Monitoring of *Ruppia tuberosa* in the southern Coorong, summer 2016-17.

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May 2017

This report may be cited as:

Paton, DC, Paton, FL and Bailey, CP 2017. Monitoring of *Ruppia tuberosa* in the southern Coorong, summer 2016-17. (University of Adelaide, Adelaide).

<u>Cover Image</u>: Dense algae smothering *Ruppia tuberosa*, Gemini Downs Bay, South Lagoon, Coorong, December 2016 (F. Paton).

Executive Summary

Three of four regional targets and two of five local population scale targets for a healthy population of *Ruppia tuberosa* were met in the 2016-17 summer season, reflecting an improvement in cover and abundance of the plant. However, the ability of *R. tuberosa* to complete its reproductive cycle, and secure future resilience, was disrupted by filamentous green algae. As a consequence, *R. tuberosa* failed to meet targets for flowering, and the production of seeds and turions for the 2016-17 summer season.

The increased cover and abundance of *R. tuberosa* in the southern Coorong was expected, given that for the first time in more than a decade, water levels were maintained through spring and did not drop rapidly before plants were able to produce flowers. The enhanced flowering that was observed compared with previous seasons was consistent with this. However, flowering was hampered by the presence of heavy loads of filamentous green algae (*Ulva* sp.) that became entangled in flower-heads, resulting in most flower-heads being lost before seeds were produced. So, despite increased flowering, there was no net increase in seed banks and hence resilience, with on-going low seed densities being reported. High algal loads were also not unexpected, as salinities in the southern Coorong in January 2017 were much lower than previous years, ranging from 58-82 gL^{-1}. Although this range of salinities is still within the targeted salinity range for *R. tuberosa* of 60-100 gL^{-1}, all populations of *R. tuberosa* were being affected by the algae, indicating that the lower limit of this range may need to be raised to at least 80gL^{-1} if *R. tuberosa* is to escape interference from algae. Enhanced algal loads are also likely to have interfered with waterbird interactions. Firstly, the algae may have prevented waterfowl from accessing the plants, reflected in only moderate levels of grazing of *R. tuberosa*, although this was also likely to be indicative of an increase in the availability of food (plant material and turions) for herbivorous waterfowl. Secondly, algal loads that were smothering the mudflats would have prohibited shorebirds from reaching food resources, such as turions and seeds. Turion abundances were low and those found were predominantly only partially-formed. A rapid drop in water levels of 0.6 m in January is also likely to have hampered any potential increase in turion abundance following sampling in early January. Finally, the presence of galls was detected on R. tuberosa for the first time in the Coorong. These galls are believed to be a response to the parasitic fungus, *Tetramyxa parasitica.* While plants with galls showed no signs of ill-health, the fungus is a potential cause for concern and should be monitored.

These findings confirm that falling water levels in spring is the critical issue that first needs to be addressed, as these falling water levels reduce the time available for plants to establish, grow and reproduce. However, rapidly falling water levels in summer must also be addressed to increase the extent of asexual reproduction. Consequently, a barrier across the middle of the Coorong to reduce the rate at which water levels drop in the southern Coorong over spring and summer, must be considered. Further, the interference caused by filamentous green algae to the productivity of this plant, which ultimately affects its capacity for future resilience, must be addressed. Given that many of the waterbirds that use the southern Coorong over summer depend on healthy and resilient populations of *R. tuberosa*, there is no time to lose.

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1 Preamble

This report builds on a series of annual reports on *Ruppia tuberosa* in the Coorong. Substantial parts of previous reports are reiterated, so that relevant background and historical perspectives, as well as details of methods and monitoring targets, are provided within this report, reducing the need to revisit previous reports for those details. However, previous reports, most of which are cited in this report, contain specific discussion of results and issues arising in those years and those reports should be consulted for those details.

2 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 *R. tuberosa* disappeared from the South Lagoon and its seed bank was severely eroded (Paton 2010; Paton & Bailey 2012). This loss of *R. tuberosa* from the southern Coorong is linked to an absence of flows over the Barrages that resulted in low water levels during spring, which 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 (Webster 2010). These factors combine to result in water levels in the southern Coorong varying seasonally by up to a metre. Water levels are usually lowest in autumn and highest in early spring. On a day-to-day basis, water levels are also influenced by changes in wind speed and direction, with wind-induced changes to water levels approaching 30 cm (Paton 2010).

Ruppia tuberosa generally germinates from seeds or resprouts from turions when water levels increase in late autumn and re-inundate exposed mudflats around the margins of the southern Coorong. If these mudflats remain covered with water, *R. 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 particularly in late spring. As a consequence, water levels dropped earlier in the southern Coorong, reducing the period of time available to *R. tuberosa* to grow and reproduce. This was exacerbated further during the millennium drought, when no water reached the Murray Mouth. Without flows to the Murray Mouth in spring, water levels in the Coorong dropped in spring, exposing the beds of *R. 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 g/L and as the salinities in the South Lagoon were consistently above 100 g/L, and at times exceeded 150 g/L during the millennium drought, high salinity has been implicated in the loss of *R. tuberosa*. When salinities are high (> 100 g/L), germination of seeds and growth of seedlings are impeded (Paton *et al.* 2011; Paton & Bailey 2010, 2012; Kim *et al.* 2013). However, *R. tuberosa* declined and had largely disappeared from much of the South Lagoon by June 2004, before high salinities were reached, suggesting other influences were responsible for its decline (Paton 2010). When substantial flows returned to the River 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

R. tuberosa would quickly recover like other aquatic biota once the salinities returned to more typical levels. This did not happen.

As the freshwater flows returned to the region, there was some recovery of *R. tuberosa* in the South Lagoon, although this was slow and limited (Paton & Bailey 2012, 2013a, 2013b; Paton *et al.* 2015a, 2016a,b). Additionally, the extensive beds that had gradually established in the North Lagoon between 2006 and 2010 were also quickly lost, probably due to interference from filamentous green algae (e.g., Paton & Bailey 2012; unpubl.). The net result was that *R. 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 was limited improvement in the few years following (Paton & Bailey 2013a,b; Paton *et al.* 2015a; 2016a,b,d,e). Furthermore, in 2016, rather than observing any further recovery, *Ruppia tuberosa* deteriorated again (Paton *et al*. 2016d,e). 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 *R. tuberosa* throughout most of the South Lagoon (Paton & Bailey 2012, 2013a, 2013b; Paton *et al*. 2015a; 2016a,b,d,e). Second, although flows returned to the region in spring 2010, during each of the next five years (2011-2015), flows diminished dramatically in spring, resulting in water levels once again falling at critical times for *R. tuberosa* production.

This intervention monitoring report summarises the distribution, abundance and resilience of *R. tuberosa* in the southern Coorong in January 2017 but includes some observations made on flowering levels conducted in November and December 2016. Two basic questions are asked:

(1) Has there been any improvement in the summer distribution and abundance of *R. tuberosa* over the last year?, and
(2) Has *R. tuberosa* recovered sufficiently to be considered healthy and resilient?

Assessing the second question requires defining some quantitative measures for healthy and resilient populations of *R. tuberosa*. In February and March 2014, the Murray Darling Basin Authority used an expert panel to define some quantitative measures that could be applied at a regional scale and applied at a local population scale (Table 1; see Paton *et al.* 2015b for details). The following were defined. At a regional scale, a healthy southern Coorong would have: (a) *R. tuberosa* with an extent of occurrence (EOO) along the southern Coorong of 50 km, excluding outliers; (b) within this distribution, 80% of the sites monitored would have *R. tuberosa* plants present in winter and summer; (c) 50% of the sites would have vigorous populations of *R. tuberosa* and (d) 50% of the sites monitored would have at least 2000 seeds/m^2 (the 2019 population resilience target). The 50 km EOO was adjusted subsequently to 43 km because the spread of regular monitoring sites where *R. tuberosa* was expected to perform well was 43 km and not 50 km. A vigorous population of *R. tuberosa* at a local site scale would have: (a) 30% cover of *R. tuberosa* in winter and summer; (b) at least 10 shoots per 75 mm diameter core; (c) at least 50% of cores with seeds; (d) at least 50 flower-heads/m^2 for 50% of the area sampled at a site level during the spring flowering season; and (e) at least 50% of cores taken across the *R. tuberosa* beds containing turions in late summer. Further, by 2029, the population resilience target has been set at an increased 10,000 seeds/m^2 at 50% of sites. These targets have been applied where relevant to the results discussed in this report.

Table 1: Criteria used to define the status of *R. tuberosa* in the southern Coorong (Paton *et al.* 2015b).

Criterion	Target
REGIONAL SCALE	
R.1 Extent of Occurrence (EOO)	*Ruppia tuberosa* plants distributed along 43 km of the southern Coorong
R.2 Area of Occupation (AOO)	*Ruppia tuberosa* plants present at 80% of sites monitored within the EOO in winter and summer
R.3 Population Vigour (VIG)	Vigorous *Ruppia tuberosa* populations at 50% of sites, where a vigorous population has at least 30% cover with at least 10 shoots per core (75mm diam) for cores with *Ruppia tuberosa*
R.4 Population Resilience (RES)	At least 2,000 seeds/m^2 at 50% of sites with *Ruppia tuberosa* (target set for 2019)
LOCAL SCALE	
L.1 Population cover	At least 30% cover in winter and in summer
L.2 Population (shoot) density	At least 10 shoots per core (75 mm diam) for cores with *Ruppia tuberosa* in winter
L.3 Reproductive output	At least 50 flower-heads/m^2 for 50% of the area sampled (with *Ruppia tuberosa*) at a site during spring flowering
L.4 Propagule (seed) density	At least 50% of surface sediment cores (75 mm diam) with seeds
L.5 Asexual reproduction	At least 50% of cores (75 mm diam) taken across the *Ruppia tuberosa* beds in late summer should contain turions
FUTURE RESILIENCE	
RS.1 By 2019	2,000 seeds/m^2 at 50% of sites (> 8 seeds per core (75 mm diam. x 4 cm deep))
RS.2 By 2029	10,000 seeds/m^2 at 50% of sites (> 0 seeds per core (75 mm diam. x 4 cm deep))

Some of these targets are used to report against the quantified environmental outcomes (QEOs) for *R. tuberosa* in the Basin-wide environmental watering strategy (Murray-Darling Basin Authority 2014). Specifically, the QEO for *R. tuberosa* is a sustained and adequate population in the south lagoon of the Coorong, including:

- by 2019, *R. tuberosa* to occur in at least 80% of sites across at least a 50 km extent
- by 2029, the seed bank to be sufficient for the population to be resilient to major disturbances

Note that Murray-Darling Basin Authority (2014) lists the extent of occurrence for *R. tuberosa* as 50km. However, this extent of occurrence has been reviewed recently and now the recommended extent of occurrence is 43km (Paton *et al.* 2015b).

3 Methods

3.1 Assessment of flowering levels in November and December 2016

Assessment of flowering activity was undertaken on 11 and 13 November 2016, when Lake Cantara and eight sites on the eastern side of the southern Coorong were visited, namely N02E, S02E, S06E, S18E, S26E, S33E, S36E and S41E (Table 2 and Figure 5 in Appendix A). With the exception of S41E and Lake Cantara, flowering activity was reassessed at these sites on 16 December 2016, with S21E (Table 2 and Figure 5 in Appendix A) also assessed on this day. For sites where *R. tuberosa* plants were present, an assessment was made as to the extent of flowering and the filamentous green algal load (*Ulva* sp.). Assessments of flowering were made by locating flower-heads at a site and then counting the number of visible flower-heads produced in 1 m x 1 m quadrats (note that visibility was poor due to turbid water, so in some instances only flower-heads on the surface and within 15cm of the surface could be counted). The flower heads that were counted were assigned to the closest of four water depths in which the plants were growing: 0.2, 0.4, 0.6 or 0.8m. In November, 30 quadrats were generally sampled at each site where *R. tuberosa* occurred, while, in December, 20 quadrats were generally sampled for each of the depths at each site where *R. tuberosa* occurred.

3.2 Distribution and abundance of *R. tuberosa* in the southern Coorong in January 2017

The main assessment of the distribution and abundance of *R. tuberosa* in the southern Coorong was conducted in January 2017, in line with the timing of monitoring in previous years. During January 2017, the abundance and reproductive activity of *R. tuberosa* was assessed at eight sites on the eastern side of the South Lagoon of the Coorong, and eight sites on the western side of the South Lagoon (Table 2, Figure 5 in Appendix A). These sites are spread along the shoreline at intervals of approximately 5 km. The western sites are approximately opposite the eastern sites. These 16 sites coincide 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 January 2017, four sites were additionally sampled along the eastern shoreline of the North Lagoon (Table 2 and Figure 5 in Appendix A), where *R. tuberosa* was recorded during the latter parts of the millennium drought. The eight sites along the eastern shoreline in the South Lagoon of the Coorong and the four sites in the North Lagoon form part of an annual monitoring program that has run since 2000, while the eight sites on the western side of the South Lagoon were added to the monitoring program in January 2013. 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 is in the South Lagoon, 6 km south of the junction and on the western side of the Coorong. In addition to these 20 sites, one additional site on the eastern shore in the South Lagoon (S33E, Gemini Downs Bay; Table 2) has been assessed in previous years. This site does not experience the same extent of water level changes as other 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 *R. tuberosa* in this Bay remained 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. For this reason, it presents an interesting comparison to sites which have regularly experienced reduced water levels.

Table 2: Location details for sampling sites used for assessing the distribution and abundance of *R. tuberosa* in January 2017. The table provides the average easting and northing of the sampling depths at each site. See Appendix A for locational map of sites.

Site	Distance from Mouth (km)	Eastern shore			Western shore		
		Zone	Easting	Northing	Zone	Easting	Northing
N19	37	54H	342533	6042174			
N12	44	54H	347959	6037285			
N08	48	54H	350522	6034249			
N02	54	54H	354684	6029538			
S06	62	54H	360454	6024694	54H	358067	6024263
S11	67	54H	363123	6022500	54H	360914	6020398
S16	72	54H	367049	6018086	54H	363817	6016002
S21	77	54H	370278	6013457	54H	367502	6012315
S26	82	54H	372526	6008937	54H	369874	6007766
S31	87	54H	374401	6004315	54H	372631	6003931
S33	89	54H	376381	6003588			
S36	92	54H	377502	6000803	54H	375476	5999686
S41	97	54H	378547	5996472	54H	377511	5995712

At each site, 25 core samples (75 mm diam., 4 cm deep) were taken at each of four water depths: (1) dry mud surface, approximately midway between the current waterline and the high water line (and, if known, positioned on areas where *R. tuberosa* was growing in winter); (2) waterline; (3) 30 cm water depth; and (4) 60 cm water depth. Each core sample was assessed for presence of *R. tuberosa* shoots and then sieved through 500 µm Endecott sieves, enabling seeds and turions to be extracted and counted. However, water levels in January 2017 were extremely high (see Section 4.1), resulting in 14 sample sites having no dry mud surface, with water abutting terrestrial vegetation (commonly samphire) and often smothered in algae several centimetres thick. This was also the case at the waterline for three sites. It was impossible to sample under these conditions, so core samples for the dry mud surface and waterline for these sites were not taken in January 2017. However, these samples are not considered a vital component of the assessment of *R. tuberosa*, as with water levels so high, these sample locations are outside the usual range of *R. tuberosa*.

4 Results and Preliminary Discussion

4.1 Water levels in the southern Coorong in spring 2016

In winter 2016, and similar to previous years, water levels fluctuated in the southern Coorong around 0.35-0.9 m AHD, but, unlike previous years, water levels increased steadily in early spring 2016, peaking in mid-spring at about 1.05 m AHD (Figure 1). Water levels then steadily declined, but unlike the preceding six years, water levels by the end of spring 2016 in the southern Coorong were still relatively high at around 0.5 m AHD (Figure 1). During December 2016, water levels steadied and even increased, which again was in contrast to the previous five years; however, water levels dropped sharply thereafter, losing 0.4 m in the first half of January 2017, and another 0.2 m over the next couple of weeks, resulting in a water level of 0.16 m AHD at the end of January 2017 (Figure 1).

Considering that most of the *R. tuberosa* beds that establish in winter are centred around the 0.0 to 0.2 m AHD contour, and given that *R. tuberosa* needs an appropriate cover of water (0.3-0.9 m) to prosper in the Coorong, when water levels start to drop below about 0.3 m AHD, those *R. tuberosa* plants that germinated in winter will progressively be exposed to desiccation. From 2011-2015, this 0.3 m AHD threshold was breached either at the beginning of spring (2014, 2015) or towards the end of spring (2011-2013) (Figure 1), resulting in poor years for *R. tuberosa* in the southern Coorong (Paton *et al.* 2016d). In contrast, the maintenance of water levels above 0.3 m AHD through spring 2016 and into mid-summer 2017, should provide suitable water levels for *R. tuberosa* to have a good season in the southern Coorong. However, there was still a sharp drop of 0.6 m over the course of January 2017 (Figure 1), following the closure of most of the barrage gates and a sharp reduction in total flow over the barrages in early January (Figure 2).

4.2 Assessment of flowering levels in November and December 2016

4.2.1 Flowering levels

In mid-November 2016, evidence of flowering was detected at six out of eight sites in the Coorong where *R. tuberosa* is expected to perform well, ranging from N02E to S33E, and by mid-December, the range had increased to include S36E (Table 3). Similarly, flowering densities generally improved at all sites from November to December 2016 (Table 3). In mid-November, the greatest density of flower-heads of 44.8 flower-heads/m^2 in the Coorong was observed at S26E at a water depth of 0.8 m, which was similar to that in mid-December, with 45.6 flower-heads/m^2 recorded at S06E in 0.6 m-deep water (Table 3) (note that water levels in the South Lagoon had decreased by about 0.2 m over this time; Figure 1). While the flowering of *R. tuberosa* in the Coorong in November and December 2016 was better than in previous years (see Paton *et al.* 2016a, 2016d), even the maximum densities observed for these two sampling periods fall short of the local population scale target of at least 50 flower-heads/m^2 for 50% of the area sampled (Table 1). This may in part be due to the turbid water conditions and poor visibility, which resulted in only flower-heads within about 15 cm of the water surface being easily detectable. Consequently, the counts did not include flower-heads in early stages of development on short peduncles, so the true number of flower-heads, particularly at the greater depths, were likely to have been higher than reported. However, even if some flower-heads were not counted, the densities are still far inferior to the mean density of 213.6 flower-heads/m^2 observed at Lake Cantara in November 2016 (Table 3) and representative of a

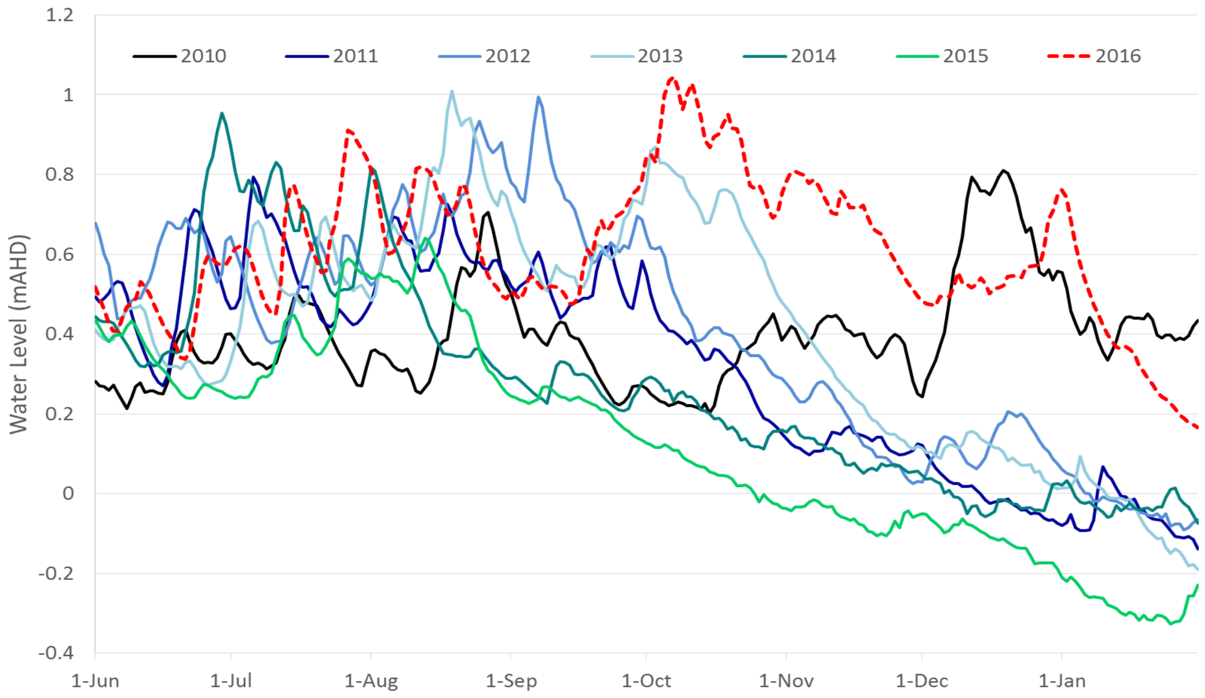

Figure 1: Changes in water levels (m AHD) for the South Lagoon from 2010 to 2016 for the period June 1st to January 31st of the following year. Data are mean levels reported from three telemetered stations in the South Lagoon (NW Snipe Island, near Woods Well and Parnka Point) (Government of South Australia, 2017).

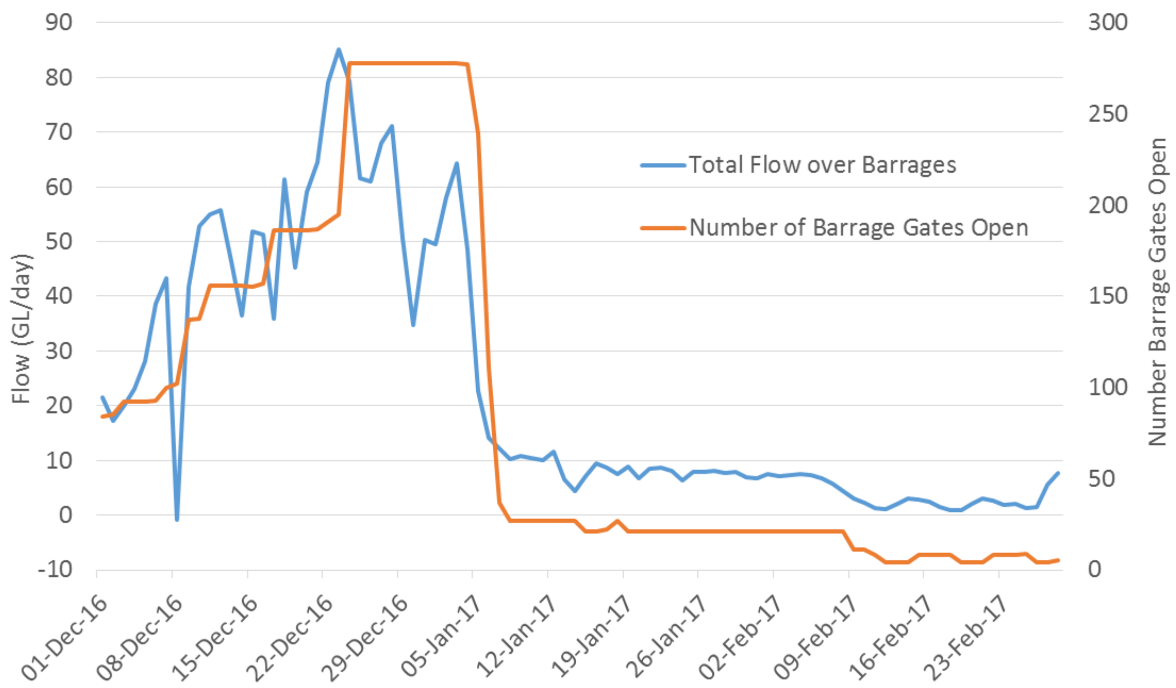

Figure 2: Total daily flow over the barrages (Adrienne Rumbelow, 2017, pers. comm., 12 May) and number of barrage gates open per day (Murray-Darling Basin Authority, 2017) from 1st December 2016 to 28th February 2017. Note that there is a difference in scale for the x-axis between Figure 1 (June 1st to Jan 31st) and Figure 2 (Dec 1st to Feb 28th).

healthy flowering event. Notably, most of the flower-heads that were counted on the surface in November and December 2016 were in their male phase.

Table 3: Assessment of flowering by *R. tuberosa* for various depths at Lake Cantara and selected sites in the Coorong where *R. tuberosa* is expected to perform well in November and December 2016. Data are the abundances of flower-heads (mean and standard error (s.e.)) per square metre, generally based on 20 1m x 1m quadrat samples, although values italicised indicate data were based on fewer than 10 samples.

Site	Depth (cm)	Mean (± s.e.) flower-heads per m^2	
		November	December
Lake Cantara	20	213.6 ± 30.1	did not sample
N02E	40	12.5 ± 3.5	25.8 ± 3.3
	60	*21.2 ± 4.0*	21.1 ± 3.1
S02E	40	*4.0 ± 1.2*	8.1 ± 1.0
	60	29.6 ± 4.6	30.2 ± 3.2
	80	*9.5 ± 1.5*	26.8 ± 2.5
S06E	40		14.7 ± 1.6
	60	7.3 ± 0.8	45.6 ± 3.5
S18E	20		3.2 ± 0.6
	40		11.8 ± 1.3
	60	7.9 ± 1.9	28.5 ± 2.8
S21E	40	did not sample	6.1 ± 2.0
	60		5.8 ± 1.2
S26E	20		*1.5 ± 0.3*
	40	*8.8 ± 3.8*	8.6 ± 1.4
	60	7.1 ± 1.3	32.4 ± 3.6
	80	*44.8 ± 11.3*	
S33E	40	#	3.8 ± 0.7
	60		18.2 ± 2.2
S36E	40		6.3 ± 1.3
	60		16.8 ± 4.0

N.B. When no value is provided in the table, the area at the depth was scouted for R. tuberosa flower-heads but either none were observed, or occurrences were rare. S41E was also sampled in November, but no flower-heads were observed.
Some plants flowering but impossible to sample due to gale-force winds.

4.2.2 Algae

Filamentous green algae (*Ulva* sp.) was present at every site with *R. tuberosa* during November and December 2016, sometimes causing a blanket cover when abundant (e.g., Figure 3) and interfering with flower-heads in either of two ways: (a) preventing flower-heads from reaching the surface; or (b) entangling around the flower-heads on the surface, in small to large amounts. The dense cover of algae also contributed to the difficulty in seeing and counting the flower-heads.

4.3 Distribution and abundance of *R. tuberosa* in the southern Coorong in January 2017

4.3.1 Vegetative Cover

Ruppia tuberosa shoots were detected at sites over a linear distance of 43 km from N02 to S41 (Table 4). Consequently, the extent of occurrence (EOO) for *R. tuberosa* within the southern Coorong was at least 43 km in January 2017, and the first of the four regional targets was met (Table 1). Similarly, the second regional target (concerning area of occupation – see Table 1) was also met, with *R. tuberosa* plants present at 89% of sites (16 out of 18 sites) within the EOO (Table 4). Twelve sites exceeded the local population scale target of 30% or more cover at one water depth at least (Table 4), while 13 sites had average densities of shoots that met or exceeded the local population scale target of 10 shoots per core at one water depth at least (Table 5). As greater shoot densities

Figure 3: Heavy algal loads at S02E, South Lagoon, Coorong, December 2016.

corresponded with sites that had greater *R. tuberosa* cover, there were also 12 out of the 16 sites with *R. tuberosa* present that had at least 30% cover *and* > 10 shoots per core at one water depth at least (Table 4 and Table 5), meaning that the third regional target of 50% of sites having vigorous populations of *R. tuberosa* was also met (Table 1).

Overall, there was an increase in the distribution and abundance of *R. tuberosa* cover in January 2017 compared with the previous three years (Figure 4). Of particular note was a reversal of the decreasing trend in cover of *R. tuberosa* over the previous three years in the northern half of the South Lagoon (Figure 4). The meeting of the regional targets and the improvement in cover and density compared with previous years is not unexpected, given that the water levels of the South Lagoon in spring and December 2016 were favourable for *R. tuberosa*, unlike previous years (Section 4.1). However, the western shoreline exhibited a greater rate of improvement in cover than the eastern shoreline, with two eastern sites continuing to have no *R. tuberosa* shoots and a further four eastern sites with less than 30% cover (Table 4; Figure 4). A possible explanation for the sites with limited *R. tuberosa* is the extent of exposure of the shoreline at these sites to prevailing north-west to south-west winds. The other sites along the eastern shoreline, where *R. tuberosa* performs better, have suitable headlands that dampen the extent of wave-induced disturbance caused by such winds. The western shoreline is similarly protected from these winds by Younghusband Peninsula, and winds from the opposite direction are not consistently strong.

Table 4: Percent of cores (75 mm diameter x 4 cm deep) with *R. tuberosa* shoots present taken at four water depths at 21 sites spread across the southern Coorong in January 2017. Data are based on 25 cores taken at each water depth at each site. If percent of cores with green shoots were different, they are shown in brackets.

Site	km from Mouth	East				West			
		dry	waterline	30cm	60cm	dry	waterline	30cm	60cm
N19	38		0	0	0				
N12	45		0	0	0				
N07	50			0	0				
N02	55	0	0	96	64				
S06	62		0	100	96		0	100	40 (32)
S11	67	0	0	0	0		0	92 (72)	100
S16	72	0	0	0	0			32 (20)	96
S21	77	0	0	0	12		0	100 (64)	100
S26	82	0	0	100 (56)	100		0	8	88
S31	87	0	0	0	4		0	0	68
S33	89			36	100				
S36	92		0	8	28		0	0	64
S41	97	0	0	0	12		0	40 (20)	100

Table 5: Mean numbers of *R. tuberosa* shoots present in cores (75 mm diameter x 4 cm deep) taken at four water depths at 21 sites spread across the southern Coorong in January 2017. 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	0	0				
N12	45		0	0	0				
N07	50			0	0				
N02	55	0	0	46.9	45.2				
S06	62		0	17.4	35.7		0	33.6	1.7
S11	67	0	0	0	0		0	10.9	34.6
S16	72	0	0	0	0			6.8	48.0
S21	77	0	0	0	2.2		0	31.6	67.1
S26	82	0	0	51.6	70.8		0	1.3	44.9
S31	87	0	0	0	0.3		0	0	32.2
S33	89			12.1	73.4				
S36	92		0	1.0	10.5		0	0	16.6
S41	97	0	0	0	2.7		0	5.4	44.6

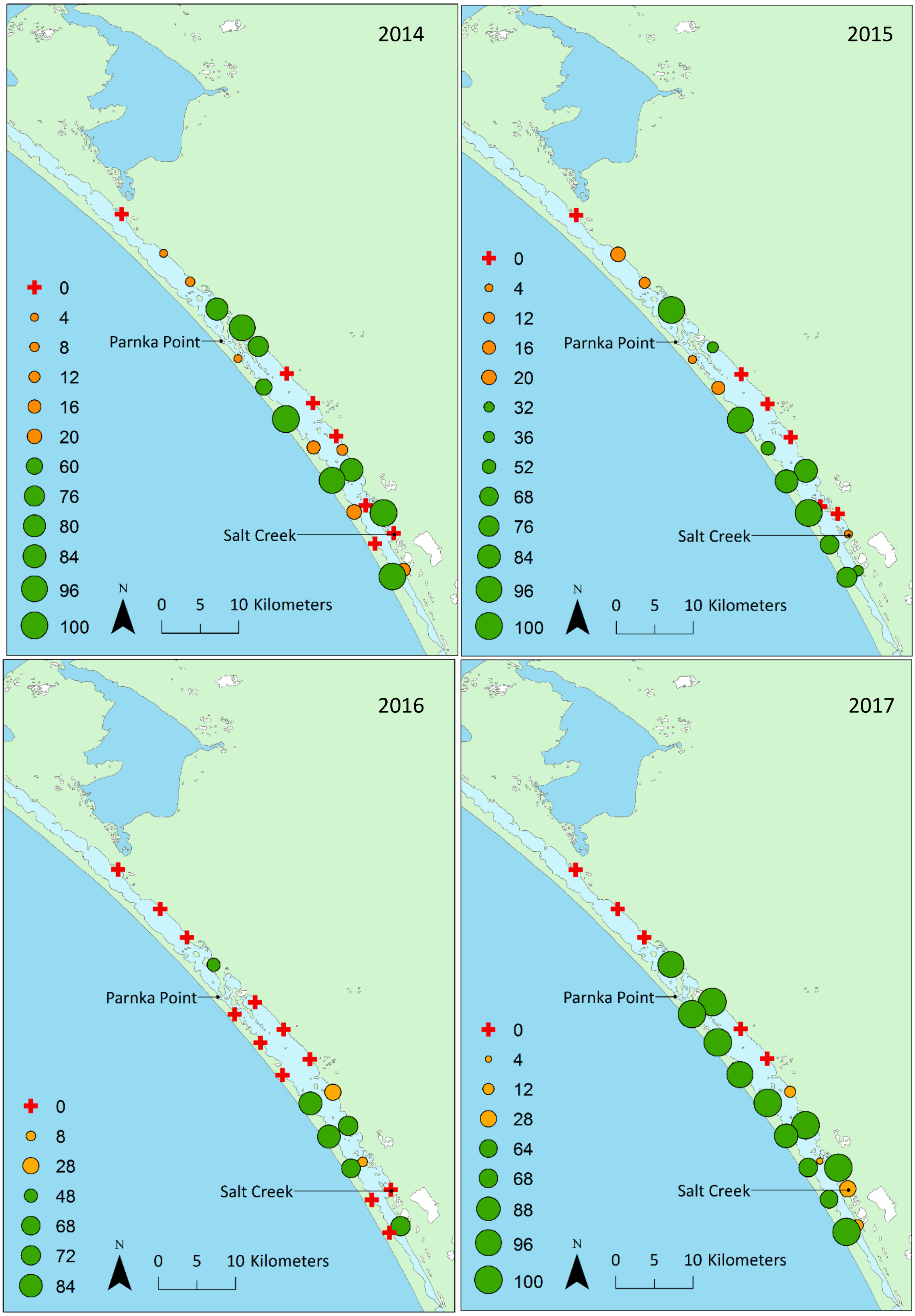

Figure 4: Changes in distribution and abundance of *R. tuberosa* along the Coorong in January 2014, 2015, 2016 and 2017. The data show the maximum percent of cores with *R. tuberosa* shoots for cores taken from sediments covered by 30 cm or 60 cm of water). Red spots show areas where there were no *R. tuberosa* 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 each Figure.

4.3.2 Turions

Propagules (or turions) of *R. tuberosa* were observed at 14 sites, although only nine sites exceeded the local population scale target of at least 50% of cores containing turions (Table 6). Furthermore, only three sites had cores with an average of >10 turions/core (Table 7). Consequently, the abundances of propagules (or turions) associated with *R. tuberosa* were generally low in January 2017. Furthermore, fully-developed turions (described as Type II by Brock 1982b) were only detected at three sites, so the majority of the propagules reported (Table 6) are partially-developed turions (described as Type I by Brock 1982b), which carry much smaller reserves than fully-developed turions and have limited capacity to survive any extended period of desiccation. Herein, fully-developed turions will be referred to as full turions, and partially-developed turions as half turions, with the use of the terms Type I and Type II turions avoided for clarity.

Sites with high abundances of turions tended to be the sites with large numbers of shoots and so the turion counts reflect the shoot data.

4.3.3 Seeds

Seeds of *R. tuberosa* were detected at 18 of the 21 sites sampled in January 2017 (Table 8). However, only eight of these sites met the local population scale target of more than 50% of cores containing seeds for at least one of the four sampling depths (Table 8). Furthermore, of the 18 sites with seeds detected, only one of these sites had > 8 seeds/core (≈ 2,000 seeds/m^2) and at 60cm only (S06W) (Table 9). Consequently, the fourth and final regional target (representing population resilience) of at least 2,000 seeds/m^2 at 50% of sites with *R. tuberosa* was not met (Table 1). This is particularly concerning, as even though the other three regional targets have been met in January 2017, the seedbank has once again failed to show signs of recovery. Without a reasonable seedbank, the ability of *R. tuberosa* to cope with long-term perturbations, such as a series of years with inadequate water levels in spring, in the future remains minimal.

4.3.4 Algae

In January 2017, high algal loads (e.g., Figure 3) persisted at all sites with *R. tuberosa*, at times forming a blanket cover. This is likely to have affected both the growth and reproduction of *R. tuberosa*.

Firstly, given that *R. tuberosa* in water deeper than 0.8m often shows signs of deterioration and this is likely due to limited light availability, then the presence of high algal loads in the water column above plants, may dampen the growth of plants by reducing light availability to an even greater extent.

Secondly, and more importantly for the future longevity of *R. tuberosa* in the southern Coorong, algae can considerably affect the reproductive cycle of *R. tuberosa*. The flowers of *R. tuberosa* are pollinated when on the surface of the water and, to do this, the inflorescences are produced at the tip of long, fine spiral peduncles. These peduncles enable the flower-head, with its two inflorescences, to stay on the surface of the water when flowering, first shedding pollen and then receiving pollen that is dispersed on the water surface. When present even in low levels, filamentous

Table 6: Percent of cores containing *R. tuberosa* turions across four water depths at 21 sites in the southern Coorong in January 2017. Data are based on 25 cores taken at each depth at each site. Sites and depths where the percent of cores with turions exceeded the target 50% are shown in red.

Site	km from Mouth	East				West			
		Dry	waterline	30cm	60cm	dry	waterline	30cm	60cm
N19	38		0	0	0				
N12	45		0	0	0				
N07	50			0	0				
N02	55	8	0	68	8				
S06	62		0	80	80		0	100	88
S11	67	0	0	0	0		0	76	92
S16	72	0	0	0	0			16	96
S21	77	0	0	0	0		0	84	92
S26	82	0	0	100	92		0	8	44
S31	87	0	0	0	0		0	0	40
S33	89			28	100				
S36	92		0	4	0		0	0	24
S41	97	0	0	0	4		0	32	88

Table 7: Mean number of turions per core (75 mm x 4 cm) across four water depths and at 21 sites within the southern Coorong in January 2017. 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. Sites and depths where there were >10 turions/core are shown in red.

Site	km from Mouth	East				West			
		dry	waterline	30cm	60cm	dry	waterline	30cm	60cm
N19	38		0	0	0				
N12	45		0	0	0				
N07	50			0	0				
N02	55	0.3	0	4.4	0.1				
S06	62		0	9.4	5.6		0	6.8	10.0
S11	67	0	0	0	0		0	14.5	7.4
S16	72	0	0	0	0			0.8	4.0
S21	77	0	0	0	0		0	12.0	6.2
S26	82	0	0	13.7	7.4		0	1.0	5.0
S31	87	0	0	0	0		0	0	3.8
S33	89			2.5	10.0				
S36	92		0	0	1.4		0	0	1.4
S41	97	0	0	0	0.1		0	0.8	8.1

Table 8: Percent of cores containing *R. tuberosa* seeds at 21 locations in the southern Coorong at four different water depths in January 2017. Data are based on 25 cores taken at each depth at each site. Sites and depths where the target of having at least 50% of cores with seeds are shown in red.

Site	km from Mouth	East				West			
		Dry	waterline	30cm	60cm	dry	waterline	30cm	60cm
N19	38		0	4	16				
N12	45		0	0	0				
N07	50			0	0				
N02	55	32	56	56	8				
S06	62		80	36	96		76	92	88
S11	67	20	8	0	4		48	40	52
S16	72	8	4	0	8			16	64
S21	77	16	28	16	56		4	48	4
S26	82	52	76	52	72		12	0	12
S31	87	0	4	4	0		4	4	4
S33	89			64	100				
S36	92		32	28	40		0	0	0
S41	97	8	0	32	40		4	0	0

Table 9: Mean number of *R. tuberosa* seeds per core (75 mm diameter x 4 cm deep) at 21 sites along the southern Coorong across four water depths in January 2017. Data are based on 25 cores taken at each depth at each site. To convert these data to seeds/m^2 multiply by 226. Sites and depths where > 8 seeds/core were detected are shown in red.

Site	km from Mouth	East				West			
		dry	waterline	30cm	60cm	dry	waterline	30cm	60cm
N19	38		0	0.04	0.24				
N12	45		0	0	0				
N07	50			0	0				
N02	55	1.00	0.88	5.20	0.12				
S06	62		2.28	2.40	3.24		4.40	3.36	9.96
S11	67	0.28	0.08	0	0.04		1.96	0.64	1.60
S16	72	0.16	0.04	0	0.16			0.40	1.60
S21	77	0.16	0.04	0.24	1.04		0.04	1.76	0.04
S26	82	1.20	2.08	0.96	1.88		0.12	0	0.36
S31	87	0	0.04	0.04	0		0.04	0.04	0.04
S33	89			1.68	4.08				
S36	92		1.24	0.44	0.84		0	0	0
S41	97	0.28	0	0.52	0.60		0.04	0	0

green algae readily attach to flower-heads increasing drag, such that the force of wave action snaps the peduncle and subsequent seed production is prevented. An extended period of time is needed on the surface, because of the protandrous nature of *R. tuberosa*, meaning the flower-heads function first as males and then as females. Consequently, there is an extended period of exposure to algal interference during the flowering process. Most of the flower-heads that were counted on the surface in November and December 2016 were in their male phase (Section 4.2.1), with small to large amounts of attached algae (Section 4.2.2). This suggests that female flowers had already been lost, because for pollination to occur, male and female flowers must both be present on the surface of the water. Furthermore, high algal loads can blanket *R. tuberosa* plants, preventing the floral spikes from even reaching the surface. Therefore, given the prominence of filamentous algae along the entire southern Coorong in 2016-17, and the extent to which filamentous algae interferes with ability of *R. tuberosa* to produce seeds, the lack of significant seed production (Section 4.3.2) was not unsurprising.

4.3.5 Galls

In January 2017, and for the first time, small rounded swellings on the rhizomes of *R. tuberosa* (known as galls or tubercles) were observed in a total of 71 cores (16% of cores with *R. tuberosa*) at 10 sites (63% of sites with *R. tuberosa*), ranging from N02 to S41. For cores with galls, there were 2.9 galls per core on average, although cores ranged from 1 to 19 galls. These galls are believed to be a pathological response to the fungus *Tetramyxa parasitica* Goebel, as described by Brock (1982b).

4.3.6 Extent of grazing on R. tuberosa

Grazing was moderate at many sites in January 2017, with an overall average of 57% of shoots being grazed across the sampling sites. On average, grazed shoots were around 1.2 cm in length, while ungrazed shoots were around 4.4 cm in length (Table 10). These levels of grazing were lower than in previous years where over 80% of shoots were grazed (e.g. Paton *et al.* 2016d). The lower levels of grazing in January 2017 are likely to be indicative of an increase in the availability of food (*R. tuberosa* plant material and turions) to herbivorous waterfowl (ducks and swan). However, the high algal loads (Section 4.3.4) could also have reduced the grazing level, as waterfowl may not have been able to access the plants growing on the bottom through the algae.

4.4 Changes in seed abundances along the Coorong 2011-2017

The abundances of seeds detected in sediment cores in January 2017 were similar to the abundances of seeds detected in January in each of the six previous years (Table 11). However, this is inconsistent with an improvement in flowering of *R. tuberosa* in the Coorong in November and December 2016 compared with previous years (Section 4.2.1). Given the relatively good level of flowering this season (Table 3), the quantities of seeds produced per square metre should have resulted in a measurable increase in seed abundances during the January sampling. A square metre with 50 flower-heads should produce in the order of 1000 seeds because a flower-head of *R. tuberosa* contains two inflorescences, each with the potential to produce 2-19 carpels (11 on average) (Brock 1982a). If such a level of productivity had been secured by *R. tuberosa* this season, then cores in January 2017 should have contained around 5 seeds, rather than less than 1 seed per core found at most sites (Table 11). As discussed in Section 4.3.4, failure of the plants to set

Table 10: Grazing levels and shoot lengths for *R. tuberosa* in the Coorong in January 2017. Grazing levels (% of shoots in a core that had been grazed) and lengths of shoots that had been grazed and ungrazed for locations along the southern Coorong are shown for each site.

Site	# cores with *R. tuberosa* shoots	Mean % grazed	Mean shoot length (cm)	
			Grazed	Ungrazed
N02E	40	67	1.6	4.7
S06E	49	61	1.6	4.1
S06W	35	41	1.3	3.9
S11W	48	2	2.0	5.1
S16W	32	80	1.2	5.1
S21E	3	57	1.2	3.8
S21W	50	77	1.1	4.3
S26E	50	73	1.0	4.7
S26W	24	50	1.1	4.3
S31W	17	59	0.9	3.7
S33E	34	33	1.4	4.9
S36E	9	52	1.3	4.1
S36W	16	42	1.0	3.5
S41E	3	58	1.2	3.3
S41W	35	90	0.8	3.3
Overall	**446**	**57**	**1.2**	**4.4**

Table 11: Abundances of *R. tuberosa* seeds (seeds per core) found in sediments at 12 sites along the eastern shore of the southern Coorong in January from 2011 to 2017. 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. To convert these data to seeds/m^2 multiply by 226.

Site	km from Mouth	January 2011	January 2012	January 2013	January 2014	January 2015	January 2016	January 2017
N19	38	0.00 ± 0.00	0.19 ± 0.07	0.01 ± 0.01	0.08 ± 0.03	0.12 ± 0.03	0.14 ± 0.05	0.09 ± 0.04
N12	45	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.03 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
N07	50	0.17 ± 0.05	0.29 ± 0.20	0.12 ± 0.04	0.78 ± 0.16	4.07 ± 1.58	0.37 ± 0.09	0.00 ± 0.00
N02	55	1.39 ± 0.22	0.27 ± 0.08	0.43 ± 0.10	1.68 ± 0.20	1.01 ± 0.19	1.90 ± 0.40	1.80 ± 0.52
S06	62	3.48 ± 0.68	1.13 ± 0.33	0.60 ± 0.19	1.03 ± 0.20	1.58 ± 0.32	5.79 ± 1.10	2.64 ± 0.46
S11	67	1.09 ± 0.38	0.10 ± 0.04	0.23 ± 0.07	0.17 ± 0.07	0.27 ± 0.08	0.33 ± 0.08	0.10 ± 0.04
S16	72	0.01 ± 0.01	0.03 ± 0.02	0.00 ± 0.00	0.10 ± 0.06	0.28 ± 0.24	0.10 ± 0.04	0.09 ± 0.05
S21	77	0.05 ± 0.04	0.07 ± 0.05	0.02 ± 0.01	0.52 ± 0.11	0.46 ± 0.25	0.18 ± 0.06	0.43 ± 0.08
S26	82	0.12 ± 0.05	1.35 ± 0.47	1.16 ± 0.35	1.72 ± 0.33	0.76 ± 0.14	2.75 ± 0.42	1.53 ± 0.2
S31	87	0.00 ± 0.00	0.00 ± 0.00	0.09 ± 0.04	0.04 ± 0.03	0.00 ± 0.00	0.01 ± 0.01	0.02 ± 0.01
S36	92	0.08 ± 0.04	0.18 ± 0.07	0.46 ± 0.29	0.49 ± 0.15	0.28 ± 0.10	0.35 ± 0.10	0.84 ± 0.21
S41	97	0.19 ± 0.07	0.57 ± 0.14	0.56 ± 0.11	1.58 ± 0.84	1.25 ± 0.17	2.27 ± 0.45	0.35 ± 0.09

significant numbers of seeds, despite producing many more floral-heads than in previous years, is likely due to interference from high algal loads.

4.5 Status of *R. tuberosa* in the southern Coorong for January 2017

Table 12 provides summary statistics for the status of *R. tuberosa* in January 2017 (including November and December 2016) and the previous six years, and against the stated benchmarks for a healthy and resilient *R. tuberosa* system. *Ruppia tuberosa* was least prominent in January 2012, when shoots of *R. tuberosa* were found at only one site (Table 12). Over the next three years, *R. tuberosa* increased in prominence; however, in 2016, *R. tuberosa* suffered an overall decline within the Coorong. In January 2017, this decline was reversed to some extent, with the first three regional targets met and the first two local population targets met (Table 12). However, given that these targets all relate to plant cover and abundance, *R. tuberosa* still performed poorly against targets for flowering, turions and seeds in January 2017. Therefore, while there were considerable immediate benefits of increased *R. tuberosa* cover, such as providing food for herbivorous waterfowl from spring 2016 through summer 2017, any considerable long-standing benefit in the future is unlikely to arise. Most importantly, the abundances of seeds at all sites and depths (Table 8, Table 9 and Table 11) were well below the levels needed for some level of resilience.

Table 12: Extent of occurrence, area of occupation and prominence of *R. tuberosa* at sites across the southern Coorong in January from 2011-2017. Flowering levels were assessed in the preceding Nov-Dec period in each year. The target values for a healthy and resilient system for *R. tuberosa* are also given. Where targets were met, they are shown in red.

Performance Indicator	Target	Year						
		2011	2012	2013	2014	2015	2016	2017
		# sites sampled						
		13	12	21	23	21	21	21
REGIONAL SCALE								
R.1. Extent of Occurrence (km, main region)	43	22	1	43 (53*)	43 (60*)	43 (53*)	43	43
R.2. Area of Occupation (% sites with *R. tuberosa* shoots)	80	31	8	57	73	76	48	89
R.3. Population vigour (% sites with *R. tuberosa* present that have > 30% cover and > 10 shoots/core)	50	15	0	5	39	29	5	75
R.4. Population resilience (% sites with *R. tuberosa* present that have > ≈ 8 seeds/core)	50	8	0	0	0	10	5	6
SITE SCALE								
L.1. % sites with > 30% cover (cores) with shoots	50	15	0	24	39	52	33	57
L.2. % sites with > 10 shoots/core for one depth	50	23	0	5	39	29	5	62
L.3. % sites with > 50 flower-heads/m^2	50	0	0	0	0#	0	0	0
L.4. % sites with > 50% cores with seeds at one depth	50	15	17	24	53	52	38	38
L.5. % sites with > 50% cores with turions at one depth	50	0	0	0	23	26	52	43

*extent of occurrence with outliers; #evidence of flower production noted for at least five sites in December 2013 when fewer than 10 sites examined but no sites would have exceeded 50 flower-heads/m^2.

5 General Discussion and Conclusions

While the first three of four regional targets set for healthy and resilient populations of *R. tuberosa* in the southern Coorong were met in January 2017, the on-going lack of an adequate seed bank, and hence population resilience within the system, is still a major concern. As far as local site targets are concerned, two of the five targets were reached in January 2017 (Table 12), and one of the two quantified environmental outcomes of the Basin Wide Environmental Watering Strategy (Section 2). However, like the regional targets, these targets related to the cover and abundance of plants, and do not reflect the ability of *R. tuberosa* to sustain this increased cover and abundance much beyond this particular annual growing season. The ability of this plant to complete its reproductive cycle, and so secure future resilience, is still limited, which is reflected by not meeting the local targets for flowering, seeds and turions in January 2017 (Table 12). Furthermore, and as in previous years (Paton *et al.*, 2016a,d), the predominant turions were the smaller half turions (type I of Brock 1982b), which carry much smaller reserves than full turions (type II of Brock 1982b) and have limited capacity to survive any extended period of desiccation.

As has been stated previously, the key factor contributing to the slow recovery of *R. tuberosa* in recent years (Table 12) has been the inability to maintain water levels in the southern Coorong over spring (Paton *et al.* 2016a,b,d,e). The maintenance of adequate water levels through spring 2016, maintained the growth of plants and allowed substantial production of flowers. This confirms that inadequate water levels in other years were limiting the ability of the plant to grow and flower, thus preventing the recovery of *R. tuberosa* in the southern Coorong. As such, the performance of *R. tuberosa* in November and December 2016 provides "proof of concept" that the performance of *R. tuberosa* will be enhanced if water levels can be maintained through spring and into summer.

However, the maintenance of adequate water levels through spring and into summer in itself may not be all that is required. There may also be a need to dampen the rate at which water levels drop because a rapid and unnatural drop in water levels is likely to result in plants having insufficient time prior to desiccation to respond by transferring resources into asexual propagules (turions). Only low levels of turions were present in January 2017 when sampling was undertaken (Table 6 and Table 7), with any additional turion production highly unlikely, given the dramatic drop in water levels of around 0.6m during January (Figure 1). Under more natural and lower rates of water level change (comparable to evaporative losses), the plants would have had time to sequester resources into more turions before desiccation, improving the ability of the plants to re-establish next season. Consequently, there is a need to address rapidly falling water levels in the southern Coorong. Currently, the only option to slow water leaving the southern Coorong is to change the operating rules and constraints to allow the delivery of environmental water at appropriate times to benefit the South Lagoon of the Coorong, for example by reducing the rate of barrage gate closure. However, the critical issue is that due to inadequate flows, barrage gates in recent years have been closed in spring before *R. tuberosa* can reproduce. In the future, even when the Murray-Darling Basin Plan is fully implemented, flows over the barrages are unlikely to be adequate to maintain water levels. Consequently, a barrier across the Coorong, to slow water leaving the southern

Coorong when barrage gates are closed, will be required to improve conditions for *R. tuberosa* in most years.

The findings in this report also highlight a further problem to the recovery of *R. tuberosa* in the southern Coorong: filamentous green algae. In November and December 2016, most of the *R. tuberosa* beds were heavily covered in algae (e.g., Figure 3), with the algae interfering with both the growth, flowering and seed production of the plants. Enhanced algal interference was expected in spring and summer of 2016-2017, due to the salinities in the southern Coorong being lower than in previous years due in part to increased flows over the barrages throughout spring and into summer. Although salinities were lower in the southern Coorong (from N02-S41), ranging from 58-82 gL^{-1} in summer 2017 (Paton *et al.* 2017), they remained largely within the target range of 60-100 gL^{-1} for *R. tuberosa*. Salinities below this range have been assumed to favour growth of filamentous green algae. Given the extent and prominence of filamentous algae in the southern Coorong in January 2017 at salinities within the bottom half of the targeted salinity range for *R. tuberosa,* the targeted salinity range may need to be adjusted upwards with the lower salinity threshold set at 80 gL^{-1}. Further work is clearly required to determine how the performance of filamentous algae is influenced by salinity and the extent to which its growth is limited at salinities on or above 80 gL^{-1}. Strategies that dampen interference from filamentous algae will also be needed to secure the recovery of *R. tuberosa* across the southern Coorong. Precautionary measures to prevent exacerbation of the current problem should include prevention of influxes of fresh water into the southern Coorong, as these will reduce salinity and may carry nutrients. Lower salinities and increased availability of nutrients will favour algal growth. However, the greatly improved performance of *R. tuberosa* in 2016-17 demonstrates the importance of maintaining adequate water levels through spring as the most critical first step to ensuring good growth and flowering of *R. tuberosa*.

The higher water levels and prominence of algae around the southern Coorong in 2016-17 is likely to have caused issues for other biota, for example, by restricting the availability and access to mudflats for shorebirds. With higher water levels, suitable mudflats for shorebirds are less available, and any mudflats that were available in January 2017, were largely covered with a dense layer of algae that had been washed ashore. In many areas, this layer was several centimetres thick. These thick blankets of algae prevented shorebirds from accessing benthic surface-dwelling invertebrates, like chironomid larvae, as well as seeds and turions of *R. tuberosa*, which are also components of their diet (e.g., Paton 1986). Thus, if the algal loads in the southern Coorong are not addressed and continue to recur, then shorebirds may struggle to secure the food they need, not only because the algae reduces the resource base of seeds and turions of *R. tuberosa*, but also because the algae prohibits the ability of the shorebirds to reach whatever resource base is present. If the cover of filamentous algae is prominent, the habitat quality of the southern Coorong for shorebirds is much diminished. This was reflected in low numbers of small shorebirds during the annual waterbird census of January 2017, with both Red-necked Stint (*Calidris ruficollis*) and Sharp-tailed Sandpipers (*Calidris acuminate*) registering their lowest abundances for the past 18 years (Paton *et al.* 2017).

The presence of galls on R. tuberosa, believed to be a response to the parasitic fungus, *T. parasitica,* in the southern Coorong for the first time is also a potential cause for concern, because this parasite is known to reduce the growth of the host plant and probably reduce the formation of inflorescences (Neuhauser *et al.* 2011). Furthermore, in marine systems, parasitic fungi have been flagged as potential agents to spread viruses that may have further ramifications for plants (Neuhauser *et al.* 2011). However, *R. tuberosa* plants with galls showed no signs of ill-health, as might be expected in a balanced plant-parasite relationship. Although, continued monitoring would be prudent, in case of deterioration of the health of *R. tuberosa*.

The findings from this report illustrates (a) how interference from filamentous algae dampens the recovery of *R. tuberosa* in the southern Coorong, and (b) how important maintaining water levels in the southern Coorong in spring is for *R. tuberosa*. So, a new challenge is now apparent, which is to prevent the interference caused by filamentous green algae to the productivity of this plant, which ultimately affects its capacity for future resilience in the southern Coorong. At present there are no simple solutions for dampening the impact of filamentous algae. Harvesting algae might ultimately assist in reducing algal impacts, because this has the potential to remove some of the nutrients, but further work is required to determine if there are feasible methods to achieve this. At the very least, as a precautionary measure, influxes of freshwater into the southern lagoon that will lower salinity and potentially increase nutrient loads should cease. Ultimately, the findings of this report confirm findings from previous reports that falling water levels in spring is the critical issue that first needs to be addressed, as these falling water levels reduce the time available for plants to establish, grow and reproduce (Paton *et al.* 2016a,d). The only option currently available to dampen rates of water level change in the southern Coorong is to adjust the rates at which barrage gates are closed. However, given that flows over the barrages in the future are unlikely to be adequate to maintain water levels in spring, even when the Murray-Darling Basin Plan is fully implemented, alternatives, such as a barrier across the middle of the Coorong to reduce the rate at which water levels drop in the southern Coorong over spring, should be implemented. There is added motivation to act because many of the waterbirds that use the southern Coorong over summer depend on *R. tuberosa*, either directly or indirectly, for food.

6 Acknowledgments

The 2016-17 work was commissioned and funded by the Murray-Darling Basin Authority. Funding for this work in 2015-16 was part of the South Australian Government's Murray Futures' program, funded by the Australian Government's *Water for the Future* initiative, while funding from 2012 to 2015 was through *The Living Murray* initiative, with funding provided by the Murray-Darling Basin Authority. Donna Belder, Tom Bradley, Tom Hunt, Grace Hodder, Emily Hoffmann, Hayley Merigot, Victoria McCarron, Casey O'Brien, Hannah Bannister, Kimberley McCallum, Alexander Harland, Katherine Hill, Michelle Sargent, Alastair Wood and Stephanie Fisher provided able field assistance. The research was conducted under a DEWNR wildlife research permit issued to David Paton.

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8 Appendix A

Figure 5: Map of the Coorong showing sites used to sample *Ruppia tuberosa* during January 2017 (yellow dots) and to assess *Ruppia tuberosa* flowering during November and December 2016 (some yellow dots and orange dots). Codes for sites have been indicated.