Annual monitoring of *Ruppia tuberosa* in the Coorong region of South Australia, July 2011

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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 this period *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*. 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 gains at the northernmost site in the South Lagoon, the overall abundance of *Ruppia tuberosa* declined between July 2010 and July 2011.

Ruppia tuberosa remains vulnerable to further losses within the Coorong as it lacks resilience (an adequate propagule bank) and hence capacity to survive further perturbations. There is an urgent need to restore this resilience and this will require translocating *Ruppia* into the South Lagoon to facilitate recovery. The mechanisms driving the loss of extensive beds of *Ruppia* in the North Lagoon between July 2010 and July 2011 are not known. Interference from filamentous green algae that apparently benefits from lower salinities is a potential factor causing these losses and this interference requires further research. In the interim, managers need to be aware of the potential risks of low salinities affecting *Ruppia tuberosa* performance and should minimize the establishment of low salinities (below 60gL^{-1}) in key areas for *Ruppia tuberosa*, like the South Lagoon. At present the likelihood of low salinities establishing in the South Lagoon seems remote as salinities in July 2011 were around 113 gL^{-1} and still above the stated target range of 60-100 gL^{-1}. Further salt still needs to be removed from the South Lagoon before pre-drought salinity regimes are reached. The need to address and deliver appropriate water levels in the Coorong during spring is once again highlighted, and future management must consider re-instating appropriate water levels and not just focus on salinities if any sustained recovery of *Ruppia tuberosa* is to occur.

Key aquatic invertebrates also showed dramatic shifts in distribution and abundance between July 2010 and July 2011 and these were generally related to changes in salinity. Polychaete worms (*Capitella* spp) recolonised sites in the middle of the North Lagoon in July 2011 after a period of absence. Similarly, the chironomid (*Tanytarsus barbitarsis*) had recolonised the South Lagoon by July 2011 despite salinities being around 113 gL^{-1} and only marginally below the reported upper salinity tolerance of this species. For the previous four years, when winter salinities were consistently above 120 gL^{-1}, chironomids were absent from the South Lagoon. *Tanytarsus barbitarsis,* like *Ruppia tuberosa*, had also vacated sampling sites in the middle of the North Lagoon by July 2011, suggesting low salinities of around 45 gL^{-1} or below may disadvantage this species. The other major change was the complete absence of brine shrimps (*Parartemia zietziana*) in the southern Coorong in July 2011. For the previous 5 years brine shrimps had been prominent throughout the South Lagoon, at least.

Introduction

This report summarises the results of monitoring of *Ruppia tuberosa* undertaken in the Coorong region in July 2011 and compares the performances of *Ruppia tuberosa* with similar data collected during the previous thirteen 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). 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 1999. This site had been identified as a potential source population for use in translocations of *Ruppia tuberosa* back into the South Lagoon.

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. When the Barrages are closed during spring, water levels in the southern Coorong drop, leaving *R. 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 gates remain open until then (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, 1-4cm 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.

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	6000905
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

Sampling procedure for *Ruppia tuberosa* and benthic invertebrates

At each sampling site a series of five parallel transects were established. The five transects were 25m apart and ran perpendicular to the 100m baseline that ran along the shore. The starting points for each transect were marked along this baseline at 25m intervals and recorded with a GPS. Along each transect the water depth was measured at 50m intervals to the nearest centimetre, until the water level was 0.9m 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 7.5cm diameter x 4cm deep mud samples were collected, with two samples coming from each of the following water depths: 0.2m, 0.4m, 0.6m, 0.8m and 0.9m. Each sample was subsequently sieved through a 500µm 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 25cm, core samples were taken every 50m 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 (7.5cm diameter x 4cm deep) in water depths ranging from 0.4 to 0.7m 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 7.5cm diameter x 4cm 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 2011 within the South Lagoon of the Coorong were typically around 113 gL^{-1} (Fig. 2). Although the salinities were lower than the salinities recorded in July 2009 (~150 gL^{-1}) they still exceeded 100gL^{-1}, the upper threshold sought for the southern Coorong despite significant releases of water (12,850 GL) over the barrages since September 2010. The salinities in the North Lagoon contrasted with those of the South Lagoon and were typically around 20-40 gL^{-1} in July 2011 except for Magrath Flat where the salinity, although lower than the previous year was still around 70 gL^{-1}. Magrath Flat is at the southern end of the North Lagoon and the salinity at this site is likely to be influenced by wind-induced incursions of more salty water travelling northwards out of the South Lagoon.

Water levels in July 2011 were 25 cm higher compared to the previous year but were similar to the water levels present in July 2008 and July 2009 (Table 2). Over the course of the 13 years of sampling, water levels have varied from year to year, with a 50cm range between the lowest and highest levels (Table 2). Given the almost identical water levels in July 2008 and July 2011 the reduction in salinity between these two periods indicates that at least some of the accumulated salt has been removed from the South Lagoon, but the actual reductions would appear to have taken place during 2009-2010 rather than 2010-11. Although the salinities dropped between July 2010 and July 2011, water levels increased by 25cm, so the overall salt load in the South Lagoon is likely to be similar between July 2010 and July 2011. Further reductions in salinity are still required before the salinities are more typical of the salinities that occurred prior to the recent drought. Prior to the onset of the drought in 2002, winter salinities were typically around 80 gL^{-1} (Fig. 2). The current average salinity for the South Lagoon in July 2011 of around 113 gL^{-1} is still precarious. Without further significant removal of salt, salinities above the critical thresholds for selected taxa may quickly re-establish and any recovery curtailed. The Small-mouthed Hardyhead (*Atherinosoma microstoma*) and the chironomid (*Tanytarsus barbitarsis*), two key biota in the South Lagoon, both have reported upper salinity thresholds of around 120 gL^{-1} (Lui 1969; Kokkinn & Williams 1988).

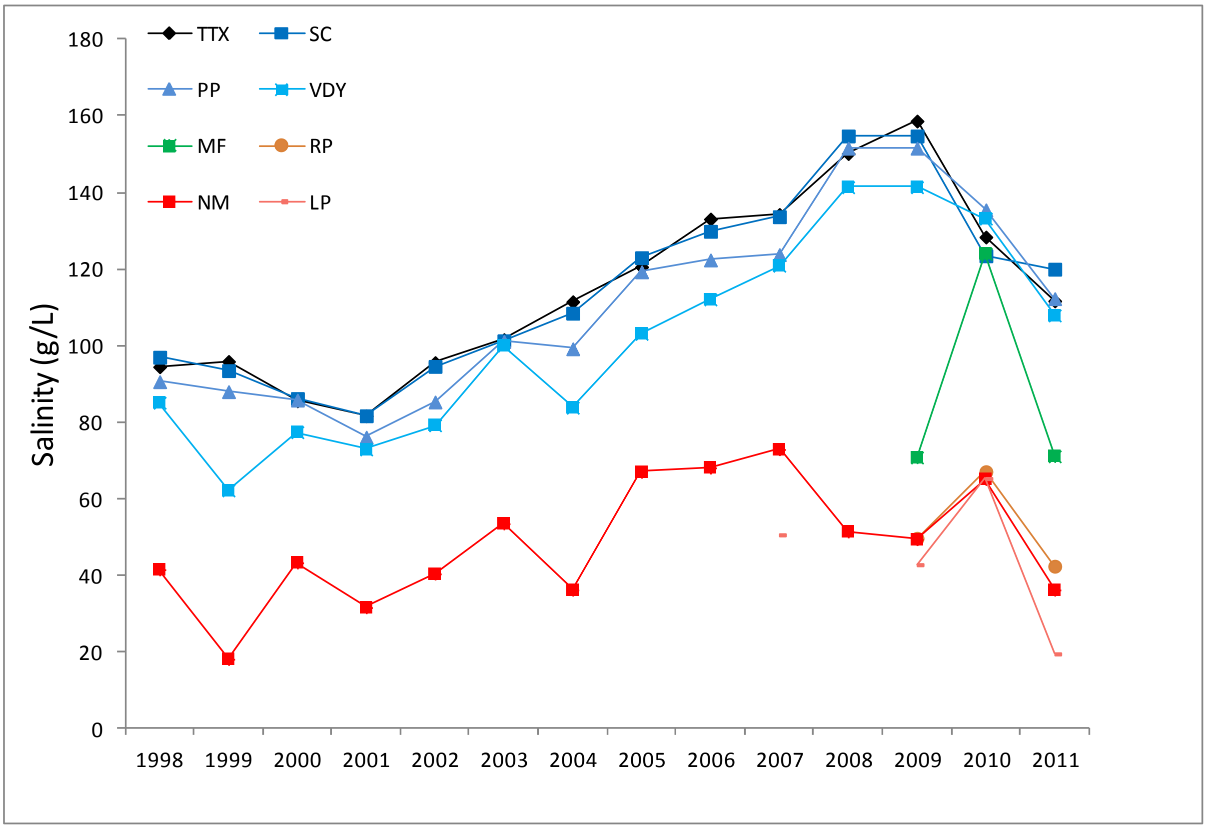

Figure 2. Winter salinities at monitoring sites for *Ruppia tuberosa* in the Coorong in July from 1998 to 2011. Sites TTX (Tea Tree Crossing), SC (Salt Creek), PP (Policermans Point) and VDY (Villa dei Yumpa) were spread along the South Lagoon, while MF = Magrath Flat, RP = (Robs Point), NM = Noonameena, 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. 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 each site, 100m out from the shoreline and averaged across 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

<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 2011 for five sites in the Coorong and for three additional sites (MF, RP and LP) from 2009 to 2011.

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). First, there was a significant decline ($p<0.01$) and then loss of *Ruppia tuberosa* from the four 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). Second, 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). Third, 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. However no *Ruppia tuberosa* plants were detected at the other monitoring sites in the South Lagoon despite similar salinities. 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.

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) and 0.28 and 0.06 shoots/core for Magrath Flat and Noonameena respectively. 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).

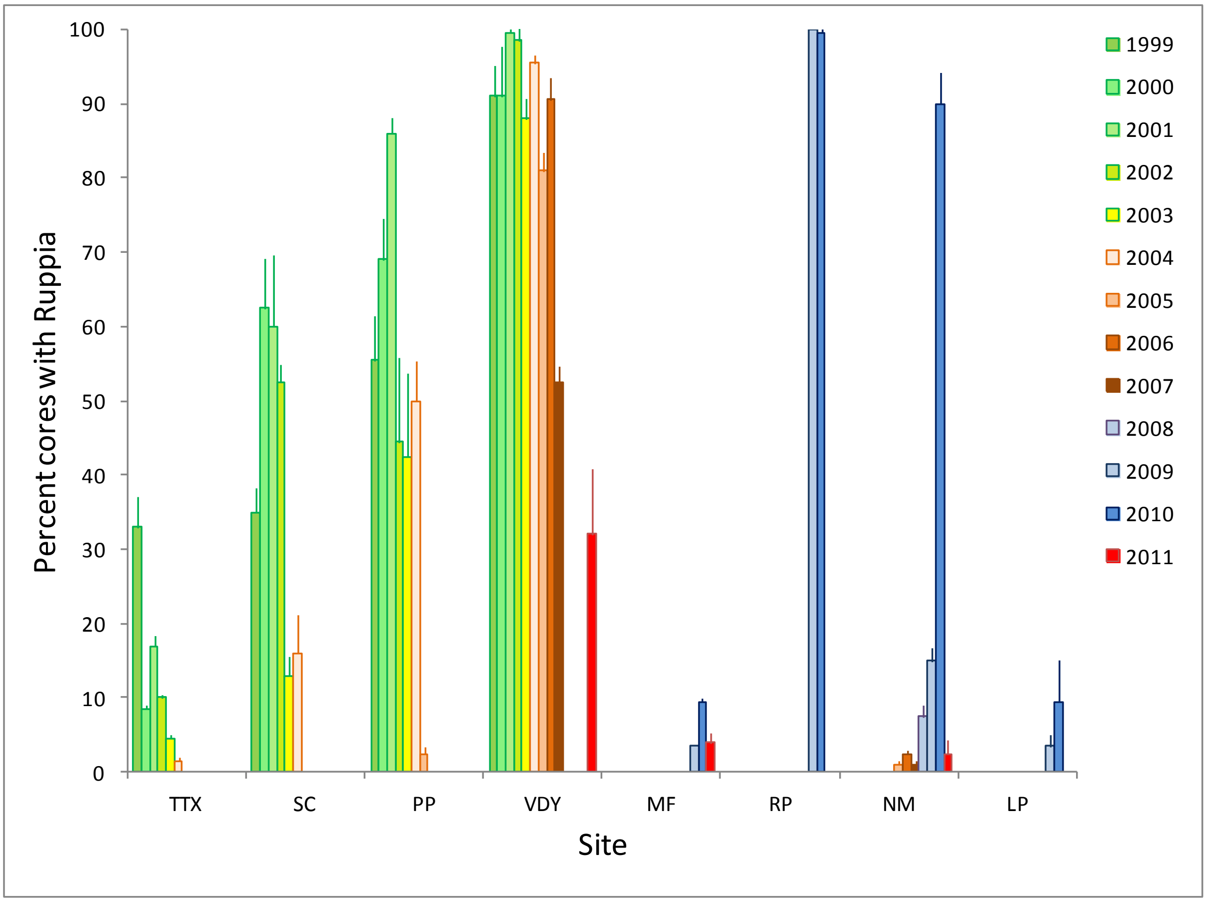

Figure 3. The percentage of 200 cores (75mm diam x 40mm deep) that contained *Ruppia tuberosa* shoots at each of 8 sites spread along the North and South Lagoons during July from 1999 to 2011. See Table 1 for the locations, but sites are arranged from the southernmost site (TTX) in the South Lagoon to 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 percent of cores with *Ruppia* for four sets of 50 cores + s.e. at each site. Blue and red colours are used to highlight more recent years.

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. 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 two years (2010 and 2011) 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 and none of the 255 found in core samples in July 2011 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. 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 and 53.3 seeds/core in July 2010 and July 2011 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).

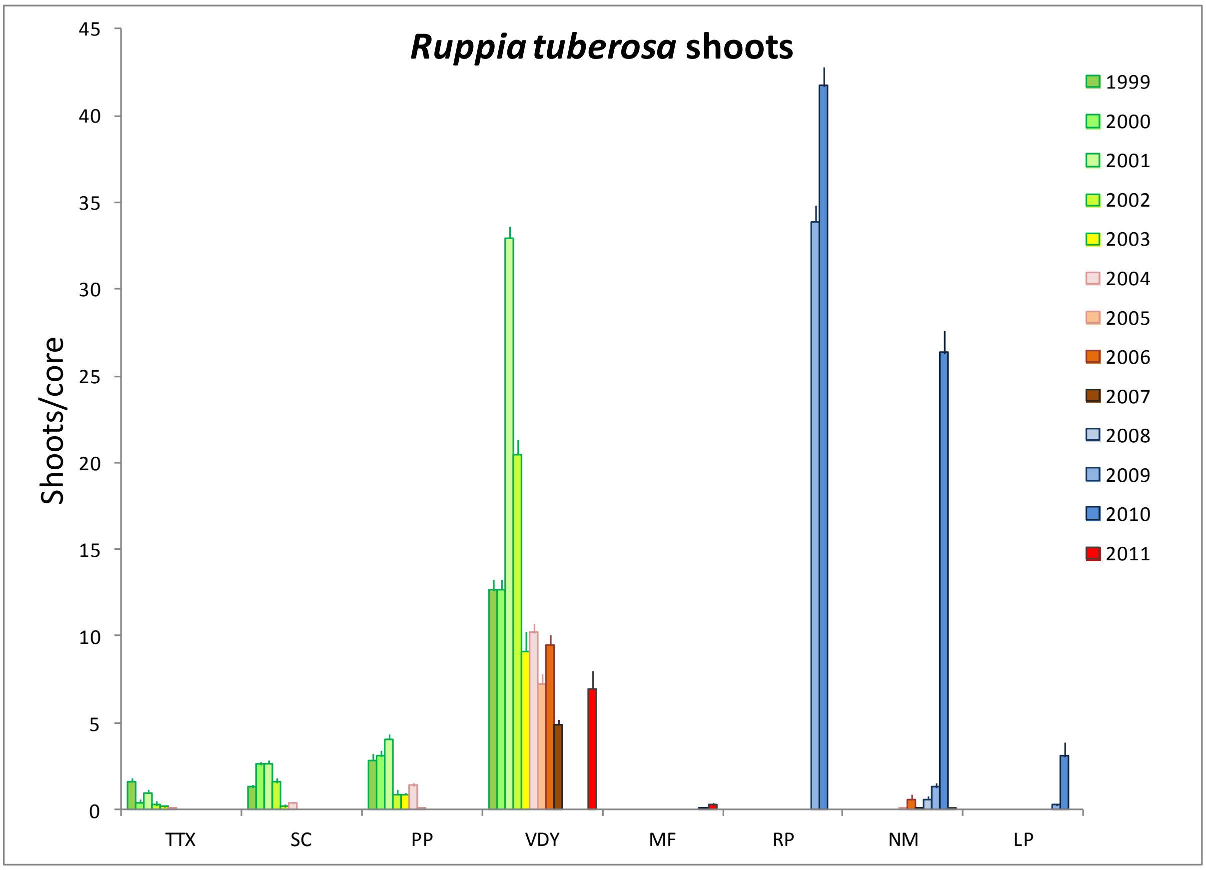

Figure 4. Mean number of *Ruppia tuberosa* shoots counted in 200 cores taken in July from eight sites spread along the Coorong from 1999 to 2011. Data show mean number of shoots per core + s.e. Shoots per core can be converted to shoots per m^2 by multiplying by 226. Blue and red colours are used to highlight data collected in recent years.

Table 3. Abundances of seeds and turions detected in core samples along transects at each of nine monitoring sites in July 2010 and for five of these sites for the three years (combined) from July 1998-00. The data for July 2010 and July 2011 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 three years.

	July 1998-2000		July 2010		July 2011	
Site	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
SC	2.34	0.12	0.04 ± 0.03	0.0	0.3 ± 0.1	0
PP	3.88	0.48	0.46 ± 0.21	0.0	0.5 ± 0.2	0
VDY	14.06	0.12	1.50 ± 0.67	0.0	3.8 ± 1.1	0.7 ± 0.4
North Lagoon						
MF			0.08 ± 0.04	0.0	1.5 ± 0.4	0.02 ± 0.02
RP			0.04 ± 0.04	0.0	2.4 ± 1.3	0
NM	0.0	0.0	0.0	0.08 ± 0.08	0.1 ± 0.1	0
LP			0.0	0.0	0.3 ± 0.3	0
Outside						
LC			51.9 ± 2.3	0.0	53.3 ± 3.9	2.1 ± 0.5

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 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}.

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. Generally the presence of chironomid larvae in surface sediments in the North Lagoon in July coincided with salinities that were on or above 50gL^{-1}, the exceptions being July 2001 and July 2004 (Fig. 2, Table 4). These data suggest that *Tanytarsus barbitarsis* may be limited to conditions where the salinity is above 50 gL^{-1} within the Coorong.

Polychaetes (*Capitella* spp) 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). These field data suggest that *Capitella* spp perform best when winter salinities are below 45 gL^{-1}. These polychaetes and the chironomid *Tanytarsus barbitarsis* both respond 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}.

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. 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 are spread along the South Lagoon, while the other sites including NM (Noonameena) are spread along the North Lagoon.
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	Mean number of chironomid larvae per core							
	TTX	SC	PP	VDY	MF	RP	NM	LP
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

Table 5. Changes in the distribution and abundance of polychaetes (*Capitella* spp) along the Coorong in July from 1998 to 2011. Data are means for 50 core samples 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 from July 2009 onwards. 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 bar 2011 (e.g. Paton & Bailey 2011). TTX (Tea Tree Crossing, SC (Salt Creek), PP (Policemans Point) and VDY (Villa dei Yumpa 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
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

Discussion

Ruppia tuberosa

The distribution, abundance and performance of *Ruppia tuberosa* in the southern Coorong has changed dramatically over the last fourteen years since the commencement of the current monitoring in July 1998. The major changes have been the gradual loss of *Ruppia tuberosa* from the South Lagoon, with plants disappearing progressively from the southernmost sites (TTX, SC) by winter 2005 and eventually the northernmost site in the South Lagoon (VDY) by winter 2008. These losses coincide with the establishment of historically high salinities in the southern Coorong and this is often proffered as the explanation for the demise of the plant. However, the loss of *Ruppia* from the South Lagoon also coincides with a sequence of years in which water levels in spring were below average in the southern Coorong because of a lack of adequate freshwater flows over the Barrages in spring (Paton 2010: Paton *et al.* 2011). Those spring flows help maintain water levels over the *Ruppia* beds allowing the plants to complete their reproduction and so maintain their presence. Not only have the plants disappeared but their propagule banks have also declined over this period consistent with an extended period of little or no reproduction.

With the return of substantial flows over the Barrages from September 2010 onwards, the salinities have dropped in the Coorong and in July 2011 were around 113 gL^{-1} across the South Lagoon. Although some of the accumulated salt has been flushed out of the South Lagoon, the salinities were still higher than stated targets which sought to maintain salinities under 100 gL^{-1}. Despite this there was a substantial recovery of *Ruppia* at Villa dei Yumpa, with *Ruppia tuberosa* shoots detected in 32% of the core samples, clearly indicating the ability of the plants to grow and establish in these high salinities. Despite the same salinities being present elsewhere in the South Lagoon there was no measurable recovery at the other South Lagoon sites. This strengthens the case that the propagule banks for *Ruppia tuberosa* are probably now inadequate to allow the species to recover quickly throughout much of the South Lagoon. At Villa dei Yumpa the propagule bank was considerably higher than at the other sites, but still more than 10-fold lower than those maintained by the population of *Ruppia tuberosa* at Lake Cantara. For comparison the propagule banks at the other monitoring sites in the South Lagoon were around 10-times lower than those at Villa dei Yumpa, and 100-fold lower than those at Lake Cantara. Furthermore, the current propagule banks at sites in the South Lagoon were around 100-fold lower than those in the early 1990s when extensive beds of *Ruppia tuberosa* beds were maintained (see Paton & Bailey 2011 and for further discussion).

A small number of plants may have also re-established at or near the other monitoring sites during winter 2011 in the South Lagoon but their abundances may have been too low to have been easily detected with the current monitoring program. Importantly such plants if they existed make an insignificant contribution to the ecological functioning and character of the system, and not until the once extensive beds of *Ruppia tuberosa* have re-established along the length of the South Lagoon can recovery be considered complete. Based on the speed with which *Ruppia tuberosa* was able to colonize and establish extensive beds in the North Lagoon (see Fig. 3), a further four to five years of favourable conditions may be required for the southern sites to recover without intervention, assuming a small number of plants have established. This may be too long to wait for a range of other biota (birds, fish etc) that depend on *Ruppia tuberosa* as a source of food or habitat. The lack of substantial recovery of *Ruppia tuberosa* in the South Lagoon continues to strengthen the argument that *Ruppia* will need to be translocated back into the lagoon to facilitate and speed the rate of recovery.

Ironically (given the volumes of water released over the barrages) the initial recovery of *Ruppia tuberosa* even at Villa dei Yumpa may be short-lived. This is because flows over the Barrages were significantly reduced in October 2011, once again exposing the re-establishing *Ruppia* beds to desiccation prior to any of the plants completing their reproductive cycle (e.g. Fig. 5). Although the stated environmental water requirements, based on salinity targets, were easily met in 2011, the maintenance of appropriate water levels through spring continues to be a critical issue that is not being addressed. This key driver of the ecology of the South Lagoon can no longer be ignored.

Figure 5. *Ruppia tuberosa* that had begun to re-establish at selected points in the South Lagoon of the Coorong during 2011 were left exposed to desiccation because water levels in the Coorong were not maintained during spring. This occurred despite the stated Environment Water Requirements based on salinity being met for 2011. (photo courtesy Pam Gillen, Woods Well).

At the same time that *Ruppia tuberosa* declined in the South Lagoon, populations of *R. tuberosa* gradually established mid-way along the North Lagoon and by July 2010 extensive beds existed at Robs Point and Noonameena (at least). With the return of flows over the Barrages from spring 2010 onwards, the salinities at these sites dropped from winter highs of over 70 gL^{-1} to less than 45 gL^{-1}. At both sites *Ruppia tuberosa* all but disappeared, as it did from Long Point as well. However, it remained at Magrath Flat where salinities were still above 70 gL^{-1} in July 2011.Given that the recovery of *Ruppia tuberosa* further south was modest, the loss of these extensive beds represents a substantial reduction in the overall abundance and distribution of *Ruppia tuberosa* in the Coorong in 2011. However, a small number of propagules (seeds) were produced and remain in the sediments, so these areas in the North Lagoon have the potential to re-establish should the ecological conditions change again.

The underlying cause(s) of the loss of these *Ruppia tuberosa* beds is not understood, but filamentous green algae appear to be favoured by lower salinities and perhaps higher nutrient loads in the incoming water. Certainly, during the previous spring and summer, filamentous green algae were prominent in the North Lagoon and appeared to interfere with *Ruppia tuberosa,* swamping them, so blocking light, but also attaching and dislodging floral stems (e.g. Paton & Bailey 2011; Paton *et al.* 2011). There is an urgent need to understand the nature of the interactions between filamentous green algae, *Ruppia tuberosa*, low salinities and nutrient availability. Until this is understood, there is merit in taking a precautionary approach by limiting the establishment of low salinities (i.e. below 60 gL^{-1}) in key areas for *Ruppia tuberosa* (i.e. most of the South Lagoon). Based on the monitoring of *Ruppia* tuberosa for the last 14 years, maintaining salinities above 60 gL^{-1} and on or below 110 gL^{-1} during winter and spring (the main growing season) appears critical, along with maintenance of appropriate water levels. The current target of maintaining salinities in the South Lagoon in the range of 60-100 gL^{-1} is consistent with this.

<u>Benthic invertebrates</u>

Polychaetes (*Capitella* spp) and the chironomid *Tanytarsus barbitarsus* had marked positive responses at least in parts of their range to reductions in salinity that took place between July 2010 and July 2011. First, *Capitella* spp expanded their distribution further south in the North Lagoon between July 2010 and July 2011 and increased in abundance. This is consistent with the distribution and abundance of this species being limited to conditions where salinities are below 70 gL^{-1}. The upper salinity threshold for this species is around 70 gL^{-1} (Dittmann *et al.* 2006; Rolston & Dittmann 2009) but based on measured abundances in winter in the Coorong *Capitella* appears to perform best when salinities are below 45 gL^{-1}. *Tanytarsus barbitarsis* also shifted their distribution following reductions in salinity, vacating low salinity areas in the North Lagoon and shifting back into the South Lagoon where they re-established their prominence. In July 2011 the salinities in the South Lagoon were around 113 gL^{-1} and just below the reported physiological upper salinity threshold for this species (around 120gL^{-1}; Kokkinn & Williams 1988). In the years from 2007 to 2010 salinities in the South Lagoon were generally above 120 gL^{-1} in July and chironomids were absent. Interestingly chironomid larvae also vacated sites in the middle of the North Lagoon between July 2010 and July 2011. In July 2011 salinities were below 45 gL^{-1} at these sites, while in the previous July when chironomids were prominent the salinities were on or above 65 gL^{-1}. These data suggest that *Tanytarsus barbitarsis* has not only an upper salinity threshold of around 120 gL^{-1} but also a lower salinity threshold of around 45 gL^{-1} or a little higher in the Coorong. Most assessments of the salinity tolerances for *Tanytarsus barbitarsis*, however, suggest the species can tolerate much lower salinities *per se* (e.g. Geddes & Butler 1984; Paton 2010) so there may be other ecological interactions accounting for changes in their distribution that are linked to reductions in salinity. *Tanytarsus barbitarsis* is an important food resource for a range of birds and fish, and salinities below 60 gL^{-1} may permit a wider range of predatory fish to access the larvae (e.g. Noell *et al.* 2009). Like *Ruppia tuberosa*, *Tanytarsus barbitarsis* is disadvantaged in the Coorong if salinities become too low. At present this seems unlikely to occur at least for the South Lagoon, but managers should be cognate of this risk.

Both the polychaete and chironomid populations adjusted their distributions quickly (within a year) in response to salinities falling, and dropping below critical levels. These contrast with the relatively slow response of *Ruppia tuberosa*. The more rapid recovery of populations of benthic invertebrates however may reflect rapid, repeated and or continual reproduction when the conditions are good, coupled with short generation times and good dispersal. Populations of chironomids may have also existed in adjacent water bodies (ephemeral lakes) to the Coorong allowing rapid and widespread re-colonisation once suitable conditions had re-established. Clearly these benthic invertebrates have the capacity to respond rapidly to improvements in ecological conditions. *Ruppia tuberosa* being an annual plant is largely restricted to reproducing in spring. Its population growth and dispersal is likely to be more limited and so a longer recovery period is required, particularly when seed banks have been severely reduced, as is the case for the Coorong.

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