Monitoring of *Ruppia tuberosa* in the southern Coorong, summer 2015-16.

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June 2016

This report may be cited as:

Paton, DC, Paton, FL and Bailey, CP 2016. Monitoring of *Ruppia tuberosa* in the southern Coorong, summer 2015-16. (University of Adelaide, Adelaide).

Cover Image: *Ruppia tuberosa* shoots smothered in salt crystals, Gemini Downs Bay, South Lagoon, Coorong, January 2016 (F. Paton).

Executive Summary

The distribution and abundance of *Ruppia tuberosa* in the southern Coorong in January 2016 was lower than in the previous year, indicating some deterioration rather than any further recovery. The extent of occurrence of *R. tuberosa* plants in January 2016, measured as the length of the southern Coorong over which *R. tuberosa* was found, was 43 km. This was the only regional target met in January 2016. This regional target was also met in the previous three years. In January 2016, only 48% of the sites sampled supported *R. tuberosa* plants, lower than the 73% and 76% in the previous two years, and well below the regional target of having at least 80% of sites supporting *R. tuberosa* plants. Furthermore, only 5% of the sites had vigorous populations of *R. tuberosa* with > 30% cover and > 10 shoots/core at one sampling depth, well short of the 50% target. Similarly, only one of the 21 sites had > 8 seeds/core (~2000 seeds/m^2) and then only at a single water depth. This was also well short of the 50% of sites required to meet this initial resilience target. However, in January 2016, 50% of sites reached the target for turions for the first time, albeit only for the smaller Type I turions. The Type I turions present in January 2016 were also smaller than in previous years and some that had been exposed to desiccation already were discoloured , suggesting they may have limited capacity to survive extended periods of exposure to desiccation. Flowering in spring was again poor with only 4 of 11 sites examined producing any flowers, with a maximum of 2.5 intact flower-heads (inflorescences) per square metre, well short of the 50 flower-heads/m^2 sought.

The on-going poor performance of *R. tuberosa* in the southern Coorong was attributed to falling water levels in spring 2015, as has been the case in recent years. In spring 2015, water levels in the southern Coorong not only fell earlier than previous years, but they also reached much lower absolute levels than in recent years. These lower water levels were likely to strand more plants, seeds and turions out of the water and expose them to desiccation. Small Type I turions may have had limited capacity to cope with extended exposures because of their small size. Interference from filamentous green algae (*Ulva* sp.) and heavy grazing are also likely to have further dampened the rate of recovery of *R. tuberosa* in the southern Coorong. The prognosis of establishing healthy and resilient populations of *R. tuberosa* in the southern Coorong in the foreseeable future remains poor unless falling water levels in spring are addressed.

Table of Contents

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.

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 with water levels usually being lowest in autumn and highest in early spring. 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).

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, *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.

Since the return of freshwater flows to the region, the recovery of *R. tuberosa* in the South Lagoon has been slow (Paton & Bailey 2012, 2013a, 2013b; Paton *et al.* 2015a, 2016a,b), and 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 has been limited improvement since (Paton & Bailey 2013a,b; Paton *et al.* 2015a; 2016a,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 *R. tuberosa* throughout most of the South Lagoon (Paton & Bailey 2012, 2013a, 2013b; Paton *et al*. 2015a; 2016a,b). 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 2016 but includes some observations made on flowering levels conducted in November 2015. 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 (distribution) 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 future population resilience target for 2019). The 50 km extent of occurrence 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 target for population resilience 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
<u>REGIONAL SCALE</u>	
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)
<u>LOCAL SCALE</u>	
L.1 Population cover	At least 30% cover in winter and in summer
L.2 Population (shoot) density	At least 10 shoots per core (75 mm diam) for cores with *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
<u>FUTURE RESILIENCE</u>	
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))

3 Methods

3.1 Assessment of flowering levels

Assessment of flowering activity was undertaken on 14 November 2015, when 11 sites on the eastern side of the Coorong were visited (Table 2). For those sites where there were *R. tuberosa* plants present, an assessment was made as to whether those 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 (*Ulva* sp.). Assessments of flowering were made by counting the number of flower-heads produced in 1 m x 1 m quadrats. Twenty of these quadrats were placed approximately every 2 m along a transect line that ran parallel to the shoreline at one of three water depths (0.2, 0.4 and 0.6 m). As the water was turbid, assessments in the deeper water involved sampling material in the water column with hands to detect those flower-heads that were on short floral stalks and were still extending. For each quadrat, the presence of *R. tuberosa* was also scored, as were the level of any grazing and the cover of filamentous algae in three categories: none, light or heavy.

3.2 Distribution and abundance of *R. tuberosa* in the southern Coorong in January 2016

The main assessment of the distribution and abundance of *R. tuberosa* in the southern Coorong was conducted in January 2016, in line with the timing of monitoring in previous years.

During January 2016, the abundance and reproductive activity of *R. tuberosa* was assessed at eight sites on the eastern side of the South Lagoon pf the Coorong, and eight sites on the western side of the South Lagoon (Table 2). These sites were spread along the shoreline at intervals of approximately 5 km. 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 (Table 2). These were sites where *R. tuberosa* was recorded in recent years (i.e., 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 experienced reduced water levels.

Table 2: Location details for sampling sites used for assessing the distribution and abundance of *R. tuberosa* in January 2015. The table provides the average easting and northing of the sampling depths at each site.

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. Water levels in January 2016 were extremely low and at several sites the sediments in areas covered with 60 cm of water were not consolidated. In these situations, core samples could not be taken because the soft mud could not be held within the corer. These unconsolidated muds were often extended for 50 cm or more below the surface of the sediment. Also, since the Gemini Downs Bay (S33E) was completely dry in January 2016, only a single set of 25 core samples was taken in the centre of the bay at this site.

4 Results

4.1 Water levels in the southern Coorong in spring 2015

In winter 2015, water levels in the southern Coorong were around 0.25-0.65 m AHD but fell substantially in late August 2015 to about 0.2 m AHD (Figure 1). This trajectory of falling water levels was similar to 2014. However, in 2015, water levels continued to steadily decline over the next three months and consistently lower than the previous five years by 10-20 cm (Figure 1)., By the end of spring 2015 water levels in the southern Coorong were around -0.1 m AHD. By comparison, in the preceding four years, -0.1 m AHD was only reached in mid-late January, while in 2010, water levels remained above 0.2 m AHD (Figure 1). Most of the *R. tuberosa* beds that establish in winter are centred around the 0.0 to 0.2 m AHD contour. Given that *Ruppia* plants need 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. For the last five years this 0.3 m AHD threshold has been breached either at the beginning of spring (2014, 2015) or towards the end of spring (2011-2013) (Figure 1). Thus, the last five years are likely to have been poor years for *R. tuberosa* in the southern Coorong, with spring 2015 being particularly poor.

4.2 Assessment of flowering levels December 2015

In November 2015, evidence of flowering was detected at just four of the eleven sites examined, with the levels of flowering generally poor. Site S02E (Parnka Point) had the highest floral densities, with an average density of just 2.45 intact inflorescences/m^2 (Table 3). At this site, 70-75% of the quadrats had flower-heads, albeit in small numbers (Table 3). Other sites had at best 35% of the quadrats with at least 1 flower-head. The bay opposite Gemini Downs (S33E) produced no flowers in spring 2015, despite flowering in the previous two years with as many as 47 flower-heads produced per square metre in 2013 (Paton & Bailey 2014; Paton *et al.* 2016a). As in previous years, the cover of filamentous algae at most sites was extremely high, smothering plants and attaching to flower-heads. However, at two sites, the density of algae was lower at some water depths. Although, areas with lower levels of algae usually suffered high levels of herbivory, suggesting that the reduced levels of algae may have allowed herbivorous waterfowl to access the plants. Alternatively, much of the algae may have been removed or dislodged by waterfowl when the birds were grazing on the plants. However, at one site, there was a low density of algae and no grazing, suggesting the former explanation is more likely.

4.3 Distribution and abundance of *R. tuberosa* in the southern Coorong in January 2016

Summary statistics for the presence of *R. tuberosa* plants across the 21 sampling sites are provided in Table 4 and Table 5. *Ruppia tuberosa* shoots were detected at 10 sites but, for two of these sites, the shoots were present only at the water line, where they were unlikely to survive due to desiccation when exposed to air (Table 4). In fact, at one of these sites (S06E), no green shoots were detected (Table 4), suggesting that *R. tuberosa* plants had already perished at this depth. Sites with *R. tuberosa* were spread over a linear distance of 43 km from N02 to S41, thus the extent of occurrence for *R. tuberosa* within the main region used in the southern Coorong was at least 43 km in January 2016 (Table 4). However, there were no green shoots observed at S41E, so for records of

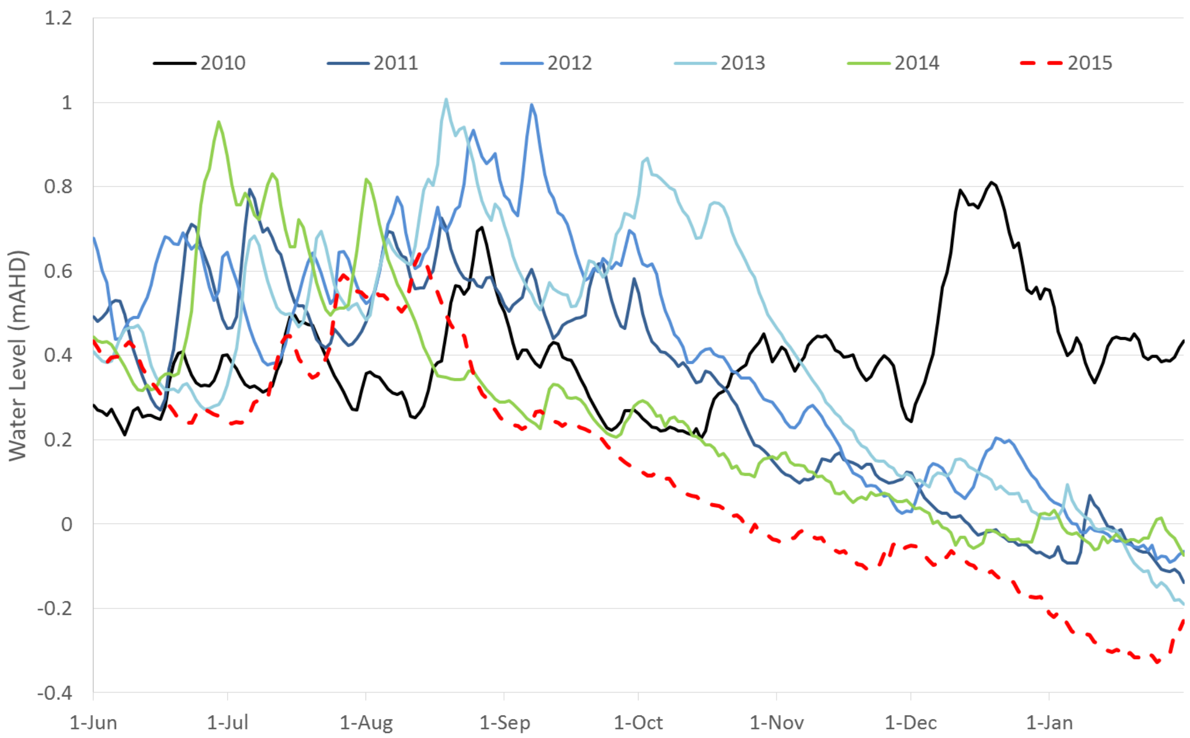

Figure 1: Changes in average water levels (m AHD) for the South Lagoon for 2010 to 2015 for the period June 1st to January 31st of the following year. Data are mean levels reported from three telemetered stations in the South Lagoon (NW Snipe Island, near Woods Well and Parnka Point) (Government of South Australia, 2016).

Table 3: Assessment of flowering by *R. tuberosa* at selected sites in mid-November 2015. Data are the percent of quadrats that had evidence of sexual reproduction (floral stalks, inflorescences), while the abundance of stalks and inflorescences are means ± s.e. for 20 1 m x 1 m quadrats. The difference between the number of stalks and the number of inflorescences reflects the number of floral stalks that have been stripped of their inflorescences. Only sites where *R. tuberosa* plants were detected are shown in the table.

Site	Water depth (cm)	% quadrats with *R. tuberosa*	% quadrats with flowering *R. tuberosa*	Stalks per m^2	Inflorescences per m^2	Algal loads	Grazing
N02E	20	100	0	0.0± 0.0	0.0 ± 0.0	heavy	
N02E	40	100	35	0.45 ± 0.17	0.45 ± 0.17	heavy	
N02E	60	85	0	0.0± 0.0	0.0± 0.0	light	heavy
S02E	20	100	70	1.30 ± 0.32	1.20 ± 0.31	heavy	
S02E	40	100	75	2.95 ± 0.62	2.45 ± 0.52	heavy	
S06E	20	100	10	0.20 ± 0.09	0.10 ± 0.07	heavy	
S06E	40	10	0	0.0 ± 0.0	0.0 ± 0.0	heavy	
S26E	20	100	0	0.0 ± 0.0	0.0 ± 0.0	light	heavy
S26E	40	100	35	1.20 ± 0.62	0.55 ± 0.23	light	

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 2016. Data are based on 25 cores taken at each water depth at each site. Bracketed values are percent of cores with green *R. tuberosa* shoots present.

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	0				
N07	50	0	0	0	0				
N02	55	0	0	48	48				
S06	62	0	84 (0)	0		0	0	0	
S11	67	0	0	0	0	0	0	0	
S16	72	0	0	0	0	0	4	0	0
S21	77	0	0	8	28	0	0	84 (20)	4 (4)
S26	82	0	0	72 (32)		0	0	84 (12)	
S31	87	0	0	0	8	0	0	24 (16)	68 (64)
S33	89	0							
S36	92	0	0	0	0	0	0	0	
S41	97	0	0	72 (0)		0	0		

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 2016. 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	0				
N12	45	0	0	0	0				
N07	50	0	0	0	0				
N02	55	0	0	4.1	10.3				
S06	62	0	10.0	0		0	0	0	
S11	67	0	0	0	0	0	0	0	
S16	72	0	0	0	0	0	0.2	0	0
S21	77	0	0	2.1	8.8	0	0	16.4	0.3
S26	82	0	0	15.0		0	0	8.2	
S31	87	0	0	0	0.8	0	0	7.7	31.8
S33	89	0							
S36	92	0	0	0	0	0	0	0	
S41	97	0	0	19.9		0	0		

live *R. tuberosa* plants, the extent of occurrence was only 33 km in January 2016 (Table 4). Six sites had average densities of shoots that met or exceeded the targeted 10 shoots per core at one water depth at least (Table 5), although two of these sites had no green shoots. The greater shoot densities coincided with sites that had greater *R. tuberosa* cover, such that 29% of sites had at least 30% cover and > 10 shoots per core at one water depth at least (Table 4 and Table 5). However, only 14% of sites had at least 30% cover of green shoots and > 10 shoots per core at one water depth at least (Table 4 and Table 5).

There was a decline in the distribution and abundance of *R. tuberosa* in January 2016 compared with January 2015. Although *R. tuberosa* increased its cover at four sites and retained its cover at a further site, it suffered a decrease in cover at 12 sites (Figure 2). Three sites continued to have no *R. tuberosa* shoots. In January 2016, *R. tuberosa* was mainly confined to the southern half of the South Lagoon. In previous years, sites with and without *R. tuberosa* shoots at 30cm and 60cm depth were intermingled along the Coorong (Figure 2). Given that salinities in the South Lagoon were: (a) greater than the North Lagoon; (b) relatively consistent at a point in time; and (c) relatively high in January 2016, ranging between 125 gL^{-1} and 147 gL^{-1} (Paton *et al.*, 2016c), factors other than salinity were likely to be affecting the establishment and maintenance of *R. tuberosa* in January 2016. These include: (a) the extremely low water levels through spring leading to greater exposure of the mudflats, (b) the bathymetry of a site and hence the amount of suitable mudflat that remained when water levels were extremely low; and (c) the presence and maintenance of viable propagules in the sediments that were still covered with water in January 2016.

As illustrated by the data in Table 6 and Table 7, the abundances of propagules (or turions) associated with these plants were generally low in January 2016. Furthermore, no Type II turions were detected in January 2016 and so only the prominence of Type I turions are presented. Type I turions carry much smaller reserves than Type II turions and have limited capacity to survive any extended period of desiccation. Additionally, most of the Type I turions observed in January 2016 were smaller than usual, reflecting an even greater limitation of the plant's capacity to store resources and survive desiccation. Furthermore, many of those detected on the exposed mudflats were discoloured, suggesting their viability may have already been compromised by extended exposure. Type I turions, however, were detected in cores at 16 sites (Table 6) and abundances in excess of 10 Type I turions per core were detected at seven sites (Table 7). Just over half the sites met the target that 50% of cores taken across the *R. tuberosa* beds in late summer should contain turions (Table 6). Sites with high abundances of shoots tended to be the sites with large numbers of Type I turions and so the turion counts reflect the shoot data.

Table 8 and Table 9 provide summary statistics for the presence and abundances of *R. tuberosa* seeds at the 21 sampling sites in January 2016. For eight sites, more than 50% of the cores contained seeds for at least one of the four sampling depths (Table 8). Seven of these eight sites had at least 2 seeds/core at one of the depths and one of these sites had more than 8 seeds/core (S06E), which was on the dry mudflat (Table 9). None of the other 13 sites surpassed 2 seeds/core at any sampling

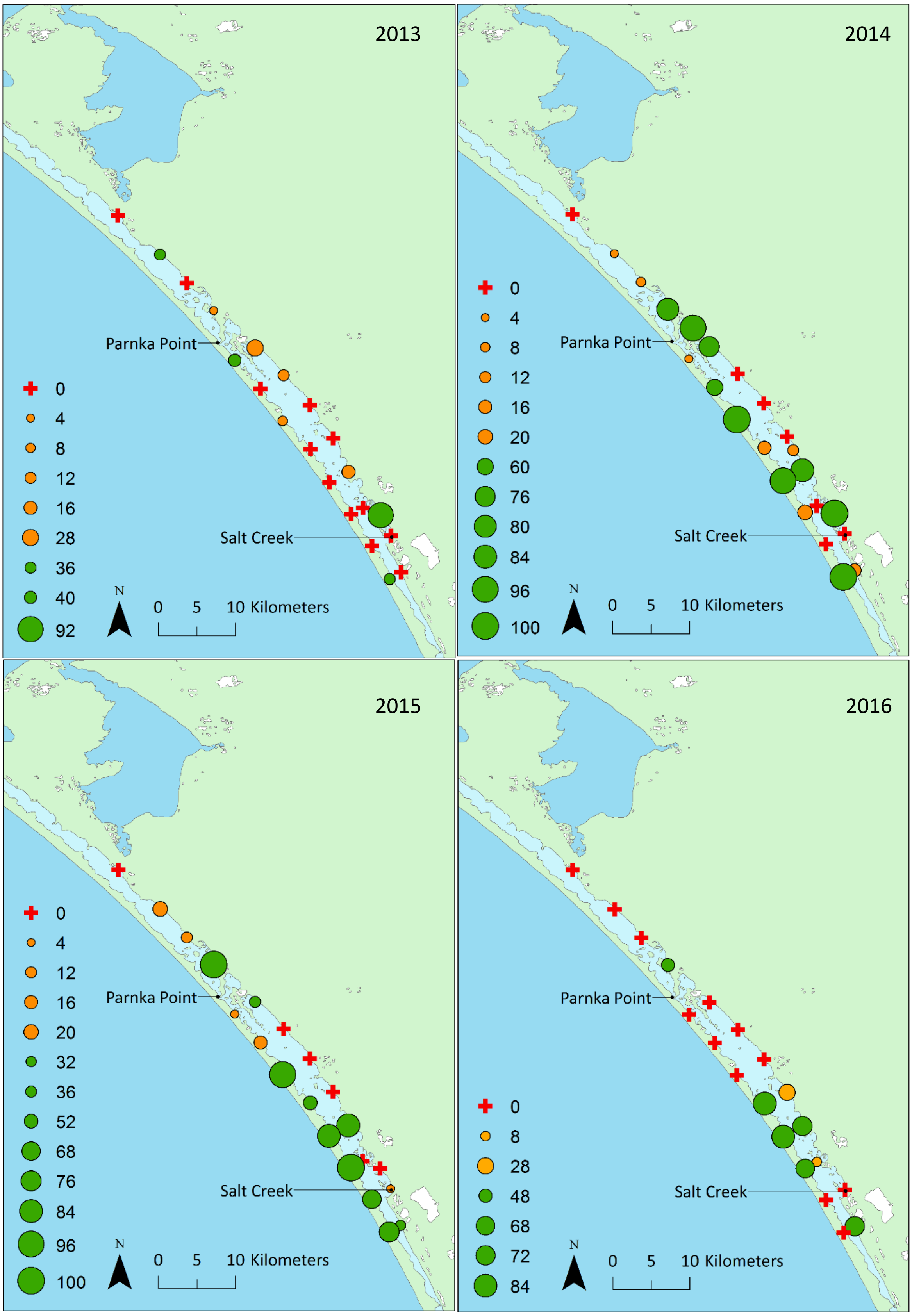

Figure 2: Changes in distribution and abundance of *R. tuberosa* along the Coorong in January 2013, 2014, 2015 and 2016. The data show the maximum percent of cores with *R. tuberosa* shoots for cores taken from sediments covered by 30 cm or 60 cm of water (Table 4). Red spots show areas where there were 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.

Table 6: Percent of cores containing *R. tuberosa* turions (Type I only) across four water depths at 21 sites in the southern Coorong in January 2016. Data are based on 25 cores taken at each depth at each site. Sites and depths where the percent of cores with turions (Type I only) 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	0				
N12	45	0	0	0	0				
N07	50	0	0	0	0				
N02	55	0	0	60	40				
S06	62	32	92	0		76	72	4	
S11	67	0	0	0	40	56	84	0	
S16	72	0	0	0	0	16	100	0	0
S21	77	0	0	4	28	56	96	92	8
S26	82	40	80	96		0	28	96	
S31	87	0	4	0	8	0	12	0	56
S33	89	100							
S36	92	0	20	0	0	0	0	0	
S41	97	0	8	68		0	44		

Table 7: Mean number of Type I turions per core (75 mm x 4 cm) across four water depths and at 21 sites within the southern Coorong in January 2016. 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	0				
N12	45	0	0	0	0				
N07	50	0	0	0	0				
N02	55	0	0	2.9	3.4				
S06	62	2.4	18.8	0		3.6	9.4	0.2	
S11	67	0	0	0	0.5	1.7	7.0	0	
S16	72	0	0	0	0	0.4	19.7	0	0
S21	77	0	0	0.2	4.5	1.2	4.2	10.8	0.2
S26	82	1.5	5.2	13.0		0	0.7	10.9	
S31	87	0	0.1	0	0.3	0	0.1	0	6.2
S33	89	11.2							
S36	92	0	0.3	0	0	0	0	0	
S41	97	0	0.2	19.0		0	0.6		

Table 8: Percent of cores containing *R. tuberosa* seeds at 21 locations in the southern Coorong at four different water depths in January 2016. 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	16	20	0				
N12	45	0	0	0	0				
N07	50	64	4	0	8				
N02	55	76	32	56	72				
S06	62	84	20	100		100	44	80	
S11	67	28	12	40	0	44	4	12	
S16	72	20	12	0	0	32	4	48	32
S21	77	44	0	0	4	32	12	12	100
S26	82	88	36	76		12	8	36	
S31	87	4	0	0	0	8	4	0	0
S33	89	88							
S36	92	16	12	4	44	0	0	0	
S41	97	80	12	88		4	20	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 2016. 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	0.20	0.36	0				
N12	45	0	0	0	0				
N07	50	1.36	0.04	0	0.08				
N02	55	3.44	0.32	2.24	1.60				
S06	62	10.48	0.20	6.68		4.88	1.68	3.00	
S11	67	0.44	0.16	0.72	0	1.12	0.08	0.12	
S16	72	0.28	0.12	0	0	0.76	0.04	0.88	0.56
S21	77	0.68	0	0	0.04	0.44	0.12	0.24	5.92
S26	82	5.68	0.56	2.00		0.16	0.12	0.80	
S31	87	0.04	0	0	0	0.08	0.04	0	0
S33	89	3.44							
S36	92	0.28	0.16	0.04	0.92	0	0	0	
S41	97	4.00	0.16	2.64		0.04	0.20	0	

depth (Table 9) and two sites, namely N12E and S36W, had no seeds detected from 100 and 75 cores, respectively.

4.4 Changes in seed abundances along the Coorong 2011-2016.

The abundances of seeds detected in sediment cores in January 2016 were similar to the abundances of seeds detected in January in each of the five previous years (Table 10). This is consistent with observations of limited flowering.

4.5 Extent of grazing on *R. tuberosa*

Grazing was extensive at many sites in January 2016, with an overall average of 84% of shoots being grazed across the sampling sites. On average, grazed shoots were around 1 cm in length, while ungrazed shoots were around 4.6 cm in length (Table 11).

4.6 Status of *R. tuberosa* in the southern Coorong in January 2016

Table 12 provides summary statistics for the status of *R. tuberosa* in January for the last 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 a decline within the Coorong. Regardless of this decline, the site target for turions was reached for the first time in January 2016, although only for Type I turions. However, the other four local site targets were not met in January 2016. Apart from the extent of occurrence being met for the past four years, none of the other regional indicators have reached the target levels, and only one or two of the five local site targets required for a healthy and resilient *R. tuberosa* system have been reached over the last three years (Table 12). Importantly, the abundances of seeds at all sites and depths (Table 8, Table 9 and Table 10) were low and well below the levels needed for some level of resilience.

Table 10: 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 2016. 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
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
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
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
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
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
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
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
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
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
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
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
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

Table 11: Grazing levels and shoot lengths for *R. tuberosa* in the Coorong in January 2016. 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	24	66	1.3	3.8
S06E	21	100	0.5	
S21E	9	52	1.4	4.0
S21W	22	93	1.0	4.2
S26E	18	92	0.9	4.9
S26W	21	90	1.0	4.2
S31E	2	25	1.0	3.5
S31W	23	84	1.3	5.0
S41E	18	90	0.7	3.5
Overall	**159**	**84**	**1.0**	**4.6**

Table 12: Extent of occurrence, area of occupation and prominence of *R. tuberosa* at sites across the southern Coorong in January from 2011-2016. 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. When targets were met they are shown in red.

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

*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

The recovery of *R. tuberosa* in the southern Coorong continues to be slow. Of the regional targets set for healthy and resilient populations of *R. tuberosa*, only one – the extent of occurrence, was met in January 2016, consistent with the previous three years (Table 12). Furthermore, although the other regional targets (e.g., area of occupation, vigour of populations) had been steadily improving in recent years, the levels reached in January 2016 were lower than those of January 2015. As far as local site targets are concerned, only one or two of the five have been reached in each of the last three years (Table 12). Furthermore, of the local site targets reached in the two previous years, none were reached in January 2016, suggesting targets once reached may not be sustained if conditions are not suitable. In January 2016, the only local site target reached was for the presence of turions and this was for the first time. However, this only involved the smaller Type I turions, which were small in size for Type I turions as well, so it seems unlikely that these would have survived for long once exposed. Overall, compared to the previous year, there was a decline in the distribution, abundance and vigour of *R. tuberosa* in the southern Coorong in January 2016.

The key factor contributing to the slow recovery is the inability to maintain water levels in the southern Coorong over spring (Paton *et al.* 2016a,b). Water levels in spring 2015 were the lowest of the last five years (Figure 1) and this may have contributed to the lack of any further recovery of *R. tuberosa* over the last year.

One of the consequences of the falling water levels in spring is that the populations of plants that were detected and assessed in January were different from those that were assessed in the previous winter. Within the southern Coorong, *R. tuberosa* is limited to growing in water that is 0.3-0.9 m deep. When the water covering the plants is less than 0.3 m, the plants risk exposure and desiccation due to short-term, wind-induced water level fluctuations of up to 0.3 m in the southern Coorong. Similarly, when water levels are high, access to light limits growth. This is because the turbidity in the southern Coorong is often high, restricting the depth of light penetration. The plants that were growing in water that was 0.3-0.6 m deep in January 2016 would have been covered by 1.2-1.5 m of water in the preceding winter, respectively. Therefore, they would have been unable to grow because of a lack of light until the water levels had dropped by at least 0.3-0.6 m. This would have likely taken place sometime between September and November in spring 2015. Those plants that were growing in water that was 0.3 to 0.9 m deep in winter, however, would have been progressively exposed to desiccation from September onwards, and all would have been completely dry by January. Thus, the plants sampled in January 2016 would have been different from those sampled in winter 2015 and would have only been growing for 2-3 months. This relatively short growing time may also account for the short shoot lengths, although the very high grazing intensity may mean that the plants are continually forced to produce new shoots.

In January 2016, the salinities in the southern Coorong ranged between 124 and 147 gL^{-1} (Paton *et al*. 2016c) and were well above the reported ideal salinity range of 60-100 gL^{-1} for *R. tuberosa*. That there were still green shoots present at these high salinities, suggests that plants, once established, can tolerate salinities that are substantially higher than the 60-100gL^{-1}. However, the 60-100 gL^{-1}

salinity range is based largely on the germination responses of *R. tuberosa,* which drop with increasing salinities and become negligible above 100gL^{-1} (e.g., Kim *et al.* 2013), and also because of concerns that salinities lower than 60 gL^{-1} would favour increased interference from filamentous algae (*Ulva* sp.). In November 2015, most of the *R. tuberosa* beds were heavily covered in filamentous algae, with the algae interfering with both the growth and flowering of the plants. Salinities in winter 2015 across the southern Coorong ranged from 70-90 gL$^{-1,}$ (Paton *et al.* 2016b), and by November 2015 would have been higher again. So, despite salinities well above 60 gL^{-1}, significant interference from filamentous algae still took place. Thus, other strategies for dampening the level of interference from filamentous algae may be needed to secure the recovery of *R. tuberosa* across the southern Coorong.

The low water levels in spring 2015 had significant consequences for the one small population of *R. tuberosa* that remained in the South Lagoon of the Coorong during the millennium drought. Gemini Downs bay (S33E) has a natural sandbar that prevents water from leaving the bay as the water levels drop below the height of the sandbar in the rest of the southern Coorong. Through the millennium drought, this small population of *R. tuberosa* continued to produce small numbers of seeds and turions. The population re-established each year because the water levels were retained for longer and because the bay was small, meaning that the day-to-day wind-induced water level changes were small, unlike for the rest of the Coorong. However, in spring 2015, the bay was disconnected much earlier. Furthermore, with limited spring rain and ongoing evaporation, this bay was completely dry by January 2016, leaving the plants covered by a layer of salt (as per the photograph on this report's title page). Small, discoloured Type I turions and some seeds remained under the salt crust, and whether these survive and are sufficient to re-establish this population in the coming years is not known. As yet, there is no information on the length of time that turions can survive periods of desiccation. Turions have little or no outer covering to prevent desiccation and so survival is likely to be of the order of weeks or, at most, a few months. Added to this, the smaller size of the turions present in January 2016 (which may be related to higher salinities when they were produced in spring 2015), is likely to lead to a reduced capacity to survive a period of desiccation. The small size of the turions, as well as the lower water levels through spring that led to an increased exposure time, are likely to result in reduced survival compared to other years, not just at S33E, but across all sites. The prognosis for *R. tuberosa* in the coming year is, therefore, not great.

The extremely high levels of grazing detected across all sites where *R. tuberosa* was growing in January 2016 are indicative of limited amounts of food being available to herbivorous waterfowl (ducks and swan). High levels of grazing will impinge on the ability of *R. tuberosa* to produce seeds and turions and, therefore, will also contribute to limiting the recovery of this plant. To harvest sufficient food from the plants, the herbivorous waterfowl were spending up to 70% of the day foraging in January 2016 (Paton *et al.* 2016c). More concerning was that some of the shorebirds using the southern Coorong were spending as much as 90% of the day foraging. These birds will include *R. tuberosa* seeds and turions in their diet (e.g., Paton 1986). Therefore, while the abundances of these two resources remain low (about 1-10% of the historical levels respectively), shorebirds may struggle to secure the food they need (Paton *et al.* 2016c). Consequently, there is a clear need to address the ongoing poor recovery of *R. tuberosa* in the southern Coorong.

Although interference from filamentous algae and high rates of herbivory dampen the recovery of *R. tuberosa* in the southern Coorong, falling water levels in spring is the critical issue that needs to be addressed, as these falling water levels reduce the time available for plants to establish, grow and reproduce. Given that flows over the barrages are unlikely to be adequate, 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 considered. Such a barrier would work in much the same way as the sandbar prevented water draining from Gemini Downs bay, as water levels dropped in the rest of the Coorong. Given that many of the waterbirds that use the southern Coorong over summer depend on *R. tuberosa* for food (either directly or indirectly), provides an added premium for taking action.

6 Acknowledgments

The 2015-16 work was commissioned by the South Australian Department of Environment, Water and Natural Resources (Coorong, Lower Lakes and Murray Mouth Recovery Program). It is part of the South Australian Government's Murray Futures program, funded by the Australian Government's *Water for the Future* initiative. *The Living Murray* initiative, with funding provided by the Murray-Darling Basin Authority, funded this work in 2012 to 2015. Joel Allan, Lydia Paton, Tom Bradley, Tom Hunt, Donna Belder, Grace Hodder, Phillip Northeast, Victoria McCarron and Hayley Merigot provided able field assistance. The research was conducted under a DEWNR wildlife research permit issued to David Paton.

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