Annual monitoring of *Ruppia tuberosa* in the Coorong region of South Australia, July 2012

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Summary

The monitoring program established in July 1998 has documented significant changes in the distribution and abundance of *Ruppia tuberosa*, within the Coorong. During the last decade *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. 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, salinities declined along the Coorong. This reduction in salinity resulted in significant reductions in *Ruppia tuberosa* in the North Lagoon, with the plant all but disappearing from the middle sections of that lagoon by July 2011. However, with the lower salinities, some *Ruppia tuberosa* re-estabalished at Villa dei Yumpa, the northernmost sampling site in the South Lagoon. Despite similar salinities at other sites further south in the South Lagoon, no *Ruppia* plants were detected at more southerly sites in July 2011. This lack of response was consistent with very low propagule banks (seeds and turions). The numbers of propagules present at these sites were about 10-fold lower compared to those at Villa dei Yumpa and about 100 times lower than historical propagule banks, or those currently present at Lake Cantara where there is a well-established population of *Ruppia tuberosa*. As a consequence of the extensive loss of *Ruppia tuberosa* from the North Lagoon and only modest re-establishment in the northern parts of the South Lagoon, the overall abundance of *Ruppia tuberosa* remained lower than it was immediately prior to the return of flows to the Murray Mouth and substantially lower compared to its distribution and abundance prior to the drought.

The distribution and abundance of *Ruppia tuberosa* in July 2012 was similar to the distribution and abundance recorded in the previous year. No further recovery of *Ruppia tuberosa* has taken place across the southern Coorong, despite the establishment and maintenance of salinities ideal for the establishment, growth and expansion of *Ruppia tuberosa*. Salinities in the southern Coorong in July 2012 were in the range of 60-70 gL^{-1}.

Two factors continue to limit the recovery of *Ruppia tuberosa* in the southern Coorong: inappropriate water levels in spring that prevent remaining plants within the Coorong from completing their reproductive cycle; and a severely depauperate and almost non-existent seed bank throughout much of the South Lagoon.

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 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 translocating *Ruppia* into the South Lagoon to facilitate recovery. There is clearly a need to do this, a need that has been flagged for several years. If a translocation program is established then a key risk to achieving successful translocation will be the maintenance of adequate water levels during spring. This is ultimately linked to the maintenance of adequate flows of water over the barrages during spring. If adequate flows cannot be provided or other interventions implemented then *Ruppia tuberosa* may not re-establish.

Introduction

This report summarises the results of monitoring of *Ruppia tuberosa* undertaken in the Coorong region in July 2012 and compares the performances of *Ruppia tuberosa* with similar data collected during the previous fourteen years (e.g. Paton 1999; Paton & Bolton 2001; Paton 2003; Paton 2005b, Paton 2006, Paton & Rogers 2007, Paton & Rogers 2008, Paton 2009; Paton & Bailey 2010, 2011, 2012a). The monitoring program was established in 1998 and the 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 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, the decline of *R. tuberosa* has critical flow-on effects for other species, and the ecological character of the Coorong as a whole.

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 2012 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. As a consequence it is not necessary to revisit a long series of annual reports, although these reports may cover additional discussion that is not re-iterated in this report.

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 1). These four sites were spread along the length of the South Lagoon (Tea Tree Crossing (TTX), Salt Creek (SC), Policemans 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 was also monitored in July from 1998 onwards, Noonameena (NM) 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, Magrath Flat (MF), Robs Point (RP) and Long Point (LP). 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 Magrath Flat but then gradually declined but was still present in 2007-08. For the sites at Robs Point and Long Point, *Ruppia tuberosa* was detected at increasing frequency from 2005 onwards for Robs Point and 2008 onwards for Long Point.

Table 1. 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
Additional sites added in July 2009			
LC	Lake Cantara (western side)	387124	5678174
MF	Magrath Flat (middle of bay)	354909	6029549
RP	Rob's Point (north of the middle of bay)	345015	6039121
LP	Long Point (2nd bay north of Long Point)	334165	6048619
Additional sites added in July 2012			
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

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 metre 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 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 7.5 cm diameter x 4 cm 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 µm endecott 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 (7.5 cm diameter x 4 cm 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. Fig. 1). This range of water depths covered the major *Ruppia tuberosa* beds at each site. 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 7.5 cm diameter x 4 cm deep core to check for presence of *Ruppia tuberosa* (right). Note the turbidity of the water. (Photo courtesy Coby Mathews)

Results

<u>Historical salinities and water depths in July</u>

The salinities in July 2012 across the sampling sites in the South Lagoon of the Coorong were typically around 60-70 gL^{-1} (Fig. 2) and the lowest that they have been for the last 15 years. The salinities at the sampling sites in the North Lagoon contrasted with those of the South Lagoon and were typically around 30-40 gL^{-1} in July 2012 and typical of the winter salinities experienced in the 1998-2004 period. These salinities indicate that the Coorong has returned to the typical winter salinities that existed prior to the recent extended drought (2002-2010).

Salinities were also collected at three sampling sites on the western side of the Coorong as well as other locations along the Coorong further north and south of the sampling sites in July 2012 (Table 2). A modest salinity gradient existed in the North Lagoon increasing slowly from Pelican Point in the north to Magrath Flat in the south. Salinities increased by around 20 gL^{-1} between Magrath Flat (North Lagoon) and Villa dei Yumpa (South Lagoon) suggesting that movements and mixing of water is restricted to some extent between the two lagoons. Salinities generally increased slowly with distance south within the South Lagoon, but the salinities were more variable, suggesting that there were bodies of slightly saltier and slightly fresher water in parts of the South Lagoon and that there had not been much recent mixing. This is consistent with an extended period of calm weather during the sampling period that would have limited the amount of wind-induced mixing of water.

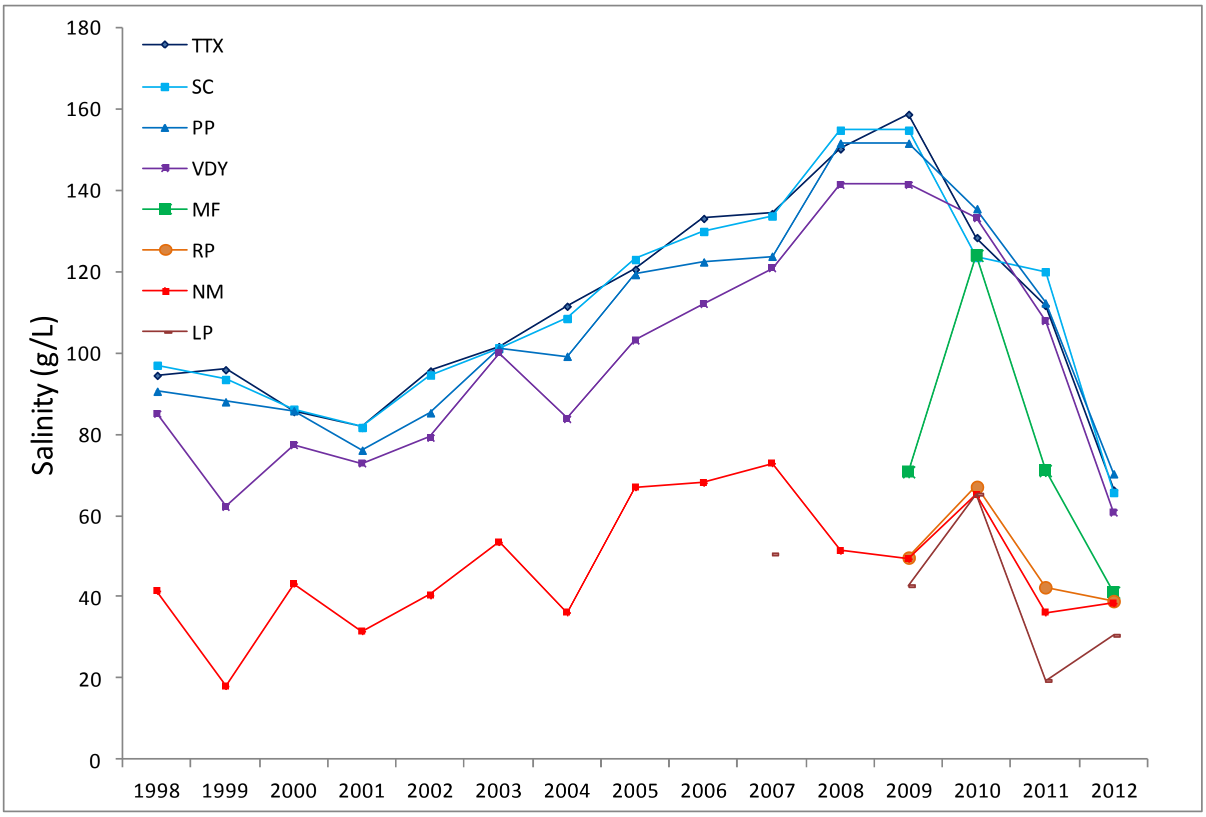

Figure 2. Winter salinities at monitoring sites for *Ruppia tuberosa* in the Coorong in July from 1998 to 2012. Sites TTX (Tea Tree Crossing), SC (Salt Creek), PP (Policermans Point) and VDY (Villa dei Yumpa) were spread along the South Lagoon, while MF = Magrath Flat, RP = (Robs Point), NM = Noonameena, 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 in July from 2009 onwards.

Table 2. Salinities (gL^{-1}) along the Coorong in July 2012.

Site Code	Site Name(s)	Distance from Murray Mouth km	Salinity (gL^{-1}) East side	Salinity (gL^{-1}) West side
N45	Pelican Point	11	23.9	
N39	Mark Point	17	26.5	
N29	Long Point	27	30.6	
N19	Noonameena	37	38.5	
N15	Rob Point	41	39.0	
N12		44	41.3	
N08		48	42.1	
N02	Magrath Flat	54	41.2	
S03	Parnka Point	59	53.2	
S06	Villa dei Yumpa / S06W	62	60.8	61.9
S11		67	61.3	
S16		72	64.7	
S21	S21E	77	67.0	
S26	Policeman Pt/ Princes Sk	82	70.3	62.9
S31		87	74.1	
S36	Salt Creek	92	65.7	
S39	S39W	95		74.3
S41	Tea Tree Crossing	97	66.3	
S46		102	78.1	
S51		107	73.8	

Water levels in July have ranged by over 50 cm over the last 15 years. They were highest in July 2002 and lowest in July 2006 (Table 3). In July 2012 water levels in the Coorong were in the middle of this historical range (Table 3), about 20 cm higher than the lowest levels and 30 cm below the highest levels. They were 14 cm lower than July 2011 and 11 cm higher than July 2010.

<u>*Ruppia tuberosa* (200 core samples) abundance at monitoring sites</u>

Figure 3 shows the percentage of 200 core samples that contained *Ruppia tuberosa* shoots in July of each year from 1999 to 2012 for five sites in the Coorong and for three additional sites (MF, RP and LP) from 2009 to 2012.

There are three striking patterns to the changes in the distribution and abundance of *Ruppia tuberosa* that have taken place in the Coorong since 1999 (Fig. 3). Firstly, there was a significant decline ($p<0.01$) and then loss of *Ruppia tuberosa* from the four long-term monitoring sites spread along the South Lagoon, such that there was no *Ruppia* detected growing in July at any of the monitoring sites in the South Lagoon from 2008-2010 (Fig. 3). Secondly, from July 2005 onwards there was a gradual colonisation of sites in the middle of the North Lagoon (i.e. at Noonameena) such that in July 2009 and July 2010 there were extensive *Ruppia tuberosa* beds (>90% of cores with plants) established in the middle of the North Lagoon (e.g. Robs Point & Noonameena; Fig.3). Thirdly, in July 2011 there was a rapid reduction in the cover of *Ruppia tuberosa* in the North Lagoon, with *Ruppia tuberosa* all but eliminated (Fig.3) 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. The extent of cover was similar in July

2012 for these sites although no shoots were found at Robs Point or Noonameena. Importantly no *Ruppia tuberosa* plants were detected at the other monitoring sites in the South Lagoon in July 2011 or in July 2012 despite these sites having similar salinities to those at Villa dei Yumpa (Table 2, Figures 2, 3, 4, 5).For comparison, the percent of cores with *Ruppia tuberosa* shoots in July at Lake Cantara has ranged from 94-100% over the last three years.

Table 3. Changes in water levels between years during the July sampling period. 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

The mean numbers of shoots per core for the 200 core samples taken over the beds of *Ruppia tuberosa* show a similar pattern to cover (Fig. 4). In July 2011 the average number of shoots per core was highest at Villa dei Yumpa (7 shoots/core) with 0.28 and 0.06 shoots/core for Magrath Flat and Noonameena respectively. In July 2012 the densities of shoots were similar to those detected in July 2011 with 5 shoots/core at Villa dei Yumpa and 0.1 shoots/core at Magrath Flat. There were no *Ruppia* plants detected at Noonameena in July 2012. These overall abundances of shoots are low compared to historical abundances and low compared to the abundances of shoots at Lake Cantara (81.7 ± 2.5 (s.e) shoots/core in July 2011 and 46.3 ± 1.7 shoots/core in July 2012).

In 2012 three additional sites were sampled on the western side of the Coorong. These were consistent with the sites sampled along the eastern side of the Coorong along the eastern shore. The site (S06W) in the northern reaches of the South Lagoon and approximately opposite Villa dei Yumpa had a reasonable density of *Ruppia tuberosa* (e.g. Fig. 5) while the two sites further south had no *Ruppia tuberosa* plants.

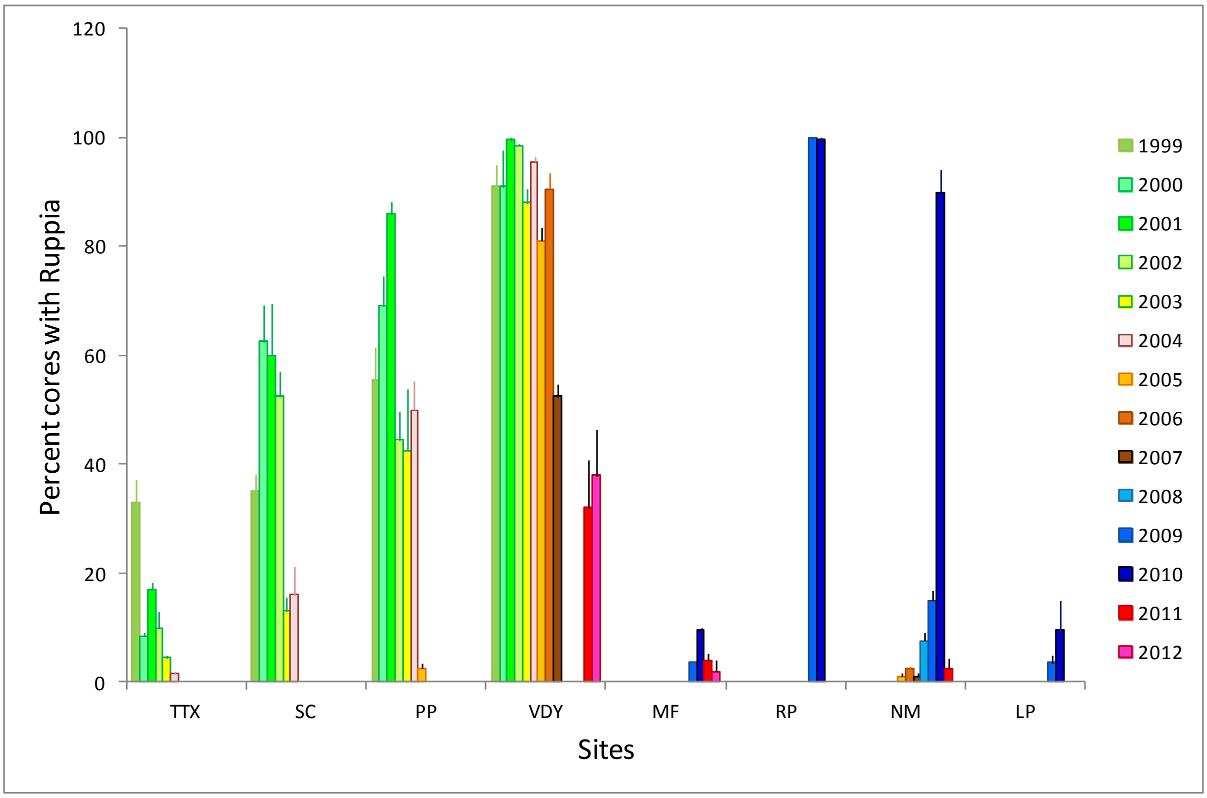

Figure 3. The percentage of 200 cores (75mm diam x 40mm deep) that contained *Ruppia tuberosa* shoots at each of 8 sites spread along the North and South Lagoons during July from 1999 to 2012. See Table 1 for the locations, but sites are arranged from the southernmost site (TTX) in the South Lagoon to 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. Blue and red colours are used to highlight more recent years.

<u>Changes in the availability of *Ruppia tuberosa* seeds and turions in July</u>.

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. The samples collected along the transects, however, 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 3 and compared to the average abundances during 1998-2000 for the five sites sampled then when abundances were generally higher. In the last three years (2010 -2012) 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 is highly variable and patchy (as indicated by the standard errors in Table 3). None of the 107 seeds found in core samples taken from the four sites in the South Lagoon in July 2010, none of the 255 found in core samples from the South Lagoon in July 2011, and none of the 250 seeds found sampled from the South Lagoon in July 2012 were viable. Close examination revealed that the contents of these seeds consisted of sand. In the North Lagoon only 6 seeds were detected across the four sites in July 2010, and 215 in July 2011 but the majority (>90%) of these seeds were intact and potentially viable. Just 9 seeds were detected in the 200 core samples at these sites in July 2012 suggesting that seeds may have germinated but not established. The low viability of seeds in the South Lagoon reflects the absence of any recent seed production in the South Lagoon, while the high levels of intact seeds in the North

Lagoon reflects the production of a few seeds in the last 1-2 years at sites in the North Lagoon. For comparison seed abundances during the initial three years of monitoring (1998-2000) in the Coorong were about 10-fold higher but the proportion of these that were viable is not known because they were not examined. In comparison the population of *Ruppia tuberosa* in Lake Cantara had a mean of 51.9, 53.3 and 30.6 seeds per core in July 2010, July 2011 and July 2012 respectively and the majority of these were intact seeds. In all 36 turions (all Type I) were found in the 800 core samples that were sieved as part of the July 2011 monitoring in the Coorong. These were all at the two sites where *Ruppia* plants were growing in July 2011 and were likely to have been recently produced. Turions were more prominent in samples taken in the initial years of sampling but still in low numbers during July (0.12-0.48 turions/core) for 1998-2000 (Table 3).

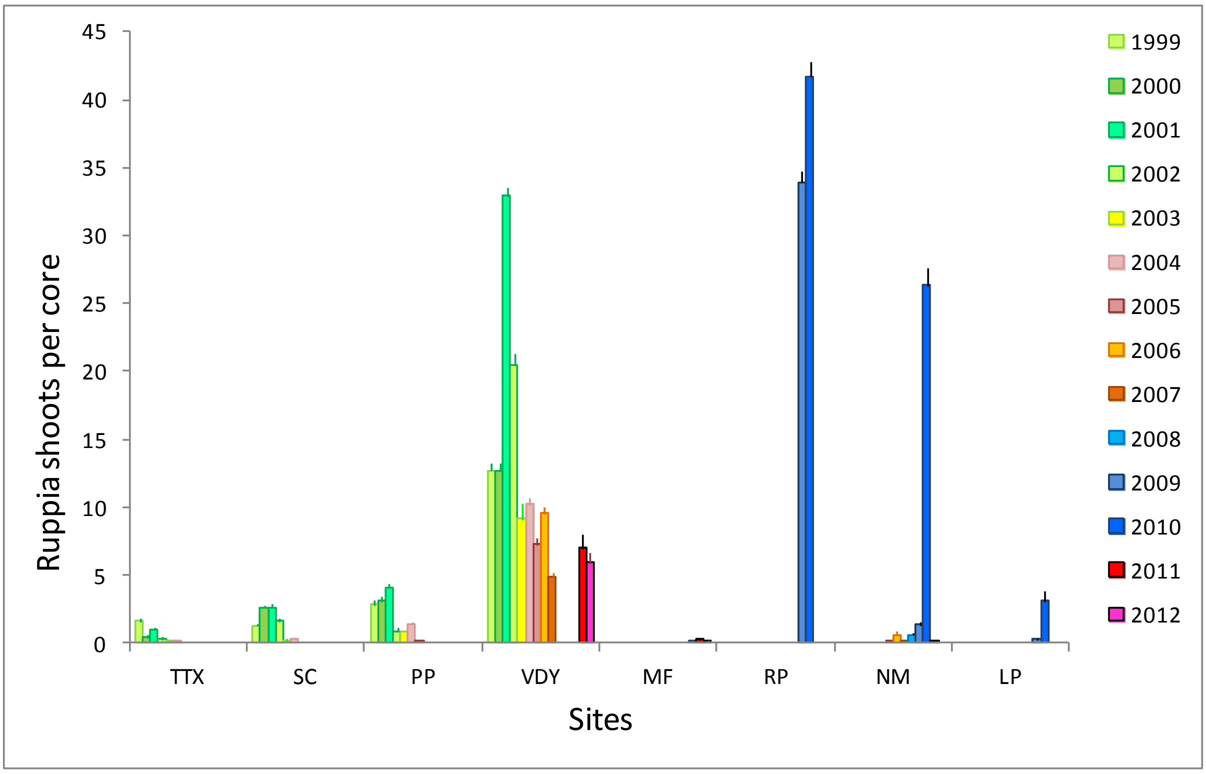

Figure 4. Mean number of *Ruppia tuberosa* shoots counted in 200 cores taken in July from eight sites spread along the Coorong from 1999 to 2012. Data show mean number of shoots per core + s.e. Shoots per core can be converted to shoots per m^2 by multiplying by 226. Blue and red colours are used to highlight data collected in recent years.

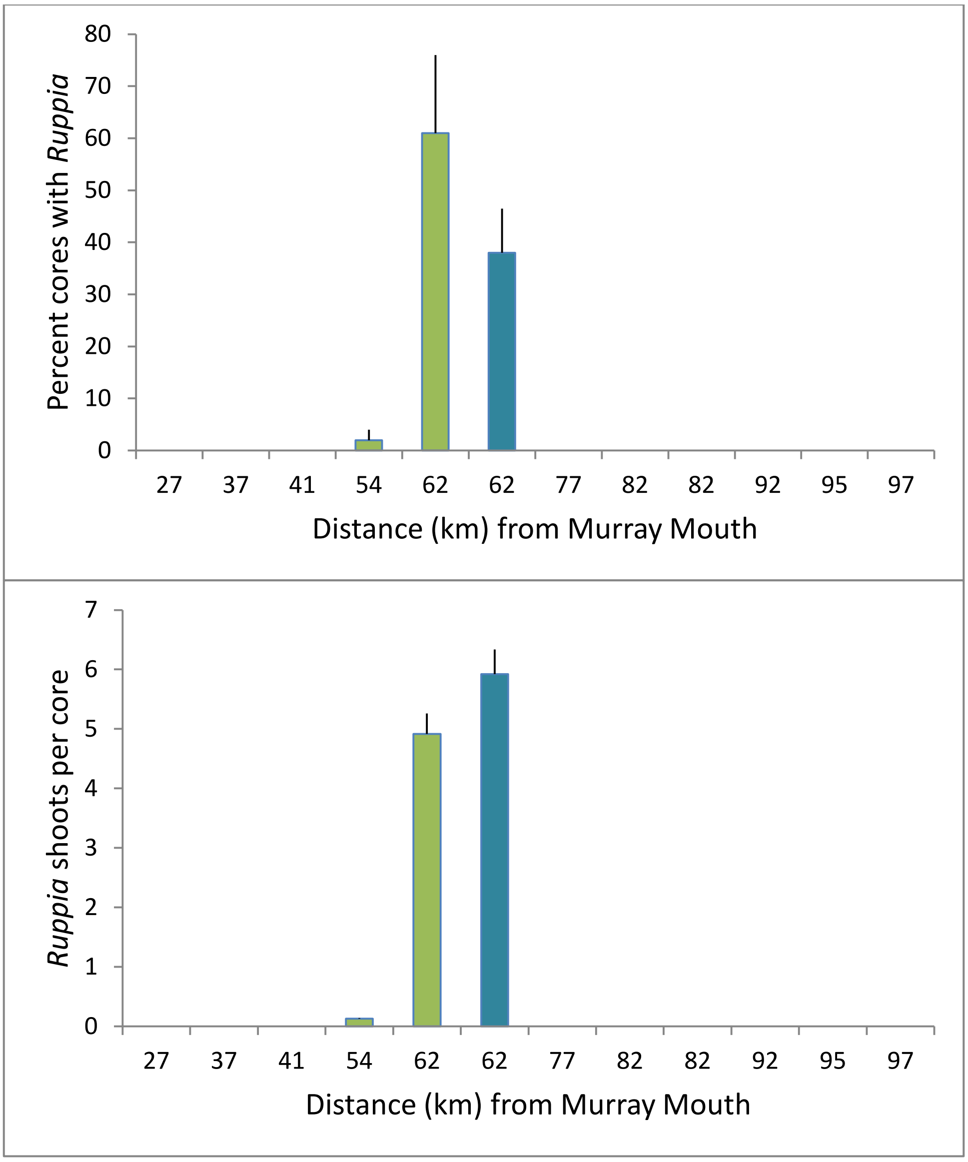

Figure 5. Percent of cores with *Ruppia tuberosa* shoots and mean number of shoots per core counted in 200 cores taken in July 2012 from 12 sites spread along the Coorong. Data show means + s.e. Shoots per core can be converted to shoots per m^2 by multiplying by 226. The junction of the two lagoons is 56 km from the Murray Mouth. Darker columns represent sites on the western side of the Coorong, paler columns are on the eastern side of the Coorong.

Table 3. Abundances of seeds and turions detected in core samples along transects at each of thirteen monitoring sites in July 2012 and for five of these sites for the three years (combined) from July 1998-00. The data for July 2010, July 2011 and July 2012 are means ± s.e. for 50 core samples except for Lake Cantara which are based on 10 samples. The 1998-2000 data are based on 150 cores, 50 in each of the three years.

	July 1998-2000		July 2010		July 2011		July 2012	
Site	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	0.14 ± 0.06	0.0	0.5 ± 0.2	0	0.16 ± 0.08	0
SC	2.34	0.12	0.04 ± 0.03	0.0	0.3 ± 0.1	0	0.10 ± 0.07	0
PP	3.88	0.48	0.46 ± 0.21	0.0	0.5 ± 0.2	0	0.44 ± 0.13	0
VDY	14.06	0.12	1.50 ± 0.67	0.0	3.8 ± 1.1	0.7 ± 0.4	1.80 ± 0.47	0.52 ± 0.33
S06W							1.26 ± 0.36	0
S21E							0.40 ± 0.17	0
PS							0.70 ± 0.28	0
S39W							0.02 ± 0.02	0
North Lagoon								
MF			0.08 ± 0.04	0.0	1.5 ± 0.4	0.02 ± 0.02	0.14 ± 0.05	0
RP			0.04 ± 0.04	0.0	2.4 ± 1.3	0	0.12 ± 0.06	0
NM	0.0	0.0	0.0	0.08 ± 0.08	0.1 ± 0.1	0	0.04 ± 0.03	0
LP			0.0	0.0	0.3 ± 0.3	0	0 ± 0	0
Outside								
LC			51.9 ± 2.3	0.0	53.3 ± 3.9	2.1 ± 0.5	30.6 ± 4.8	0

Changes in the distribution and abundances of benthic invertebrates in July

Changes in the distributions and abundances of chironomids (*Tanytarsus barbitarsis*) and polychaetes (*Capitella* spp) during winter along the Coorong are shown in Tables 4 and 5, and are based on the 50 cores taken along the five replicate transects at each site. These reflect similar patterns to those of *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 4). Salinities in the South Lagoon in winter were consistently below 120 gL^{-1} from 1998- 2005, but slightly exceeded 120gL^{-1} in July 2006 when chironomid larvae were abundant. During the winters of 2007-2010 salinities were consistently above 120 gL^{-1} with salinities exceeding 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 2012 was similar to the distribution in July 2011 but the abundances were lower (Table 4). Salinities were lower in July 2012 (60-70 gL^{-1}) and lower abundances may be in response to lower salinities and or to higher numbers of predatory fish in the southern Coorong in July 2012 (Paton and Bailey 2012b).

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. Robs Point; Table 4). In July 2010 chironomid larvae were present at all four monitoring sites in the North Lagoon, but were particularly abundant at Robs 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 these sites in July 2012. Generally the presence of chironomid larvae in surface sediments in the North Lagoon in July coincided with salinities that were on or above 40gL^{-1}. These data suggest that *Tanytarsus barbitarsis* may be limited to conditions where the salinity is above 40 gL^{-1} within the Coorong.

Polychaetes (*Capitella* sp.) were only detected in the North Lagoon (Table 5). They were generally prominent at Noonameena in July from 1998 to 2002 when salinities at this site were typically on or below 45 gL^{-1} (Fig. 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 40-70 gL^{-1}. From 2007-2010 they were absent from Noonameena but present at Long Point. Salinities at Noonameena and nearby Robs Point (4km S) were typically in the range of 50-70 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 Robs Point to Long Point were in the range of 20-42 gL^{-1} and polychaetes were abundant across all three sampling sites (Table 5). They were even more abundant at these sites in July 2012. These field data suggest that *Capitella* sp. perform best when winter salinities are below 45 gL^{-1}. These polychaetes and the chironomid *Tanytarsus barbitarsis* both responded quickly to the re-instatement of appropriate salinities.

<u>Other observations</u>

One striking difference in July 2011 compared to the previous six years was there were no brine shrimps (*Parartemia zietziana*) detected in the South Lagoon. For the previous six years brine shrimps were conspicuously abundant throughout this lagoon, first appearing in substantial numbers in July 2005. They were still conspicuously abundant throughout the South Lagoon in January 2011 but had disappeared by July 2011. The period from July 2005 to July 2010 largely spans the period when July salinities in the South Lagoon were on or above 120 gL^{-1}. No brine shrimps were detected in July 2012.

Table 4. Changes in the distribution and abundance of chironomid (*Tanytarsus barbitarsis*) larvae along the Coorong in July from 1998 to 2011. Data are means for 50 core samples taken from each site in each year of sampling (1998-2011) except for Magrath Flat (MF), Robs Point (RP) and Long Point (LP) which were sampled only from July 2009 onwards and S06W, S21E, Princes Soak (PS) and S39W which were sampled only from July 2012. To convert these mean values to chironomid larvae/m^2 multiply by 226. Standard errors were typically around 15% of the means and have been provided in other reports for all years bar 2011 (e.g. Paton & Bailey 2011). TTX (Tea Tree Crossing, SC (Salt Creek), PP (Policemans 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*	6.52	5.30	9.94	6.50

*different species of chironomid

Table 5. Changes in the distribution and abundance of polychaetes (*Capitella* sp.) along the Coorong in July from 1998 to 2012. Data are means for 50 core samples from each site in each year of sampling (1998-2012) except for Magrath Flat (MF), Robs Point (RP) and Long Point (LP) which were sampled from July 2009 onwards and S06W, S21E, Princes Soak (PS) and S39W which were sampled only in July 2012. To convert these mean values to polychaetes/m^2 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 (Policemans Point), VDY (Villa dei Yumpa), S06W, S21E, Princes Soak (PS) and S39 W 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

Discussion

Ruppia tuberosa continues to be largely absent from most of its former range in the Coorong. This was despite the salinities being suitable for the plants to grow and reproduce during the preceding year. For example, the salinities over the southern Coorong were typically under 100gL^{-1} from August to December 2011 (Paton & Bailey unpubl.) the main growing period for *Ruppia tuberosa*. Furthermore, the salinities in July 2012 were in the range of 60-70 gL^{-1}, salinities that are known to be suitable to stimulate the germination of seeds. These 2011-12 salinities were typical of the salinities when the plant performed well in the southern Coorong prior to the drought, if not a little lower (Figs 2 & 3; Paton 2010; Paton & Bailey 2012b). Salinity, therefore is not limiting recovery. Instead inadequate water levels in spring and a depauperate seed bank continue to prevent recovery.

Those places (e.g. Villa dei Yumpa) where there was recovery of *Ruppia tuberosa* ,coincided with the last places occupied by the plant in the South Lagoon prior to disappearing towards the end of the drought (Fig. 3). These locations were in the northern parts of the south lagoon. They had higher densities of seeds in the sediments and more of those seeds were likely to have been recently produced and hence more of them were likely to be viable. This may account for why these sites have been able to respond while others further south have not. The majority of the seeds found by sieving sediments, however, consisted of testa that had filled with sand. In fact all of the seeds found by sieving sediments collected in the South Lagoon were sand-filled testa. These may simply be some of the remaining seed coats of seeds that had germinated in previous years and then subsequently the split seed coats have filled with sand. The numbers of ‘seeds’ found (a few hundred) and the total areas sampled, however, were small in total, equivalent to sampling a surface area of a few square metres each year. Given this there may still be a few intact seeds present at sites within the South Lagoon, but the prognosis for a speedy recovery is negligible, as evidenced by an absence of shoots at most sites despite ideal conditions in July 2012.

The inability of *Ruppia tuberosa* to expand its distribution and consolidate its presence in those places where it had begun to re-establish between July 2011 and July 2012 is consistent with the prognosis that *Ruppia tuberosa* will not re-establish quickly without assistance. The absence of further recovery was predictable given the on-going inadequate water levels in spring 2011. Those areas where plants that had begun to grow in winter 2011 were all exposed to dessication in spring 2011 because water levels dropped substantially once barrage flows ceased in spring. Once exposed to the air for even a few hours *Ruppia tuberosa* dies and fails to reproduce. This failure to reproduce just exacerbates the already depauperate seed bank. This was flagged as an issue likely to hinder any natural recovery in the previous annual monitoring report (Paton & Bailey 2012a) and the findings of no improvements in distribution or abundance in July 2012 are consistent with this. Unfortunately water levels also dropped during spring 2012 and this has once again exposed the plants that were detected growing at monitoring sites in July 2012. This suggests there will be low or no improvement in the recovery of *Ruppia tuberosa* for at least another year, with yet a further impost on a depauperate seed bank.There is clearly a need to facilitate the recovery by translocating *Ruppia tuberosa* material back into the southern Coorong. Lake Cantara appears to be a strong candidate as a source population for this material. .

The issue of inadequate water levels, however, will also need to be addressed for *Ruppia tuberosa* to be able to re-establish in the southern Coorong and have any chance of accumulating an adequate seed bank to provide any resilience to future perturbations. The maintenance of adequate water levels will be difficult to deliver because it will require the re-establishment of, and then maintenance of, adequate spring flows over the barrages and unfortunately there are issues at both Commonwealth and State Government level that

currently hinder this approach. Alternative interventions, such as building structures across the Coorong to hold water levels up during spring are also not favoured.
In comparison to *Ruppia tuberosa,* the prominent aquatic invertebrates, the chironomid *Tanytarsus barbitarsis* and the polychaete *Capitella* sp. have been able to quickly re-colonise and so re-establish their former distributions and abundances.

In summary*, Ruppia tuberosa* is a keystone species in the Coorong, a quintessential element that helps define the ecological character of this Ramsar Wetland of International Importance. Its continued absence from most of the South Lagoon indicates an inability for the ecological character of this system to recover on its own. Clearly the ecological resilience of a key component of this wetland has been lost and continues to struggle. The re-establishment of the species across its former range in the Coorong is now urgent. This will require *Ruppia tuberosa* to be translocated back into much of the South Lagoon. If this cannot be done the southern Coorong will need to be transitioned to a different ecological state. Such an outcome will be a constant reminder of the inadequacies of the Murray Darling Basin Plan to secure important ecological assets as well as highlighting the impotency of the legislation that was meant to protect a key ecological character of this wetland.

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