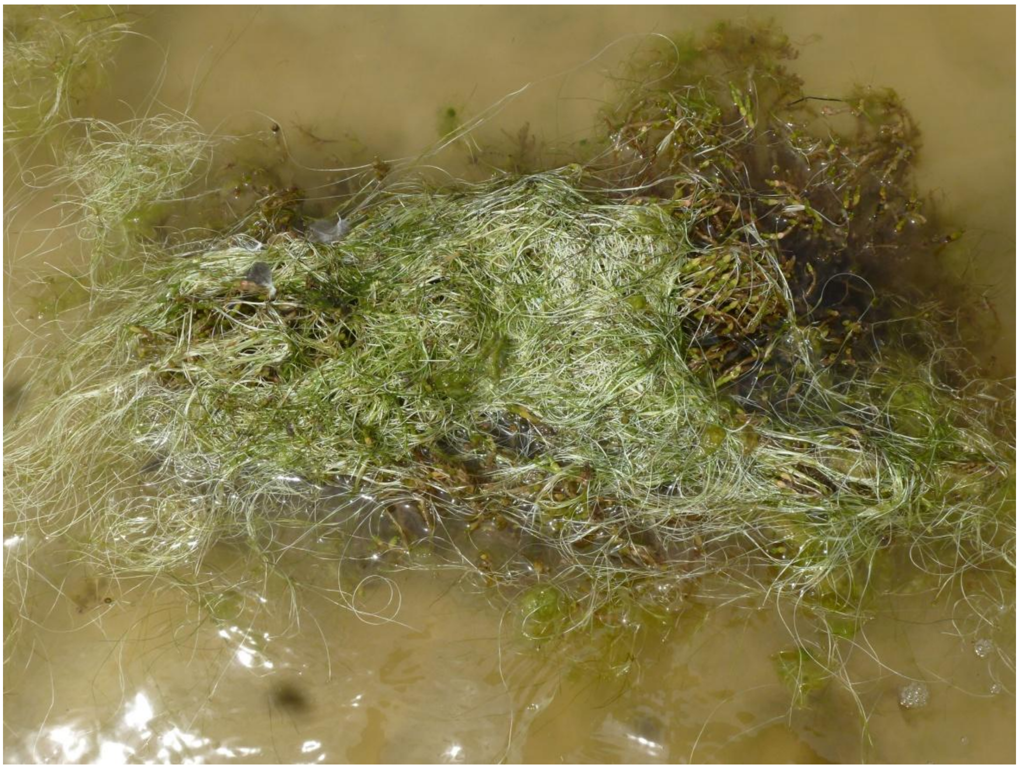
Condition monitoring of *Ruppia tuberosa* in the southern Coorong, summer 2013-14.



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<u>Front image</u>: Floral stalks of *Ruppia tuberosa* entangled in filamentous green algae and washed ashore (photo courtesy of D. Paton)

Summary

The distribution and abundance of *Ruppia tuberosa* in the southern Coorong has increased over the last 2 years since January 2012 with further increases detected in January 2014. The extent of occurrence of *Ruppia tuberosa* plants in January 2014 measured as the length of the southern Coorong over which *Ruppia tuberosa* is found was 43 km. Although this was the same as January 2013, there was an increase in the number of sites with *Ruppia tuberosa* plants, and in the abundance of the plants at sites. In January 2014, 70% of sites sampled had *Ruppia tuberosa* plants present with 39% of sites having greater than 30% cover and greater than 10 shoots per 75mm diameter core. Despite this improvement the distribution and abundance of *Ruppia* was still well short of the levels expected if *Ruppia tuberosa* populations had recovered their health and resilience. Although flowering was detected at sites in December 2013, the numbers of seeds in the seed banks did not increase and were typically less than 1 seed/core in January 2014 and well short of the 8 seeds/core set as an initial resilience target. However a much higher number of the seeds (71%) were intact in January 2014 compared to January 2013 suggesting that there had been some successful reproduction in spring 2013 and that the seed bank had more capacity Several factors may have contributed to poor seed outputs, including interference from filamentous green algae and grazing by waterfowl. The links between lower salinities, releases of water from Salt Creek and the performance of filamentous green algae require investigation to allow the ecological character of the southern Coorong to be managed in the future. The maintenance of higher water levels in the southern Coorong over September and October 2013 is likely to have facilitated flower production but these elevated water levels need to be maintained for a little longer to maximize reproductive success. When the water levels dropped by about 0.6-0.7m during November 2013 many of the plants that were still producing flowers were left out of water, disrupting their reproduction. Other factors not just water levels and salinities appear important in securing recovery of *Ruppia tuberosa*, and wind-induced dispersal of fragments of plants may have facilitated the recolonisation of some areas of the southern Coorong over the last year.

Introduction

Ruppia tuberosa was once widespread along the length of the South Lagoon of the Coorong. However during the millennium drought the River Murray did not flow to its mouth for extended periods and *Ruppia tuberosa* disappeared from the South Lagoon and its seed bank was severely eroded (Paton 2010, Paton & Bailey 2012). This loss of *Ruppia tuberosa* from the southern Coorong is linked to an absence of flows over the Barrages that resulted in low water levels during spring that left the plants exposed and unable to complete their reproductive cycle.

Seasonal changes in sea level, changes in evaporation and precipitation, plus flows over the Barrages all contribute to changes in water levels. Water levels are also influenced on a day-to-day basis by wind speed and direction, with these wind-induced water level changes approaching 30 cm (Paton 2010). Typically water levels in the southern Coorong vary seasonally by up to a metre with water levels being lowest in autumn and highest in spring. *Ruppia tuberosa* generally germinates from seeds or resprouts from turions when water levels increase in winter and re-inundate exposed mudflats around the margins of the southern Coorong. If these mudflats remain covered with water *Ruppia tuberosa* grows and reproduces, flowering in late spring. Historically and in the absence of extraction of water for human uses, flows over the Barrages peaked in late spring, and maintained water levels into summer. However, with increased extraction the volumes reaching the Barrages were reduced in volume particularly in late spring and water levels would have dropped earlier. This was highlighted further during the millennium drought, when no water reached the Murray Mouth and water levels in the Coorong dropped in spring exposing the beds of *Ruppia tuberosa* to desiccation before the plants had set seeds or produced turions.

Salinity may also play a role. *Ruppia tuberosa* performs poorly when salinities exceed 100 gL^{-1} and as the salinities in the South Lagoon were consistently above 100 gL^{-1} and at times exceeded 150 gL^{-1} during the millennium drought high salinity has been implicated in the loss of *Ruppia tuberosa*. When salinities are high (>100 gL^{-1}) germination of seeds and growth of seedlings are impeded (Paton *et al.* 2011; Paton & Bailey 2010, 2012; Kim *et al.* 2013). However *Ruppia tuberosa* declined and had largely disappeared from much of the South Lagoon by June 2004 before high salinities were reached (Paton 2010). When substantial flows returned to the Murray in the latter half of 2010 an emphasis was placed on restoring salinities to more typical levels with little emphasis placed on water levels. The expectation was that *Ruppia tuberosa* would, like other aquatic biota, quickly recover once the salinities returned to more typical levels. This did not happen.

Since the return of freshwater flows to the region the recovery of *Ruppia tuberosa* in the South Lagoon has been slow (Paton & Bailey 2012, 2013a,b) and the extensive beds that had gradually established in the North Lagoon between 2006 and 2010 were also quickly lost (e.g. Paton & Bailey 2012; unpubl.). The net result was that *Ruppia tuberosa* became even less abundant following the return of freshwater flows to the Murray Mouth, than immediately prior to the end of the drought and there has been no improvement since (Paton & Bailey 2013a,b). Two factors have contributed to this poor recovery. First, the quantities of propagules (seeds) remaining in the sediments are extremely low and on their own unlikely to facilitate the rapid recovery of *Ruppia tuberosa* throughout most of the South Lagoon (Paton & Bailey 2012, 2013a,b). Second, although flows returned to the region in spring 2010 during each of the next three years (spring 2011, spring 2012 and spring 2013) flows diminished dramatically in spring resulting in water levels once again falling at critical times.

This condition monitoring report summarizes the distribution, abundance and resilience of *Ruppia tuberosa* in the southern Coorong in January 2014. Two basic questions are asked:

(1) Has there been any improvement in the status of *Ruppia tuberosa* over the last year?, and
(2) Has *Ruppia tuberosa* recovered sufficiently to be considered healthy and resilient?

Assessing the second question requires defining some quantitative measures for healthy and resilient populations of *Ruppia tuberosa*. In February and March 2014, the MDBA used an expert panel to define some quantitative measures that could be applied at a regional scale and applied at a local population scale. The following were defined. At a regional scale a healthy southern Coorong, would have; (a) *Ruppia tuberosa* with an extent of occurrence (distribution) along the southern Coorong of 50 km. excluding outliers; and (b) within this distribution 80% of the sites monitored would have *Ruppia tuberosa* plants present in winter and summer. At the local site scale: (a) 80% of sites should have at least 30% cover in winter; (b) with at least 10 shoots per 75mm diameter core for cores with *Ruppia*; and (c) with 50 flower heads/m^2 for 50% of the area sampled at a site level during the spring flowering season. In addition by 2019 a target was set for resilience where there needed to be 2000 seeds/m^2 (~8 seeds/75 mm diameter core). A further set of targets was also set for 2029 where 50% of sites would have 60% cover in winter and there would be 10,000 seeds/m^2 (~40 seeds/75 mm diameter core).

Methods

Reconnaissance surveys in early December 2013

A brief reconnaissance trip in December was undertaken to determine if any reproductive activity had taken place by the time water levels had dropped in the southern Coorong (see Figure 1). This reconnaissance trip primarily assessed whether plants had produced flower heads and the extent to which flowering may have been disrupted by either falling water levels or interference from filamentous green algae (*Enteromorpha* sp.). At the time of this reconnaissance survey many of the *Ruppia tuberosa* beds had become recently exposed. To assess the level of cover and numbers of flower heads that had been produced 20m x 1m transects were established in several areas running parallel to the shoreline and percent cover of *Ruppia tuberosa*, percent cover of filamentous algae and the numbers of flower heads and floral stalks (without flower heads) recorded for each 1m x 1m quadrat along the transects.

Distribution and abundance of *Ruppia tuberosa* in the southern Coorong in January 2014

The main assessment of the distribution and abundance of *Ruppia tuberosa* in the southern Coorong was conducted in January 2014 in line with the timing of monitoring in previous years.

During January 2014 the abundance and reproductive activity of *Ruppia tuberosa* was assessed at eight sites on the eastern side of the South Lagoon in the Coorong, and eight sites on the western side of the South Lagoon. These sites were spread along the shoreline at 5 km intervals. The western sites were approximately opposite the eastern sites. These 16 sites coincided with sites that were originally sampled in 1984-85 as part of an initial monitoring program for the South Lagoon. *Ruppia tuberosa* was detected at all sites in 1984-5. In addition, four sites were sampled along the eastern shoreline of the North Lagoon in January 2013. These were sites where *Ruppia tuberosa* was recorded in recent years (i.e. during the latter parts of the millennium drought). The eight sites in the South Lagoon of the Coorong along the eastern shoreline and the four sites in the North Lagoon form part of an annual monitoring program that has run since 2000. A system for defining sites was adopted that incorporated the lagoon, the distance (km) north or south from the junction of the North and South Lagoons (respectively), and the eastern or western shoreline, unless the site also had a well-defined place name. For example, site S06W was in the South Lagoon, 6 km south of the junction and on the western side of the Coorong. In addition to these 20 sites, 3 additional sites in the South Lagoon are included in the assessment in January 2014. One of these sites (S33E, Gemini Downs Bay) has been assessed in previous years. This site did not experience the same extent of water level changes as parts of the South Lagoon because a sandbar helps retain water in that Bay when water levels are low in the rest of the southern Coorong. The population of *Ruppia tuberosa* in this Bay hung on during the millennium drought (despite high salinities) and has not experienced the same extent of low water levels as other sites since the return of flows in late 2010. The other two sites were sites used for intensive waterbird observations in January 2014 (e.g. Moore 2014).

At each site 25 core samples (75 mm diam, 4 cm deep) were taken at each of four water depths: dry mud surface approximately midway between the current waterline and the high water line (and if known positioned on areas where *Ruppia tuberosa* was growing in July 2013 (e.g. sites Villa dei Yumpa (S06E) and S06W); waterline; 30 cm water depth; and 60 cm water depth. Each core sample was assessed for presence of *Ruppia tuberosa* shoots and then sieved through 500 µm Endecott sieves enabling seeds and turions to be extracted and counted. Since the water levels in Gemini Bay (S33E) did not exceed 35 cm, no samples were taken in water that was 60 cm deep at this site.

Results

<u>Water levels in the southern Coorong in spring 2013</u>

In spring 2013 water levels in southern Coorong were sustained on or above 0.6m AHD during September and October (unlike the previous two springs) but fell substantially over November (Figure 1). This extended period of higher water levels during spring should provide a greater opportunity for *Ruppia tuberosa* to reproduce.

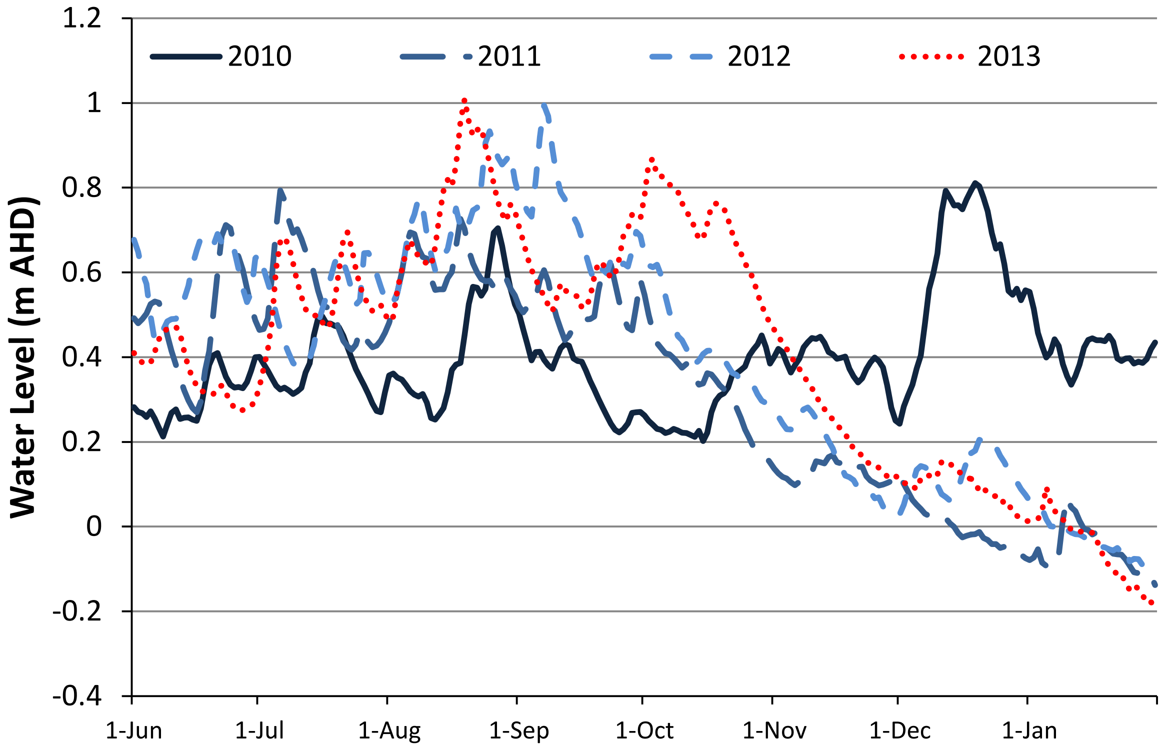

Figure 1. Changes in average water levels (m AHD) for the South Lagoon during spring 2010-2013. Data are mean levels reported from three telemetered stations in the South Lagoon (NW Snipe Island, nr Woods Well and Parnka Point). Data are shown for each year from 1 June to 31 January of the following year.

Reconnaissance surveys in early December 2013

In early December most of the higher elevation *Ruppia tuberosa* beds were exposed and starting to desiccate. The three exposed areas examined all had evidence of low levels of flowering (1.5 – 6.0 floral stalks.m^{-2}, Table 1), but none of these floral stalks had attached flower heads, suggesting that either the flower-heads had been removed (e.g. by grazing waterfowl or by interference from filamentous algae) or if they had set seeds the seed-heads had been dropped. At each of the three sites there was evidence of floral stalks and other *Ruppia* plant material being washed ashore.

Two other areas where *Ruppia tuberosa* was still covered by around 30 cm of water were also assessed (Table 1). At Gemini Bay (S33E) there were on average 26 intact floral stalks.m^{-2} (i.e. with flower heads) and a further 21 floral stalks.m^{-2} that lacked flower heads. Many of the intact floral stalks at this site were still short and growing. At this site there was an 85% cover of filamentous green algae over the *Ruppia* beds and evidence of grazing in 25% of the 1m x 1m quadrats examined. At the second site (S26E) there were just 3 intact stalks.m^{-2}, on average. There were a further 4 floral stalks.m^{-2} without flower heads at this site as well (Table 1). 31% of the *Ruppia* bed at this site was covered with filamentous green algae, and evidence of grazing was detected for 75% of the quadrats with *Ruppia*.

Table 1. Assessment of flowering effort by *Ruppia tuberosa* at selected sites in early December 2013. Data are means of 20-360 assessments of 1m x 1m quadrats arranged along 20m transects. % cover of algae was estimated by eye, while evidence of grazing was assessed by taking a plug from each quadrat and scoring if the shoots had been grazed. The numbers of floral heads, floral stalks and floral stalks washed ashore are the mean numbers counted per m^2.

SITE # 20m transects	# 20m transects	% Ruppia cover	% algal cover	% grazed	# floral heads	# floral stalks	# floral stalks washed ashore
Exposed mudflats							
S26E	18	37	-	-	0	3.5	0.4
S18E	18	18	-	-	0	1.5	0
S43E	2	11	-	-	0	6.0	7.0
Covered mudflats							
S26E (29 cm)	2	-	31	75	3	4	-
S33E (34 cm)	1	-	85	25	26	21	-

<u>Distribution and abundance of *Ruppia tuberosa* in the southern Coorong in January 2014</u>

Summary statistics for the presence of live *Ruppia tuberosa* plants across the 23 sampling sites are provided in Tables 2 and 3. *Ruppia tuberosa* shoots were detected at 16 sites but for one of these sites the shoots were exposed or present only at the water line where they were unlikely to survive. Including this site, 70% of the sites examined had *Ruppia tuberosa* shoots in January 2014. Sites with *Ruppia tuberosa* were spread over a linear distance of 60 km, although the three most northern sites (N07E, N12E and N19E) are considered outlying areas for *Ruppia tuberosa* under current conditions, thus the extent of occurrence for *Ruppia tuberosa* within the main region used in the southern Coorong was at least 43 km in January 2014.

Nine sites had average densities of shoots that exceeded the targeted 10 shoots per core at one water depth at least (Table 3). These shoot densities coincided with the sites with high cover. Overall 39% of sites had at least 30% cover and >10 shoots per core at one water depth at least (Tables 2 & 3).

Table 2. Per-cent of cores with *Ruppia tuberosa* plants present at different water depths across 23 sites in the southern Coorong in January 2014. Twenty-five cores were taken at each depth at each site.

Site	km from Mouth	East				West			
		dry	waterline	30cm	60cm	dry	waterline	30cm	60cm
N19	38	4	20	0	0				
N12	45	0	0	4	0				
N07	50	0	0	8	0				
N02	55	0	0	72	80				
S03	59	0	0	96	72				
S06	62	36	32	76	20	0	0	4	0
S11	67	0	0	0	0	0	0	60	0
S16	72	0	0	0	0	0	0	100	16
S21	77	0	0	0	0	0	0	16	0
S23	79	8	0	0	12				
S26	82	0	0	12	84	0	0	24	96
S31	87	4	0	0	0	0	0	20	12
S33	89	4	0	100					
S36	92	0	0	0	0	0	0	0	0
S41	97	0	0	16	16	0	0	96	100

There was a marked improvement in the distribution and abundance of *Ruppia tuberosa* in January 2014 compared to January 2013 (Fig. 2). Sites with and without *Ruppia tuberosa* were intermingled along the Coorong. This suggests that factors other than salinity were likely to be affecting the establishment of *Ruppia tuberosa*, since the salinity changes gradually along the southern Coorong (Paton & Bailey 2014). The other factors likely to be involved include the level of exposure to wave action, the bathymetry of a site and the presence of viable propagules in the sediments.

Table 3. Mean numbers of *Ruppia tuberosa* shoots present in cores (75 mm diameter x 4 cm deep) taken at four water depths at 23 sites spread across the southern Coorong in January 2014. Data are based on 25 cores taken at each water depth at each site. To express these data as shoots.m^{-2} multiply by 226.

Site	km from Mouth	East				West			
		Dry	waterline	30cm	60cm	dry	waterline	30cm	60cm
N19	38	0.04	0.68	0	0				
N12	45	0	0	0.12	0				
N07	50	0	0	0.52	0				
N02	55	0	0	25.6	21.1				
S03	59	0	0	18.2	10.9				
S06	62	0.92	0.56	11.8	1.6	0	0	0.2	0
S11	67	0	0	0	0	0	0	23.3	0
S16	72	0	0	0	0	0	0	78.8	4.0
S21	77	0	0	0	0	0	0	3.12	0
S23	79	0.2	0	0	0.1				
S26	82	0	0	2.6	32.4	0	0	2.1	18.4
S31	87	0	0	0	0	0	0	3.5	2.5
S33	89	0.08	0	11.5					
S36	92	0	0	0	0	0	0	0	0
S41	97	0	0	1.5	4.6	0	0	29.4	18.2

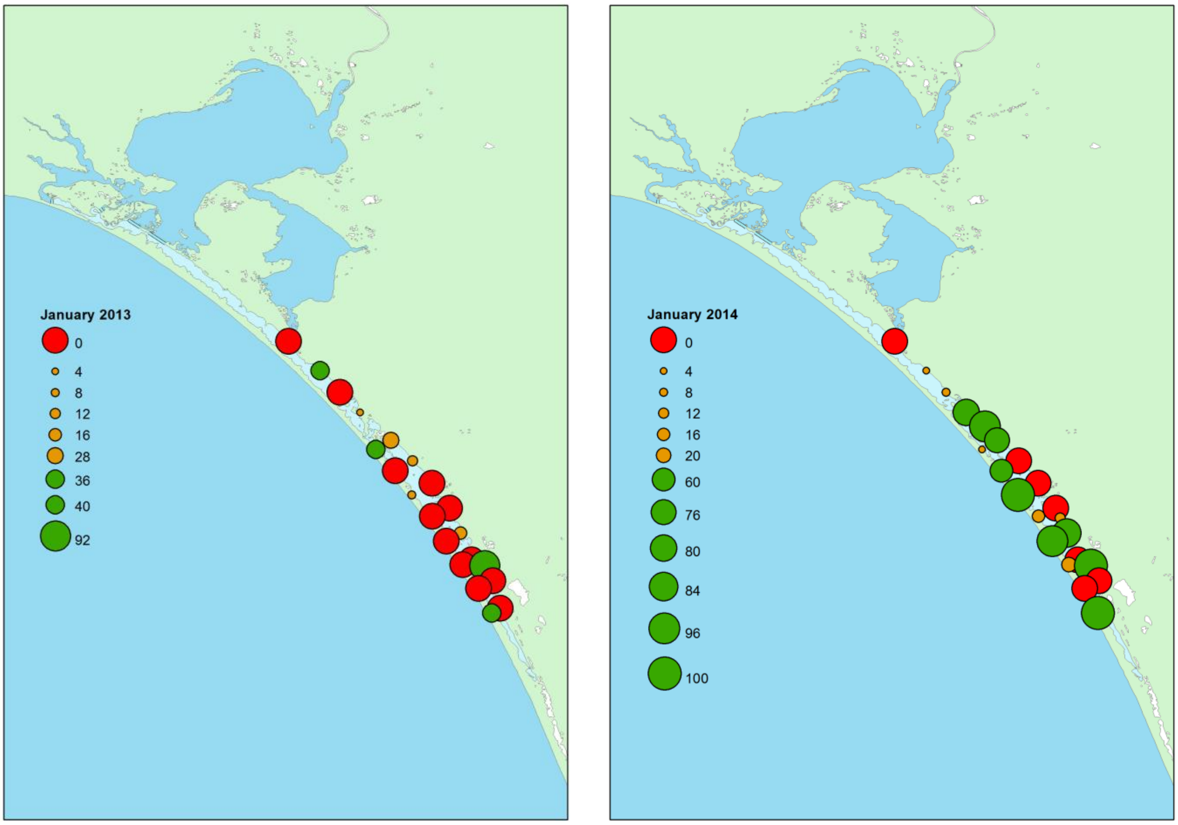

Figure 2. Changes in the distribution and abundance of *Ruppia tuberosa* along the Coorong in January 2013 and January 2014. The data show the maximum percent of cores with *Ruppia* shoots for cores taken in 30 cm or 60 cm water depths (Table 2). Red spots show areas where there were no *Ruppia* shoots at these depths, orange spots where the cover was less than 30% and green spots where the cover exceeded 30% (i.e. > 30% of cores had shoots). The actual percentages are shown on the Figure.

The abundances of propagules associated with these plants were generally low. Tables 4 and 5 show the data for turions. Only type II turions were detected. Type II turions carry much smaller reserves than type I turions and have limited capacity to survive any extended period of desiccation. Type II turions were detected in cores at 18 sites and abundances in excess of 10 type II turions per core were detected at four sites all in water 30 cm deep. Sites with high abundances of shoots tended to be the sites with large numbers of type II turions and so the turion counts reflect the shoot data.

Table 4. Per-cent of cores containing *Ruppia tuberosa* turions (Type II only) across 4 water depths at 23 sites in the southern Coorong in January 2014. Data are based on 25 cores taken at each depth at each site.

Site	km from Mouth	East				West			
		Dry	waterline	30cm	60cm	dry	waterline	30cm	60cm
N19	38	0	0	0	0				
N12	45	0	0	4	0				
N07	50	0	0	4	0				
N02	55	16	68	68	48				
S03	59	100	100	96	28				
S06	62	32	80	20	24	32	0	0	0
S11	67	0	0	0	0	0	24	52	0
S16	72	12	0	0	0	48	92	96	0
S21	77	0	8	0	0	48	0	8	0
S23	79	0	0	0	0				
S26	82	4	28	4	68	4	0	4	28
S31	87	0	0	0	0	0	16	12	0
S33	89	20	92	100					
S36	92	4	0	0	0	0	0	0	0
S41	97	0	0	8	12	0	16	64	52

Table 5. Mean number of type II turions per core (75 mm x 4 cm) across 4 water depths and at 23 sites within the southern Coorong in January 2014. Data are based on 25 cores taken at each water depth at each site. To express these data as turions.m^{-2} multiply by 226.

Site	km from Mouth	East				West			
		Dry	waterline	30cm	60cm	dry	waterline	30cm	60cm
N19	38	0	0	0	0				
N12	45	0	0	0.04	0				
N07	50	0	0	0.12	0				
N02	55	0.88	3.96	10.6	4.12				
S03	59	7.96	8.64	11.9	0.84				
S06	62	0.84	4.88	0.36	0.6	0.84	0	0	0
S11	67	0	0	0	0	0	0.64	7.28	0
S16	72	0.36	0	0	0	1.12	5.80	20.1	0
S21	77	0	0.24	0	0	3.16	0	0.4	0
S23	79	0	0	0	0				
S26	82	0.04	0.92	0.08	8.08	0.12	0	0.04	2.08
S31	87	0	0	0	0	0	0.32	0.68	0
S33	89	0.24	4.20	20.1					
S36	92	0.08	0	0	0	0	0	0	0
S41	97	0	0	4.64	1.76	0	0.13	1.50	0.42

Tables 6 and 7 provide summary statistics for the presence and abundances of *Ruppia tuberosa* seeds at the 23 sites in January 2014. For ten sites more than 50% of the cores contained seeds for at least one depth sample (Table 6). Only six of the 23 sites had at least 2 seeds per core (Table 7) and no sites had more than 8 seeds/ core. Site S33E had the highest density with 7.24 seeds per core. Two sites had no seeds detected from 100 cores.

Table 6. Per-cent of cores containing *Ruppia tuberosa* seeds at 23 locations in the southern Coorong at four different water depths in January 2014. Data are based on 25 cores taken at each depth at each site.

Site	km from Mouth	East				West			
		Dry	waterline	30cm	60cm	dry	waterline	30cm	60cm
N19	38	8	0	12	4				
N12	45	0	0	0	0				
N07	50	68	32	12	36				
N02	55	96	68	68	72				
S03	59	76	64	84	56				
S06	62	44	40	32	56	40	60	24	52
S11	67	0	0	4	32	0	0	12	8
S16	72	12	4	0	0	16	8	12	4
S21	77	32	52	20	0	8	20	8	4
S23	79	12	8	4	0				
S26	82	92	40	32	12	0	0	12	16
S31	87	4	0	4	0	56	32	20	16
S33	89	80	92	88					
S36	92	36	32	4	0	0	0	0	0
S41	97	40	64	4	12	8	8	0	0

Table 7. Mean number of *Ruppia tuberosa* seeds per core (75 mm diameter x 4 cm deep) at 23 sites along the southern Coorong across four water depths in January 2014. Data are based on 25 cores taken at each depth at each site. Note that 29% of the 281 seeds checked lacked intact contents and so were not viable, so the numbers of viable seeds will be lower than the numbers indicated in the table. To convert these data to seeds.m^{-2} multiply by 226.

Site	km from Mouth	East				West			
		Dry	waterline	30cm	60cm	dry	waterline	30cm	60cm
N19	38	0.08	0	0.20	0.04				
N12	45	0	0	0	0				
N07	50	2.16	0.36	0.20	0.40				
N02	55	4.32	0.44	0.28	1.68				
S03	59	3.14	1.52	3.56	1.32				
S06	62	1.60	0.68	0.72	1.12	0.84	3.48	1.12	0.88
S11	67	0	0	0.04	0.64	0	0	0.36	0.16
S16	72	0.32	0.08	0	0	0.20	0.12	0.16	0.04
S21	77	1.04	0.76	0.28	0	0.12	0.80	0.12	0.04
S23	79	0.28	0.16	0.04	0				
S26	82	5.36	0.92	0.36	0.24	0	0	0.16	0.24
S31	87	0.12	0	0.04	0	1.88	0.76	0.24	0.16
S33	89	2.40	2.24	7.24					
S36	92	0.76	1.08	0.12	0	0	0	0	0
S41	97	1.12	4.88	0.04	0.25	0.12	0.08	0	0

Changes in seed abundances along the Coorong 2011-2014.

The abundances of seeds detected in sediment cores in January 2014 were similar to (and not statistically different from) the abundances of seeds detected in January in each of the three previous years (Table 8). This confirms that there has been no increase in the abundances of 'seeds' for *Ruppia tuberosa* across the southern Coorong during the last 3-4 years, despite salinities being favourable since early 2011. However, in January 2014 of 281 seeds examined 200 (71%) were intact and likely to be viable. In the previous three years only around 1% of seeds were intact (e.g. Paton & Bailey 2013). The much higher levels of intact and presumably viable seeds in January 2014 is consistent with some plants succeeding in completing their flowering cycle and setting at least a few seeds. So, although the quantity of seeds present is still low overall, the capacity of the seeds to germinate is likely to have greatly improved. At the time of writing this report germination rates of the intact seeds collected in January 2014 were yet to be determined.

Table 8. Abundances of *Ruppia tuberosa* seeds (seeds per core) found in sediments at 12 sites along the eastern shore of the southern Coorong in January from 2011 to 2014. Data are based on 75-100 cores (75 mm diameter x 4 cm deep) taken at a range of water depths at each site in each year and are means ± s.e.. In each year over 200 of the seeds were checked for contents. In Jnaury 2013 all but one of these (in 2013) was sand-filled and so not viable. However in January 2014 71% of the seeds were intact. To convert these data to seeds.m^{-2} multiply by 226.

Site	km from Mouth	January 2011	January 2012	January 2013	January 2014
N19	38	0.00 ± 0.00	0.19 ± 0.07	0.01 ± 0.01	0.08 ± 0.03
N12	45	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00
N07	50	0.17 ± 0.05	0.29 ± 0.20	0.12 ± 0.04	0.78 ± 0.16
N02	55	1.39 ± 0.22	0.27 ± 0.08	0.43 ± 0.10	1.68 ± 0.20
S06	62	3.48 ± 0.68	1.13 ± 0.33	0.60 ± 0.19	1.03 ± 0.20
S11	67	1.09 ± 0.38	0.10 ± 0.04	0.23 ± 0.07	0.17 ± 0.07
S16	72	0.01 ± 0.01	0.03 ± 0.02	0.00 ± 0.00	0.10 ± 0.06
S21	77	0.05 ± 0.04	0.07 ± 0.05	0.02 ± 0.01	0.52 ± 0.11
S26	82	0.12 ± 0.05	1.35 ± 0.47	1.16 ± 0.35	1.72 ± 0.33
S31	87	0.00 ± 0.00	0.00 ± 0.00	0.09 ± 0.04	0.04 ± 0.03
S36	92	008 ± 0.04	0.18 ± 0.07	0.46 ± 0.29	0.49 ± 0.15
S41	97	0.19 ± 0.07	0.57 ± 0.14	0.56 ± 0.11	1.58 ± 0.84

Status of *Ruppia tuberosa* in the southern Coorong in January 2014

Table 9 provides summary statistics for the status of *Ruppia tuberosa* in January for the last four years and against the stated benchmarks for a healthy and resilient *Ruppia tuberosa* system. *Ruppia tuberosa* was least prominent in January 2012 when shoots of *Ruppia tuberosa* were found at only 1 site. Since then there has been an improvement over 2012 and again over 2013 for both regional scale indicators and for three of the five site scale performance indicators. However none of the indicators have reached the target levels required for a healthy and resilient *Ruppia tuberosa* system. Importantly the abundances of seeds at all sites (and depths, Tables 7, 8 and 9) were low and well below the levels needed for some level resilience.

Table 9. Extent of occurrence, area of occupation and prominence of *Ruppia tuberosa* at sites across the southern Coorong in January from 2011-2014. The target values for a healthy and resilient system for *Ruppia tuberosa* are also given.

Performance Indicator	Target	2011	2012	2013	2014
# sites sampled		13	12	21	23
REGIONAL SCALE					
- Extent of Occurrence (km, main region)	50	22	1	43 (53*)	43 (60*)
- Area of occupation (% sites with *Ruppia* shoots)	80	31	8	57	73
SITE SCALE					
- % sites with > 30% cover (cores) with shoots	80	15	0	24	39
- % sites with > 10 shoots/core for one depth	80	23	0	5	39
- % sites with > 50 flower-heads.m $^{-2}$	80	0	0	0	+
- % sites with > 50% cores with seeds	80	15	17	24	53
- % sites with > ~8 seeds/core	80	8	0	0	0

*extent of occurrence with outliers; + evidence of flower production noted for at least 5 sites in December 2013 but fewer than 10 sites examined

General Discussion and Conclusions

There was a marked improvement in the distribution and abundance of *Ruppia tuberosa* in the southern Coorong over the last year (e.g. Fig. 2). Although the extent of occurrence along the southern Coorong did not increase *Ruppia tuberosa* plants were present at more sites, and their abundance at sites was higher. Despite the improvement, the recovery was still short of meeting a healthy and resilient system as none of the regional and site specific targets for *Ruppia tuberosa* had been met.

Several factors are likely to have contributed to this steady recovery. First the sudden appearance of *Ruppia tuberosa* at a number of sites where it had been absent for up to 10 years is likely to be related to a series of storm events during spring where strong winds and wave action dislodged growing plants and dispersed them in the water column. Although most of this dislodged plant material washes to shore somewhere, some of the material is likely to settle in shallow water and establish. This mechanism is likely to account for the sudden prominence of *Ruppia tuberosa* at sites where it had been absent for years (e.g. Fig. 2).

A second factor likely to have contributed to the recovery has been the maintenance of higher water levels over a longer period of spring which would have provided plants that had established during winter a longer period to grow and flower. This should lead to greater cover at sites where *Ruppia tuberosa* was present and also, if the plants completed their flowering cycle, added seeds to the depleted propagule banks. Despite some areas producing over 40 floral heads per m^2, the numbers of seeds detected in the seed banks changed little, although the numbers of intact seeds in the seed bank did. Assuming that each floral head can produce around 10 seeds, floral densities of 40 floral heads per m^2 should add around 400 seeds per m^2 or about 1.8 seeds per core. This increase was not detected suggesting that many of the floral heads failed to set seeds.

Failure to set seeds could be due to water levels dropping prior to all of the floral heads having completed their flowering cycle and setting seeds. Alternatively poor conversion rates of flowers to seeds could be due to excessive losses of floral heads due to interference from filamentous green algae and or grazing by waterfowl. In December around half of the floral stalks that were still attached to plants had been snapped (Table 1). Large numbers of floral stalks were washed ashore at many sites with filamentous green algae attached to the flower heads (e.g. see image on title page), particularly during strong winds associated with storm events. This suggests that interference from filamentous green algae is a key factor reducing reproductive outputs of *Ruppia tuberosa* and dampening re-establishment. The lower salinities that established in the southern sections of the South Lagoon as a consequence of releases of freshwater at Salt Creek may have also contributed. Lower salinities are likely to favour filamentous green algae and exacerbate this interference. This interference is not just limited to disrupting reproductive outputs for *Ruppia tuberosa*. In many areas mats of filamentous algae established around the plants reducing light and potentially dampening the growth of the plants as well. Future management of water in the region should aim to extend the period of high spring water levels at least through November and limit the effect of releases of fresh water at Salt Creek on salinities that could favour the growth of filamentous green algae. Monitoring programs should also be developed for filamentous green algae and the conditions that favour this species defined so that these conditions can be avoided in the future.

Water levels in January when the summer monitoring program was conducted were around 0.7 m lower than they were in winter (Fig. 1). Thus the plants that were detected in January in water that was 0.3 and 0.6m deep were likely to be covered with 1-1.3m of water in winter. Healthy growth of *Ruppia tuberosa* is usually limited to water depths below 0.9m in the Coorong (Paton & Bailey 2010, Paton *et al.* 2011). Thus the *Ruppia tuberosa* plants being monitored in summer are different to those being monitored in winter and will experience different ecological conditions. For example, they will be continuously inundated with water. Most of the plants detected at least in 0.6m in January had short shoots (1-3 cm in length) suggesting that they had only recently started to grow, perhaps only growing for the last 1-2 months once water levels had dropped sufficiently in mid-November. Whether these plants are permanently present at these depths or whether plants recolonised these areas each year from shallower areas is not known and deserves study. There is the potential that if the higher spring water levels cannot be sustained that lower water levels in spring may shift Ruppia tuberosa to these 'deeper' areas or favour the plants growing in these deeper areas.

A series of quantitative measures have been established for assessing the status of *Ruppia tuberosa* in the Coorong, and those measures and targets have been applied to the data collected in January 2014. There are, however, some refinements needed to those measures. In applying them to the data collected in January 2014, a site was regarded as having met the target if the target was met at just one of the water depths sampled. This is likely to over-estimate the extent of recovery and the quantitative measures may need to define a range of water depths over which the targets are to be met and or determine and report the actual range of water depths and the width of mudflat over which the target was met. Both may be important where the bathymetry of the site is such that depending on spring water levels either a narrow or a broad strip of suitable water depths is available. Refining these quantitative measures is beyond the scope of this report.

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