The effects of flow regimes, prey availability and environmental parameters on shorebird abundance and diversity in the Coorong, Murray Mouth and Lower Lakes 2002 to 2012/2013

Short communication for Adam Watt

July 2014

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Please note: The information contained in this short communication is for reference only and is to be used as a basis for further discussion on the next steps for analyses of the bird data. The findings here are preliminary and have not been through a peer-reviewed process. Please consider this when using this data for future monitoring plans. This data has been taken from a combination of two manuscripts that are in preparation using the long-term datasets from David and Margaret Dadds' bird surveys and A/Prof Sabine Dittmann's macroinvertebrate and environmental monitoring data that were both funded by DEWNR and the SAMDBNRM Board. Further analyses are to be conducted, and suggestions and ideas for the focus of these analyses are provided throughout.

Preliminary findings

Overall abundance

Between late 2002 and early 2013, 39 species of shorebirds were recorded from the Coorong, Lower Lakes and Murray Mouth, with 26 of these species being migratory shorebirds (Table 1). The most abundant shorebirds were a permanent resident (Banded Stilt) and a migratory shorebird (Red-necked Stint) (Table 1). Other numerically abundant shorebirds over this time period were Sharp-tailed Sandpipers and Red-necked Avocets, while several other species were moderately abundant and 13 species were recorded with less than 100 individuals (Table 1).

Overall, shorebird abundance peaked at the height of the drought in 2008-09 in the Murray Mouth, Coorong (North and South Lagoons), Goolwa Channel, and Lower Lakes (Lake Alexandrina and Lake Albert) and declined markedly in 2010-11 (Figure 1); this pattern was mainly driven by the local shorebirds (Figure 2). Declines in abundance in 2010-11 coincided with recommencing flows and high water levels throughout the Coorong, Lower Lakes and Murray Mouth that submerged foraging habitat causing macroinvertebrate prey to become inaccessible to some species. As 2010 was the third wettest year for Australia on record—at the same time as flows recommenced—many inland lakes filled across southern Australia that had not seen water for many years (BOM 2012) potentially providing alternative shorebird habitats (Collard et al. 2013). Macroinvertebrate abundance in the Coorong and Murray Mouth was low towards the end of the drought and in the first year of recommenced flows, but increased again in 2011/12 (Dittmann et al. 2014).

Table 1. Total number of shorebird observations from October 2002 to March 2013 in the Coorong, Lower Lakes and Murray Mouth. Resident shorebirds have local breeding, while migratory shorebirds spend their non-breeding period in the southern hemisphere.

Species		**Observations**	**Breeding**
Banded Stilt	*Cladorhynchus leucocephalus*	929,290	Local
Red-necked Stint	*Calidris ruficollis*	521,495	Migratory
Sharp-tailed Sandpiper	*Calidris acuminata*	284,734	Migratory
Red-necked Avocet	*Recurvirostra novaehollandiae*	119,326	Local
Calidris sp.	*Calidris indet.*	98,817	Migratory
Black-winged Stilt	*Himantopus himantopus*	56,056	Local
Masked Lapwing	*Vanellus miles*	38,107	Local
Curlew Sandpiper	*Calidris ferruginea*	32,519	Migratory
Common Greenshank	*Tringa nebularia*	30,700	Migratory
Red-capped Plover	*Charadrius ruficapillus*	23,853	Local
Pied Oystercatcher	*Haematopus longirostris*	15,312	Local
Sanderling	*Calidris alba*	5,964	Migratory
Marsh Sandpiper	*Tringa stagnatilis*	3,519	Migratory
Black-tailed Godwit	*Limosa limosa*	3,231	Migratory
Bar-tailed Godwit	*Limosa lapponica*	3,139	Migratory
Godwit sp.	*Limosa. Indet.*	2,934	Migratory
Double-banded Plover	*Charadrius bicinctus*	2,162	Migratory
Red-kneed Dotterel	*Erythrogonys cinctus*	1,982	Local
Banded Lapwing	*Vanellus tricolor*	1,663	Local
Sooty Oystercatcher	*Haematopus fuliginosus*	1,265	Local
Eastern Curlew	*Numenius madagascariensis*	1,219	Migratory
Pacific Golden Plover	*Pluvialis fulva*	1,138	Migratory
Grey Plover	*Pluvialis squatarola*	664	Migratory
Black-fronted Dotterel	*Elseyornis melanops*	172	Local
Red Knot	*Calidris canutus*	155	Migratory
Wood Sandpiper	*Tringa glareola*	151	Migratory
Hooded Plover	*Thinorsis rubricollis*	85	Local
Lesser Sand Plover	*Charadrius mongolus*	81	Migratory
Great Knot	*Calidris tenuirostris*	56	Migratory
Ruddy Turnstone	*Arenaria interpres*	54	Migratory
Common Sandpiper	*Actitis hypoleucos*	42	Migratory
Beach Stone-curlew	*Esacus neglectus*	15	Local
Grey-tailed Tattler	*Heterocelus brevipes*	14	Migratory
Australian Pratincole	*Stiltia isabella*	14	Local
Long-toed Stint	*Calidris subminuta*	12	Migratory
Terek Sandpiper	*Xenus cinereus*	9	Migratory
Common Redshank	*Tringa totanus*	3	Migratory
Broad-billed Sandpiper	*Limicola falcinellus*	2	Migratory
Latham's Snipe	*Gallinago hardwickii*	1	Migratory

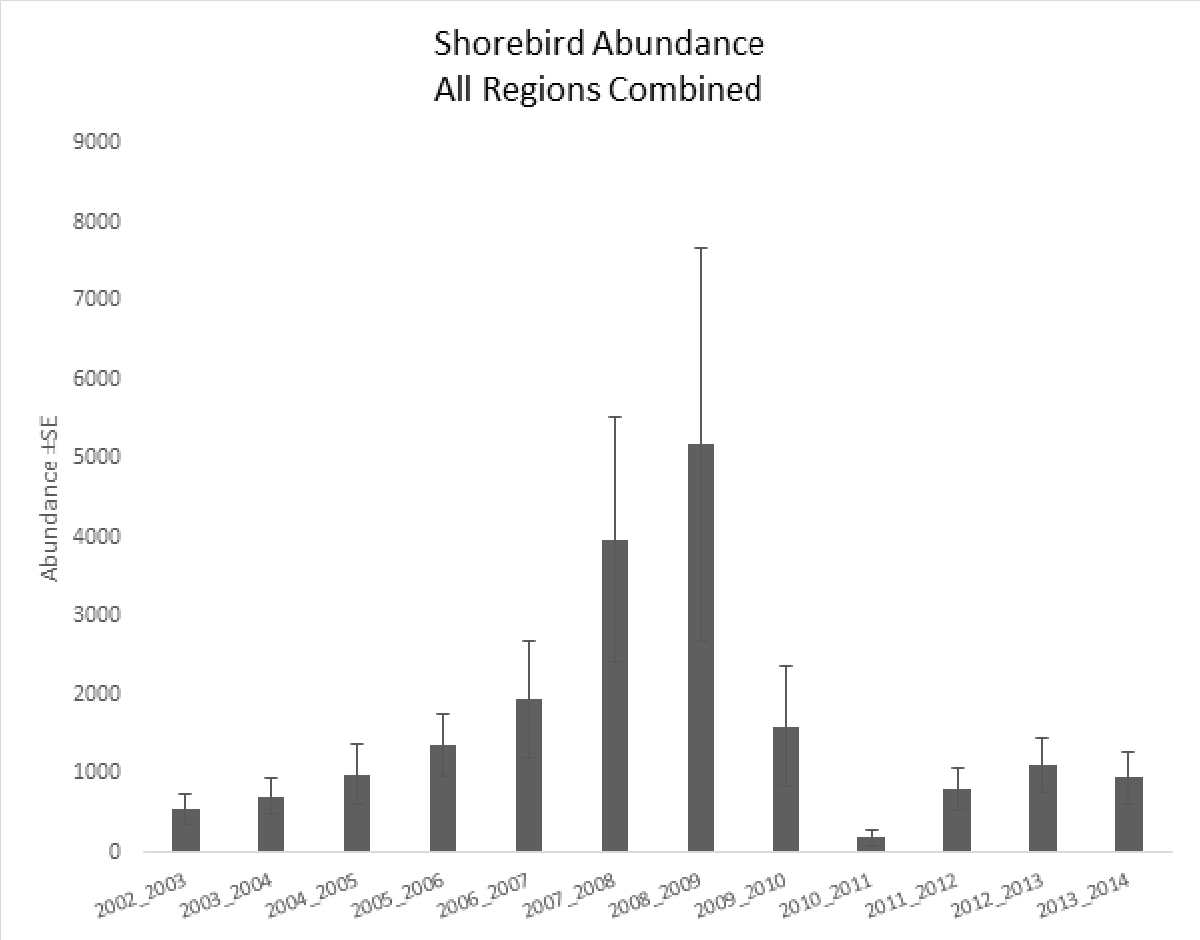

Figure 1. Abundance (±SE) of all shorebird species surveyed in the Goolwa Channel, Lower Lakes, Murray Mouth and the Coorong combined.

Resident and migratory shorebirds

Annual abundance patterns over the timespan 2002-2013 differed when shorebirds were divided between those that breed locally (permanent residents) and those that migrate to breed (migratory shorebirds). The abundance of permanent residents gradually increased in the Coorong, Lower Lakes and Murray Mouth during the drought (Figure 2); possibly as inland lakes were becoming too dry to sustain birds and were thus using the Coorong wetlands as a refuge. For migratory shorebirds, a clear delineation became apparent between periods of pre-drought (2002-03 to 2005-06), severe drought (2006-07 to 2009-10) and flow (since 2010-11) (Figure 2). The higher counts for migratory shorebirds during the drought could be affected by Red-necked Stints remaining in the Coorong, Lower Lakes and Murray Mouth over the southern winter in 2008 and 2009 (see Phenology and Figure 7). The long-term abundance patterns indicate that drought, and the resulting effects on food and habitat availability, effected local and migratory shorebirds differently. More investigation is needed to determine what caused the differences between permanent resident and migratory shorebird abundances and species specific patterns will be explored further.

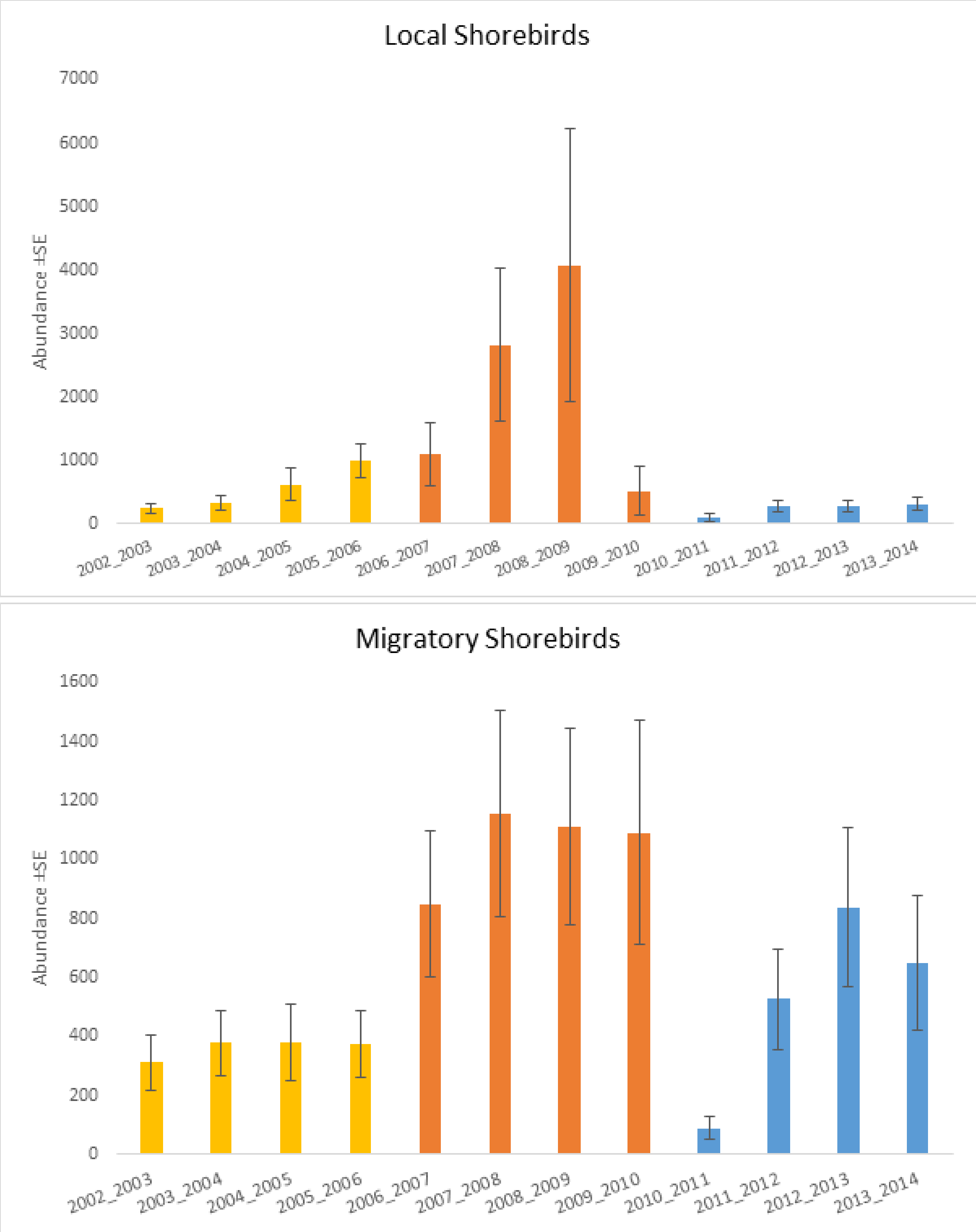

Figure 2. Abundance (±SE) of local shorebirds (permanent residents) and migratory shorebirds surveyed in the Coorong, Lower Lakes and Murray Mouth. Drought years are coloured yellow, severe drought years orange, and flow years are coloured blue. Note the different y axis scales. The patterns of abundance differ between locally breeding shorebirds and those that migrate to breed, indicating that their population sizes and abundances in the study area are affected by different parameters.

Habitat use of the main regions within the Coorong, Lower Lakes and Murray Mouth varied between resident and migratory shorebirds over the longer term period. The South and North Lagoons of the Coorong became increasingly important during the drought for permanent residents (Figure 3) that rarely utilised the Lower Lakes and Goolwa Channel. Conversely, migratory shorebirds utilised the Lower Lakes and Goolwa Channel in times of drought as well as the North Lagoon, while their numbers progressively dropped in the Murray Mouth and South Lagoon (Figure 3). Migratory shorebirds were making use of the Murray Mouth and Coorong during the pre-drought period, but were rarely recorded from the Lower Lakes. In the Murray Mouth, migratory shorebird numbers have exceeded their pre-drought and drought abundances over the last three overwintering periods (Figure 3). This increase in abundances in the Murray Mouth was mainly due to Red-necked Stints, Sharp-tailed Sandpipers and unidentified birds of the same genus (*Calidris*).

The pattern of diversified habitat use during periods of drought also emerges when looking at individual migratory shorebird species (Figure 4); however, two other species of migratory shorebird (Eastern Curlew and Sanderling) were only recorded from the Murray Mouth irrespective of drought or high flow and are therefore restricted in their habitat use (Figure 5). The resident Banded Stilts did not diversify their habitat use, occurring almost exclusively in the Coorong lagoons (Figure 5). Another resident shorebird, the Red-capped Plover, did occur in multiple habitats of the Coorong, Lower Lakes and Murray Mouth during the drought (Figure not shown). A generalisation of habitat use patterns in the study regions over the longer time period by resident or migratory shorebirds has to be treated with caution and more information on individual species will be provided as analysis progresses.

We propose that further analyses of species-specific habitat use over time and drought/flow periods is worthy of exploration, as are the questions of whether species with and without habitat diversification showed different trends in abundances over time and what were their patterns of recovery.

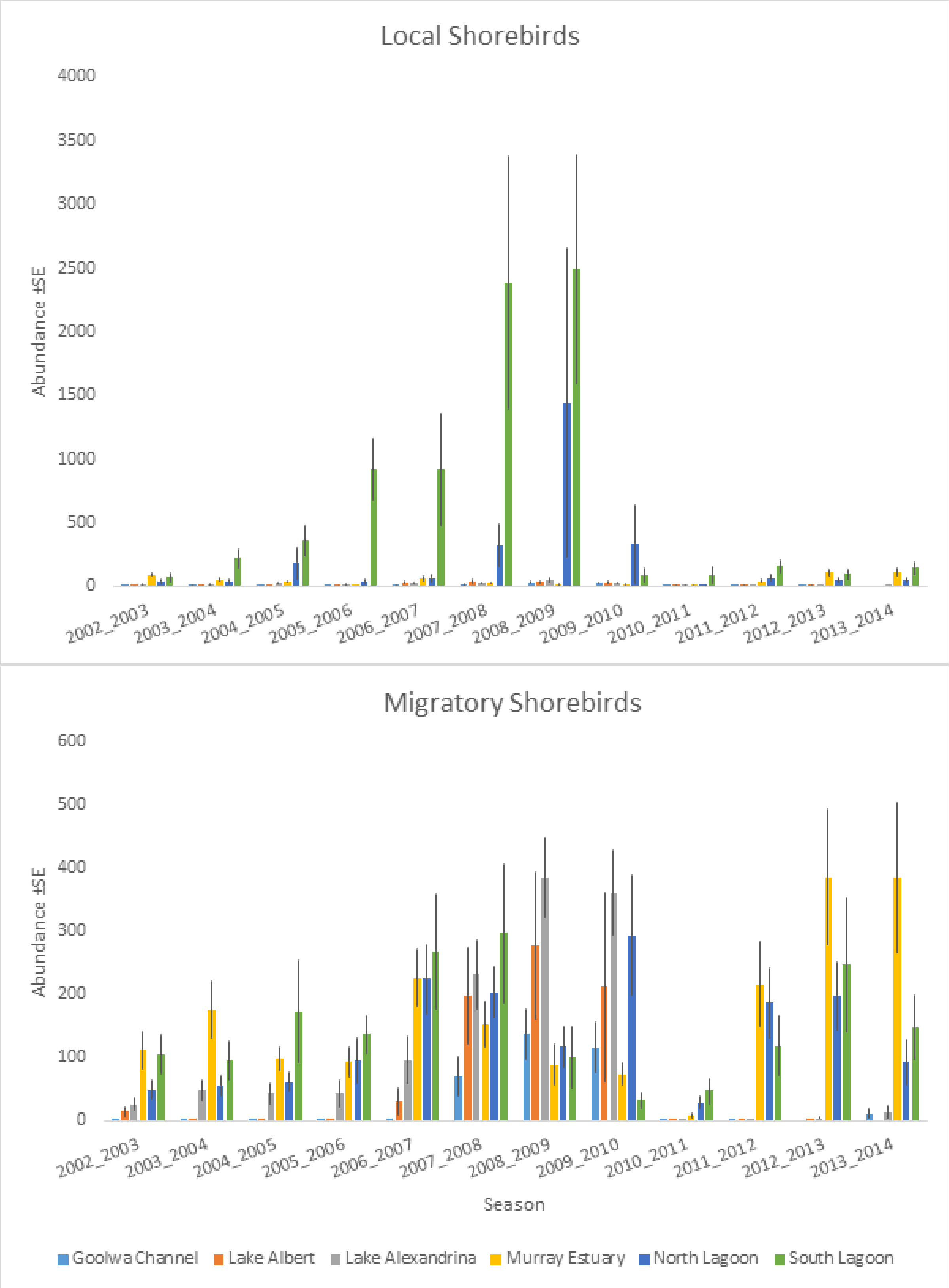

Figure 3. Abundance (±SE) of a) local shorebirds and b) migratory shorebirds divided into regions. The Lower Lakes and Goolwa Channel were not utilised by local shorebirds during the period of severe drought (2007-2009). Conversely, migratory shorebirds diversified their habitat use and were found in the Lower Lakes and Goolwa Channel in periods of drought.

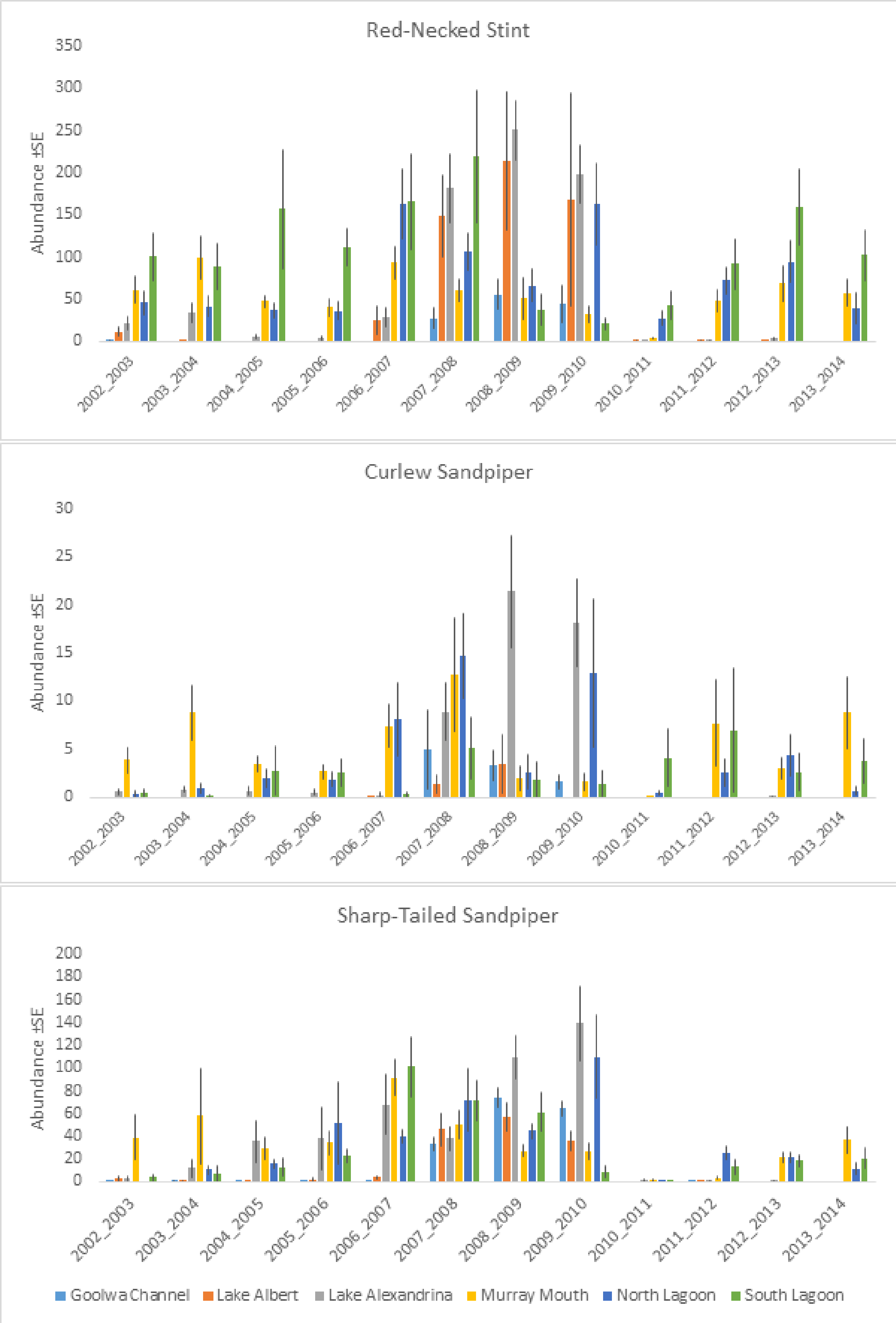

Figure 4. Long term patterns of abundance of three migratory species that diversified their habitat use by utilising the Lower Lakes and Goolwa Channel during the severe drought.

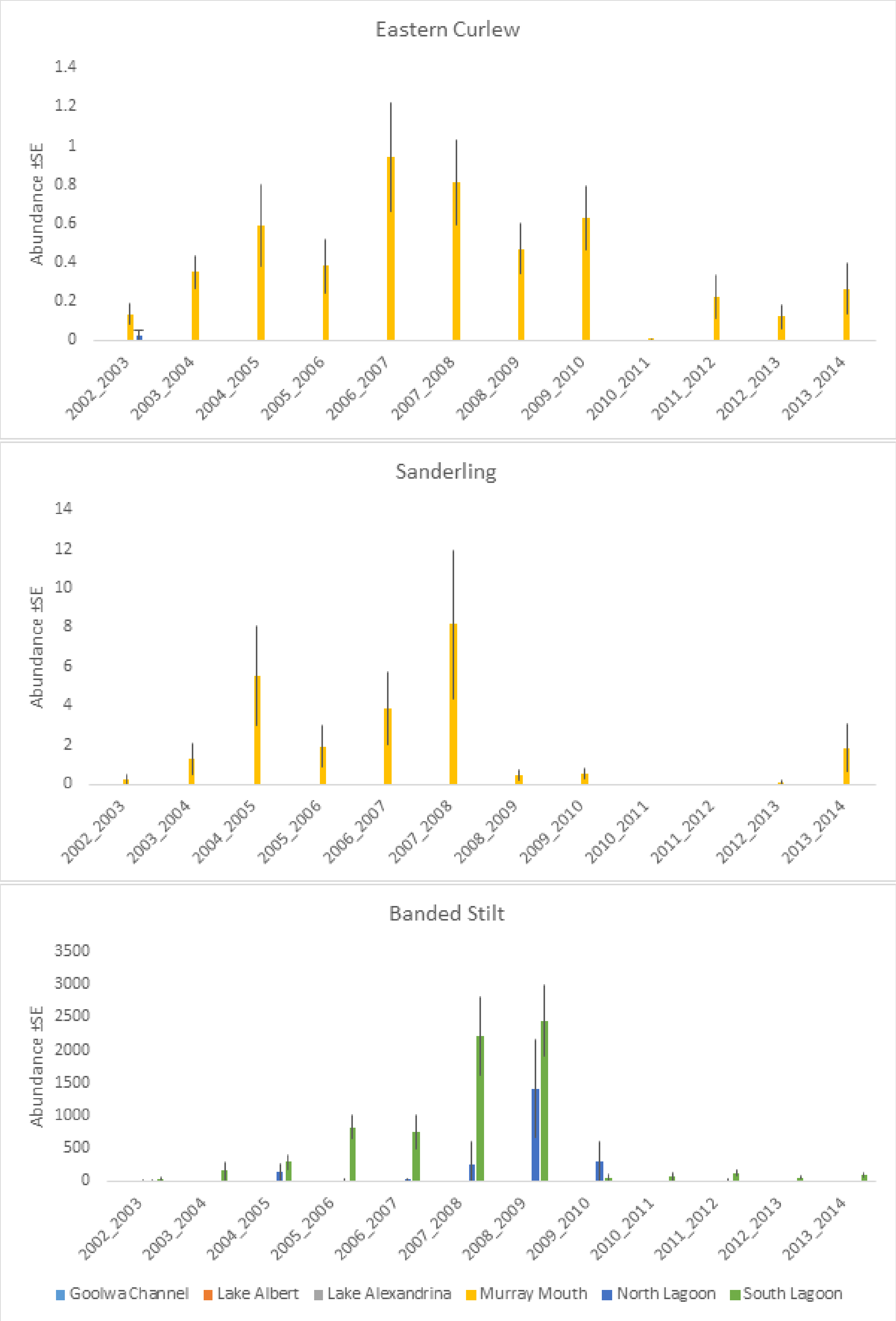

Figure 5. Long term patterns of abundance of three species that did not utilise the Lower Lakes and Goolwa Channel during the drought.

Phenology

The phenology of migratory shorebirds in their southern overwintering region is characterised by arrival in September/October, and a departure to Northern Hemisphere breeding grounds in March/April. This typical phenology was apparent in the Coorong, Lower Lakes and Murray Mouth in the years before the drought (Figure 6). The phenology over the drought years indicated that some species stayed over the Australian winter period when they would have usually returned to the Northern Hemisphere to breed (Figure 6).

The lack of return migration was most obvious in the phenology of Red-necked Stint, which was the most abundant migratory shorebird observed in this survey (Figure 7). In 2003-2007, their abundances increased and declined throughout the year according to their breeding periods; however, in the drought years of 2008 and 2009, many individuals remained in the Coorong, Lower Lakes and Murray Mouth instead of returning to their Northern Hemisphere breeding sites. In 2009, abundances of Red-necked Stints was unusually high in the Austral autumn and winter. In 2010, when the drought broke and flows recommenced, numbers of Red-necked Stints declined across the year, irrespective of breeding season. This decline could have been due to the increased rainfall filling inland lakes for the first time in many years and thus providing suitable habitat, and/or due to the high water levels from the main flow peak that prevented access to food in the Coorong, Lower Lakes and Murray Mouth.

The phenology of Sharp-tailed Sandpipers was not affected by the drought periods, as these migratory shorebirds did not remain in the Coorong during the Southern Hemisphere winter in any of the survey years (Figure 8). Their numbers, however, appeared to be higher during the drought years and declined in 2010, similar to the pattern seen for other species of shorebirds. Curlew Sandpipers (Figure 9) had a similar pattern to Red-necked Stints. Some individuals remained in the Coorong, Lower Lakes and Murray Mouth over the southern winter in 2006, 2008 and 2009 and their numbers declined in 2010, but have since returned to levels similar to those before the drought. A few Common Greenshanks also remained in the Coorong in 2006, but had a more typical phenology for a migratory shorebird for 2008 and 2009 (Figure 10). A high number of observations of *Calidris* species (unidentified) (Figure 11) were counted from November 2011 onwards (this is when some observations of *Calidris sp* were not differentiated in the dataset) and the graph is included here to indicate that declines may not be as low as indicated in the Red-necked Stints graph (Figure 7).

In October 2010, birds appear to have arrived in the Coorong, Lower Lakes and Murray Mouth, but departed earlier than usual as no foraging habitat was accessible (Figure 6). In the following years, migratory shorebirds arrived slowly with numbers increasing in November (Figure 6). The phenology of migratory shorebirds in the Coorong, Lower Lakes and Murray Mouth could be affected by 1) environmental changes affecting food availability and foraging habitats; 2) climate driven wet and drought cycles affecting inland and coastal wetlands; and 3) changes along the flyway.

In 2006, the construction of a 33 km sea wall at Saemangeum in Korea caused declines in shorebirds as large mudflat habitat became unavailable for migratory birds. In 2010, the construction of the largest Chinese port ‘Caofeidien’ was completed in Bohai Bay in the

Yellow Sea, one of the most important stopover sites for migrating birds. The reclamation of land for industrial use has seen the shorebirds become more concentrated in other areas of Bohai Bay (Yang et. al. 2011). The loss of stop-over habitats in the Yellow Sea could have also contributed to the decline in migratory shorebird numbers seen in the Coorong.

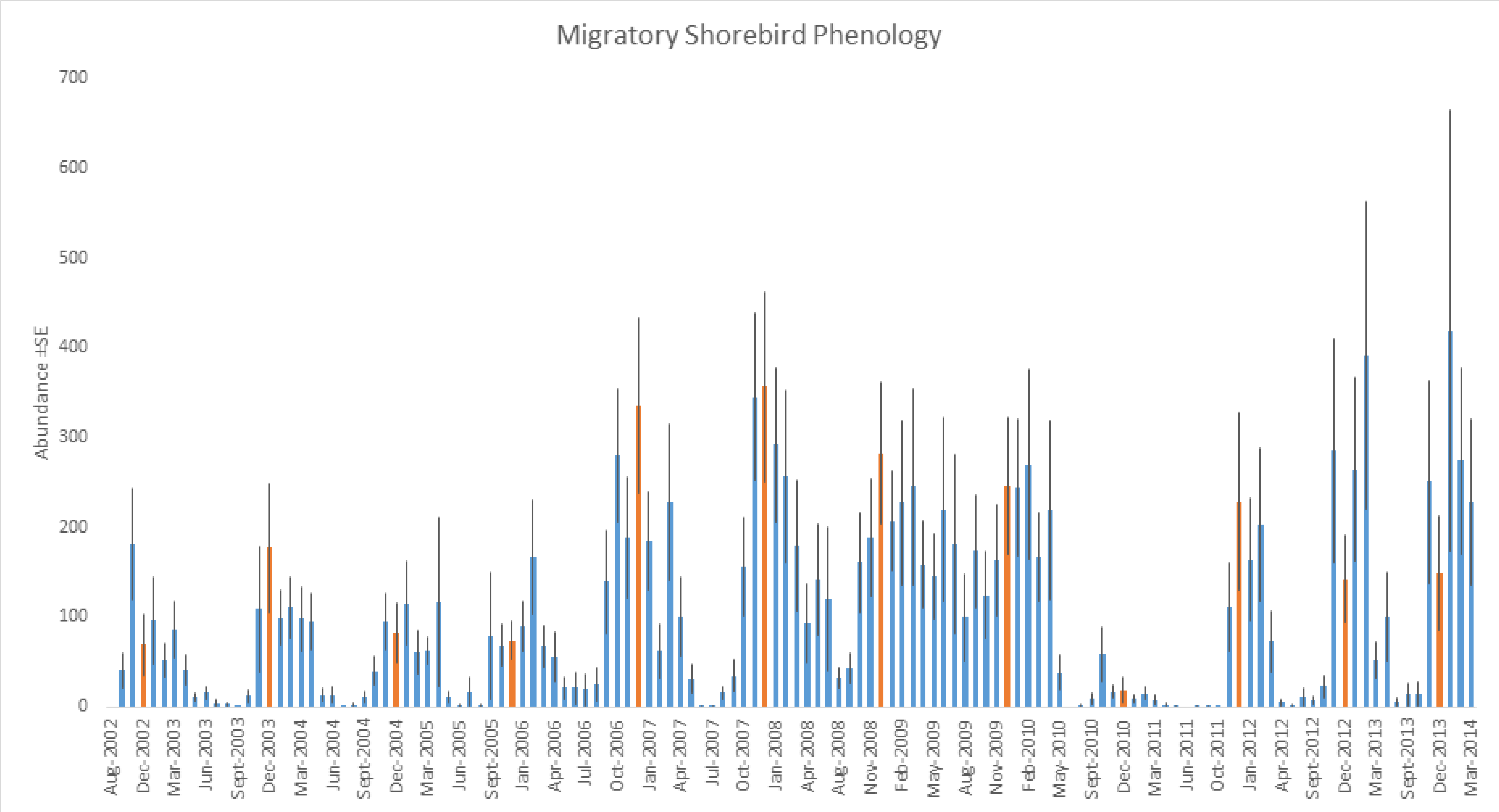

Figure 6. Monthly average abundance of migratory shorebird observations across all regions of the Coorong, Lower Lakes, and Murray Mouth. Orange bars indicate December of each year to highlight the cyclical nature of migrating bird abundance throughout the years 2002-2008. In mid-2009, average abundance did not decline mid-year as markedly as it had in previous years. The typical phenology for migratory shorebirds resumed in the second year since flows commenced in late 2010.

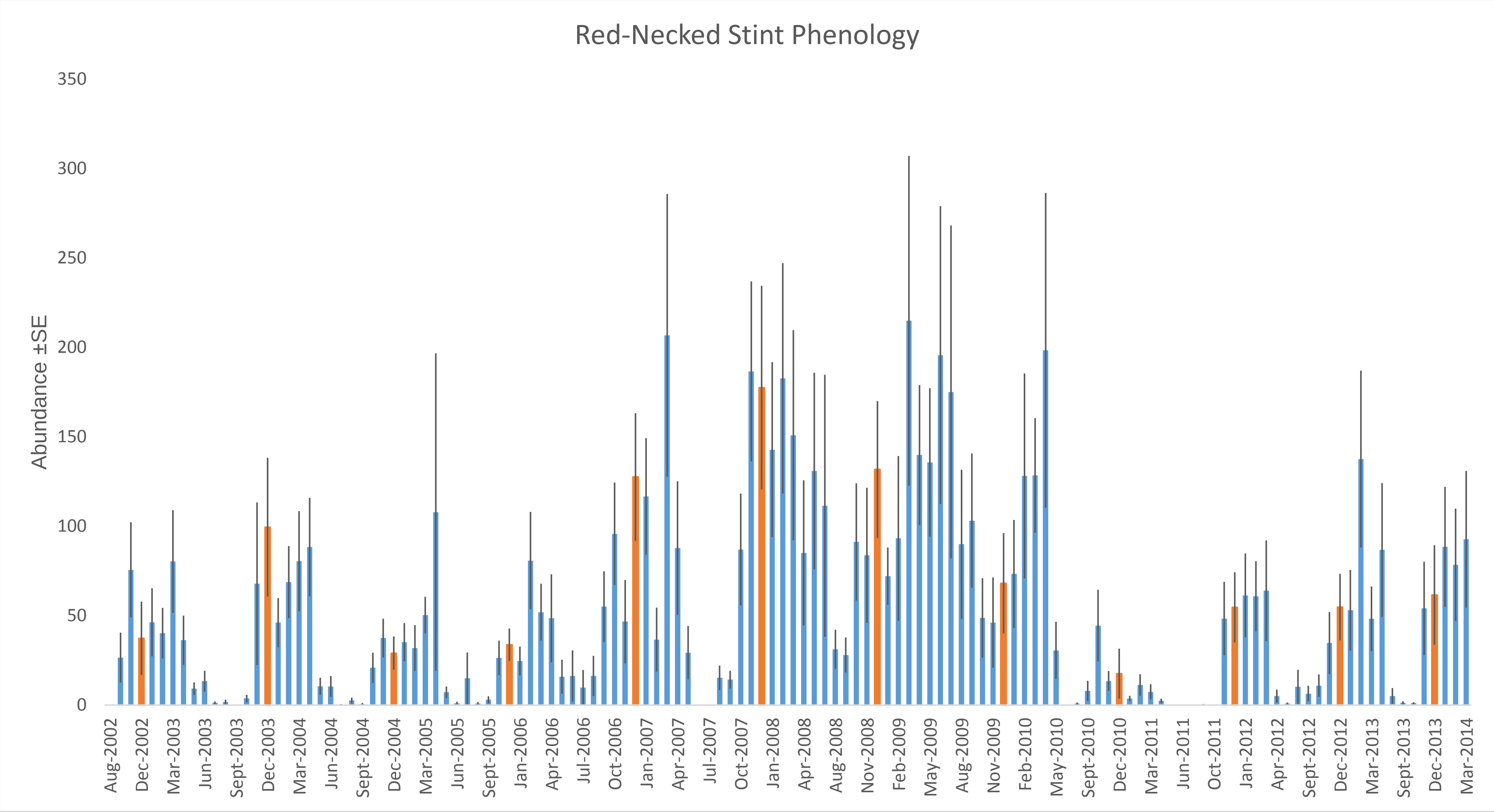

Figure 7. Monthly average of observations (±SE) of Red-necked Stints in all regions of the Coorong, Lower Lakes, and Murray Mouth. Orange bars indicate December of each year.

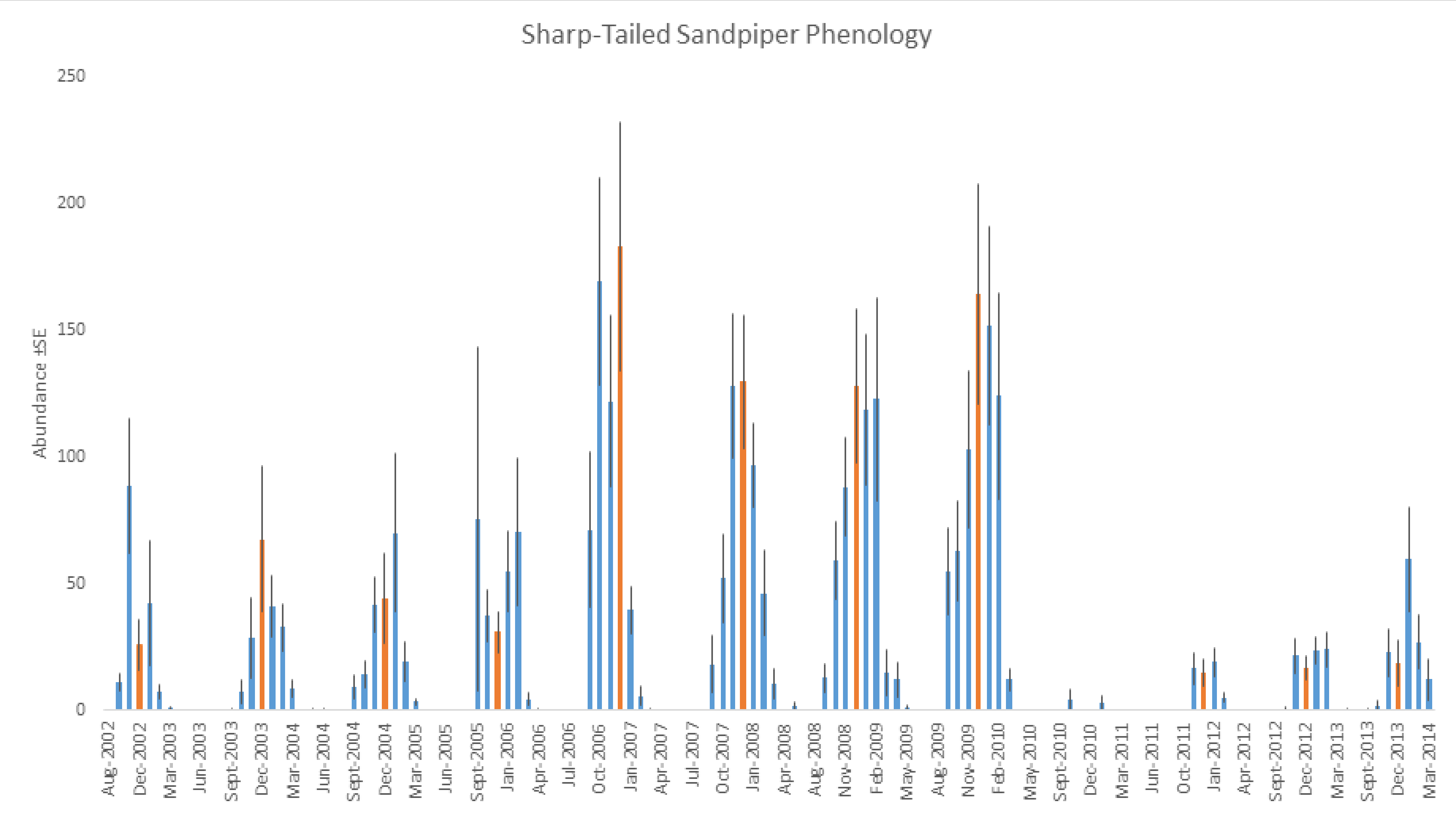

Figure 8. Phenology of Sharp-tailed Sandpipers across all regions of the Coorong, Lower Lakes, and Murray Mouth. Orange bars indicate December of each year, except in 2010 when no Sharp-tailed Sandpipers were present in December.

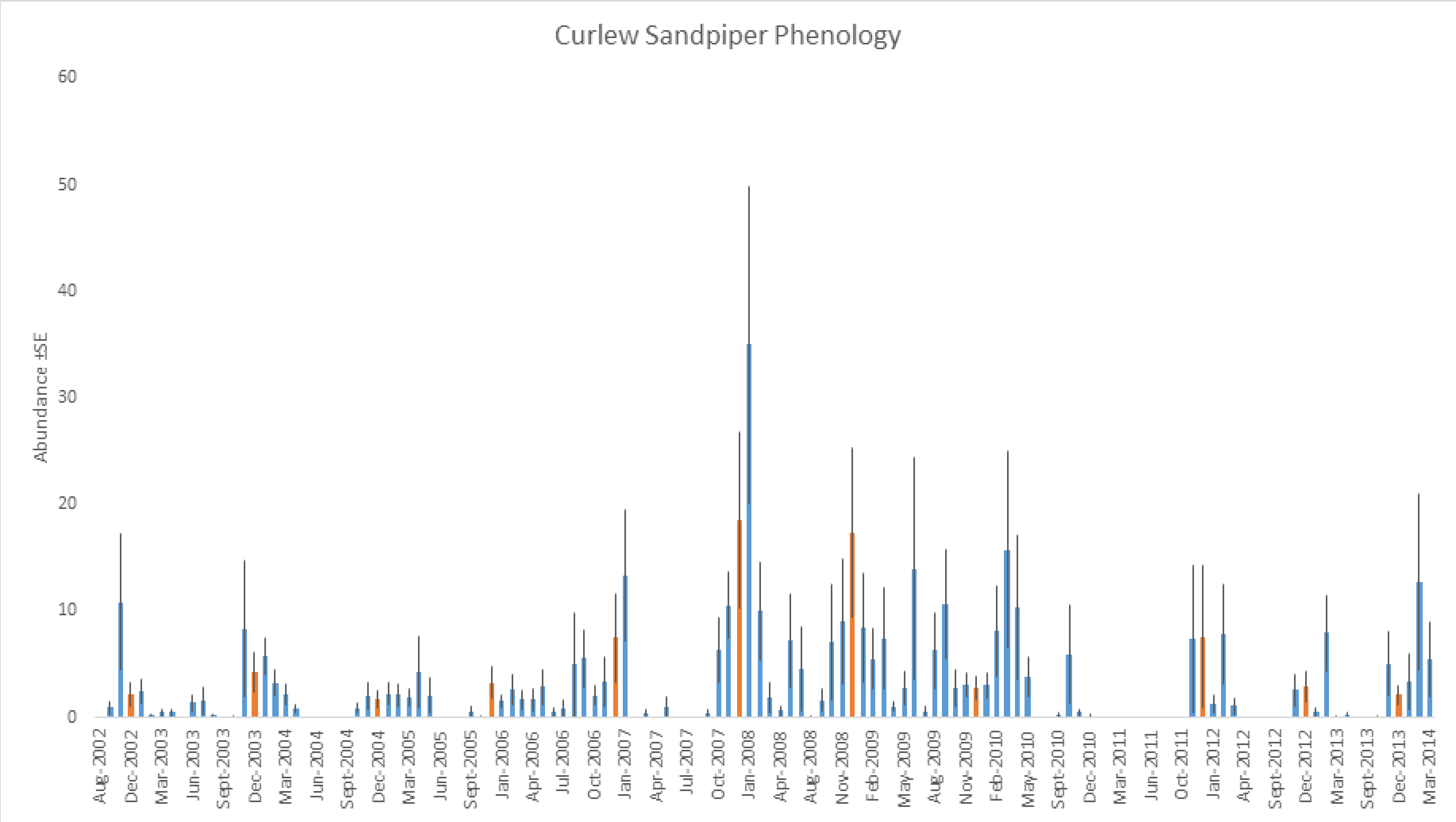

Figure 9. Phenology of Curlew Sandpipers in all regions of the Coorong, Lower Lakes, and Murray Mouth. Orange bars indicate December of each year.

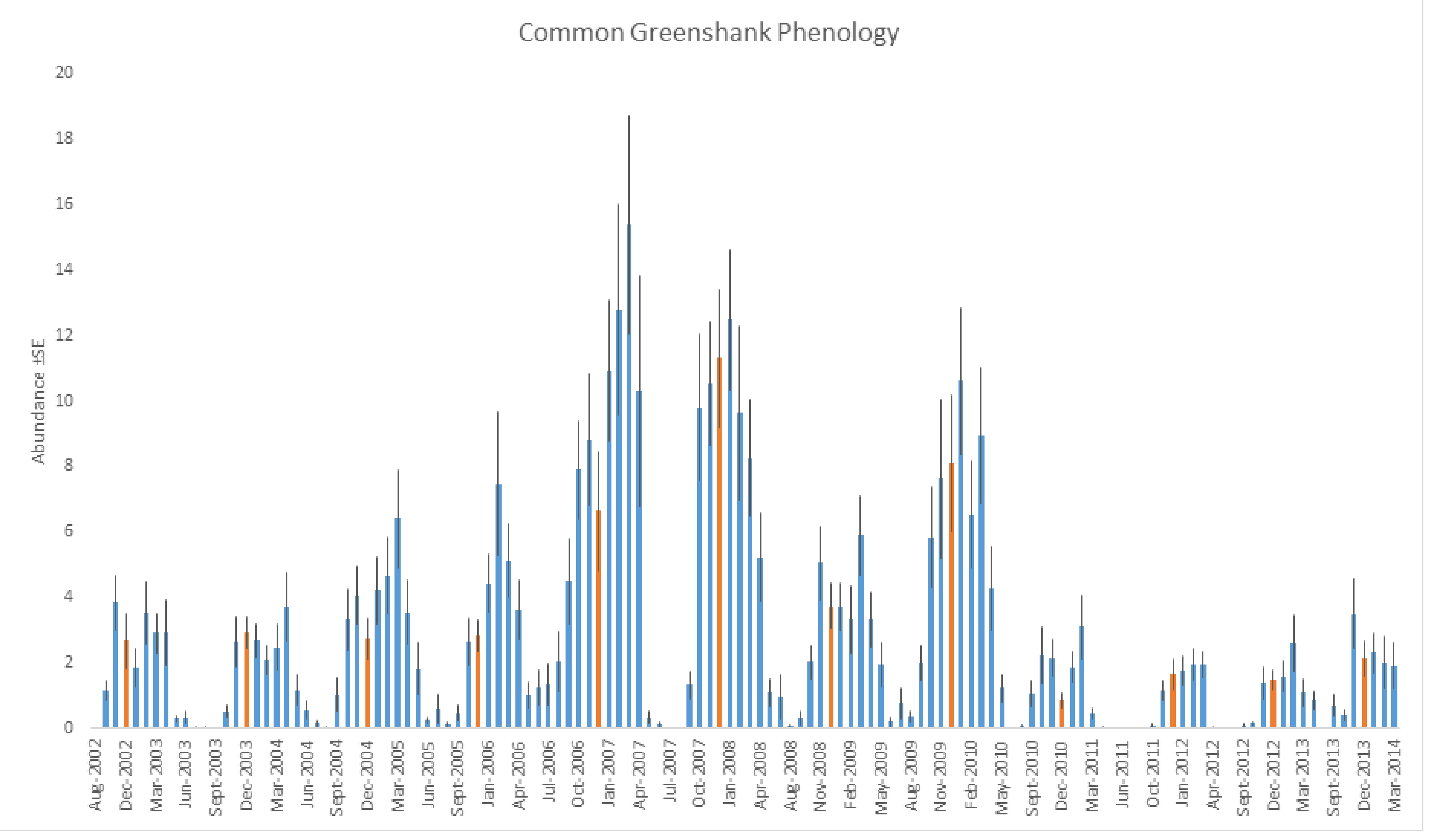

Figure 10. Phenology of Common Greenshanks in all regions of the Coorong, Lower Lakes, and Murray Mouth. Orange bars indicate December of each year.

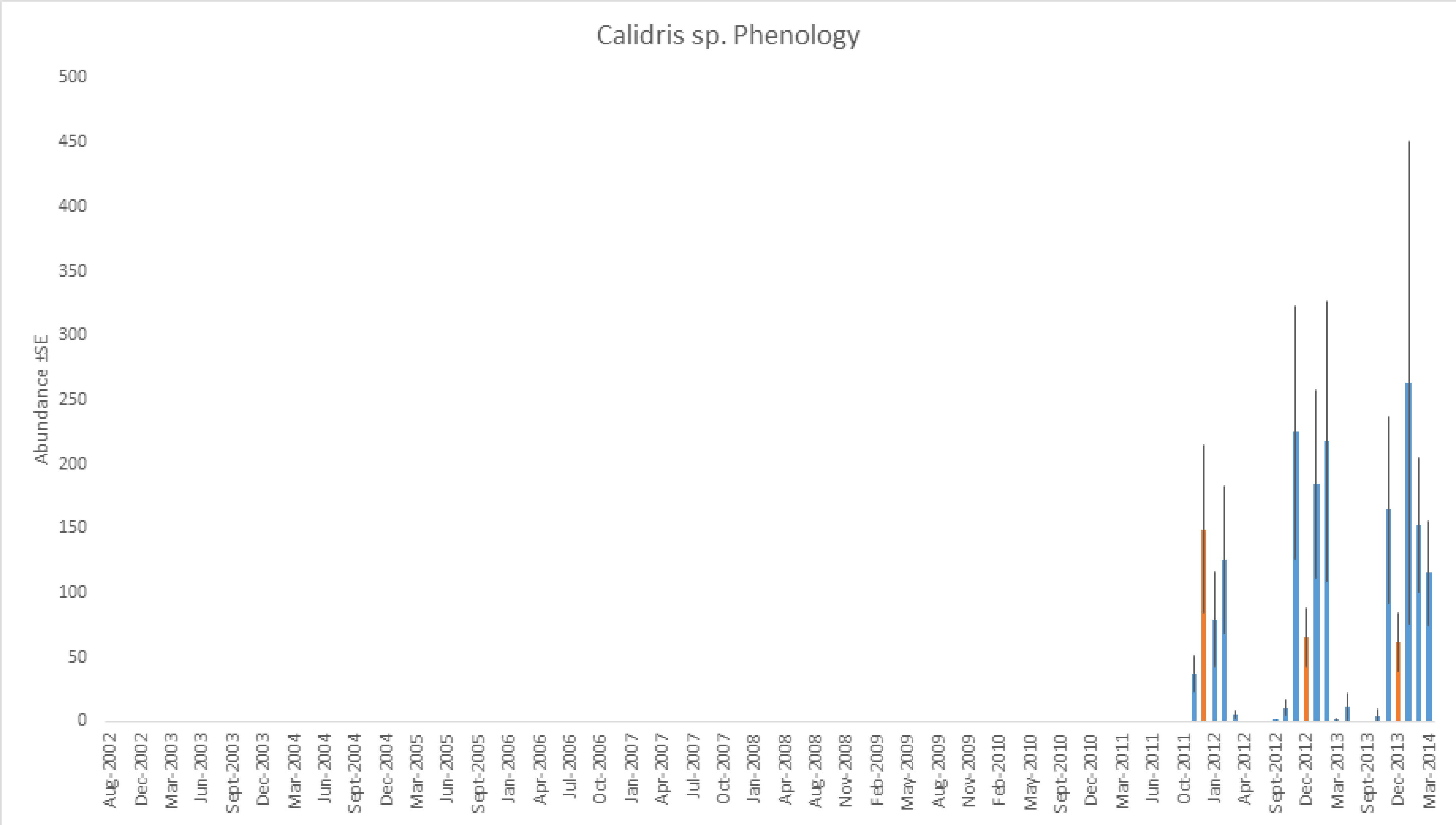

Figure 11. Phenology of unidentified *Calidris* sp. in all regions of the Coorong, Lower Lakes, and Murray Mouth. Orange bars indicate December of each year to highlight a year's cycle. Entries of *Calidris* sp. began in November 2011.

Shorebird species assemblages

After assessing abundance patterns by regions (Figures 3-5 and phenology Figures 6-11), we have only included analyses from the North Lagoon, South Lagoon and Murray Mouth for further analyses below, as these were the regions most utilised by shorebirds in pre-drought and flow years.

Over the entire period from 2002 to 2014, shorebird assemblages in the Murray Mouth and North Lagoon overlapped, and were distinct from the shorebird assemblage in the South Lagoon, which was also more variable over the years (Figure 12). Common Greenshanks, Sharp-tailed Sandpipers and Curlew Sandpipers were characteristic for the differentiation of the assemblage in the Murray Mouth and North Lagoon, while Banded Stilts, Red-capped Plover, Red-necked stints and Red-necked Avocets were more characteristic of the shorebird assemblage in the South Lagoon (Figure 12, Table 2).

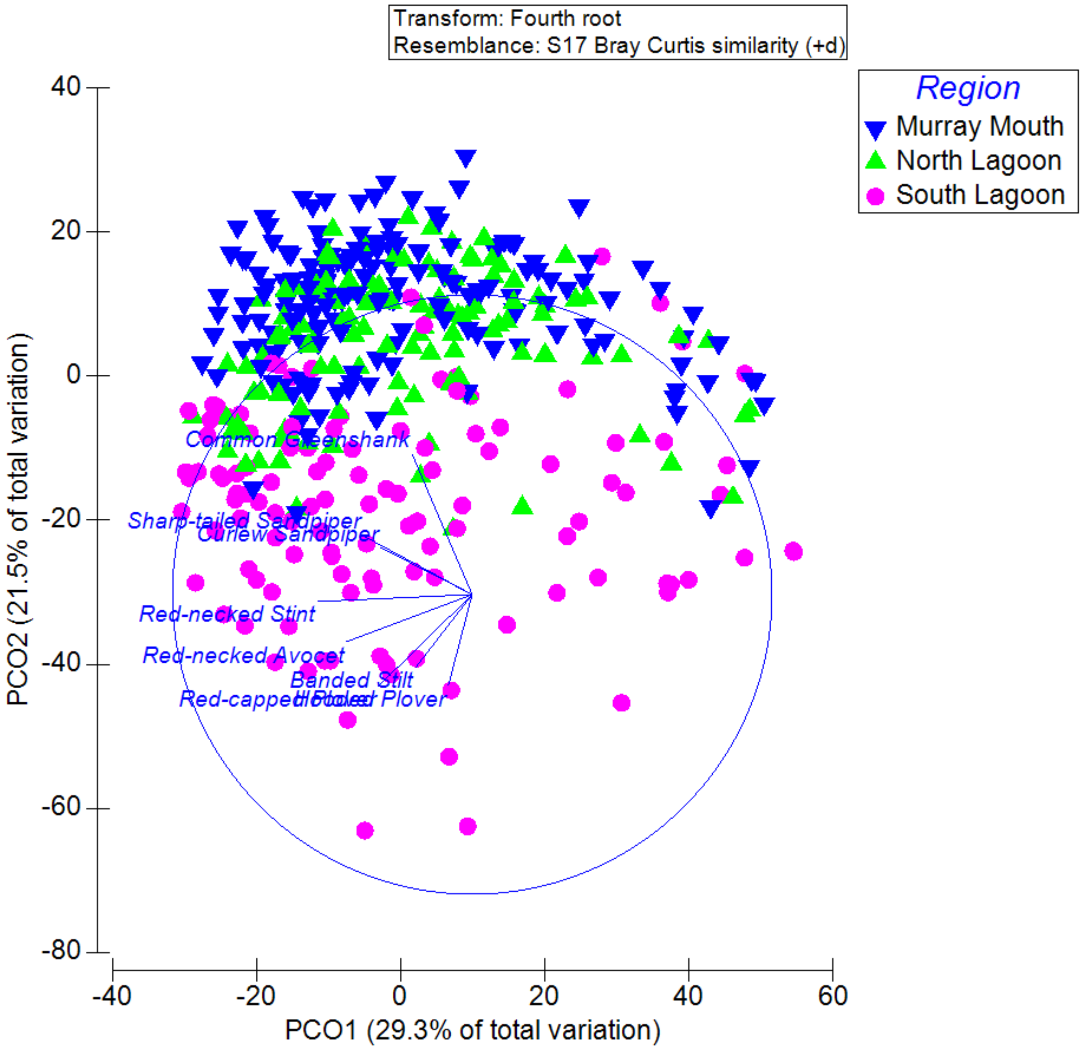

Figure 12. PCO plot of local and migratory shorebird assemblage from 2004-2012. Vector overlay (base variables > 0.3) shows the species that contribute to the variation across the Murray Mouth, North Lagoon and South Lagoon 2004-2013. Symbols represent sites and colours represent regions. Symbols that are closer together represent sites that have more similar bird community assemblages. The vector indicates the relative strength and direction of the effect of individual species on bird community structure.

However, the PCO plot explains only a small percentage of the variation in the shorebird assemblage data, and the low dissimilarity between regions in the SIMPER analysis also indicates much overlap. The shorebird assemblages frequenting the three regions of the Murray Mouth, North and South Lagoon of the Coorong shared similarity, as 7 - 9 species accounted for up to 90% of the characteristics of the species assemblages, and five of the species contributing to these characteristics occurred in each region (Table 2).

Table 2. SIMPER results of similarity percentages of sites within regions (shaded cells) and dissimilarity percentages among regions (unshaded cells) of shorebirds for the survey period November 2002 – March 2014.

	Murray Mouth	**North Lagoon**	**South Lagoon**	**Characterising Taxa**	**Cumulative %**
Murray Mouth	52.2			Red-necked stint, sharp-tailed sandpiper, common greenshank, masked lapwing, black-winged stilt, pied oystercatcher, red-necked avocet, curlew sandpiper, red-capped plover.	92.1
North Lagoon	46.8	58.0		Red-necked stint, masked lapwing, common greenshank, sharp-tailed sandpiper, black-winged stilt, red-capped plover, pied oystercatcher, red-necked avocet.	93.4
South Lagoon	60.4	54.4	46.5	Banded stilt, masked lapwing, red-necked stint, red-capped plover, red-necked avocet, sharp-tailed sandpiper, black-winged stilt.	92.6

There was little variation in the shorebird assemblage over the drought and flow periods, yet the shorebird assemblage in the flow period was more dissimilar to the earlier periods, which could have been affected by the summer of 2010-11 (see Phenology section). About nine species made up to 90% of the assemblages between drought and flow regimes and there was great overlap with the shorebird species characterising each period (Table 3). The relative contribution to characterising species showed that Sharp-tailed Sandpipers were more typical for the severe drought period than during other periods. Banded Stilts were not among the characterising species of the early and severe drought, and Black-winged Stilts did not emerge as characteristic during the flow period. Unidentified *Calidris* sp. which were only differentiated in the data sheets since 2011, were listed as typical for the flow period. More distinct patterns may emerge when only migratory shorebirds are considered in the community analysis, which is planned for the next step.

Table 3. SIMPER results of similarity percentages of sites drought and flow regimes (shaded cells) and dissimilarity percentages across flow regimes (unshaded cells) of shorebirds.

	Pre-drought (2002-2003)	**Early Drought (2004-2006)**	**Severe Drought (2007-2009)**	**Flow (2010-2012)**	**Characterising Taxa**	**Cumulative %**
Pre-drought (2002-2003)	53.0				Red-necked stint, masked lapwing, red-necked avocet, common greenshank, black-winged stilt, sharp-tailed sandpiper, red-capped plover, banded stilt, pied oystercatcher	94.3
Early Drought (2004-2006)	47.1	54.3			Red-necked stint, masked lapwing, sharp-tailed sandpiper, common greenshank, red-necked avocet, black-winged stilt, red-capped plover, pied oystercatcher, curlew sandpiper	93.7
Severe Drought (2007-2009)	49.8	47.8	51.3		Sharp-tailed sandpiper, red-necked stint, masked lapwing, common greenshank, black-winged stilt, red-capped plover, pied oystercatcher, red-necked avocet	92.4
Flow (2010-2012)	53.4	53.2	55.5	45.2	Red-necked stint, masked lapwing, common greenshank, sharp-tailed sandpiper, red-necked avocet, Calidris sp., red-capped plover, banded stilt, pied oystercatcher	92.8

Macroinvertebrates as predictors for shorebird assemblages

We explored whether macroinvertebrate abundances can be used as predictors of resident and migratory shorebird abundance and distribution in the Murray Mouth and Coorong. Distance-based linear models (DistLM) were used to test for correlations between shorebirds and macroinvertebrates for the survey period from 2004 to 2013, when macroinvertebrate data became available.

Macroinvertebrates explained a higher percentage of the variation in the resident shorebird assemblages of the three regions over time than for the migratory shorebirds (Figures 13 and 14). Resident shorebirds were significantly ($P_{(perm)}$<0.05 or better) correlated with (in order of the most to least % contribution); *Capitella sp., Arthritica helmsi, Tipulidae, Simplisetia aequisetis, Dolichopodidae, Isopod sp., Amphipoda,* and *Salinator fragilis*.

For migratory shorebirds, similar macroinvertebrate species could explain the assemblages in the regions over time, with significant correlations for *Arthritica helmsi, Tipulidae, Capitella sp., Amphipoda, Hydrobiid sp., Salinator fragilis, Simplisetia aequisetis,* and *Mysid sp.*

Further analyses of relationships between shorebird assemblages and macroinvertebrate abundances are under way, including site and region specific analyses, differentiation of drought and flow periods, and differentiation of the shorebird assemblages by bill lengths. Further links with biomass are yet to be tested.

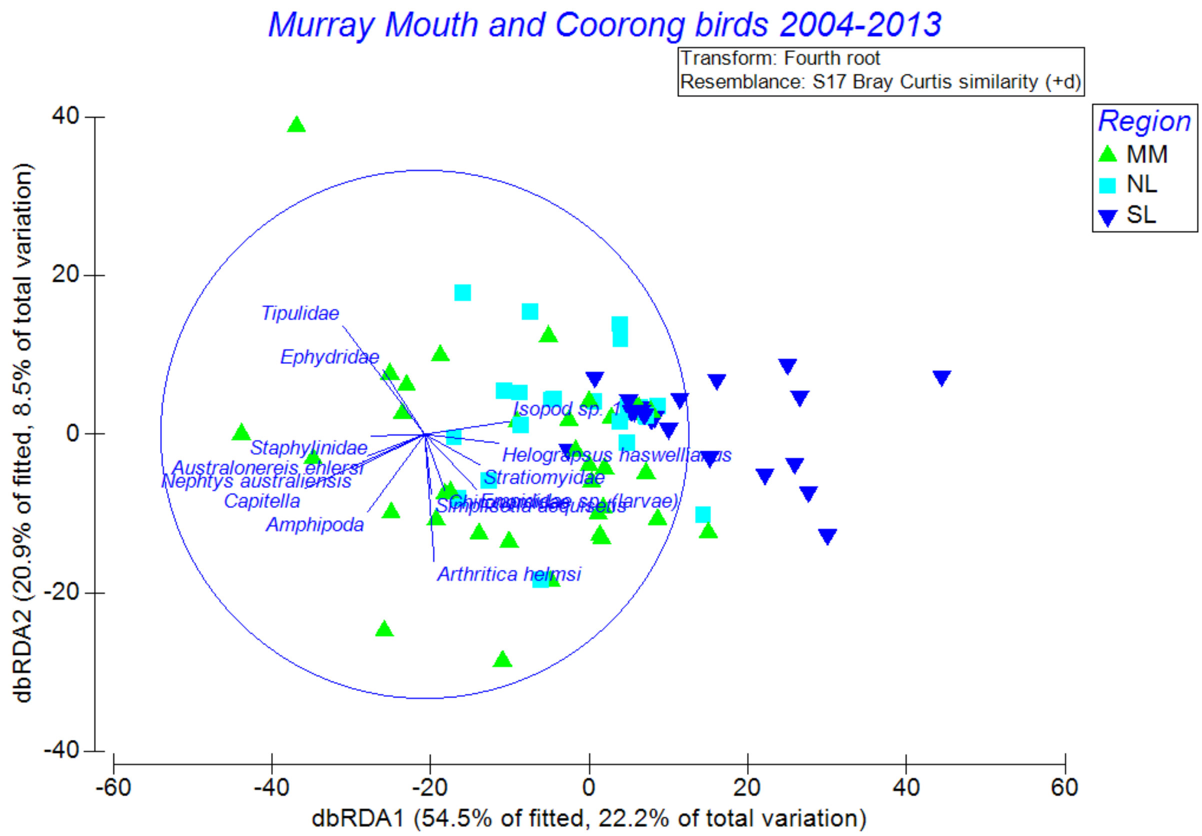

Figure 13. dbRDA (distance based redundancy analysis) plot of resident shorebird assemblages from 2004-2013 across the Murray Mouth (MM), North Lagoon (NL) and South Lagoon (SL) with macroinvertebrates as predictor variables, indicated by the vector overlay using base variables of macroinvertebrate data.

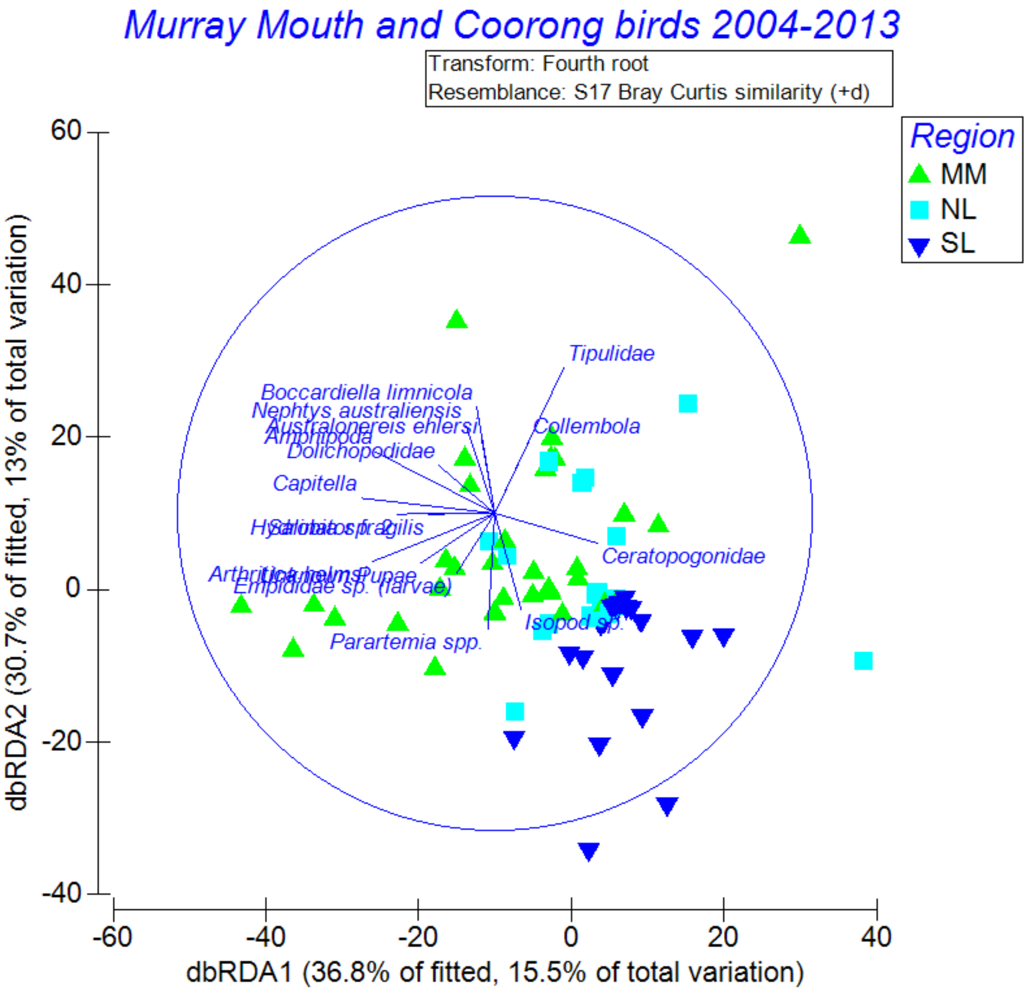

Figure 14. dbRDA (distance based redundancy analysis) plot of migratory shorebird assemblages from 2004-2013 across the Murray Mouth (MM), North Lagoon (NL) and South Lagoon (SL) with macroinvertebrates as predictor variables, indicated by the vector overlay using base variables of macroinvertebrate data.

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