Inland Waters & Catchment Ecology

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Environmental Flow Trials in the Western Mount Lofty Ranges: Vegetation Monitoring 2014

Jason Nicol and Rod Ward

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Executive Summary

The construction of large reservoirs can severely change the hydrological regime of the rivers they are constructed on, especially the reaches immediately downstream of dam walls. Changes to the hydrological regime downstream of reservoirs typically involve the reduction (or elimination) of base flows, elimination of small to medium sized floods and the reduction in magnitude and duration of large floods. The changes to the hydrological regime result in changes to the ecology and aquatic and riparian plant communities. Changes to the aquatic and riparian plant community include: encroachment of woody species into river channels, invasion of terrestrial species in the riparian zone, changes to the disturbance regime and subsequent domination of competitive species, invasion of exotic taxa, reduction in the abundance of species with high water requirements (e.g. submergent species), vegetation encroachment in riffle habitats and interruption of hydrochory, gene flow and reproduction cues.

The provision of environmental flows to restore elements of the hydrograph can result in improvements to the aquatic and riparian vegetation downstream of reservoirs and it was the aim of this study to investigate the benefits of environmental flows in four reaches of Mount Lofty Ranges streams affected by reservoirs. Direct evidence of the benefit of environmental flows could not be collected due to the lack of suitable control reaches; however, the change in the plant community through time at reaches where environmental flows were provided can provide a line of evidence. The change in the plant community through time in the South Para River downstream of the South Para Reservoir, the River Torrens between Gumeracha and Kangaroo Creek Reservoir (upper Torrens) and between Gorge Weir and Torrens Lake (lower Torrens) and the Onkaparinga River downstream of Clarendon Weir (all sites where fish and macroinvertebrate surveys were also undertaken) was determined by undertaking vegetation surveys every autumn and spring between autumn 2012 and spring 2014. It was expected that with the extra water provided by environmental flows there would be an increase in the cover of species with high water requirements (e.g. submergent and emergent species) and a decrease in terrestrial taxa over the study period.

There was no significant change in the plant community through time at the lower Torrens and in riffle habitats in the South Para River and upper Torrens. There was a significant change in the plant community in all habitats in the Onkaparinga and in pools in the upper Torrens and South Para River. However, the changes at these sites could not be attributed to environmental flows because the change in the South Para was due to several pools drying in autumn 2013 and the changes at the other sites were not due to an increase in emergent or submergent taxa. Furthermore there was a decreasing trend in open water in pools at all sites except the lower Torrens.

Results suggested that much larger volumes of water are required before significant changes in the plant community that can be attributed to environmental flows are observed. The species that established in the river channels and riparian zones since reservoirs were constructed often have extensive root and rhizome networks and will require higher flows to be displaced. The lower Torrens sites were located largely in the Torrens Linear Park, where landscaping work was probably why no change was observed.

Furthermore, below average rainfall occurred in late winter and spring in 2013 and 2014 and was the cause of the decline of open water in pools at all sites except the lower Torrens. Whilst environmental flows alone were not sufficient to improve the plant community, complementary actions such as weed control, clearing vegetation from riffles and domestic stock exclusion, in conjunction with environmental flows may result in improvements to plant communities.

1 Introduction

The need to provide a reliable water supply for the city of Adelaide and its surrounds has resulted in the construction of ten large reservoirs on streams in the western Mount Lofty Ranges. Whilst such infrastructure undoubtedly has benefits for the human population the riverine ecosystems where the reservoirs are constructed are severely impacted, particularly reaches immediately downstream of large dams or reservoirs. The construction of water supply infrastructure such as large reservoirs causes significant changes to the hydrological regime of the rivers they are constructed on. Hydrological changes brought about by the construction of reservoirs downstream of the dam wall include:

- Reduced (or absent) base flow or shortened flow duration downstream of the reservoir (e.g. Petts 1996, Shafroth et al. 2002, Assani et al. 2006).
- Small and medium sized floods are captured in the reservoir and often completely eliminated downstream of the dam, unless there is sufficient catchment with unregulated streams that enter the main stream downstream of the dam (e.g. Petts 1996, Maingi and Marsh 2002, Shafroth et al. 2002, Bejarano et al. 2011).
- The duration and magnitude of floods are smaller compared to unregulated events (e.g. Petts 1996, Maingi and Marsh 2002, Shafroth et al. 2002, Alldredge and Moore 2014). For the streams in this study these flows are often completely eliminated because the dams are large relative to flow volumes of the streams (i.e. the dams rarely spill) and water inputs from the catchment downstream of the dam are often small.
- The duration and magnitude of large floods is often smaller (unless the dam is at capacity) compared to unregulated events (e.g. Petts 1996, Maingi and Marsh 2002, Shafroth et al. 2002, Bejarano et al. 2011).
- Aseasonal flows may occur; however, this does not usually occur downstream of storage reservoirs unless the stream is part of the delivery network, it is usually a problem with hydroelectric dams (e.g. Jansson et al. 2000, Renofalt et al. 2010). In the study reaches this does not occur, except in the upper Torrens reach that is an aqueduct for River Murray water, the seasonality of flows generally remain the same.

Hydrology is the primary driver in riverine ecology (e.g. Poff *et al.* 1997, Lytle and Poff 2004); therefore, changes to the hydrological regime will result in changes to riverine ecology.

Changes to the physical environment and aquatic and riparian plant community brought about by changes to hydrology due to reservoir construction include:

- The loss of submergent species (or species with high water requirements) due to permanent reaches becoming temporary.
- Reduced scouring flows resulting in altered disturbance regimes, subsequently resulting in the dominance of competitive species and encroachment and dominance of emergent species (e.g. Shafroth et al. 2002, Braatne et al. 2007).

- Changes to the sediment characteristics of the channel and riparian zone (e.g. Merritt and Cooper 2000, Beauchamp and Stromberg 2008).
- Encroachment of woody species into the river channel (e.g. Bejarano et al. 2011).
- Encroachment of terrestrial species on the stream bed or the historical littoral zone (e.g. Mortenson and Weisberg 2010, Reynolds et al. 2014).
- Riffle habitats colonised by emergent and terrestrial species (e.g. Merritt and Cooper 2000, Nicol and Bald 2006, Mortenson and Weisberg 2010).
- Invasion of exotic species (e.g. Birken and Cooper 2006, Stromberg et al. 2007, Merritt and Poff 2010, Mortenson and Weisberg 2010, Lehnhoff et al. 2012, Greet et al. 2013b).
- Interruption of hydrochory (dispersal of propagules by water); a reservoir may act as a sink for propagules transported from upstream by flow and prevent dispersal downstream of the dam (Merritt and Wohl 2002, Merritt and Wohl 2006, Merritt et al. 2010, Greet et al. 2013a).
- Interruption of cues for reproduction and recruitment (e.g. Pettit and Froend 2001a; Pettit and Froend 2001b, Pettit et al. 2001, Lytle and Poff 2004, DeWine and Cooper 2007, Mallik and Richardson 2009, Greet et al. 2012, Jardine et al. 2015).
- Disruption of gene flow between plant populations (e.g. Werth et al. 2014).

The provision of environmental flows aims to partially restore elements of the natural hydrograph or provide a hydrological regime that will protect or enhance the riverine ecosystem (Arthington and Pusey 2003). The size of the reservoirs in the western Mount Lofty Ranges relative to annual stream flow results in all but the largest flows being captured in the reservoir; hence, changes to the ecology downstream of the dam walls is likely to be large. Nevertheless, relatively small volumes of environmental water have been shown to have a benefit for the riverine ecology downstream of large dams (e.g. Hall *et al.* 2011). Four reaches in three rivers, downstream of large reservoirs in the southern Mount Lofty Ranges were chosen to receive environmental flows between 2012 and 2014. The South Para River downstream of the South Para Reservoir, the River Torrens between Gameracha and Kangaroo Creek Reservoir and between Gorge Weir and the Torrens Lake and the Onkaparinga River downstream of Clarendon Weir (Figure 1). The hydrology of all the study reaches has been impacted by the construction of reservoirs with significantly reduced flows.

The total annual volumes of water available for environmental flows were small (16.74 GL/year across all catchments), due to water security for the city of Adelaide being paramount; hence, a scaled down natural hydrograph was not feasible (*sensu* Hall *et al.* 2011). Nevertheless, components of the flow regime were able to be provided using the available water and it provided an opportunity to investigate the benefits of these flows on the aquatic and riparian plant communities. The flow regime components, timing and volumes of water are presented in Table 1.

Overall the environmental flows were expected to improve water quality (particularly over summer), lengthen the flow season, increase water availability (again particularly during summer) and provide small pulses. The expected changes to the plant community were primarily an increase in abundance (cover) of species with high water requirements (e.g. emergents and submergents) and a corresponding decrease of terrestrial species.

Whilst flow is the primary driver in riverine ecology (e.g. Poff *et al.* 1997; Lytle and Poff 2004), other factors also influence aquatic and riparian plant communities and the benefits of flow restoration may not be realised if these factors are not taken into consideration (*sensu* Robertson and Rowling 2000). Non flow factors that influence aquatic and riparian plant communities include:

- Grazing by domestic stock (e.g. Jansen and Robertson 2001; Nicol et al. 2007).
- Nutrient concentrations (e.g. Deegan et al. 2012).
- Invasive species (e.g. Piper 1996; Price et al. 2010).
- Pollution (e.g. Haury et al. 2006; Szoszkiewicz et al. 2006).
- Catchment land use (e.g. Chambers et al. 2008; Akasaka et al. 2010; Rosso and Fernandez Cirelli 2013).

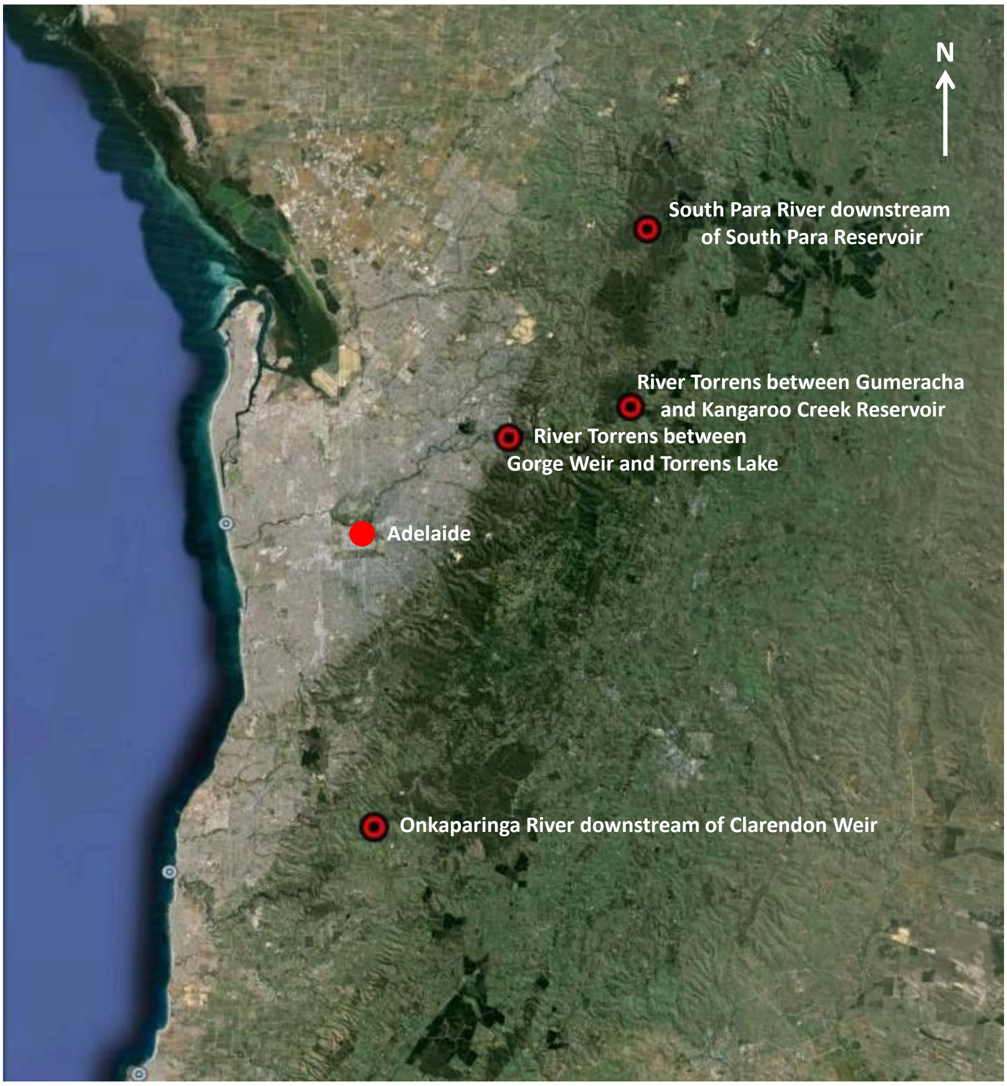


Figure 1. Satellite image showing the location of the study reaches.

Table 1. Flow regime components, the volume of water used, timing and duration provided by the available environmental water for each study reach.

Study Reach	Flow component	Volume	Timing	Duration (days)
South Para River downstream of South Para Reservoir	Cease to flow	NA	December-May	NA
	Freshes	120 ML	April-May	3
	Baseflow	7.3 ML/day	June-November	NA
	Flushes	231 ML	June and September	5
	Fresh	72 ML	November	3
River Torrens between Gumeracha and Kangaroo Creek Reservoir	Low Flow	2.5 ML/day	October-June	NA
	Low Flow	9 ML/day	July-September	NA
	Flushes	Rising to peak at 200 ML/day	May and July	5
	Flush	Rising to peak at 200 ML/day	September	5
River Torrens between Gorge Weir and Torrens Lake	Low Flow	0.25 ML/day	All year	NA
	High Flow	40 ML/day	November	20
Onkaparinga River downstream of Clarendon Weir	Cease to flow	NA	January-March	NA
	Autumn rain freshes	100 ML/day	March-May	4
	Low Flow	30 ML/day	April-October	NA
	Low Flow	10 ML/day	November-December	NA
	Flushes	Up to 400 ML/day	June and September	9

The aim of this study was to provide evidence of the benefit to the plant community by providing environmental water at the four study reaches by investigating the changes through time of the riparian and aquatic plant community between autumn 2012 and spring 2014.

2 Methods

2.1 Vegetation Survey Protocol

Vegetation surveys were undertaken in autumn 2012, spring 2012, autumn 2013, spring 2013, autumn 2014 and spring 2014 and corresponded to the fish and most macroinvertebrate sites. Each of the three pools and the corresponding upstream riffle was assessed separately and vegetation cover in or overhanging the pool or riffle was assessed for the entire sampling area (spring water level and below). This included some riparian species but was limited to individuals that directly overhang the sampling area (Figure 2). Percent cover was estimated visually for each taxon to a level of <1% when only a few individuals were present covering <1%, with 'exposed substrate' and 'open water' included for each pool or riffle to result in a minimum of 100% total for each pool and riffle replicate (values greater than 100% were recorded if there was overhanging vegetation). Percentage cover values for overstorey (trees) were included as separate measurements in order to accurately display watercourse sampling area percent cover and were included in the analysis.

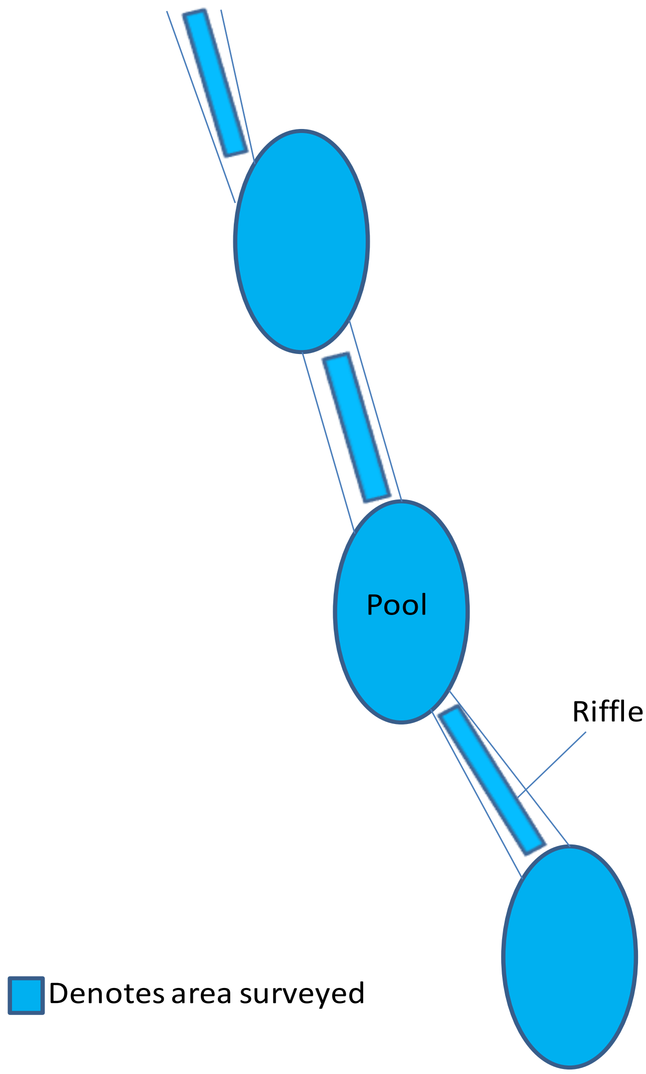


Figure 2. Stylised plan view of a site, showing areas where vegetation was surveyed.

Plants present were identified to species where possible using keys in Jessop and Toelken (1986), Dashorst and Jessop (1998), Romanowski (1998), Sainty and Jacobs (1981; 2003), Prescott (1988) and Jessop *et al.* (2006). In some cases due to immature individuals or lack of floral structures, plants were identified to genus only or in the case of some exotic grasses where genera were not able to be distinguished the plants were recorded as invasive annual grasses. Nomenclature follows the Centre for Australian National Biodiversity Research and Council of Heads of Australasian Herbaria (2015). Plants were also classified in water regime functional groups (*sensu* Casanova 2011); submergent (grows completely submerged and intolerant of exposure), floating (floats on the water surface unattached to the sediment), emergent (requires leaves or stems to extend above the water) and terrestrial (intolerant of extended inundation or waterlogging). The mean percentage cover of the different functional groups, bare substrate and open water are displayed graphically for each reach.

2.2 Data Analysis

The changes in floristic composition through time for pools and riffles at the site and reach scale in each catchment were analysed using single factor PERMANOVA (Anderson 2001; Anderson and Ter Braak 2003) using the package PRIMER version 6.1.12 (Clarke and Gorley 2006). If significant differences were detected, Indicator Species Analysis (Dufrene and Legendre 1997) using the Package PCOrd version 5.12 (McCune and Mefford 2006) was used to determine the species that drove the change through time.

2.3 Indicator Species Analysis

Dufrene and Legendre's (1997) Indicator Species Analysis combines information on the concentration of species abundance in a particular group (survey date) and the faithfulness of occurrence of a species in a particular group (McCune et al. 2002). A perfect indicator of a particular group should be faithful to that group (always present) and exclusive to that group (never occurring in other groups) (McCune et al. 2002). This test produces indicator values for each species in each group based on the standards of the perfect indicator. Statistical significance of each indicator value was tested by using a Monte Carlo (randomisation) technique, where the real data were compared against 5000 runs of randomised data (Dufrene and Legendre 1997). For this study, the groups were assigned according to survey date to compare differences in the plant community over the four surveys. A species that was deemed not to be a significant indicator of a particular group is either uncommon or widespread. An uncommon species was only found in one group but in low numbers and a widespread species is found in more than one group in similar numbers (Dufrene and Legendre 1997).

3 Results

3.1 General Trends

A total of 124 plant taxa (72 exotics including 13 proclaimed pest plants in South Australia and six weeds of national significance) were recorded across the four catchments between autumn 2012 and spring 2014 (Appendix 1). Species richness was usually higher in spring across the three catchments in pools and riffles (due to the presence of winter annuals) and generally higher in riffles (Appendix 1). Despite the high number of exotic species present at all sites (over 50% of the species recorded were exotic across sites) cover was generally low (Appendix 1) with native emergent species such as *Typha domingensis* and *Phragmites australis* having the highest cover (Figure 3, Figure 4, Figure 5 and Figure 6). Significant change in the plant community over the study period was observed in pools in the South Para and upper Torrens rivers and across all habitats in the Onkaparinga River (Table 2). A more detailed summary of vegetation dynamics is presented in the following sections.

Table 2: PERMANOVA results comparing the plant community between the six surveys in pool and riffle habitats in the four monitored catchments.

Catchment	**Habitat**	***DF***	***Pseudo-F***	***P***
South Para	Pool	5,53	3.34	0.001
	Riffle	5,53	1.50	0.064
Onkaparinga	Pool	5,53	2.96	0.001
	Riffle	5,53	1.56	0.041
Upper Torrens	Pool	5,35	1.73	0.031
	Riffle	5,35	0.55	0.985
Lower Torrens	Pool	5,53	1.02	0.456
	Riffle	5,53	1.24	0.169

3.1.1 South Para River

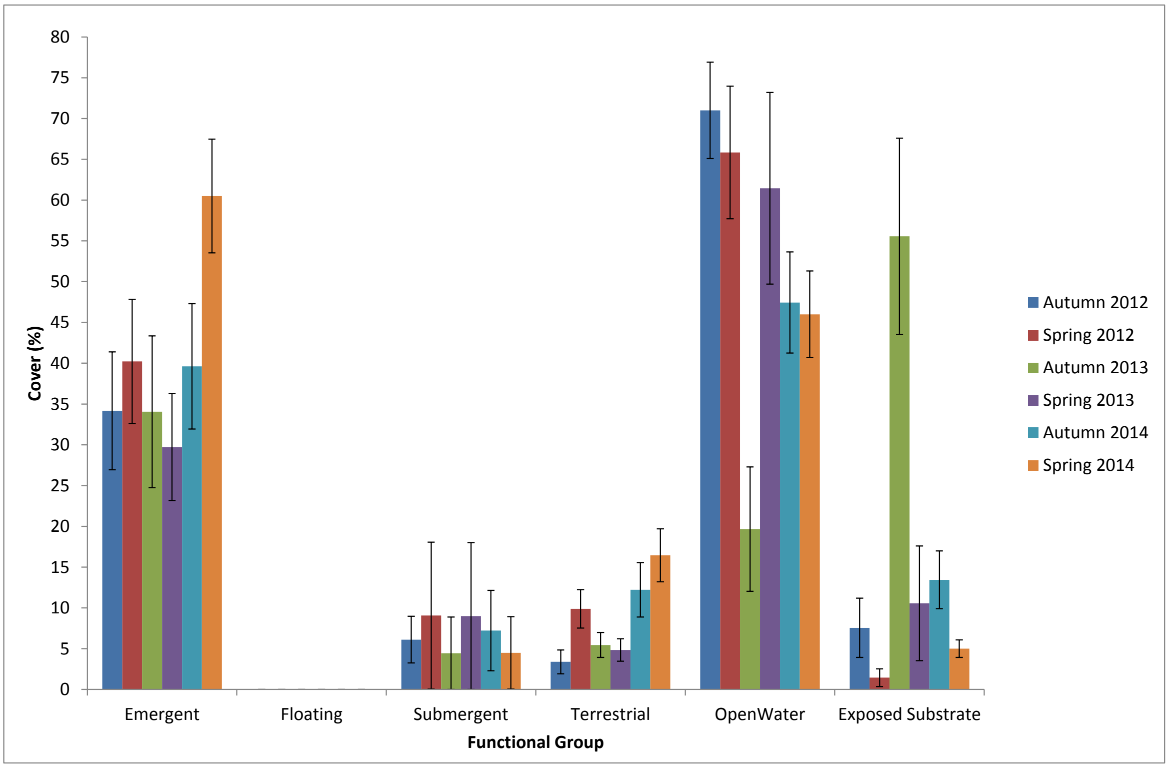
A total of 76 taxa (38 exotics including five weeds of national significance and 10 proclaimed pest plants in South Australia) were recorded in the South Para River from the six surveys (Appendix 1). Species richness was higher in riffles and generally higher in spring (Table 3), due to the presence of winter annuals. Despite the high number of exotic species present at times, native species (especially emergent species) consistently occupied a greater area (nearly as high as in 90% in riffle habitats) than the exotics (maximum cover never exceeded 15% in either habitat) (Table 3, Figure 3). Floating species were uncommon but submergents (predominantly charophytes) (Appendix 1) were present in pools throughout the study period (Figure 3). Pools were dominated by open water and emergents and riffles by emergent and terrestrial taxa (Figure 3).

The plant community in pools in the South Para changed significantly over the study period (Table 2). The change in plant community was driven by significantly higher percentage cover of *Carex* sp. in autumn 2012, *Cyperus vaginatus* and *Cenchrus clandestinus* in spring 2012, exposed substrate in autumn 2013 (due to low water levels), *Cyperus exaltatus* in spring 2013 and *Juncus usitatus* and *Oxalis pes-caprae* in spring 2014. Whilst not able to be detected by Indicator Species Analysis, open water trended downwards in pools in the South Para River over the study period (Figure 3a) indicating a drying trend between 2012 and 2014 despite the provision of environmental water. In contrast, no significant change in the plant community was observed in riffles over the study period (Table 2), which were dominated by dense stands of native emergent species such as *Typha domingensis* and *Phragmites australis*, which probably prevented the establishment of other species (Figure 3b, Appendix 1).

Table 3. Native and exotic species richness and percentage cover of native and exotic taxa (± standard error) for the autumn 2012, spring 2012, autumn 2013, spring 2013, autumn 2014 and spring 2014 surveys in pools and riffles for the South Para River.

Survey	Habitat	No. Native Taxa	No. Exotic Taxa	Total	Mean Native Taxa Cover (%)	Standard Error	Mean Exotic Taxa Cover (%)	Standard Error
Autumn 2012	Pool	13	3	16	41.83	7.28	1.28	1.10
	Riffle	12	9	21	56.41	13.76	14.37	9.47
Spring 2012	Pool	19	9	28	53.06	8.50	6.11	1.54
	Riffle	17	14	31	76.22	10.59	6.89	3.32
Autumn 2013	Pool	16	5	21	41.20	8.74	2.74	1.06
	Riffle	15	12	27	76.24	12.11	2.59	0.82
Spring 2013	Pool	17	9	26	41.22	9.09	2.33	0.60
	Riffle	15	13	28	76.72	5.90	3.33	0.82
Autumn 2014	Pool	21	11	32	53.44	7.47	5.61	0.97
	Riffle	23	16	39	78.06	7.90	8.44	2.25
Spring 2014	Pool	17	13	30	72.06	5.94	9.39	2.57
	Riffle	15	19	34	89.56	10.15	11.78	3.45

a.



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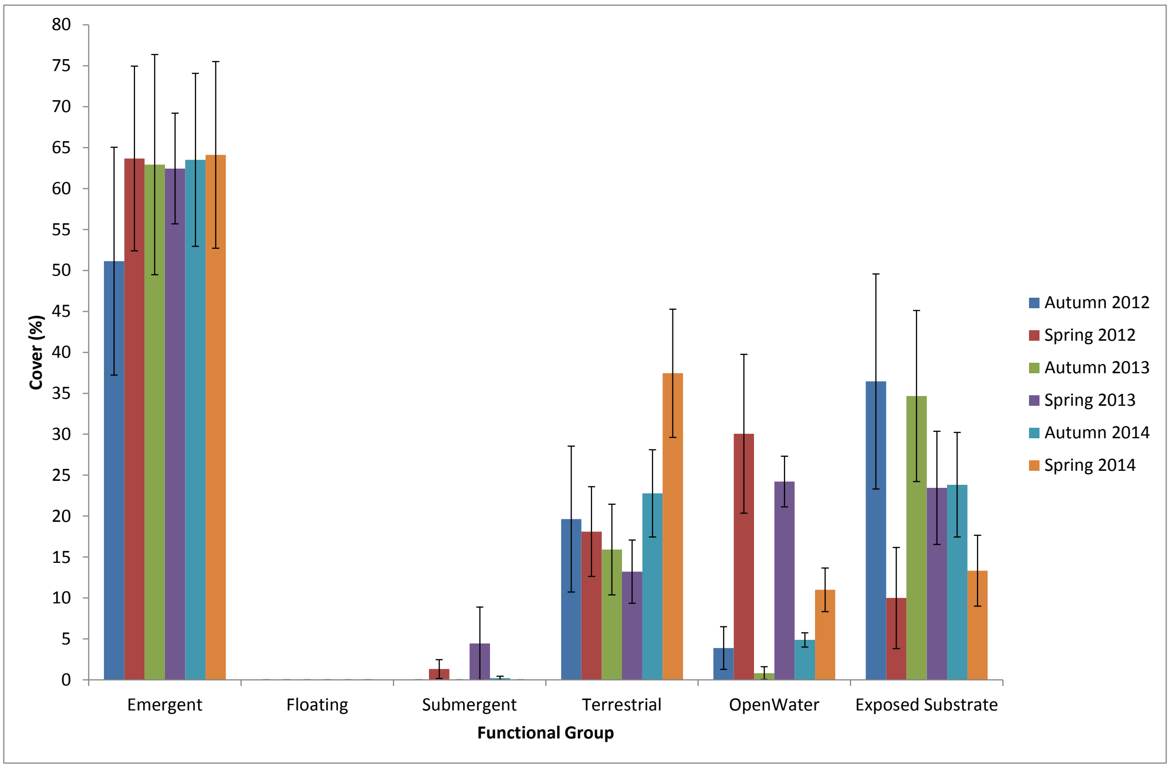


Figure 3. Cover of different functional groups, exposed substrate and open water in a. pools and b. riffles sampled in the South Para River in autumn 2012, spring 2012, autumn 2013, spring 2013, autumn 2014 and spring 2014 (error bars = ± 1 S.E.).

3.1.2 Onkaparinga River

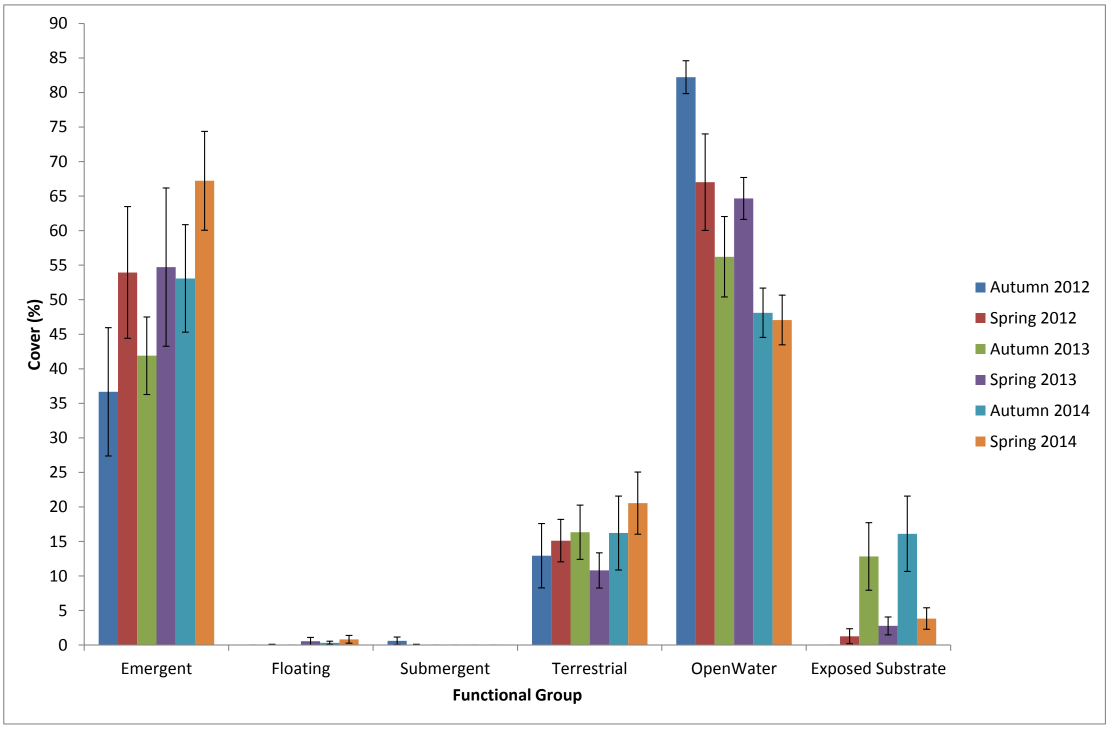
The Onkaparinga River was the most species rich river with a total of 81 taxa (43 exotics including three weeds of national significance and seven proclaimed pest plants in South Australia) recorded from the six surveys (Appendix 1). Similar to the South Para River, species richness was higher in riffles and generally higher in spring (Table 4). In contrast to the South Para River, exotic species occupied a larger area (with exotics occupying over 40% of riffle habitats below the spring high water mark at times) (Table 4). The species that covered large areas of riffle habitats were primarily *Pennisetum vilosum* and *Hedera helix* (exotic terrestrial species) (Figure 4). Nevertheless, the dominant functional group was the emergents (particularly in riffles) and there was an upward trend in both habitats over the study period. There was a downward trend in terrestrial taxa in riffles over the study period, which corresponded with the upward trend in emergents but in pools there was an upward trend of terrestrials (Figure 4) Open water dominated the pools; however, (similar to the South Para River) open water trended downwards over the study period (corresponding with the upward trend in terrestrial species) (Figure 4a) indicating a drying trend. Submergent and floating species were uncommon and only covered small areas (Figure 4).

The plant community changed significantly over the study period in pools and riffles in the Onkaparinga River (Table 2). In pools the change was driven by a significantly higher cover of open water in autumn 2012, *Cyperus exaltatus* in spring 2013, *Callistemon* sp. and exposed substrate in autumn 2014 and *Carex* sp., *Cyperus gymnocaulos, Typha domingensis* and *Rosa canina* in spring 2014. The change through time in riffle habitats was due to significantly higher cover of *Carex* sp. in autumn 2012, *Phalaris arundinacea, Vicia sativa* and *Senecio pterophorus* in spring 2012, *Leptospermum* sp., open water and *Schoenoplectus validus* in spring 2013 and *Lycopus australis* in autumn 2014.

Table 4. Native and exotic species richness and percentage cover of native and exotic taxa (± standard error) for the autumn 2012, spring 2012, autumn 2013, spring 2013, autumn 2014 and spring 2014 surveys in pools and riffles for the Onkaparinga River.

Survey	Habitat	No. Native Taxa	No. Exotic Taxa	Total	Mean Native Taxa Cover (%)	Standard Error	Mean Exotic Taxa Cover (%)	Standard Error
Autumn 2012	Pool	13	11	24	40.44	9.50	9.78	4.50
	Riffle	13	13	26	72.89	16.33	37.61	11.43
Spring 2012	Pool	20	20	40	57.44	10.83	11.72	2.42
	Riffle	17	25	42	81.28	11.01	39.81	10.12
Autumn 2013	Pool	12	11	23	46.06	6.64	12.17	2.88
	Riffle	22	20	42	66.58	9.75	45.70	10.94
Spring 2013	Pool	16	15	31	58.17	11.99	7.92	1.80
	Riffle	19	19	38	67.22	13.59	41.17	10.51
Autumn 2014	Pool	14	10	24	57.58	8.34	12.06	4.34
	Riffle	20	18	38	100.39	8.77	22.17	8.85
Spring 2014	Pool	17	21	38	73.44	7.89	15.17	4.86
	Riffle	17	28	45	90.50	10.19	31.06	11.95

a.



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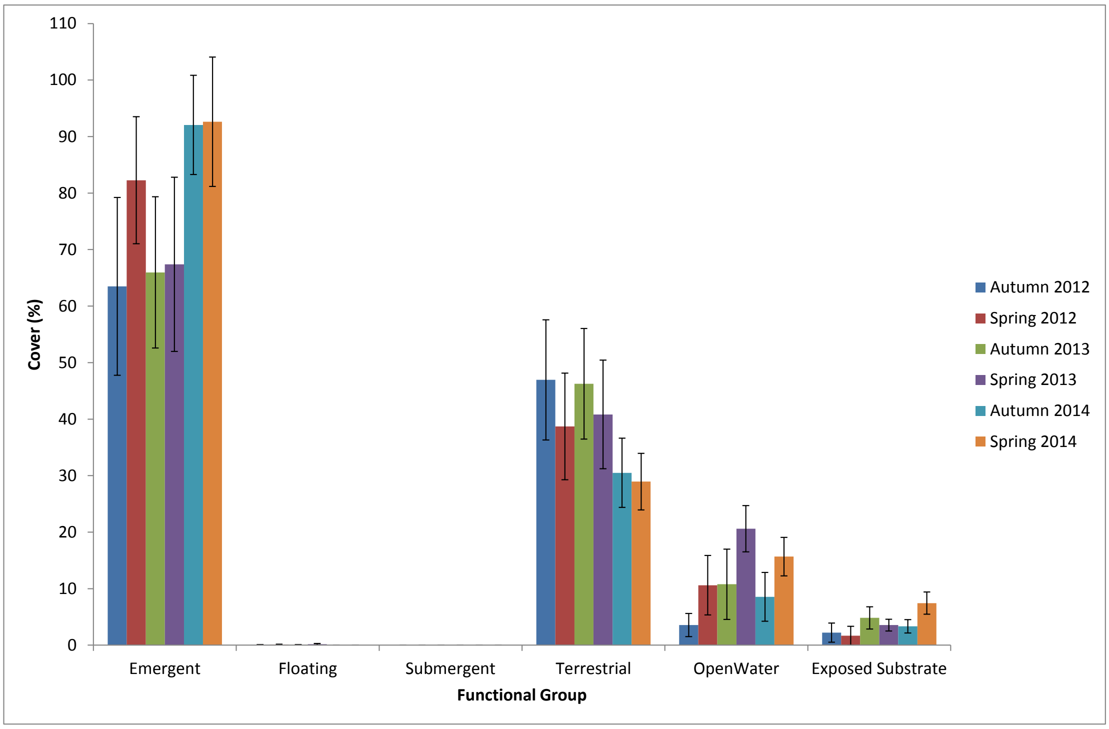


Figure 4. Cover of different functional groups, exposed substrate and open water in a. pools and b. riffles sampled in the Onkaparinga River in autumn 2012, spring 2012, autumn 2013, spring 2013, autumn 2014 and spring 2014 (error bars = ± 1 S.E.).

3.1.3 Upper River Torrens

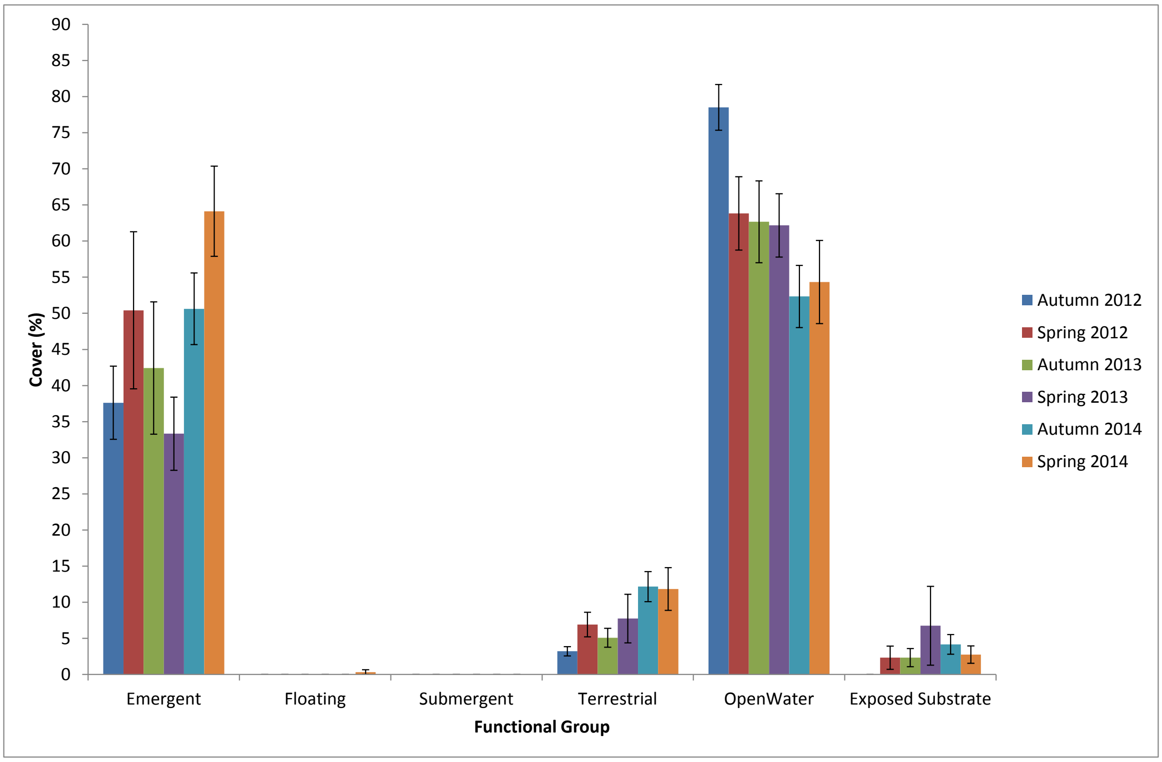
A total of 60 species (32 exotics including four weeds of national significance and seven proclaimed pest plants in South Australia) were recorded in the upper River Torrens between autumn 2012 and spring 2014 (Appendix 1). Species richness was generally higher in spring and in riffle habitats (Table 5). Exotic species accounted for over 50% of the species present with cover scores generally lower than the Onkaparinga but higher than the South Para (Table 3, Table 4, Table 5). The most abundant exotic taxa were *Cenchrus clandestinus* and *Rubus fruiticosus* (Appendix 1), which are both capable of rapid expansion by clonal growth. Native emergent species were the dominant functional group (especially in riffle habitats) and there was an upward trend in cover in pool habitats (Figure 5). Open water dominated pool habitats; however, there was a downward trend over the study period and a corresponding increase in terrestrial species indicating a drying trend (Figure 5a).

The plant community in pools changed significant over the study period (Table 2), which was driven by significantly higher cover of open water in spring 2012 and invasive annual grasses and *Salix babylonica* in spring 2014. There was no significant change in the vegetation of riffle habitats between autumn 2012 and spring 2014 (Table 2). The plant community in riffles over the study period was dominated by native emergent species, predominantly *Phragmites australis* and *Typha domingensis* (Figure 5b, Appendix 1).

Table 5. Native and exotic species richness and percentage cover of native and exotic taxa (± standard error) for the autumn 2012, spring 2012, autumn 2013, spring 2013, autumn 2014 and spring 2014 surveys in pools and riffles for the upper River Torrens.

Survey	Habitat	No. Native Taxa	No. Exotic Taxa	Total	Mean Native Taxa Cover (%)	Standard Error	Mean Exotic Taxa Cover (%)	Standard Error
Autumn 2012	Pool	14	11	25	34.37	5.81	6.47	2.21
	Riffle	13	8	21	62.90	15.99	20.10	9.58
Spring 2012	Pool	13	14	27	41.92	8.78	15.42	2.70
	Riffle	13	17	30	60.25	15.01	30.58	9.46
Autumn 2013	Pool	12	9	21	34.42	10.06	13.08	4.12
	Riffle	15	11	26	76.25	14.14	19.92	10.56
Spring 2013	Pool	15	8	23	30.67	3.97	10.42	3.86
	Riffle	14	11	25	49.00	13.23	21.67	8.57
Autumn 2014	Pool	12	10	22	46.04	5.56	16.75	2.13
	Riffle	19	12	31	65.50	13.26	23.08	12.69
Spring 2014	Pool	16	14	30	53.92	8.72	22.38	1.41
	Riffle	17	17	34	62.30	11.74	40.30	19.43

a.



b.

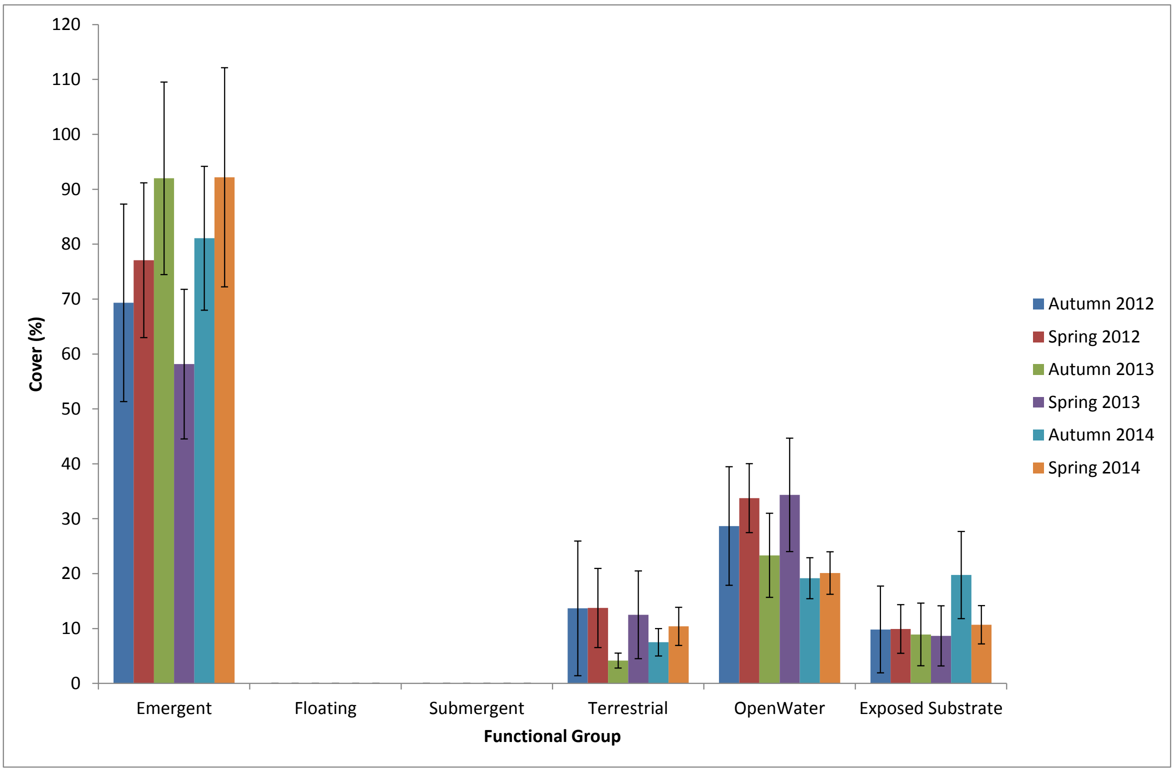


Figure 5. Cover of different functional groups, exposed substrate and open water in a. pools and b. riffles sampled in the upper River Torrens in autumn 2012, spring 2012, autumn 2013, spring 2013, autumn 2014 and spring 2014 (error bars =± 1 S.E.).

3.1.4 Lower River Torrens

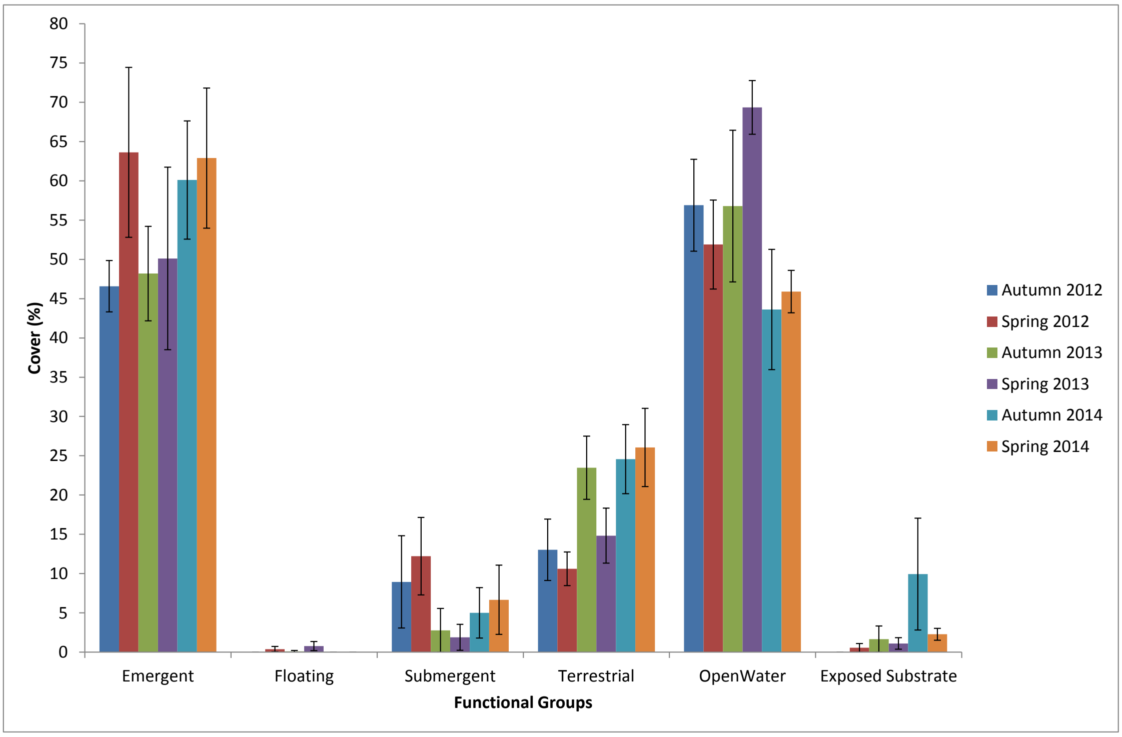
A total of 59 species (37 exotics including one weed of national significance and three proclaimed pest plants in South Australia) were recorded in the lower River Torrens over the study period (Appendix 1). The lower Torrens had the lowest species richness and highest proportion of exotic species with the cover of exotic species comparable to the Onkaparinga River (Table 4) and trending upwards over the study period (Table 6). Nevertheless, pool habitats in the lower River Torrens had the highest cover of submergent species (Figure 6a) and greatest submergent species richness (Appendix 1). Open water and native emergent species (primarily *Typha domingensis* and *Phragmites australis*) dominated pool habitats (Figure 6a). Open water peaked in spring 2013 in pool habitats but after then it trended downwards and there was generally an upward trend in the cover of terrestrial species over the study period (Figure 6a) indicating a drying trend. There was also an upward trend in terrestrial species (primarily exotic species) and exposed substrate in riffle habitats over the study period (Figure 6a).

There was no significant change in the plant community detected over the study period in pools or riffles (Table 2). Between autumn 2012 and spring 2014 pools were dominated by open water and emergent species (Figure 6a) and riffles by emergent and terrestrial taxa (Figure 6b).

Table 6. Native and exotic species richness and percentage cover of native and exotic taxa (± standard error) for the autumn 2012, spring 2012, autumn 2013, spring 2013, autumn 2014 and spring 2014 surveys in pools and riffles for the lower River Torrens.

Survey	Habitat	No. Native Taxa	No. Exotic Taxa	Total	Mean Native Taxa Cover (%)	Standard Error	Mean Exotic Taxa Cover (%)	Standard Error
Autumn 2012	Pool	11	12	23	53.32	7.62	14.68	5.15
	Riffle	13	9	22	95.48	10.62	16.41	3.39
Spring 2012	Pool	12	16	28	74.00	12.72	12.61	3.59
	Riffle	13	15	28	80.72	13.02	38.94	12.77
Autumn 2013	Pool	15	14	29	53.50	5.22	20.28	3.80
	Riffle	12	14	26	83.63	6.21	26.98	11.46
Spring 2013	Pool	14	10	24	49.44	8.19	17.61	4.48
	Riffle	12	10	22	64.72	10.71	27.17	7.59
Autumn 2014	Pool	16	15	31	67.42	6.45	21.63	5.13
	Riffle	13	10	23	80.33	11.32	41.44	10.67
Spring 2014	Pool	14	13	27	71.50	7.74	23.56	4.88
	Riffle	13	21	34	70.00	10.81	49.78	13.02

a.



b.

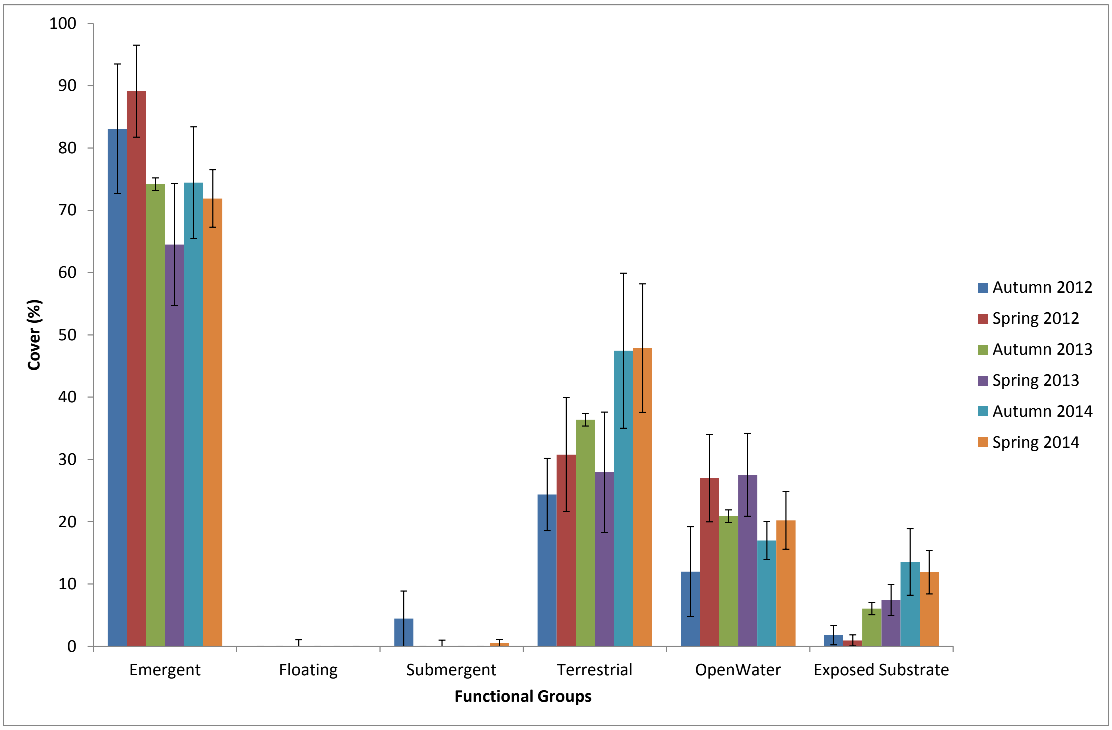


Figure 6. Cover of different functional groups, exposed substrate and open water in a. pools and b. riffles sampled in the lower River Torrens in autumn 2012, spring 2012, autumn 2013, spring 2013, autumn 2014 and spring 2014 (error bars =± 1 S.E.).

4 Discussion

There was no evidence to suggest that the provision of environmental water between autumn 2012 and spring 2014 has significantly changed the vegetation of the four river reaches monitored during this period. It was expected that the cover of terrestrial taxa would decrease and the cover of emergent, submergent and floating species would increase significantly over the study period, which has not been the case. With the exception of the Onkaparinga River, there was no significant change in the plant community at any of the riffle habitats. The change in vegetation in riffle habitats in the Onkaparinga was not due to a significant sustained increase in emergent, floating or submergent species or a decrease in terrestrial taxa. Similarly, the significant difference in pools in the Onkaparinga, South Para and upper Torrens rivers was not due to a sustained increase in emergent, floating or submergent species or a decrease in terrestrials. Where significant differences were detected it was due to the rapid change in cover of individual species between two survey dates.

The most probable reason for the lack of change in the plant community was due to the volumes of water available for environmental flows. Nicol and Bald (2005) monitored the plant community before and after a one in ten year flood in the Onkaparinga River between Clarendon Weir and Old Noarlunga, which resulted in Mount Bold Reservoir and Clarendon weir spilling and reported no change of the plant community immediately downstream of Clarendon Weir. The plant community changed significantly further downstream but was primarily due to an increase in bare substrate due to scouring (Nicol and Bald 2005).

It is unlikely that the volume of water available for environmental flows would result in any scouring; however, improvements in water quality may result, which could have positive outcomes for the plant community at small spatial scales that are difficult to detect.

The dominant plant functional group are the emergent species (especially *Typha domingensis* and *Phragmites australis*), which were especially prevalent in riffle habitats. The provision of environmental flows will increase water availability during autumn and was expected to result in an increase in the abundance of emergent species. However, the cover of emergent species generally remained stable over the study period in all rivers and habitats suggesting the environmental water was not promoting further vegetation encroachment in riffle habitats.

No change was observed in pools or riffles in the lower River Torrens. This was probably due to the highly managed nature of one of the sites (Felixstow), which is located in the Torrens Linear Park, surrounded by mowed grass and paths. Nevertheless this site had the highest species richness of submergent taxa across the four study reaches. It is unclear why submergent species were more diverse at this site but one of the sites is a weir pool and probably has more stable water levels compared to other sites.

The cause of the downward trend in open water at all sites except the lower Torrens was due to the low rainfall in late winter and spring in 2013 and 2014 in the western Mount Lofty Ranges (Bureau of Meteorology 2015a; 2015b), which may become more frequent in the future with climate change. The below average rainfall over this period has exacerbated the reduction in flow downstream of large storages and unless there is an increase in rainfall or more environmental water is delivered shallow permanent pools may dry resulting in the loss of these habitats and associated biota.

5 Conclusions and Management Implications

Cooper and Andersen (2012) suggested that the provision of flows alone are not sufficient to change plant communities downstream of large dams due to the novel plant communities being well established. This was the case in the study reaches as the provision of environmental flows over the study period did not significantly change the plant community; nevertheless, there are complementary actions that (in conjunction with environmental flows) may enhance vegetation. There were a large number of exotic species present in all rivers; however, (with the exception of the Brookes Road site in the Onkaparinga River where *Pennisetum vilosum* and *Hedera helix* occupied large areas) cover scores were generally low. Nicol and Bald (2006) reported that the aforementioned site was dominated by exotics in spring and summer 2005 and results from this study show that this is still the case. Weed control and planting of appropriate native species should be undertaken at this site; however, it is probably unnecessary at the other sites due to low abundances of exotics.

Fencing streams and protecting them from grazing by domestic stock is another action that can enhance the benefit of environmental flows. There is evidence to suggest that the impacts of domestic stock can cancel out any benefits gained from the provision of environmental flows (e.g. Robertson and Rowling 2000).

All of the sites in the Onkaparinga River and one site in the South Para River are in conservation or recreation parks and not subjected to grazing by domestic stock. Furthermore, the sites in the lower Torrens are not grazed but sites in the upper River Torrens and South Para River may be grazed and could benefit from stock exclusion.

The historical disturbance regime may be able to be simulated by periodic removal of vegetation from riffles. With the roots and rhizomes of emergent vegetation absent the provision of environmental water may be sufficient to scour fine sediment from riffle habitats and provide greater habitat diversity for fish and invertebrates. In addition, the environmental water (in conjunction with natural flows) may prevent or slow recolonisation. If such a management action was undertaken monitoring downstream impacts is important to determine whether the action was detrimental to downstream freshwater habitats (e.g. sediment slugs, increased biochemical oxygen demand) to the estuarine and near shore marine environment.

Environmental flows are one, but not the only, potential technique to improve stream condition downstream of large water storages. Results from this study showed that environmental flows alone had no significant impact on the aquatic plant community; however, coupled with certain complementary activities, improvements may be achieved.

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7 Appendices

Appendix 1. Plant species and functional group list for the autumn 2012, spring 2012, autumn 2013, spring 2013, autumn 2014 and spring 2014 surveys in pools and riffles for the three surveyed catchments (*denotes exotic species; **denotes proclaimed pest plant in South Australia; ***denotes weed of national significance, A denotes autumn, S denotes spring, P denotes pool and R denotes riffle).

		South Para												Onkaparinga												Upper Torrens												Lower Torrens											
		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014	
Taxon	**Functional Group**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**
Acacia paradoxa	Terrestrial			x		x																																											
Acacia sp.	Terrestrial			x	x	x	x	x	x	x	x	x	x	x	x				x		x	x	x	x	x	x				x	x	x	x	x	x	x	x						x						
*Acer psuedoplatanus**	Terrestrial																																					x										
Allocasurina verticillata	Terrestrial	x		x				x		x										x											x						x			x	x	x		x		x	x	x	
Alternanthera denticulata	Emergent					x				x	x															x																							
*Anagallis arvensis**	Terrestrial																x																															
*Apium graveolens**	Terrestrial									x			x												x												x												
*Arundo donax**	Emergent																																						x	x	x	x	x	x	x	x	x	x	x
*Asparagus asparagoides****	Terrestrial				x																																											
*Asparagus virgatus**	Terrestrial																											x																				
*Aster subulatus**	Emergent												x						x				x																									
Atriplex australasica	Terrestrial						x																																									
*Atriplex prostrata**	Terrestrial						x																																									
Atriplex spp.	Terrestrial									x	x																																					
Azolla filiculoides	Floating																																			x													
Baumea spp.	Emergent										x	x	x																																			
Berula erecta	Emergent														x	x	x	x	x	x			x				x		x		x				x		x	x			x	x	x	x	x	x		x	x
Betula sp.*	Terrestrial																	x			x	x		x	x													x			x	x				x			x
Bolboschoenus caldwellii	Emergent	x								x	x	x									x																	x	x	x	x								
Brassica spp.*	Terrestrial															x	x							x	x				x						x		x												
Briza sp.*	Terrestrial				x																																											
*Bromus carthaticus**	Terrestrial																x																															
Callistemon sp.	Terrestrial	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x
Callitriche sp.	Emergent											x	x			x			x					x															x		x				x	x	x		x
Calystegia sepium	Emergent													x	x	x	x	x	x	x	x	x	x	x	x													x	x	x	x	x	x	x	x	x	x	x	x
Carex spp.	Emergent	x												x		x	x					x	x	x	x																							
*Cenchrus clandestinus**	Terrestrial		x	x	x	x	x	x	x		x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Chara sp.	Submergent	x		x		x		x		x		x																									x		x		x		x		x		x	
*Centaurea calcitrapa**	Terrestrial												x																																			
*Chenopodium album**	Terrestrial		x													x							x																									
*Chrysanthemoides monolifera****	Terrestrial			x	x			x		x	x																																					
*Cirsium vulgare***	Terrestrial																																				x												

		South Para												Onkaparinga												Upper Torrens												Lower Torrens											
		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014	
Taxon	**Functional Group**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**
Cotula coronopiflia	Emergent																				x				x																								
*Crataegus monogyna**	Terrestrial												x																																				
*Cynara cardunculus***	Terrestrial		x	x	x		x	x	x	x	x	x	x						x																														
*Cynodon dactylon**	Terrestrial		x				x	x	x	x	x														x		x								x														
Cyperus exaltatus	Emergent	x	x					x	x	x	x								x	x	x		x			x						x	x	x	x			x		x		x		x	x	x		x	x
Cyperus gymnocaulos	Emergent	x	x	x	x					x	x	x	x					x	x			x	x	x	x							x			x	x	x		x								x	x	x
Cyperus vaginatus	Emergent	x	x	x	x	x	x	x	x		x		x		x	x	x			x	x	x	x					x	x	x		x	x						x	x	x					x	x		
Dauchus glochidiartus	Terrestrial															x	x																																
*Delairia odorata**	Terrestrial																		x																														
Distichlis distichophylla	Terrestrial										x																																						
*Echium plantagineum***	Terrestrial										x	x	x																								x												
Eleocharis acuta	Emergent			x	x									x		x																																	
Eleocharis spacthelata	Emergent			x		x	x			x	x								x																														
Eucalyptus camaldulensis	Emergent	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Eucalyptus sp.	Terrestrial						x																																										
*Euphorbia terracina***	Terrestrial										x																																						x
Ficus sp.*	Terrestrial													x	x	x	x	x	x	x	x	x	x	x	x				x														x					x	
*Foeniculum vulgare**	Terrestrial						x				x	x	x	x	x	x	x		x				x	x	x	x	x				x	x	x		x	x	x						x						
*Fraxinus excelsior**	Terrestrial													x	x	x	x	x	x	x	x	x	x	x	x			x	x			x	x	x		x		x	x	x	x	x	x	x	x	x	x	x	x
*Fumaria capreolata**	Terrestrial								x											x	x			x	x												x							x				x	x
*Genista monspessulana****	Terrestrial									x			x				x			x	x	x	x	x	x			x				x	x	x	x	x	x												
Geranium solanderi	Terrestrial															x																																	
Invasive Annual Grasses*	Terrestrial											x	x																						x	x	x											x	x
Hakea rostratus	Terrestrial					x											x			x	x																												
*Hedera helix**	Terrestrial													x		x	x				x		x	x	x																								
*Hordeum vulgare**	Terrestrial																																							x									
Hydrocotyle verticillata	Emergent		x		x		x	x		x	x	x							x				x	x	x				x		x		x		x	x	x												
Isolepis producta	Emergent																									x	x	x		x			x	x	x		x								x	x			
*Juncus acutus**	Emergent									x		x																								x													
Juncus kraussii	Emergent													x														x	x																				
Juncus usitatus	Emergent	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x												
Lactuca spp.*	Terrestrial																																																x
Lemna minor	Floating														x	x	x																																
Leptospermum sp.	Terrestrial	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x		x			x		x		x	x	x	
Lobelia anceps	Terrestrial																				x		x	x	x																								
Lycium	Terrestrial			x									x						x	x	x			x	x	x		x	x																				

		South Para												Onkaparinga												Upper Torrens												Lower Torrens											
		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014	
Taxon	**Functional Group**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**
*ferocissimum****																																																	
Lycopus australis	Emergent										x				x	x	x		x	x	x	x	x	x	x	x		x	x		x	x			x	x	x		x			x	x	x	x	x	x	x	x
Medicago spp.*	Terrestrial				x				x																			x	x																				x
*Melilotus albus**	Terrestrial																									x														x	x								
Mentha sp.*	Emergent														x				x				x	x	x						x		x		x		x					x		x	x	x			
Mimulus repens	Emergent						x			x	x												x						x						x	x													
*Morus albus**	Terrestrial																																					x											
Nitella spp.	Submergent											x																																					
*Nothoscordum inodoratum**	Terrestrial																x							x	x				x				x							x	x				x	x			x
*Olea europea***	Terrestrial	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x																								
*Oxalis pes-caprae***	Terrestrial							x	x		x	x	x										x		x												x												
*Oxalis purpurea**	Terrestrial								x		x																																						
*Paspalum dilatatum**	Terrestrial				x						x															x		x	x	x	x											x	x				x		
*Paspalum distichum**	Emergent	x	x																																														
*Pennisetum vilosum**	Terrestrial			x				x				x		x	x	x	x	x	x	x	x			x	x	x		x		x	x	x	x	x	x	x	x	x						x		x		x	x
Persicaria lapathifolia	Emergent							x	x						x	x	x		x		x		x		x		x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
*Phalaris arundinacea**	Emergent									x						x	x					x				x	x	x	x	x	x			x															
Phragmites australis	Emergent	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Picris echioides	Terrestrial																																		x						x								
*Pinus radiata**	Terrestrial													x																																		x	x
*Pinus halpensis***	Terrestrial															x											x		x						x			x				x				x	x		
*Plantago lanceolata**	Terrestrial															x	x				x		x		x				x				x				x				x								
*Populus deltoides**	Terrestrial													x		x	x	x	x																							x	x						
Potamogeton crispus	Submergent			x	x			x	x		x					x																						x	x	x		x		x		x		x	x
Potamogeton pectinatus	Submergent											x																																					
*Prunus domestica**	Terrestrial																x		x				x		x																								
Pteridium esculentum	Terrestrial																									x		x		x	x	x	x	x		x													
*Ranunculus tribolus**	Emergent		x						x						x		x			x	x			x	x														x	x	x				x	x	x		x
*Ricinis communis**	Terrestrial														x																							x	x	x		x	x			x		x	x
*Rorippa nasturtium-aquaticum**	Emergent								x												x								x				x																
*Rosa canina***	Terrestrial		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x															x			x						
Rubus fruticosus agg.***	Emergent					x					x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rumex bidens	Emergent		x	x	x			x	x	x	x	x	x		x	x	x		x	x	x		x	x	x	x	x	x	x		x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x
Ruppia tuberosa	Submergen			x	x	x		x		x																																							

		South Para												Onkaparinga												Upper Torrens												Lower Torrens											
		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014		A 2012		S 2012		A 2013		S 2013		A 2014		S 2014	
Taxon	**Functional Group**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**	**P**	**R**
	t																																																
*Salix babylonica**	Emergent													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
*Schinus areira**	Terrestrial																						x		x																								
Schoenoplectus pungens	Emergent			x	x	x	x		x	x	x	x	x					x	x								x																						
Schoenoplectus validus	Emergent				x	x	x					x	x					x	x							x	x			x	x	x	x	x	x	x	x	x				x	x						
*Senecio pterophorus**	Terrestrial		x	x	x		x		x	x	x	x	x		x	x	x		x	x	x					x	x	x	x	x	x			x	x	x	x	x				x	x						x
*Solanum mauritianum**	Terrestrial																																							x									
*Solanum nigrum**	Terrestrial						x						x																												x		x		x	x			
*Sonchus oleraceus**	Terrestrial				x		x	x	x	x	x	x	x		x		x		x						x	x	x	x	x						x			x		x	x		x						x
Spathiphyllum sp.*	Terrestrial																			x	x																												
Suaeda australis	Emergent																		x		x		x																										
Trifolium spp.*	Terrestrial				x		x																								x																		
Triglochin procera	Emergent	x		x		x		x	x	x		x	x	x		x	x	x	x	x		x	x	x																									
*Tropaeolum majus**	Terrestrial																																					x		x	x	x		x	x	x		x	x
Typha domingensis	Emergent	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
*Ulex europaeus****	Terrestrial																													x		x		x		x	x												
Vallisneria australis	Submergent			x	x									x																																			
*Verbena officinalis**	Terrestrial				x										x	x	x	x	x																					x	x								
*Vicia sativa**	Terrestrial															x	x							x	x			x	x	x	x					x	x			x				x					
*Vinca major**	Terrestrial																x			x	x	x	x	x	x									x		x											x	x	x
*Vitis vitifiera**	Terrestrial																								x																								
Watsonia meriana var. *bulbillifera***	Terrestrial	x		x	x	x	x	x	x	x	x	x	x																							x													
Wolffia sp.	Floating																x		x	x	x	x		x																x		x	x	x					
Xanthorrhoea semiplana	Terrestrial		x								x																																						
*Zantedeschia aethiopica**	Emergent															x	x		x					x	x														x		x	x			x	x	x		x
Total native taxa		13	12	19	17	16	15	17	15	21	23	17	15	13	13	20	17	12	22	16	19	14	20	17	17	14	13	13	13	12	15	15	14	12	19	16	17	11	13	12	13	15	12	14	12	16	13	14	13
Total exotic taxa		3	9	9	14	5	12	9	13	11	16	13	19	11	13	20	25	11	20	15	19	10	18	21	28	11	8	14	17	9	11	8	11	10	12	14	17	12	9	16	15	14	14	10	10	15	10	13	21
Total		**16**	**21**	**28**	**31**	**21**	**27**	**26**	**28**	**32**	**39**	**30**	**34**	**24**	**26**	**40**	**42**	**23**	**42**	**31**	**38**	**24**	**38**	**38**	**45**	**25**	**21**	**27**	**30**	**21**	**26**	**23**	**25**	**22**	**31**	**30**	**34**	**23**	**22**	**28**	**28**	**29**	**26**	**24**	**22**	**31**	**23**	**27**	**34**