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Current Distribution and Abundance of *Ruppia tuberosa* in the Coorong

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Executive Summary

Ruppia tuberosa is an extremely salt tolerant submergent macrophyte that historically formed extensive beds in the South Lagoon of the Coorong in areas that were inundated over the winter and spring and dried in the summer and autumn. Since 2000 the abundance of *Ruppia tuberosa* in the South Lagoon declined to the point where it was absent from the system by 2009. The decline was due to increased salinity and lower water levels during the drought, which lasted from 1996 to 2010. Floods in 2010/11 resulted in higher water levels and lower salinity in the South Lagoon and there was limited colonisation of *Ruppia tuberosa* in the South Lagoon and southern end of the North Lagoon. The aim of this study was to quantify the distribution and abundance of *Ruppia tuberosa* (including the propagule bank) and filamentous algae in December 2011.

A total of 14 sites (13 in the South Lagoon and one in the North Lagoon) were sampled using a grab sampler to a maximum depth of 100 cm at 20 cm intervals. Grab samples were sieved and *Ruppia tuberosa* shoots were counted and dried to determine biomass. Filamentous algae percentage cover was visually estimated, separated from *Ruppia tuberosa* shoots in the grab samples and also dried to determine biomass.

The distribution and abundance of *Ruppia tuberosa* and filamentous algae was patchy but the highest abundances of both species were on shallow sand bars on the western shoreline of the South Lagoon. *Ruppia tuberosa* was restricted to shallow depths and filamentous algae were more widespread but with higher biomass in deeper water. No *Ruppia tuberosa* turions were detected and only one viable seed was found indicating an extremely depauperate propagule bank. All plants sampled had not flowered or developed turions and, due to plants being restricted to shallow water, there is a risk of desiccation before the propagule bank is replenished.

Results from this study showed that *Ruppia tuberosa* was present the South Lagoon but not to the extent prior to the drought. Furthermore, it has only colonised the shallow margins and is at risk of desiccation before it sets seed or develops turions to replenish the propagule bank. The fate of the plants present in December 2011 is unknown because this study was a one off snapshot and no follow up surveys have been undertaken.

1. Introduction

Ruppia tuberosa is a highly salt tolerant submergent macrophyte (Brock 1982), commonly found in temporary saline lakes throughout southern Australia (Brock 1981; Brock and Shiel 1983). From the 1970s to the early 2000s, *Ruppia tuberosa* was the dominant submergent plant in the South Lagoon of the Coorong. It formed extensive beds between Salt Creek and Hells Gate, growing in water depths ranging from 30 to 80 cm in the winter and spring (Womersley 1975; Geddes and Brock 1977; Gilbertson and Foale 1977; Paton 1982; Geddes and Hall 1990; Leary 1993; Paton 1996; Paton 2000; Paton 2001; Paton *et al.* 2001; Paton and Bolton 2001; Paton 2002; Paton 2003; Nicol 2005). However, between 2000 and 2010, *Ruppia tuberosa* declined in abundance in the South Lagoon of the Coorong. During this decade, the Murray-Darling Basin experienced one of the most severe droughts in recorded history (Bond *et al.* 2008) and prior to widespread flooding across most of the MDB in 2010/11 (MDBA 2011), *Ruppia tuberosa* was completely absent from the South Lagoon and only present in the southern end of the North Lagoon of the Coorong (Whipp 2010; Brookes *et al.* 2009). The decline in abundance and subsequent disappearance from the South Lagoon was attributed to the steady increase in salinity between 2000 and 2010, which at times exceeded 160‰ TDS (Paton and Rogers 2008; Brookes *et al.* 2009; Whipp 2010). Since the 2010/11 flood, water levels in the South Lagoon have risen, salinities have decreased, *Ruppia tuberosa* was present in areas of the South Lagoon and remains present in the North Lagoon (H. Stewart pers. comm.).

Ruppia tuberosa is a key component of the biota of the South Lagoon of the Coorong. It is one of only two submergent macrophytes (the other being the charophyte *Lamprothamnium macropogon*) that have been recorded in the hypermarine South Lagoon. It is thought to provide habitat for small mouth hardyhead and the shoots, rhizomes, seeds and turions are an important component of the diet of herbivorous waterfowl and waders (Paton *et al.* 2001; Paton 2005). *Ruppia tuberosa* was historically restricted to the higher salinities of the South Lagoon of the Coorong because at lower salinities (such as those of the North Lagoon), whilst exhibiting higher growth rates in the absence of competition, it was smothered by the filamentous green algae *Enteromorpha* sp. (Paton 1996). The recent lowering of salinity in the Coorong may provide conditions suitable for colonisation of *Enteromorpha* in the North Lagoon and northern end of the South Lagoon.

Since the 2010/11 floods there is no published quantitative information regarding the current distribution, abundance and biomass of *Ruppia tuberosa* or filamentous algae in the Coorong. Furthermore, there is little information regarding propagule (seed and turion) abundance and current abiotic conditions (e.g. water quality). This information is important for the short to medium-term management of the Coorong as it will provide information about the conditions required for establishment of *Ruppia tuberosa*, provide a baseline for future monitoring activities and determine whether there is a viable propagule bank.

The objectives of this project were to record and map the current distribution, abundance and biomass of *Ruppia tuberosa* and filamentous green algae in the Coorong, determine whether *Ruppia tuberosa* has established a viable propagule bank and gain information regarding the conditions required for the establishment of *Ruppia tuberosa* in the Coorong.

2. Methods

2.1. Study Site

The Coorong is a shallow, elongate coastal lagoon confined by the coastal dune barrier of the Younghusband and Sir Richard Peninsulas. The Coorong stretches for 140 km (Geddes 1987; Department of Environment and Heritage 2000; Seaman 2003) (Figure 1) and is comprised of two main lagoons (the North and South Lagoons) of similar size, almost separated by a spit of land (Hells Gate) (Lothian and Williams 1988) (Figure 1).

Salinity is the primary factor that influences the plant community in the Coorong (Womersley 1975; Noye and Walsh 1976; Geddes and Brock 1977; Gilbertson and Foale 1977; Geddes 1987; Geddes and Hall 1990; Webster 2005b; Webster 2005a; Brookes *et al.* 2009; Lester and Fairweather 2009) Salinity levels in the Coorong vary substantially at spatial and temporal scales, ranging from fresh near the barrages (when large quantities of water are being released from Lake Alexandrina) through brackish, to the salinity of seawater (35‰ TDS) in the Murray Mouth area, grading to hypersaline (>35-115‰ TDS) in the southern end of the North Lagoon and the South Lagoon (Geddes 1987; Lothian and Williams 1988; Department of Environment and Heritage 2000; Paton 2000; Paton 2001; Paton and Bolton 2001; Paton 2003; Seaman 2003).

Water level is also an important factor in the South Lagoon where water levels fluctuate (up to 1 m) at longer seasonal temporal scales from winter/spring highs to late summer/autumn lows (Geddes 1987; Seaman 2003) and over shorter temporal scales due to seiching caused by the speed and direction of the wind (Noye and Walsh 1976).

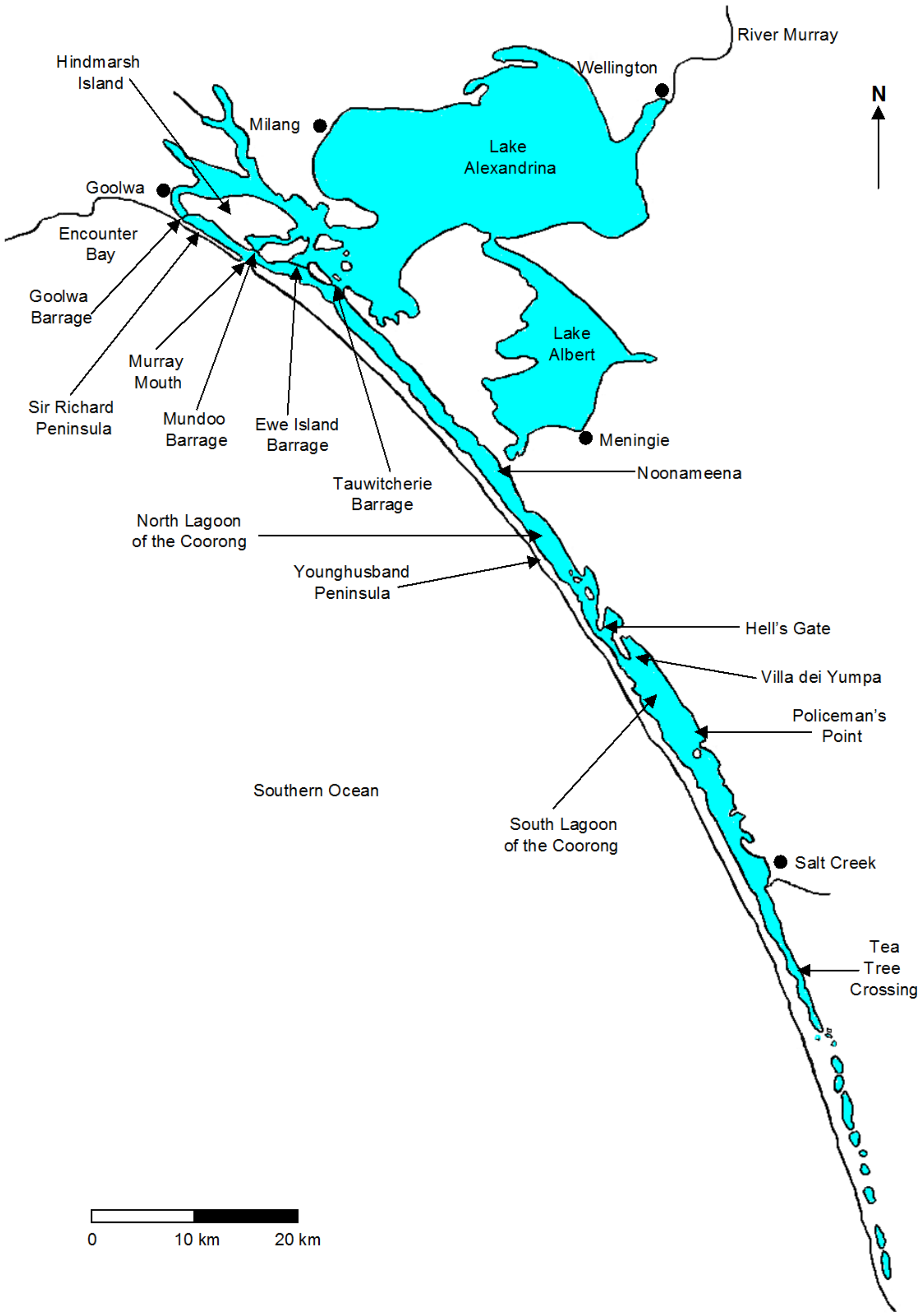

Figure 1: The Lower Lakes and Coorong.

A total of 14 sites were sampled in the North and South Lagoons of the Coorong in December 2011 (Figure 2). The sites were determined in consultation with DENR staff, generally in areas where *Ruppia tuberosa* has been reported since the 2010/11 flood. Several sites where *Ruppia tuberosa* was historically present, but now absent were also selected to gain information about potential abiotic factors that may be unfavourable for recruitment.

Figure 2: Aerial photo of the southern end of the North Lagoon and South Lagoon of the Coorong showing the vegetation sampling sites.

At each site three transects were established running perpendicular to the shoreline separated by 50 m. Along each transect grab samples (five at each depth) were taken using a small (area sampled 156.25 cm^2) van Veen grab at 20, 40, 60, 80 and 100 cm water depths. Samples were then washed through a 500 µm sieve and live shoots, turions and viable seeds were counted. Seed viability was tested by pressing, if a seed did not crumble when pressed it was assumed to be viable (*sensu* Gross 1990). All shoots, rhizomes and filamentous algae were then collected and taken back to SARDI and dried at 40ºC to a constant weight, to determine biomass (dry weight).

At each site spot measurements of water quality (salinity, pH, temperature, and turbidity) were taken and the percentage cover of filamentous algae was visually estimated. GPS coordinates were recorded for each elevation along each transect and used to produce GIS layers, using ARCGIS.

Biomass and shoot number of *Ruppia tuberosa* and biomass of filamentous algae were converted to grams dry weight and densities m^{-2} and also used to produce GIS layers using ARCGIS. Maps were then produced from these GIS layers to determine spatial patterns of biomass, shoot number and propagule bank density.

3. Results

Water quality

Water quality parameters varied from site to site (Table 1). The salinity at sampled sites ranged from 71.4 to 90.1‰ TDS, pH from 7.63 to 8.35, temperatures from 18.8to 26.6°C and turbidity from 17.6 to 34.8 NTU. Sites 4 and 5 recorded the highest salinity and turbidity values, while sites 1 and 2 recorded the lowest salinity, and mid-range turbidity.

Table 1: Water quality (salinity, pH, turbidity and temperature) at each sampling site in December 2011.

Site #	Salinity ‰ (TDS)	pH	Turbidity (NTU)	Temperature
1	71.4	8.35	23.4	22.3
2	71.4	8.35	23.5	22.3
3	84.4	8.23	27.5	26.6
4	90.1	7.63	34.3	24.1
5	89.4	8.28	32.8	24.3
6	88.6	7.85	22.6	19.5
7	85.7	8.27	26.2	24.8
8	84.1	8.27	23.0	23.7
9	80.8	8.29	20.6	22.0
10	83.1	8.25	17.6	22.4
11	84.1	8.28	27.3	19.4
12	84.1	8.25	25.9	23.5
13	87.2	8.06	24.4	24.8
14	82.8	8.30	22.3	18.8

Ruppia tuberosa *and filamentous algae distribution and abundance*

Ruppia tuberosa was recorded at seven of the 14 sites (Figure 3; Figure 4) at depths of 20, 40, 60 and 80 cm (Figure 5; Figure 6). The highest biomass of *Ruppia tuberosa* was recorded at site 11 at depths of 20 and 60 cm (Figure 6). At Site 12, *Ruppia tuberosa* was recorded across the most sampled depths (i.e. 20, 40, 80 cm) (Figure 6). Overall, the highest biomass of *Ruppia tuberosa* was found at the shallowest water depth sampled (20 cm) whereas there was no *Ruppia tuberosa* found at the deepest water depth (100 cm). Sites that contained *Ruppia tuberosa* were generally located on the western (ocean) side of the South Lagoon. No turions were found and only one viable seed was recorded. No live specimens of *Ruppia tuberosa* were present at the sites with the highest salinities (sites 3 and 8) (Figure 3; Figure 4; Table 1).

Filamentous algae were sampled at 11 sites out of 14 sites (Figure 7; Figure 8) and present at all sampled depths (Figure 9; Figure 10). Filamentous algae tended to be present more often at the shallower depths (20-40 cm (Figure 9), but the highest biomass was sampled at depths of 80 cm (Figure 10). In general filamentous algae biomass was greater at the sites with lower salinities (Figure 8; Table 1).

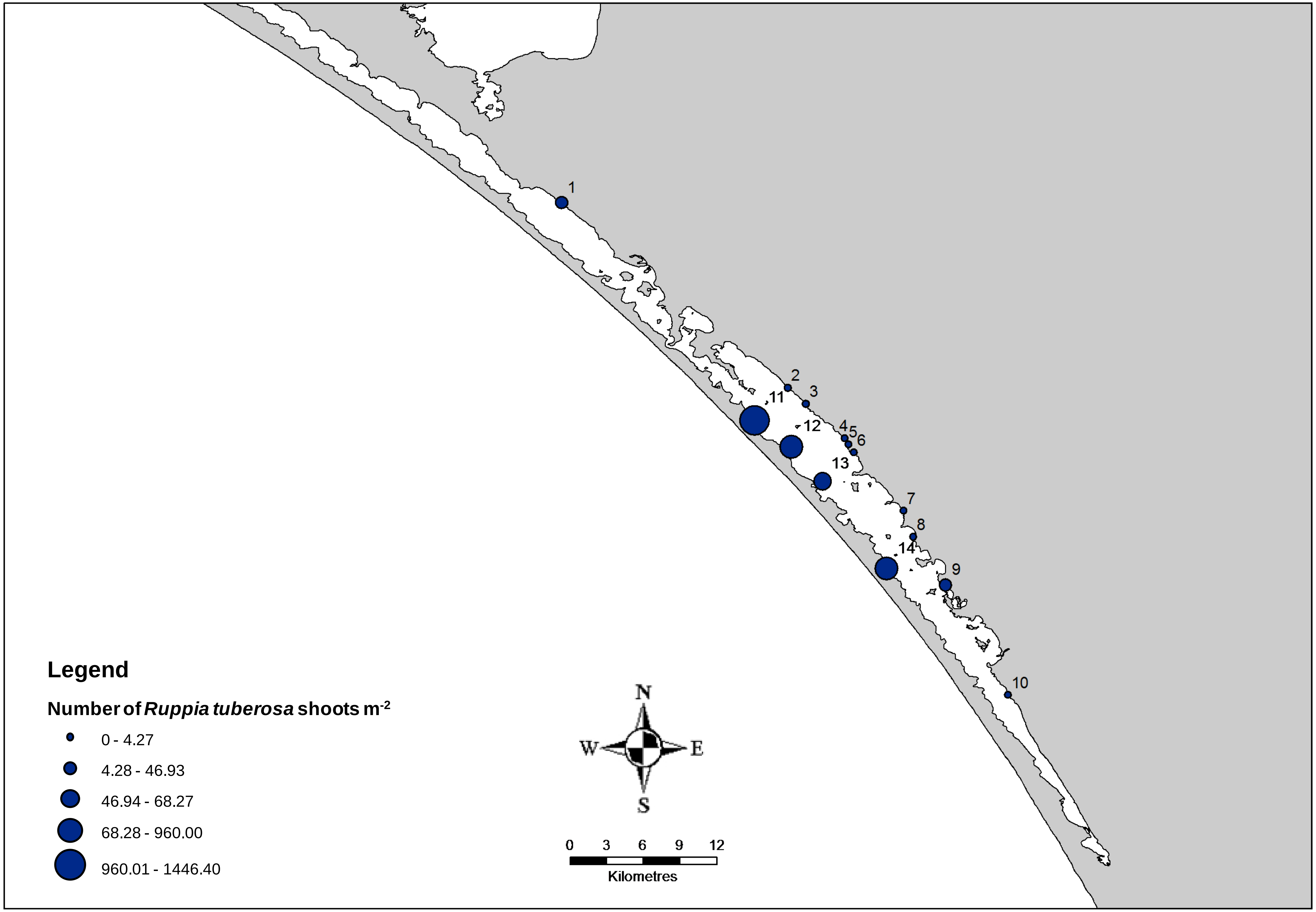

Figure 3: Map of the Coorong showing mean *Ruppia tuberosa* shoot abundance (shoots m^{-2} for all depths) at each site in December 2011.

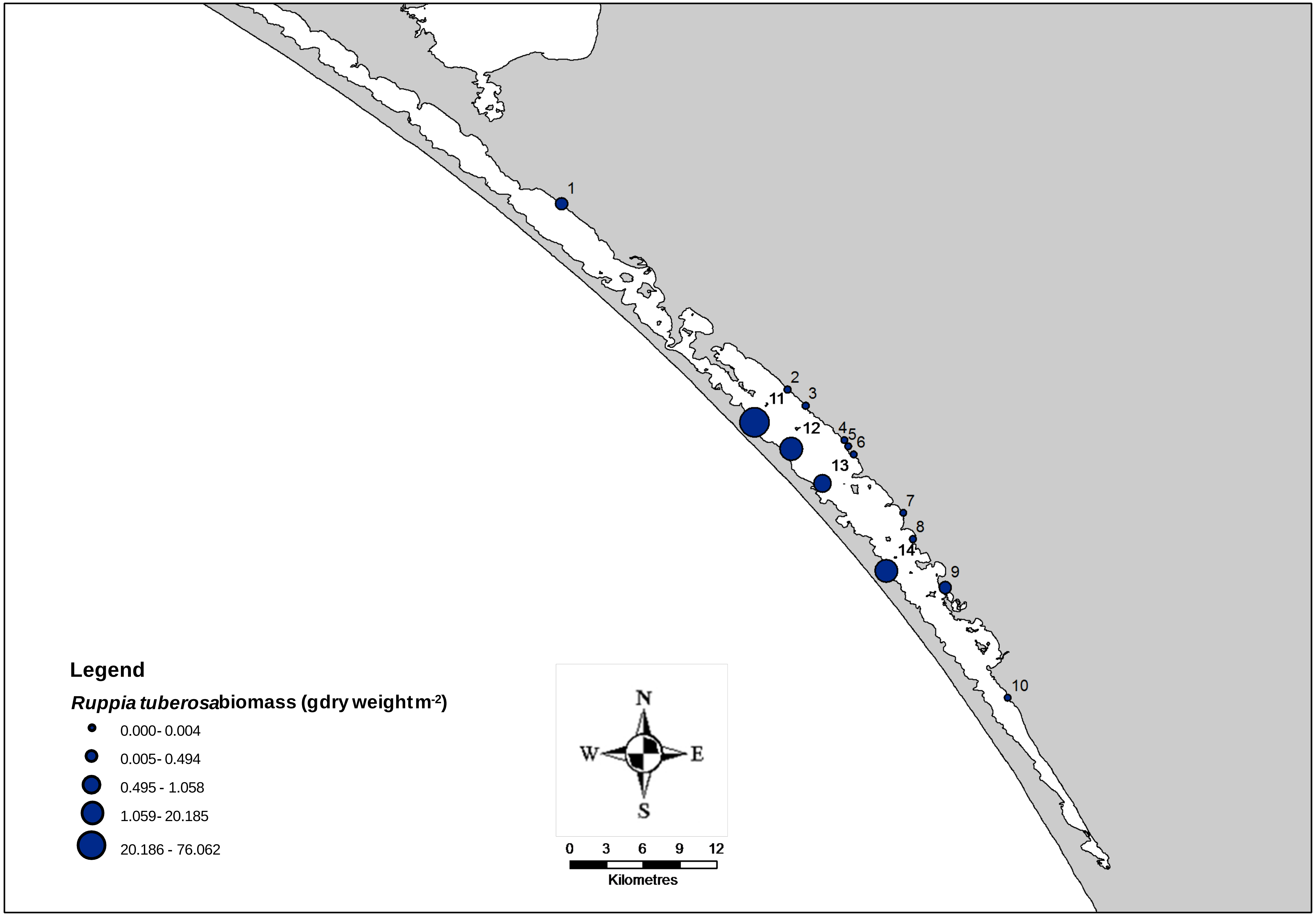

Figure 4: Map of the Coorong showing mean *Ruppia tuberosa* biomass (g dry weight m^{-2} for all depths) at each site in December 2011.

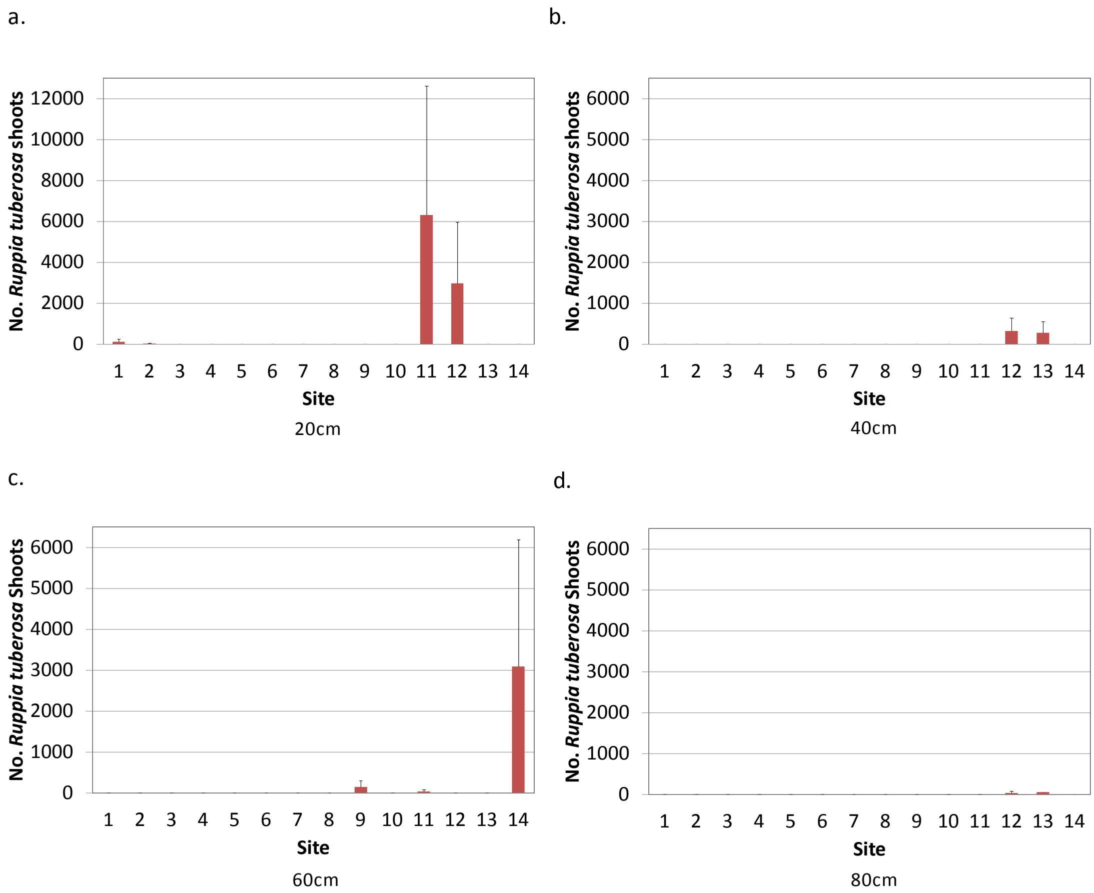

Figure 5: *Ruppia tuberosa* shoot abundance (no. shots m^{-2}) at each site in the Coorong in December 2011 at a. 20 cm, b. 40 cm, c. 60 cm and d. 80 cm (note: no *Ruppia tuberosa* was present at 100 cm) (error bars =+1 S.E.).

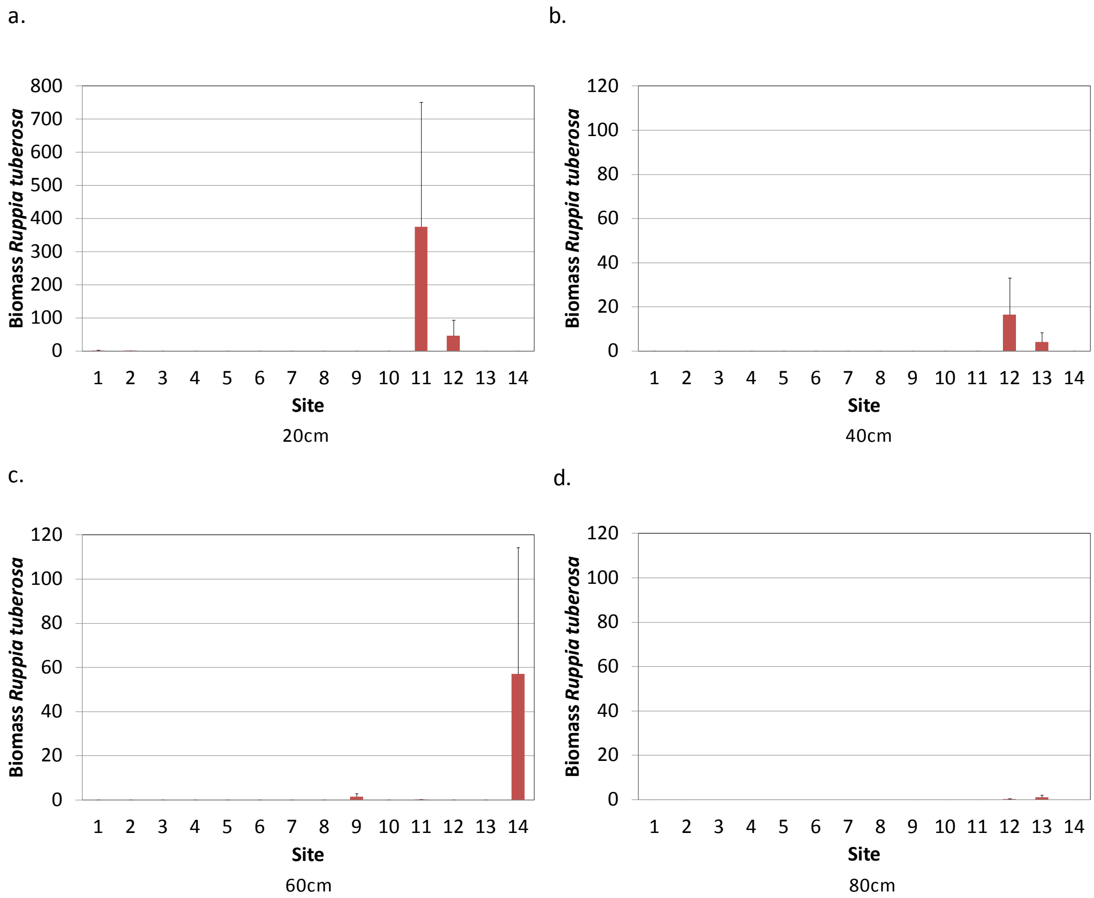

Figure 6: *Ruppia tuberosa* biomass (g dry weight m^{-2}) in the Coorong at each site, in December 2011 at a. 20 cm, b. 40 cm, c. 60 cm and d. 80 cm (no *Ruppia tuberosa* was present at 100 cm) (error bars =+1 S.E.).

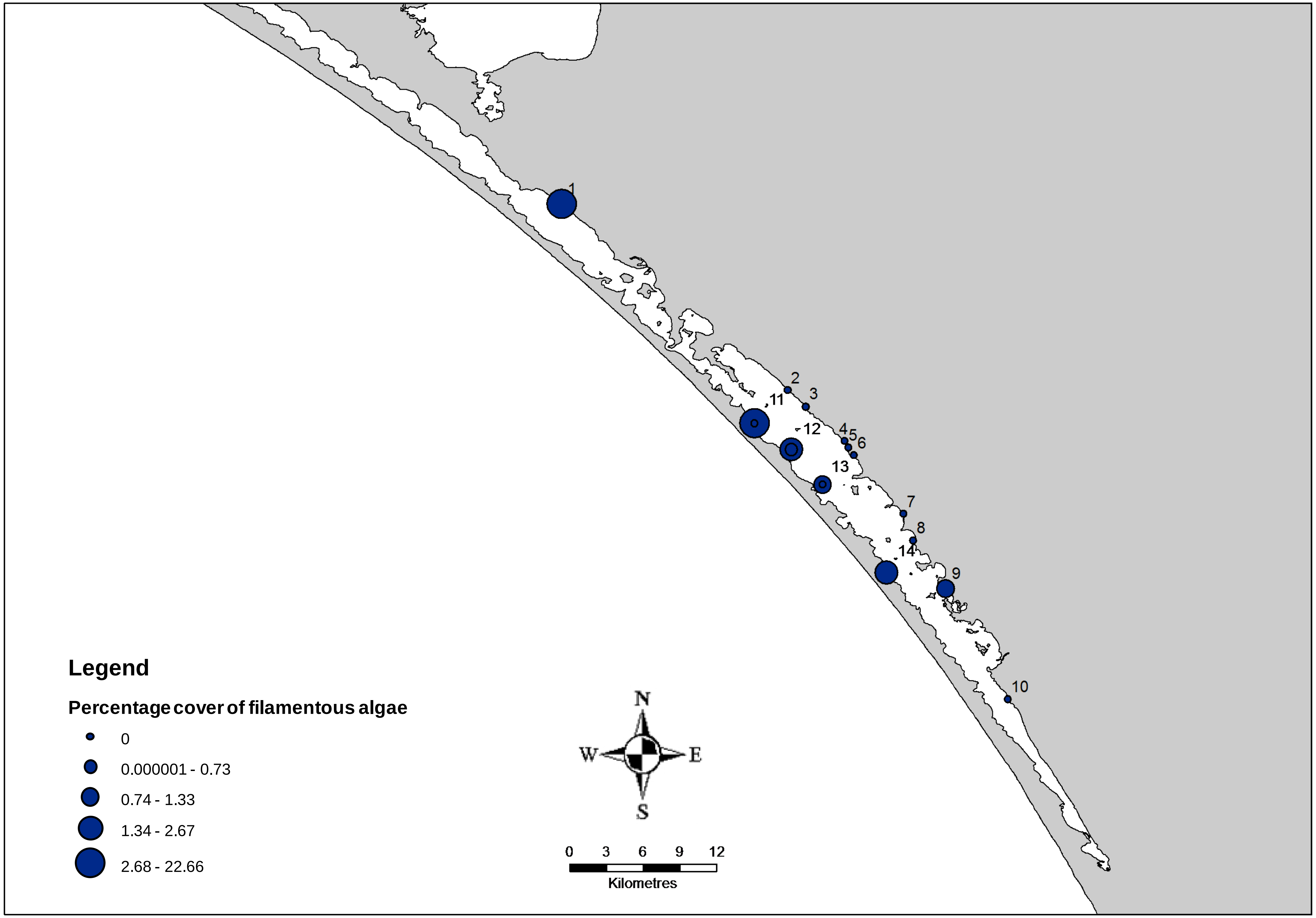

Figure 7: Map of the Coorong showing mean filamentous algae percentage cover abundance for all depths at each site in December 2011.

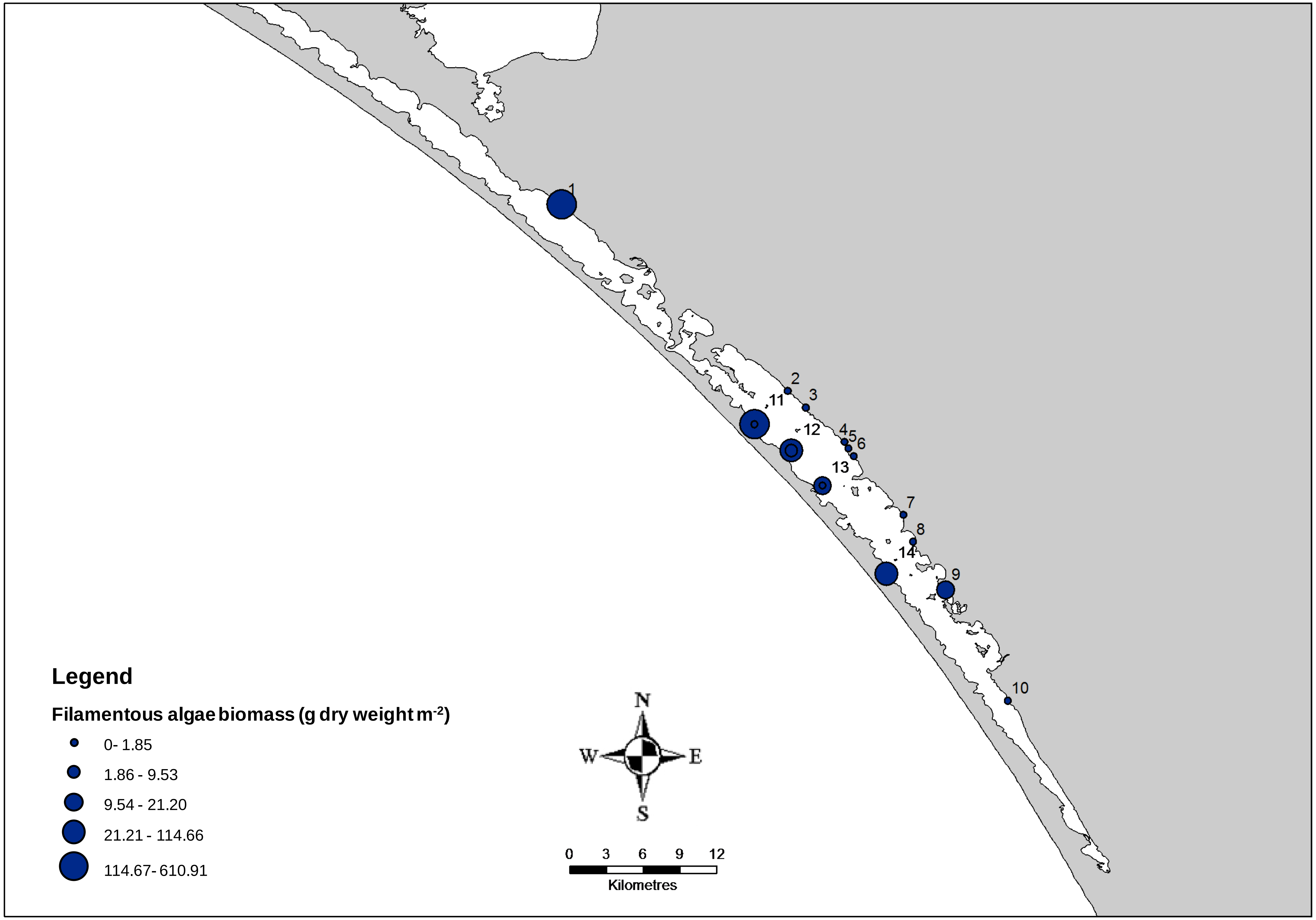

Figure 8: Map of the Coorong showing mean filamentous algae biomass (g dry weight m^{-2} for all depths) at each site in December 2011.

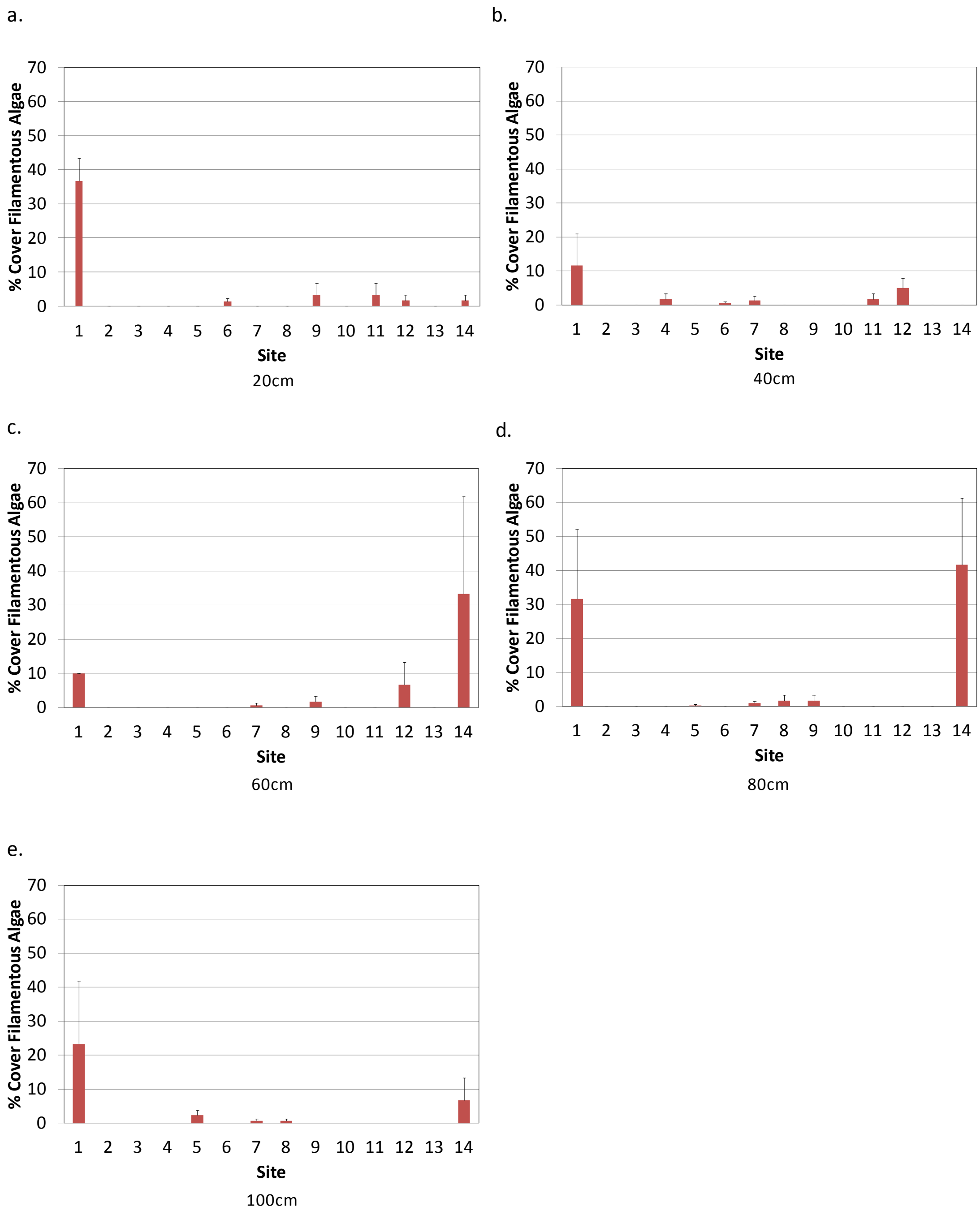

Figure 9: Percentage cover of filamentous algae at each site in the Coorong in December 2011 at a. 20 cm, b. 40 cm, c. 60 cm, d. 80 cm and e. 100 cm.

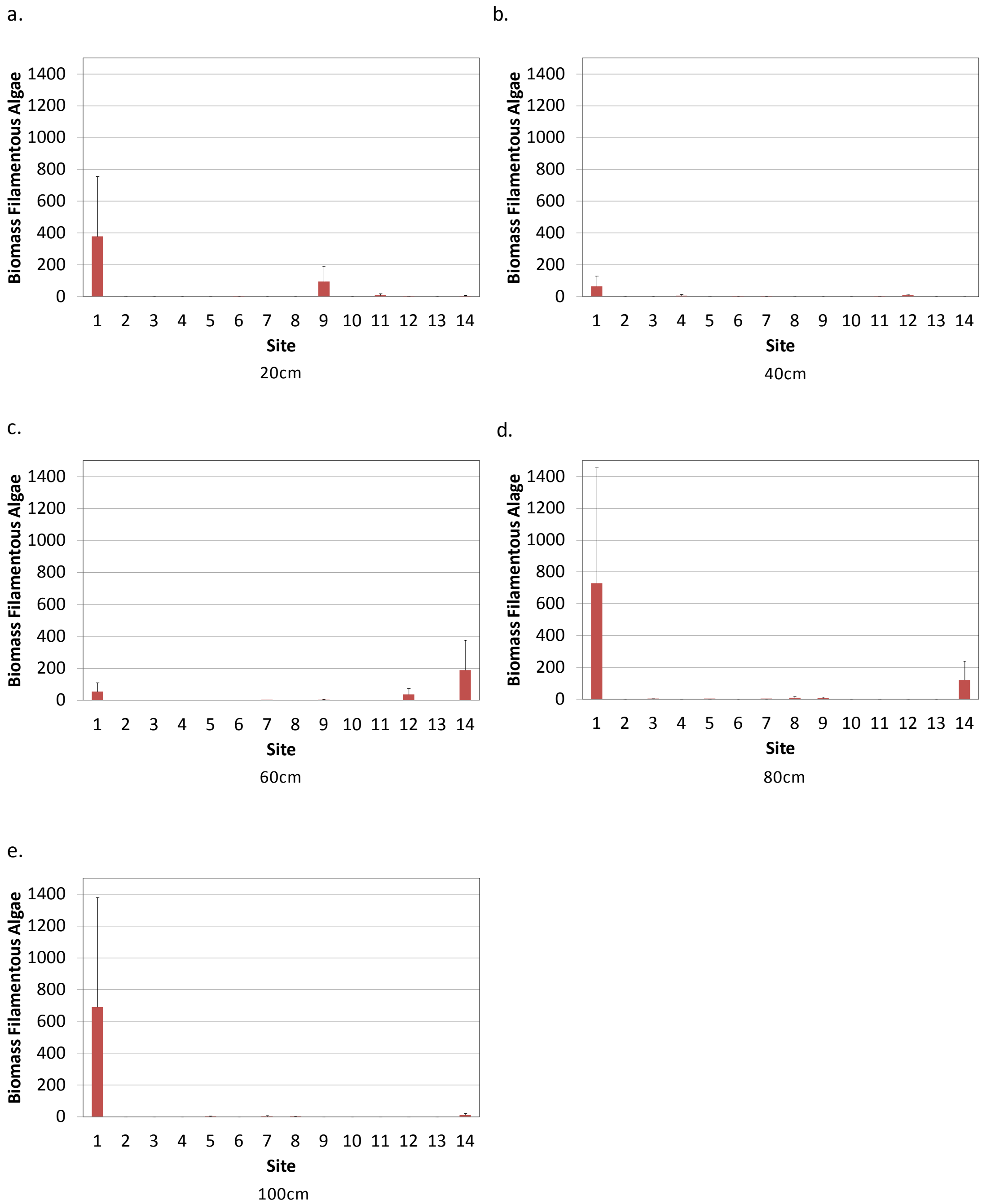

Figure 10: Biomass of filamentous algae (g dry weight m^{-2}) at each site in the Coorong December 2011 at a. 20 cm, b. 40 cm, c. 60 cm, d. 80 cm and e. 100 cm.

4. Discussion

Live *Ruppia tuberosa* plants were found at numerous sites in the South Lagoon demonstrating its reappearance since the 2010/11 flood, as a 2008 survey found no live specimens in the South Lagoon and the species rare in the southernmost parts of the North Lagoon (Rogers and Paton 2009). The decline of *Ruppia tuberosa* in the South Lagoon of the Coorong during the 2000's was due to very low flows over the barrages, consequently limiting freshwater flows, increasing salinity and lowering water levels (Nicol 2005; Whipp 2010; Dick *et al.* 2011). The return of *Ruppia tuberosa* to the South Lagoon of the Coorong is important to the entire ecosystem as it is one of the main primary producers in the hypersaline environment (Nicol 2005; Whipp 2010), and the primary food source for many herbivorous waterfowl and waders (Rogers and Paton 2009; Whipp 2010; Dick *et al.* 2011), as well as habitat for invertebrates and small fish (Rogers and Paton 2009). The decline in migratory bird abundance previous to the 2010/11 flood was also attributed to the loss of *Ruppia tuberosa* (Dick *et al.* 2011).

The highest abundance and biomass of *Ruppia tuberosa* was on the western (ocean) shore of the South Lagoon where sediments were generally coarser and appeared to be lower in organic matter. There is conflicting evidence whether *Ruppia* species prefer coarse or fine sediments or sediments with high or low organic contents (Nicol 2005). Evidence from this study suggests that *Ruppia tuberosa* prefers coarser sediment; nevertheless, this species was historically abundant in areas with fine sediments (Nicol 2005). Furthermore, *Ruppia tuberosa* was only present on bars, not in areas of steeply sloping shoreline on the western shoreline (pers. obs.).

The major factors that influence the distribution and abundance of *Ruppia tuberosa* are salinity, turbidity (which in turn determines the underwater light climate) and hydroperiod. The maximum reported salinity tolerance of *Ruppia tuberosa* is 210‰ TDS (Brock 1982); however, this value was determined under controlled greenhouse conditions and does not take into consideration multiple stressors (*sensu* Salter *et al.* 2007). The preferred salinity range for *Ruppia tuberosa* in the Coorong is 40-80‰ TDS (Whipp 2010) and in this study *Ruppia tuberosa* was more abundant at the sites with lower salinities and absent at the sites with the highest salinity levels.

In this study *Ruppia tuberosa* was not found in the 100 cm depth samples but was most common at the shallowest depth (20 cm) and was observed in even shallower water. However, due to barrage operations and reductions in flow, water levels in the South Lagoon had recently fallen approximately 20 cm from the spring water level highs at the time of sampling. Hence, the depth these plants established was probably 40 to 60 cm. Turbidity in the Coorong at the time of sampling resulted in a euphotic depth (1% of incidence irradiance) of greater than 1 m (Cenzato and Ganf 2001). Therefore, despite its high light requirement (Whipp 2010), turbidity probably was not the factor that resulted in *Ruppia tuberosa* being restricted to shallow water. Filamentous algae was more abundant at sites where *Ruppia tuberosa* was present; although, it tended to higher biomass in deeper water and may have excluded *Ruppia tuberosa* from colonising deeper water.

The presence of *Ruppia tuberosa* only in shallow water leaves it at risk of desiccation before it has an opportunity to replenish the propagule bank. Only one viable seed was sampled, turions were absent and all plants sampled had not flowered or produced turions. Therefore, if water levels fall more than 20 cm or there is periodic exposure by seiching there may be no resident propagule bank for colonisation when water levels rise, leaving colonisation reliant on dispersal into the system. The cosmopolitan distribution of *Ruppia tuberosa* (Jacobs and Brock 1982) suggests that it is capable of wide dispersal; however, reliance on dispersal for recolonisation has a lower chance of success than colonisation from a resident propagule bank.

The distribution of both *Ruppia tuberosa* and filamentous algae was patchy throughout the southern end of the North Lagoon and the South Lagoon (generally on the western shoreline of the South Lagoon on sandbars). When sampled the salinity was below 100‰ TDS throughout the South Lagoon, which is well below its physiological threshold of *Ruppia tuberosa* and turbidity indicates that there is potential for colonisation to depths of at least 1 m. The patchy distribution may be due to differences in sediment texture or chemistry or patchy dispersal into the system (the propagule bank was depleted prior to the 2010/11 flood (Brookes *et al.* 2009). Furthermore, plants had not reproduced (or showed signs of flower or turion development) and there was an extremely depauperate propagule bank. Finally, this study was a one off snapshot and provides no information regarding the temporal population dynamics of *Ruppia tuberosa* (or submergent vegetation in general).

Ruppia tuberosa has been described as a "keystone species" for the Coorong, which almost became locally extinct during the recent drought (Brookes *et al.* 2009). Whilst there has been limited reappearance (indicating conditions suitable for establishment have been met in the South Lagoon), the short to medium-term population dynamics have not been investigated. It is not known whether the population detected during this study has persisted, plants have reproduced or a propagule bank has developed. In addition, the affect of abiotic factors such as sediment chemistry on the recruitment and survival of *Ruppia tuberosa* in the Coorong are not well understood and are important for the management of the system.

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