic levels, will be best suited to understanding these requirements. Research into broader landscape-scale responses of waterbirds to regional, national or international conditions will also assist managers in understanding the contextual role of local LLCMM habitat conditions.

Table 2. General trend for each selected species, in each subregion, during three survey periods. The 3 periods are pre-drought (01-06), drought (06-09) and post-drought (09-13)

	Lake Albert			Lake Alexandrina			Goolwa Channel			Murray Estuary			Coorong North Lagoon			Coorong South Lagoon		
	01-06	06-09	09-13	01-06	06-09	09-13	01-06	06-09	09-13	01-06	06-09	09-13	01-06	06-09	09-13	01-06	06-09	09-13
Australian Pelican	→	↘	↗	↘	↘	↗	→	↘	↗	→	↘	↗	→	→	↗	↘	↘	↗
Fairy Tern	na	na	na	na	na	na	na	na	na	↘	→	↘	→	→	↘	↘	↘	↗
Common Greenshank	↘	↗	↘	→	→	↘	→	↗	↘	↘	↘	→	↗	→	↗[1]	→	↘	↗
Black Swan	→	↘	↘	→	↘	↗	→	↘	→	→	↘	↗	→	↘	↗	→	→	↗
Chestnut Teal	↘	→	↗	↘	→	→	↘	↗	→	→	↘	↗	→	→	↗	↘	→	↘
Curlew Sandpiper	→	↗	↘	→	↗	↘	→	↗	↘	↘	↘	→	↗	→	→	→	↘	↗[1]
Red-necked Stint	→	↗	↘	→	↗	↘	→	↗	↘	↘	↘	↗	→	↘	↗[1]	↘	↘	↗[1]
Sharp-tailed Sandpiper	→	↗	↘	→	↗	↘	→	↗	↘	↘	↘	→	→	→	→[1]	→	→	→[1]
Red-capped Plover	→	↗	↘	→	↗	↘	→	↗	↘	→	→	↗[1]	↗	↘	↗[1]	→	↘	↗[1]
Sanderling	na	na	na	na	na	na	na	na	na	↗	→	↘[2]	na	na	na	na	na	na
Red-necked Avocet	→[3]	↗	↘	→[3]	↗	↘	→[3]	↗	↘	↘	↘	↗	↘	↘	↗	↗	→	↗
Banded Stilt	na	na	na	na	na	na	na	na	na	↘	→[4]	↗	↘	↘	↗	→[5]	→	↗
Australian Pied Oystercatcher	na	na	na	na	na	na	na	na	na	↗	→	↘	→	↗	↘	↗	→	↘

[1] Migratory shorebirds have declined dramatically in the Coorong in the first year following the return of flows, but have recovered slightly in the year since. Overall, however, a net decline has been recorded since the return of flows, relative to their abundance during drought.
[2] Sanderling have not been recorded in the Coorong since 2009-2010.
[3] Red-necked Avocet were rarely recorded in the lakes, even though a slight increase in reporting rate was detected during the drought.
[4] Banded Stilt were very rare in the Murray Estuary subregion during and following the drought, essentially declining to 0.
[5] While the overall reporting rate for Banded Stilt was relatively stable during each period, inter-annual variation varied widely within each period. See Figure 7.

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