

**Annual winter monitoring of *Ruppia tuberosa* in the Coorong region of South
Australia, July 2014**

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Summary

In the 1990s, *Ruppia tuberosa* was widespread and abundant within the southern Coorong, with populations present throughout the South Lagoon and into the southernmost sections of the North Lagoon. From around 2002, *Ruppia tuberosa* progressively declined from the southern end of the South Lagoon northwards. By July 2008, no plants were detected growing in the South Lagoon and the remaining propagule banks were low compared to historical levels. This coincided with a period of increasing salinities and low water levels in spring. During the same period of time, *Ruppia tuberosa* established in the middle of the North Lagoon and, by July 2010, there were extensive beds of *Ruppia tuberosa* in the North Lagoon. With the return of substantial flows of freshwater over the barrages from spring 2010, the extremely high salinities along the Coorong declined. In the North Lagoon, the reduction in salinity resulted in significant reductions in *Ruppia tuberosa*, with the plant all but disappearing from the middle sections of that lagoon by July 2011. However, despite the return of more typical salinities to the South Lagoon, the recovery of *Ruppia tuberosa* has been slow.

Compared with July 2013, a small improvement in the distribution and abundance of *Ruppia tuberosa* was detected in July 2014 but, in general, the recovery of *Ruppia tuberosa* across the southern Coorong remains slow. In July 2014, *Ruppia tuberosa* was detected at 11 of the 12 monitoring sites and had an extent of occurrence of 60 km along the Coorong. This included two sites in the middle of the North Lagoon that would normally be outside the range of the species. However, only two of the 11 sites (18%) had healthy populations of *Ruppia tuberosa*. This falls short of the requirement that 50% of populations of *Ruppia tuberosa* should be healthy, with healthy populations defined as having at least 30% cover with at least 10 shoots per core (75mm diam.). In addition, only one of the 11 sites had seeds present in at least 50% of cores and the overall densities of seeds remained extremely low, indicative of little, if any, effective reproduction over the previous 12 months. Low water levels in spring are likely to have restricted the capacity for seed production.

Ruppia tuberosa remains vulnerable to further losses within the Coorong as it lacks resilience (an adequate propagule bank) even in the few places where it has re-established in the southern Coorong. Given this, the plant's capacity to survive further perturbations (such as additional years with inadequate water levels in spring) remains limited. There is an urgent need to restore this resilience and this will require the provision of suitable flows over the barrages to maintain water levels in the southern Coorong through spring. If adequate flows cannot be provided or other interventions cannot be implemented then *Ruppia tuberosa* may not re-establish at the scale required to protect the ecological character of the southern Coorong.

Introduction

This report summarises the results of monitoring of *Ruppia tuberosa* undertaken in the Coorong region in July 2014 and compares the performances of *Ruppia tuberosa* with similar data collected during the previous sixteen years (e.g., Paton 1999; Paton & Bolton 2001; Paton 2003; Paton 2005, Paton 2006, Paton & Rogers 2007, Paton & Rogers 2008, Paton 2009; Paton & Bailey 2010, 2011, 2012a, 2013a, 2014a). The monitoring program was established in 1998 and the initial four monitoring sites in the South Lagoon were within the distribution of *Ruppia tuberosa* in the Coorong at that time. A fifth site at Noonameena in the North Lagoon was outside the distribution of *Ruppia tuberosa* in the Coorong when the monitoring began but in response to the species extending its distribution northwards three additional sites in the North Lagoon were added to the monitoring program from July 2009, to better capture changes in distribution and abundance. A further monitoring site outside the Coorong (Lake Cantara) was also established in July 2009. This site had been identified as a potential source population for use in translocations of *Ruppia tuberosa* back into the South Lagoon. In 2012, a further four monitoring sites were added to the monitoring program to further enhance the documentation of any recovery.

Ruppia tuberosa is essentially an annual plant that exploits the ephemeral mudflats around the shores of the southern Coorong and ephemeral saline lakes such as Lake Cantara. These ephemeral areas are covered with water from late autumn through spring and into summer but are often dry from late summer through autumn. During this dry period, the plant remains on the mud surface as seeds and turions. Most, if not all, of the turions that survive this period of desiccation sprout and some of the seeds germinate, when water levels rise again in late autumn and winter. The plants then grow over winter and, provided water levels remain adequate, reproduce sexually (producing seeds) and asexually (producing turions) during spring and early summer. The extent to which water remains over the ephemeral mudflats during spring and summer, however, is related to releases of water over the barrages. If the barrages are closed during spring, water levels in the southern Coorong drop, leaving *Ruppia tuberosa* plants exposed before they have the opportunity to reproduce. However, water levels in the southern Coorong can remain higher even into February, if the barrage gates remain open until this time (Paton 2010, & unpubl.). Given this, a sequence of years with little or no spring releases of water over the barrages is likely to restrict the ability of this annual plant to reproduce and hence maintain its presence in the southern Coorong. Because of its importance in the South Lagoon (e.g., as a major food source for herbivorous waterfowl), the decline of *Ruppia tuberosa* has critical flow-on effects for other species, and the ecological character of the Coorong as a whole (Paton 2010).

The best time to monitor the performance of *Ruppia tuberosa* is during winter after the seeds and turions have germinated. At this time, the shoots are relatively short (1-4 cm in length), and are more easily counted. Later in the season, individual plants are larger and can form dense mats that are difficult to quantify.

This report builds on previous reports by adding the monitoring results for July 2014 to those of previous years. This is required to understand how the distribution and abundance of *Ruppia tuberosa* has changed over time and provides the basis for assessing the extent of any recovery. There is a need to set some qualitative and quantitative criteria to define when *Ruppia tuberosa* has recovered within the southern Coorong as a whole, and also for individual sites. Over the last year there has been a concerted effort to define a series of measures at both a regional and local (site) scale that can be used to assess the health of *Ruppia tuberosa* in the Coorong (Table 1, Paton & Bailey 2014a; Paton 2014). The July 2014 monitoring results will be assessed against these targets as well.

Table 1: Criteria used to define the status of *Ruppia tuberosa* in the southern Coorong.

Criterion	Target
<u>REGIONAL SCALE</u>	
R.1 Extent of Occurrence (EOO)	<i>Ruppia tuberosa</i> plants distributed along 43 km of the southern Coorong
R.2 Area of Occupation (AOO)	<i>Ruppia tuberosa</i> plants present at 80% of sites monitored within the EOO in winter and spring
R.3 Population Vigour (VIG)	Vigorous <i>Ruppia tuberosa</i> populations at 50% of sites with <i>Ruppia tuberosa</i> present, where a vigorous population has at least 30% cover with at least 10 shoots per core (75mm diam) for cores with <i>Ruppia tuberosa</i>
R.4 Population Resilience (RES)	At least 2,000 seeds/m ² at 50% of sites with <i>Ruppia tuberosa</i> (target set for 2019)
<u>LOCAL SCALE</u>	
L.1 Population cover	At least 30% cover in winter and in summer
L.2 Population (shoot) density	At least 10 shoots per core (75 mm diam) for cores with <i>Ruppia tuberosa</i> in winter
L.3 Propagule (seed) density	At least 50% of surface sediment cores (75 mm diam) with seeds
L.4 Reproductive output	At least 50 flower heads/m ² for 50% of the area sampled (with <i>Ruppia tuberosa</i>) at a site during spring flowering
L.5 Asexual reproduction	At least 50% of cores (75 mm diam) taken across the <i>Ruppia tuberosa</i> beds in late summer should contain turions
<u>FUTURE RESILIENCE</u>	
RS.1 By 2019	2,000 seeds/m ² at 50% of sites (> 8 seeds per core (75 mm diam))
RS.2 By 2029	10,000 seeds/m ² at 50% of sites (> 40 seeds per core (75 mm diam))

Methods

Study sites

Four sites in the South Lagoon where *Ruppia tuberosa* was known to exist in previous years were selected for annual monitoring in 1998 (Table 2). These four sites were spread along the length of the South Lagoon (Tea Tree Crossing (TTX), Salt Creek (SC), Policeman's Point (PP), and Villa dei Yumpa (VDY)) and were sites that were also monitored in 1984-85. Three of the four sites (all but SC), were also monitored intensively from July 1990 to June 1993. One site in the North Lagoon (Noonameena (NM)) was monitored in July from 1998 onwards, where *Ruppia tuberosa* had not been formerly detected. In July 2009, a further four sites were added to the annual winter monitoring program. These were Lake Cantara (LC), an ephemeral lake south of the Coorong that supported a population of *Ruppia tuberosa*, and three additional sites in the North Lagoon, namely Magrath Flat (MF), Rob's Point (RP) and Long Point (LP) (Table 2). These sites were added to the annual monitoring program because *Ruppia tuberosa* had gradually shifted its distribution into the North Lagoon. Based on other monitoring conducted during January from 2001 onwards (e.g., Paton 2003; Paton & Rogers 2008; Paton 2010), *Ruppia tuberosa* was known to be present and abundant in 2000-2001 at MF, then gradually declined but was still present in 2007-08. *Ruppia tuberosa* was detected at increasing frequency from 2005 onwards for RP and 2008 onwards for LP.

In July 2012, a further four sites were added to the winter sampling program (Table 2). Three of the sites were on the western side of the South Lagoon and the fourth site was on the eastern shore between Policeman's Point and Villa dei Yumpa. These additional sites were intended to confirm the patterns found on the eastern shore and to provide a little more precision along the South Lagoon.

Sampling procedure for *Ruppia tuberosa* and benthic invertebrates

At each sampling site a series of five parallel transects were established. The five transects were 25 m apart and ran perpendicular to the 100 m baseline that ran along the shore. The starting points for each transect were marked along this baseline at 25 m intervals and recorded with a GPS. Along each transect, the water depth was measured at 50 m intervals to the nearest centimetre, until the water level was 0.9 m deep or deeper. Midway along each of the five transects, a litre water sample was collected and a Secchi disc lowered into the water to estimate turbidity. The salinities of the water samples were subsequently measured in the laboratory with a Hanna conductivity meter or a TPS meter, with samples being diluted when conductivities were above the optimum measuring range of the meters. Conductivities were converted to salinities using the conversion equation developed by Ian Webster (unpubl.). This equation

Table 2: Location of monitoring sites for *Ruppia tuberosa* in the Coorong with Eastings and Northings (Datum WGS84, Map 54H) for the start of the third transect (see methods) at each site.

Site	Site details	Easting	Northing
TTX	5 km south of Salt Creek outlet	378832	5996641
SC	Bay north of Salt Creek entrance	377782	6000984
PP	Bay just north of Policeman's Point	372607	6009074
VDY	Bay just north of shack at Villa dei Yumpa	360339	6025095
NM	Opposite NPWS store shed at Noonameena	342635	6042214
<u>Additional sites added in July 2009</u>			
LC	Lake Cantara (western side)	387124	5978174
MF	Magrath Flat (middle of bay)	354909	6029549
RP	Rob's Point (north of the middle of bay)	345015	6039121
LP	Long Point (2 nd bay north of Long Point)	334165	6048619
<u>Additional sites added in July 2012</u>			
S39W	western side of Coorong 3km S of SC	376658	5997276
PS	Princes Soak (western side of Coorong opp. PP)	369797	6008099
S21E	Near Woods Well	370410	6013413
S06W	western side of Coorong opposite VDY	357927	6024000

provides a better measure of the actual salinities, particularly when salinities are high, compared to the equation developed by Williams (1986). Along each transect, ten 75-mm diameter x 40-mm deep mud samples were collected, with two samples coming from each of the following water depths: 0.2 m, 0.4 m, 0.6 m, 0.8 m and 0.9 m. Each sample was subsequently sieved through a 500- μ m endcott sieve and all of the seeds, turions, and shoots of *Ruppia tuberosa* were counted, along with the numbers of chironomid larvae and/or polychaete worms. In 1998 and 1999, transect lines and distances along them were determined using tape measures but, from 2000, a Garmin 12 XL GPS was used to follow a transect line and estimate the distances along the line. Since the water levels in Lake Cantara did not exceed 25 cm, core samples were taken every 50 m along the 5 transects and water depths noted at each sampling location.

In 1999, an additional monitoring program was established to better capture changes in the local distribution and performance of *Ruppia tuberosa*. This involved collecting 50 core samples (75-mm diameter x 40-mm deep) in water depths ranging from 0.4 to 0.7 m between the first and second transects, second and third transects, third and fourth transects, and fourth and fifth transects (e.g., Figure 1). This range of water depths covered the major *Ruppia tuberosa* beds at each site in the Coorong. This sampling gave four sets of 50 core samples and a total of 200 core samples for a site. These samples were not sieved, but the number of shoots present in each sample was counted *in situ* and recorded.



Figure 1: Colin Bailey sampling *Ruppia tuberosa* in the Coorong region using a corer (left) to collect a 75-mm diameter x 40-mm deep core to check for presence of *Ruppia tuberosa* (right). Note the turbidity of the water. (Photo courtesy Coby Mathews).

Results

Historical salinities and water depths in July

The salinities in July 2014 across the sampling sites in the South Lagoon of the Coorong were typically around 65-90 gL⁻¹ (Figure 2), and similar to the salinities in July 2013, except for Villa dei Yumpa (VDY) which were 44 gL⁻¹ and below the recommended lower range for the South Lagoon (60 gL⁻¹). The salinities in the South Lagoon, nevertheless, were typical of the winter salinities recorded during 1998-2002 prior to the extended drought (2002-2010).

The salinities in July 2014 at the sampling sites in the North Lagoon contrasted with those of the South Lagoon and ranged from 27-36 gL⁻¹. These salinities were similar to those recorded in recent years and typical of the winter salinities experienced in the 1998-2002 period prior to the extended drought (2002-2010).

Salinities were also collected at the three sampling sites on the western side of the Coorong (Table 3). These were generally consistent with the salinities measured on the adjacent eastern shore, except for S06W where the salinity (70 gL⁻¹) was much higher than for Villa dei Yumpa (VDY = 44 gL⁻¹). These two sites were measured on different days and may reflect local shifts of water into and out of the South Lagoon with limited mixing in the short term, particularly in the narrow parts of the Coorong. Villa dei Yumpa was



Figure 2: Winter salinities at monitoring sites for *Ruppia tuberosa* in the Coorong in July from 1998 to 2014. Sites TTX (Tea Tree Crossing), SC (Salt Creek), PP (Policeman’s Point) and VDY (Villa dei Yumpa) were spread along the South Lagoon, while MF (Magrath Flat), RP (Rob’s Point), NM (Noonameena), and LP (Long Point) were spread along the North Lagoon. South Lagoon sites are shown in blue to black colours and those in the North Lagoon in green to red colours. TTX is the southernmost site and LP the northernmost site amongst the eight sites. MF, RP and LP were only sampled annually in July from 2009 onwards.

Table 3: Salinities (g/L) along the Coorong in July 2014.

Site Code	Site Name(s)	Distance from Murray Mouth km	Salinity (g/L)	
			East side	West side
N29	Long Point	27	36.2	
N19	Noonameena	37	30.8	
N15	Rob Point	41	30.6	
N02	Magrath Flat	54	27.0	
S06	Villa dei Yumpa / S06W	62	44.2	69.9
S21	S21E	77	65.3	
S26	Policeman’s Pt/ Princes Sk	82	78.0	75.8
S36	Salt Creek	92	89.0	
S39	S39W	95		83.0
S41	Tea Tree Crossing	97	87.8	

sampled after a period of strong northerly winds. These winds would have pushed water of lower salinity into the northern parts of the South Lagoon. The site S06W, which sits within the narrow section of the Coorong connecting the north and south lagoon, was sampled after a period of calm weather. Under those conditions any water of lower salinity that may have been pushed into the South Lagoon may have shifted back northwards and out of the South Lagoon by then.

In most years, a systematic gradient in salinity establishes along the Coorong with the salinities gradually increasing from north to south. In July 2014, this gradient had been disrupted around the junction of the two lagoons with slightly fresher water present at Magrath Flat (North Lagoon) than either to the north or south of this site. This pattern of a marked change in salinities between the two lagoons is similar to the previous year, and similar to the winter salinities recorded prior to 2002. Water levels in July 2014 were higher than in any of the previous 16 years, exceeding the previous highest water levels by 0.15 m and 0.5 m higher than the previous year (Table 4).

Ruppia tuberosa (200 core samples) abundance at monitoring sites

Figure 3 shows the percentage of 200 core samples that contained *Ruppia tuberosa* shoots in July of each year from 1999 to 2014 for five sites in the Coorong and for three additional sites (MF, RP and LP) from 2009 to 2014.

There are four striking patterns to the changes in the distribution and abundance of *Ruppia tuberosa* that have taken place in the Coorong since 1999 (Figure 3). First, there was a significant decline and then loss of *Ruppia tuberosa* from the four long-term monitoring sites spread along the South Lagoon, such that there was no *Ruppia tuberosa* detected growing in July at any of these sites from 2008-2010 (Figure 3). Second, from July 2005 onwards, there was a gradual colonisation of sites in the middle of the North Lagoon such that, in July 2009 and July 2010, extensive *Ruppia tuberosa* beds (>90% of cores with plants) had established midway along the North Lagoon (e.g., Rob's Point & Noonameena; Figure3). These populations were outside the historic distribution of *Ruppia tuberosa* within the Coorong. Third, by July 2011, following the return of flows to the Murray Mouth in spring 2010, there had been a rapid reduction in the cover of *Ruppia tuberosa* in the North Lagoon, with *Ruppia tuberosa* all but eliminated (Figure3) except for a few plants at Magrath Flat and Noonameena (<5% of cores with plants). While *Ruppia tuberosa* was lost from the North Lagoon, some *Ruppia tuberosa* (present in 32% of cores), re-appeared at Villa dei Yumpa, the northernmost monitoring site in the South Lagoon in July 2011. Fourth, despite suitable salinities throughout the South Lagoon for the last four years, the recovery of *Ruppia tuberosa* across the South Lagoon has been slow. By July 2013, only the northernmost sites of the South Lagoon (S06W, Villa dei Yumpa) and, albeit to a lesser

Table 4: Changes in water levels between years during the July sampling for *Ruppia tuberosa*. The table shows the average water level difference relative to the water levels measured in July 1998. Average water level difference is calculated from the difference in water levels recorded at five sites, 100m out from the shoreline and averaged across the five sites (Tea Tree Crossing, Salt Creek, Policeman Point, Villa dei Yumpa, and Noonameena).

Year	Water level (cm)
1998	0
1999	34
2000	18
2001	3
2002	40
2003	13
2004	37
2005	2
2006	-10
2007	2
2008	25
2009	28
2010	-1
2011	24
2012	10
2013	5
2014	55

extent, the southernmost site in the North Lagoon (Magrath Flat), had moderate to high levels of cover for *Ruppia tuberosa* while other sites had limited or no cover. In July 2014, these northerly sites had maintained or increased their level of cover, such that Villa dei Yumpa had comparable cover to the historical levels (1998-2002) prior to the drought. Sites midway along the South Lagoon (PP, PS) had also increased in cover from around 1% to around 10%, while all other sampling sites now had a low presence of *Ruppia tuberosa* (around 1% of cores; Figures 3, 4 and 5).

Changes in the mean numbers of shoots per core for the 200 core samples taken over the beds of *Ruppia tuberosa* show a similar pattern to changes in cover from one year to the next (Figure 4). In July 2014, the average number of shoots per core was highest at Villa dei Yumpa (19.9 shoots/core), with two other sites

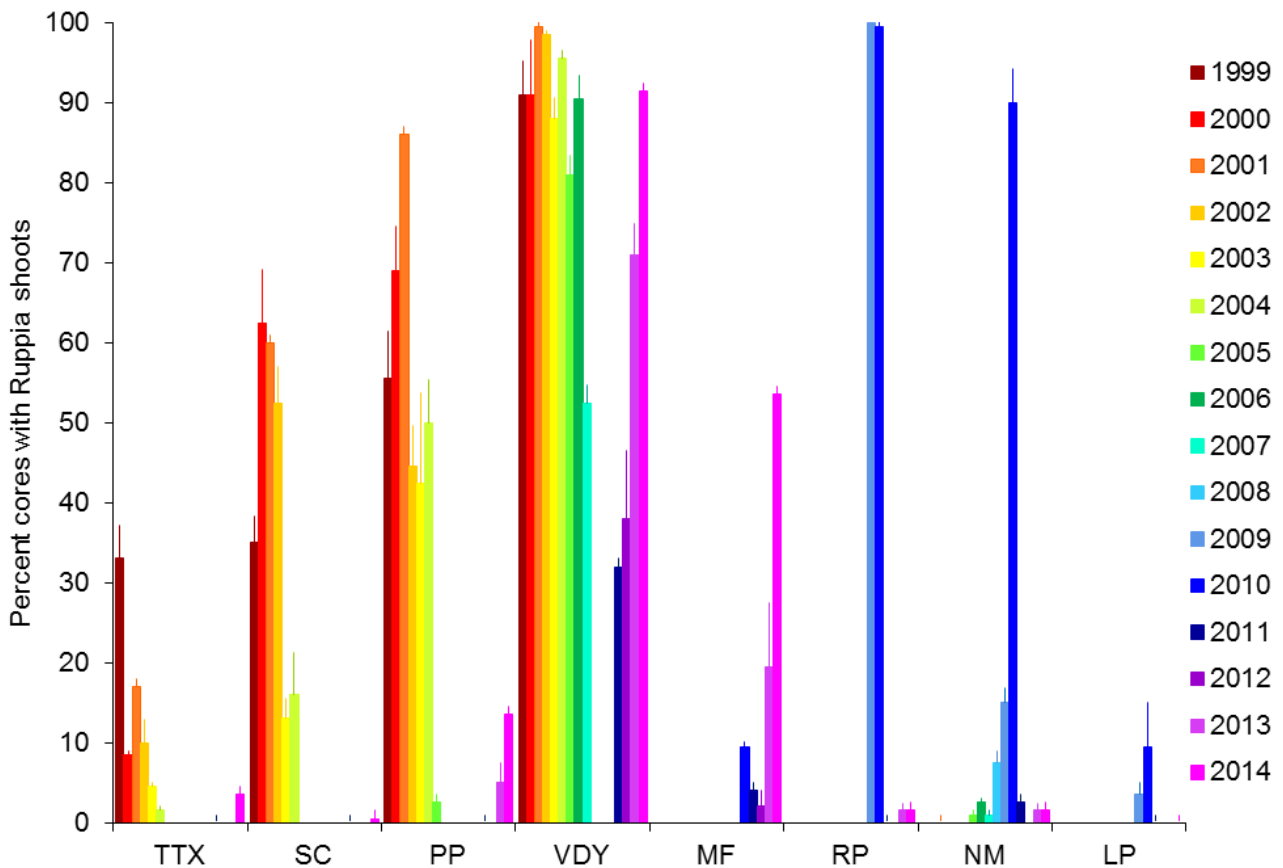


Figure 3: The percentage of 200 cores (75-mm diam x 40-mm deep) that contained *Ruppia tuberosa* shoots at each of 8 sites spread along the North and South Lagoons during July from 1999 to 2014. See Table 1 for the locations, but sites are arranged from the southernmost site (TTX) in the South Lagoon to the northernmost site (LP) in the North Lagoon, with the four sites on the left in the South Lagoon and the four on the right the North Lagoon. Data are shown as the mean (+s.e.) percent of cores with *Ruppia* for four sets of 50 cores at each site. Purple and pink colours are used to highlight more recent years.

(S06W, Magrath Flat) having average densities of around 10 shoots per core. For all other sites, the mean number of shoots per core was typically much less than 1, consistent with limited cover.

Changes in the availability of *Ruppia tuberosa* seeds and turions in July

The data collected along the five transects at each site provide a comparable but less robust data set for shoots of *Ruppia tuberosa* relative to the 200 core samples and are not presented in this report. However, the samples collected along the transects provide a basis for assessing changes in the prominence of seeds and turions in the sediments in July over time. The abundances of seeds and turions at each site are provided in Table 5 for 1998-2000, 2010-2012, 2013 and 2014. In the last five years (2010 - 2014), only small numbers of seeds have been detected at sites in the Coorong with abundances generally highest at Villa dei Yumpa. However, the numbers of seeds in samples was highly variable and patchy (as indicated by the standard errors in Table 5).

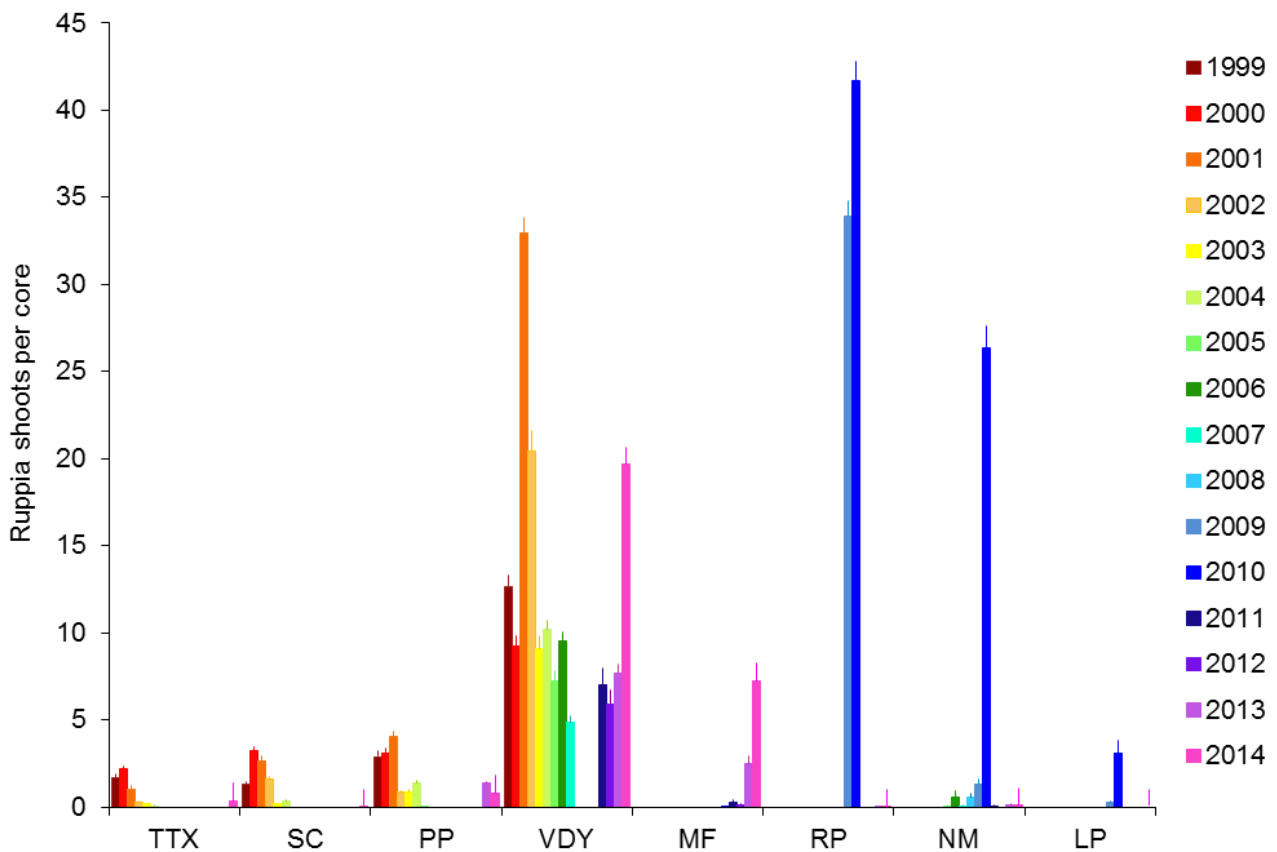


Figure 4: Mean number of *Ruppia tuberosa* shoots counted in 200 cores taken in July from eight sites spread along the Coorong from 1999 to 2014. Data show mean number of shoots per core + s.e. Shoots per core can be converted to shoots per m² by multiplying by 226. Purple and pink colours are used to highlight more recent years.

In previous years (2010-2012), over 600 seeds from the South Lagoon were examined and none contained internal contents (see Paton & Bailey 2013a). Thus the reported abundances of seeds in Table 5 in recent years will over-estimate the functional seed abundance. The low viability of seeds in the South Lagoon reflects the absence of any recent seed production in the South Lagoon.

Seed abundances for *Ruppia tuberosa* during the initial three years of monitoring (1998-2000) in the Coorong were about 10-fold higher compared to current abundances (Table 5), but seed abundances in the Coorong were 10-100 fold lower compared to Lake Cantara, where there have been 20-50 seeds per core in July in recent years. Very few turions have been detected in recent years (Table 5).

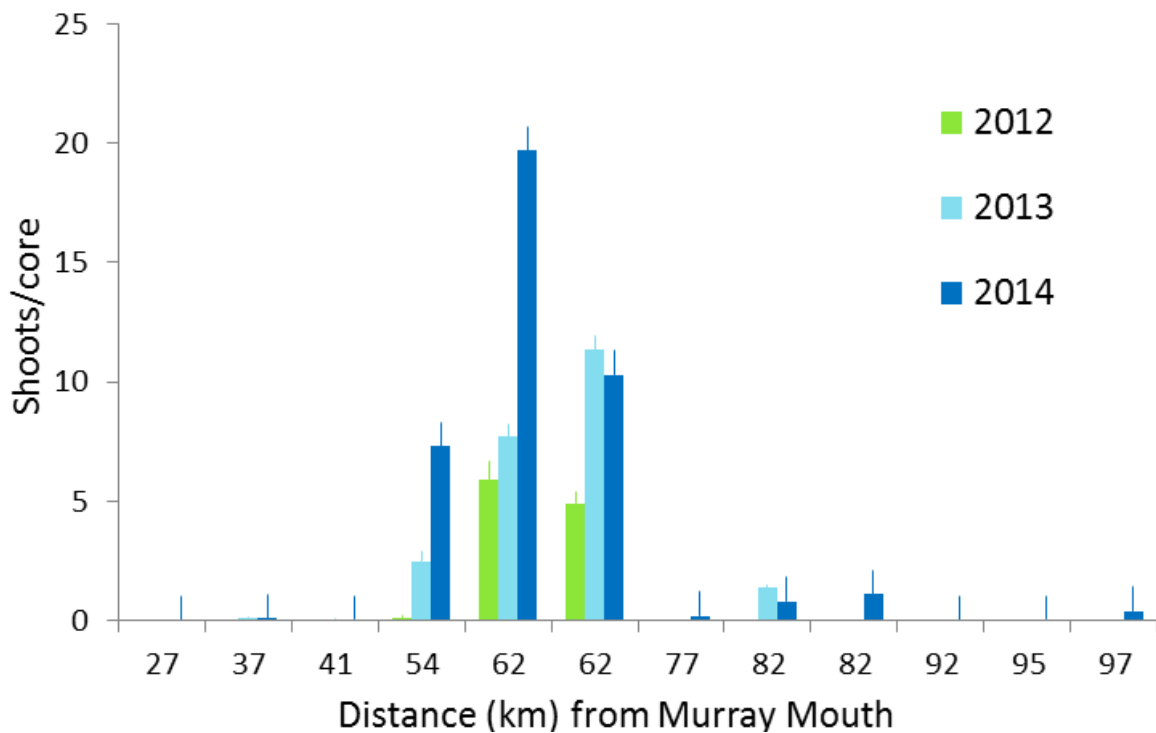
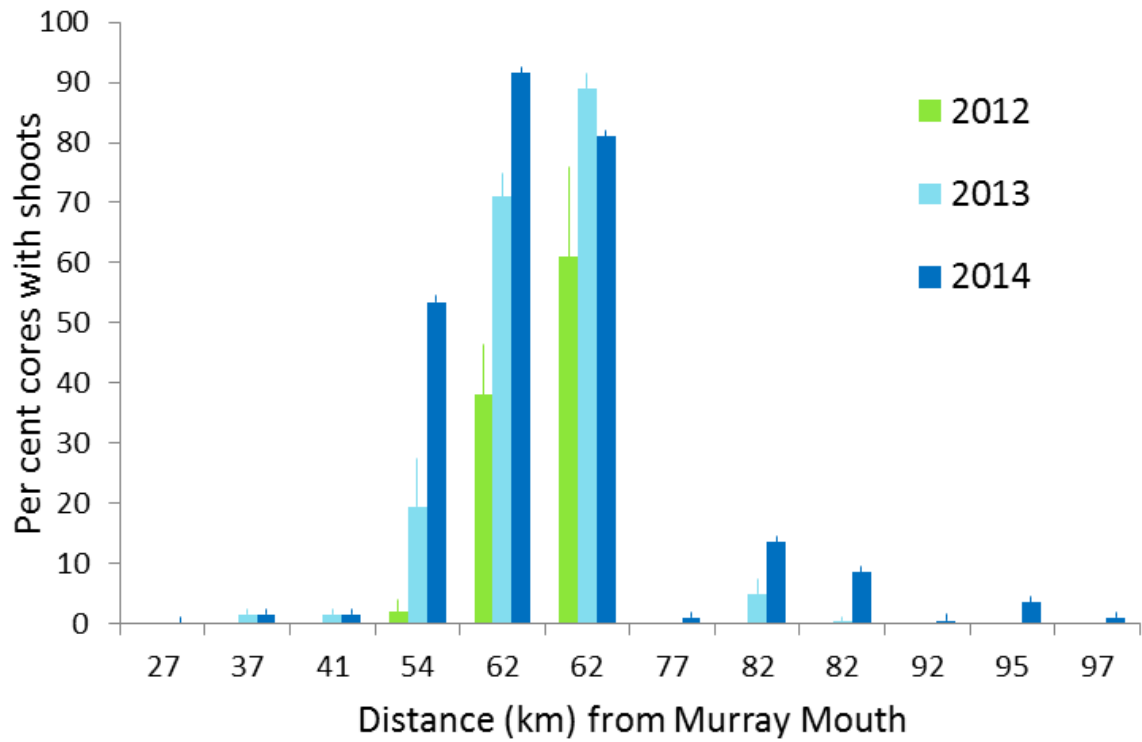


Figure 5: Percent of cores with *Ruppia tuberosa* shoots and mean number of shoots per core counted in 200 cores taken in July 2012 (green), July 2013 (light blue) and July 2014 (mid blue) from 12 sites spread along the Coorong. Data show mean number of shoots + s.e. Shoots per core can be converted to shoots per m² by multiplying by 226. The junction of the two lagoons is 56 km from the Murray Mouth. The right-hand series of data for 62 km and 82km, and the data for 95 km are from sites on the western side of the Coorong, while all other sites are on the eastern side of the Coorong.

Table 5: Abundances of seeds and turions detected in core samples along transects at each of thirteen monitoring sites for July 1998-2000, July 2010-12, July 2013 and July 2014. The data for all years except July 2014 show the mean number of seeds and turions based on 50 cores from each site in each year. Data for July 2014 are means \pm s.e. for 50 core samples except for Lake Cantara, which are based on 10 samples in each year. The 1998-2000 data and the 2010-12 data are based on 150 cores, 50 in each of the three years (30 for Lake Cantara with 10 taken in each year).

Site	July 1998-2000		July 2010-2012		July 2013		July 2014	
	seeds per core	turions per core	seeds per core	turions per core	seeds per core	turions per core	seeds per core	turions per core
South Lagoon								
TTX	1.57	0.23	0.23	0.0	0.52	0	0.4 \pm 0.1	0.0
SC	2.34	0.12	0.15	0.0	0.04	0	0.68 \pm 0.16	0.0
PP	3.88	0.48	0.47	0.0	1.28	0	2.08 \pm 0.63	0.0
VDY	14.06	0.12	2.38	0.41	1.04	0.08	2.46 \pm 0.54	0.0
S06W			1.26	0.0	2.56	0	0.74 \pm 0.21	0.22 \pm 0.14
S21E			0.40	0.0	0.02	0	0.28 \pm 0.09	0.0
PS			0.70	0.0	0.02	0	0.26 \pm 0.12	0.0
S39W			0.02	0.0	0.00	0	0.0	0.0
North Lagoon								
MF			0.57	0.0	0.40	0	1.02 \pm 0.24	0.02 \pm 0.02
RP			0.78	0.0	0.32	0	0.04 \pm 0.02	0.0
NM	0.0	0.0	0.05	0.01	0.04	0	0.0	0.0
LP			0.10	0.0	0.00	0	0.0	0.0
Outside								
LC			48.6	0.0	20.7	0	22.1 \pm 2.8	0.0

Status of *Ruppia tuberosa* in the southern Coorong in July 2012-2014

Ruppia tuberosa met only two of the three regional criteria that can be assessed in winter (Table 6). Both the Extent of Occurrence (R.1) and the Area of Occupation (R.2) were met in July 2014 but the number of sites that were considered healthy was less than 50% (target for R.3 not met). Only 27% of sites (3 of 11) in the southern Coorong had >30% cover and more than 10 shoots per core for cores with *Ruppia* in July 2014. All sites continued to have <2000 seeds/m², so resilience was negligible. Most sites had <200 seeds/m² in July 2014. For comparison, there were >4500 seeds/m² for *Ruppia tuberosa* at Lake Cantara. There has been a steady, albeit slow, recovery of *Ruppia tuberosa* in the southern Coorong over the last 3 years (Table 6).

Table 6: Status of *Ruppia tuberosa* in the Coorong in July 2012-2014. R.1 was assessed using all 12 sites, while 11 sites were used in assessing other criteria. The shaded section of the Table provides the statistics (number of sites reaching target) on which the regional indices were based.

Criterion	Target	July 2012	July 2013	July 2014	Comments for 2014
R.1 distribution along Coorong (km) EOO	43	8	45	60	Although target met, abundances at limits of distribution were low and include sites outside normal range
R.2 % sites with plants AOO	80	27	64	100	Although target met, abundances at many sites were low, particularly at the periphery of the range (EOO)
R.3 % sites with vigorous populations VIG	50	9	18	27	Only 3 of 11 sites had good population densities (based on L.1 & L.2)
R.4 % sites with resilience (> 2,000 seeds/m ²) RES	50	0	0	0	No sites had resilience - all sites still lack an adequate seed bank
L.1 # sites > 30% cover		2	2	3	
L.2 # sites > 10 sh/core		1	3	6	
Both L.1 & L.2		1	2	3	
RS.1 # sites with > 2,000 seeds/m ²		0	0	0	

Changes in the distribution and abundances of benthic invertebrates in July

Changes in the distributions and abundances of chironomids (*Tanytarsus barbitarsis*) and polychaetes (predominantly *Capitella* sp.) during winter along the Coorong are shown in Tables 7 and 8, and are based on the 50 cores taken along the five replicate transects at each site. Over the last 17 years, chironomids have shown shifts in distribution that match the changes in distribution for *Ruppia tuberosa*.

Chironomid larvae were prominent in the South Lagoon in July from 1998 to 2006 but for the next four years (2007-2010), none were detected in winter at the four long-term monitoring sites in the southern Coorong (Table 7). Salinities in the South Lagoon in winter typically ranged from 80-120 gL⁻¹ during 1998 to 2005 but

Table 7: Changes in the distribution and abundance of chironomid (*Tanytarsus barbitarsis*) larvae along the Coorong in July from 1998 to 2014. Data are means for 50 core samples taken from each site in each year of sampling (1998-2014) except for Magrath Flat (MF), Rob's Point (RP) and Long Point (LP), which were sampled only from July 2009 onwards and S06W, S21E, Princes Soak (PS) and S39W, which were only sampled from July 2012 onwards. To convert these mean values to chironomid larvae/m² multiply by 226. Standard errors were typically around 15% of the means and have been provided in other reports for earlier years (e.g. Paton & Bailey 2011). TTX (Tea Tree Crossing, SC (Salt Creek), PP (Policeman's Point) and VDY (Villa dei Yumpa), S06W, S21E, PS (Princes Soak) and S39W are spread along the South Lagoon, while the other sites, including NM, (Noonameena) are spread along the North Lagoon.

	Mean number of chironomid larvae per core											
	TTX	SC	PP	VDY	MF	RP	NM	LP	S06W	S21E	PS	S39W
1998	2.1	1.6	10.4	1.9			0					
1999	0.1	0.5	1.4	6.5			0					
2000	0.1	1.9	3.2	2.4			0.1					
2001	3.8	7.8	9.8	14.6			0					
2002	0.1	0.4	0.5	2.0			0.5					
2003	0.02	0.02	0.12	5.6			15.2					
2004	0	0	0	1.2			3.2					
2005	0.1	0.5	3.2	0.3			7.5					
2006	0.3	10.1	12.6	10.8			1.9					
2007	0	0	0	0			0.6					
2008	0	0	0	0			3.3					
2009	0	0	0	0	0	7.4	0	0.5				
2010	0	0	0	0	4.7	21.5	15.3	3.8				
2011	3.2	10.5	14.3	4.1	2.2	0	0	0				
2012	1.5	2.7	5.6	1.8	1.3	0	0	0.04*	6.5	5.3	9.9	6.5
2013	3.4	5.0	9.4	5.2	10.4	1.8	0	0	2.3	7.0	14.1	17.7
2014	0.1	0.4	0.6	0.02	0.3	0.3	0.04	0	5.9	5.1	0.9	3.1

*different species of chironomid

Table 8: Changes in the distribution and abundance of polychaetes (*Capitella* sp.) along the Coorong in July from 1998 to 2014. Data are means for 50 core samples from each site in each year of sampling (1998-2014), except for Magrath Flat (MF), Rob's Point (RP) and Long Point (LP), which were sampled from July 2009 onwards and S06W, S21E, Princes Soak (PS) and S39W, which were only sampled from July 2012 onwards. To convert these mean values to polychaetes/m² multiply by 226. Standard errors were typically around 15% of the means and have been provided in other reports for all years except 2011 (e.g. Paton & Bailey 2011). TTX (Tea Tree Crossing, SC (Salt Creek), PP (Policeman's Point), VDY (Villa dei Yumpa), S06W, S21E, Princes Soak (PS) and S39W are spread along the South Lagoon, while the other sites, including NM (Noonameena), are spread along the North Lagoon.

	Mean number of polychaetes per core											
	TTX	SC	PP	VDY	MF	RP	NM	LP	S06W	S21E	PS	S39W
1998	0	0	0	0			21.9					
1999	0	0	0	0			15.1					
2000	0	0	0	0			6.4					
2001	0	0	0	0			5.5					
2002	0	0	0	0			14.7					
2003	0	0	0	0			0.5					
2004	0	0	0	0			0.04					
2005	0	0	0	0			2.4					
2006	0	0	0	0			1.4					
2007	0	0	0	0			0					
2008	0	0	0	0			0					
2009	0	0	0	0	0	0	0	35.4				
2010	0	0	0	0	0	0	0	1.2				
2011	0	0	0	0	0	4.7	11.7	8.2				
2012	0	0	0	0	0	37.7	37.1	14.3	0	0	0	0
2013	0	0	0	0	9.6	11.9	20.5	54.8	0	0	0	0
2014	0	0	0	0	0	20	32.9	48	0	0	0	0

slightly exceeded 120 gL^{-1} in July 2006 (Figure 2). During the winters of 2007-2010, salinities in the South Lagoon were above 120 gL^{-1} and exceeded 140 gL^{-1} in the winters of 2008 and 2009. In July 2011, however, the salinities were around 113 gL^{-1} and chironomid larvae were once again widespread across the South Lagoon. This suggests that the upper salinity tolerance for *Tanytarsus barbitarsis* in the Coorong is around 120 gL^{-1} . The distribution of *Tanytarsus barbitarsis* in the Coorong in July 2014 was similar to the distribution in the previous two years but the abundances were generally much lower at all sites (Table 7), particularly for many of the sites along the eastern shore of the South Lagoon (TTX, SC, PP, VDY; Table 7).

Chironomid larvae were not detected at Noonameena in the North Lagoon of the Coorong in July 1998 and July 1999. However, from 2002-2010 they were generally prominent at Noonameena or at nearby sites in the North Lagoon (e.g., Rob's Point; Table 7). In July 2010, chironomid larvae were present at all four monitoring sites in the North Lagoon, but were particularly abundant at Rob's Point and Noonameena, where *Ruppia tuberosa* was also most abundant. This distribution, however, changed dramatically in July 2011, with no chironomids detected at the three northernmost sites (RP, NM and LP) in the North Lagoon. *Tanytarsus barbitarsis* was also absent from the northernmost of these sites in July 2012, 2013 and 2014. Generally, the low numbers and or absence of chironomid larvae in surface sediments in the North Lagoon in July coincided with salinities that were below 40 gL^{-1} . These data suggest that, within the Coorong, *Tanytarsus barbitarsis* may be limited to conditions where the salinity is above 40 gL^{-1} .

Polychaetes (predominantly *Capitella* sp.) have been detected only in the North Lagoon during the seventeen years of sampling (Table 8). Polychaetes were generally prominent at Noonameena in July from 1998 to 2002 when salinities at this site were typically on or below 45 gL^{-1} (Figure 2). From 2003 to 2006, polychaetes were still present in July at Noonameena but their abundances were lower. Winter salinities during this period typically ranged from $40\text{-}70 \text{ gL}^{-1}$. From 2007-2010, they were absent from Noonameena but present at Long Point. Salinities at Noonameena and nearby Rob's Point (4 km S) were typically in the range of $50\text{-}70 \text{ gL}^{-1}$ during this period, while salinities at Long Point were 42 gL^{-1} in July 2009 (when polychaetes were abundant) and 65 gL^{-1} in July 2010 (when abundances were low). In July 2011, the salinities from Rob's Point to Long Point were in the range of $20\text{-}42 \text{ gL}^{-1}$ and polychaetes were abundant across all three sampling sites (Table 8). They were even more abundant at these sites in July 2012 and still prominent at these sites in July 2013 and July 2014. The expansion in the distribution of polychaetes southwards in July 2013, with large numbers of polychaetes detected at Magrath Flat for the first time in that year, were not maintained and no polychaetes were detected at this site in July 2014 (Table 8), despite suitable salinities. Overall, these field data suggest that *Capitella* sp. performs best when winter salinities are below 45 gL^{-1} . Unlike *Ruppia tuberosa*, these polychaetes and the chironomid *Tanytarsus barbitarsis* both responded quickly to the re-instatement of appropriate salinities in the Coorong.

Discussion

In general, *Ruppia tuberosa* was more abundant in July 2014 than in the previous July, with plants being detected at all sites within the plant's extent of occurrence in July 2014. The cover of *Ruppia tuberosa* (% cores with shoots) was also higher in July 2014 than in July 2013. However, cover was still low for sites across the southern half of the South Lagoon, where *Ruppia tuberosa* was prominent in the late 1990s and early 2000s (Figures 3 and 4). So, although there were signs of recovery with respect to the distribution of the plant along the Coorong, the species has yet to recover its former abundance. On these grounds, *Ruppia tuberosa* has not fully recovered in the Coorong.

At all of the monitoring sites within the Coorong, the numbers of seeds present in cores in July continues to be very low and this reflects ongoing limited reproductive output for *Ruppia tuberosa* in the Coorong. As has been the case in recent years, falling water levels in spring 2013 prevented many plants from completing their reproductive cycle (Paton & Bailey 2014b). The maintenance of low seed abundances since 2010 is consistent with negligible seed production in recent years. Given the on-going low numbers of seeds at sites, *Ruppia tuberosa* has limited capacity to re-establish and maintain a substantive presence at most sites within the Coorong on its own, even for those sites (S06W, VDY, MF) where there were substantial numbers of shoots in July 2014. Ongoing failure to reproduce during spring continues to limit the recovery of this species and ultimately threatens its long-term persistence within the Coorong.

Two management issues arise as a consequence of this slow recovery. The first is the need to address falling water levels in spring. If adequate water levels cannot be delivered to maintain water levels over spring and into summer, then alternatives, such as building a barrier across the Coorong to hold water back in the southern Coorong during spring, need to be explored. Alternatively, the Coorong needs to be transitioned to some alternative ecological state that is sustainable if water levels cannot be sustained over spring. Second, assuming that *Ruppia tuberosa* recovers, strategies for preventing populations from declining again in the future need to be developed. The first step in such a strategy would be to set some limits to acceptable change (LAC) that, if breached, would indicate a loss of ecological character for the Coorong. The loss of 50% of the sites with *Ruppia tuberosa* would indicate a significant change in ecological character. Since the intention is to prevent this from happening, identifying conditions when such an outcome is likely in the near future is important. For example, when populations have less than 5% cover in one year, there is a reasonable likelihood that these populations will disappear over the next year if the conditions continue to be unsuitable. This is more likely if there is a limited seed bank as is the case at the moment. Thus, a simple LAC could be "more than 50% of sites having <5% cores with *Ruppia tuberosa*" within the 43 km stretch of the southern Coorong (TTX to MF inclusive) that represents the normal extent of occurrence. The linked

management trigger would be “more than 50% of sites having <10% of cores with *Ruppia tuberosa*” within this extent of occurrence. Based on sampling in July 2014, five of nine sites still had <10% of cores with *Ruppia tuberosa* and so the management trigger was reached, but the LAC was not breached as only four of the nine sites had less than 5% of cores with *Ruppia tuberosa*. This was the first time in the last three years, and since the re-establishment of river flows to the Coorong, that the LAC has not been breached.

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