Ecological Character Description for *Ruppia tuberosa* in the Coorong

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Introduction

This report provides background information on which the Ecological Character Description for *Ruppia tuberosa* in the Coorong is based. The description that is provided is consistent with the proposed long-term monitoring targets for the species in the Coorong. A simple Limit of Acceptable change is also given.

Submerged aquatic plants in the Coorong

Submerged aquatic plants were a prominent feature of the Coorong in the 1980s and 1990s. These submerged plants provided resources (habitat, foraging substrates, and food) for aquatic invertebrates, fish and herbivorous birds, as well as dampening wave action along shorelines. These ecological services and benefits, however, have not been measured quantitatively.

The prominence of submerged aquatic plants has changed since the Coorong was listed as a wetland of international importance in the mid-1980s. First, the composition of the submerged aquatic plants was more diverse in the Coorong at the time of nomination than is currently the case. In the early 1980s, *Ruppia megacarpa, Lepilaena cylindrica* and *Zostera muelleri* were reported from the North Lagoon (Geddes 1987), while *Ruppia tuberosa* and *Lamprothamnium papulosum* were in the South Lagoon (Paton pers. obs.). Of these, only *Ruppia tuberosa* remains. Second, the prominence (abundance) of submerged aquatic plants along the Coorong has also declined (e.g., Paton 2010). A combination of changes in salinity and water levels are likely to have caused these changes in distribution and abundance, with the plant populations likely to have been in a state of change even at the time of nomination as a wetland of international importance.

There is limited quantitative data on the historical distribution of submerged aquatic plants in the Coorong. Most surveys were snap shots at a particular time that indicate the presence of species at different points along the Coorong but were not adequate to provide quantitative measures of abundance at sampling sites from which changes could be assessed. However, some quantitative data exist for *Ruppia tuberosa* along the South Lagoon for 1984-85 and for a subset of the same sites in 1990-93. These observations from 20-30 years ago, coupled with annual monitoring since 1998, provide a basis for the Ecological Character Description for this species and the setting of some benchmarks (see below).

Ecology of *Ruppia tuberosa* in the southern Coorong

Ruppia tuberosa is essentially an annual plant that exploits the ephemeral mudflats around the shores of the southern Coorong. These ephemeral areas are covered with water from late autumn through spring and into summer but are often dry from late summer through autumn. Annual water level changes in the southern Coorong are typically around 1 m. During the dry period when the water levels are lowest, the plant remains on or in the mud surface as seeds and turions. When water levels rise again in late autumn and winter, most, if not all, of the turions that survive the dry period sprout and some of the seeds germinate. The plants then grow over winter and, provided water levels remain adequate, reproduce sexually (producing seeds) and asexually (producing turions) during spring and early summer.

Within the Coorong, *Ruppia tuberosa* is restricted to water that is no more than ~0.9 m deep because the turbidity of the water restricts light penetration to the floor of the Coorong at deeper depths. Furthermore, although seeds and turions sprout in shallow water, those that are growing in water less than ~0.3 m in depth rarely survive to reproduce. This is because wind-induced changes in water levels from one day to the next can approach 0.3 m in the southern Coorong and, when this occurs, these plants are exposed to desiccation. Thus the core populations of *Ruppia tuberosa* exist in water that is typically 0.3-0.9 m deep during winter and spring within the southern Coorong, with peak performances at the intermediate depths within this range.

However, the extent to which water remains over the ephemeral mudflats during spring and summer is related to releases of water over the barrages. If the barrages are closed during spring, water levels in the southern Coorong drop, leaving *Ruppia tuberosa* plants exposed before they have the opportunity to reproduce. However, water levels in the southern Coorong can remain elevated even into February, if the barrage gates remain open until this time (Paton 2010, & unpubl.). Given this, years with little or no spring releases of water over the barrages are likely to restrict the ability of this annual plant to reproduce, while a sequence of such years is likely to exhaust seed banks and restrict the ability of this plant to maintain its presence in the southern Coorong.

Historically, flows of freshwater to the Murray Mouth increased during spring and into summer, with these flows maintaining water levels in the southern Coorong, as well as preventing incursions of marine water and hence salt into the southern Coorong (Paton 2010; Webster 2010). These conditions were favourable for *Ruppia tuberosa* to reproduce both sexually and asexually. However, over the last 30-40 years, the volumes reaching the Murray Mouth have been drastically reduced with increases in upstream extraction of water for human use. In recent years (last 10-15 years), not only has the volume been greatly reduced, but the usual spring peaks in releases have been infrequent or non-existent, particularly during the peak of the millennium drought. Consequently, during this drought, conditions ensued that did not facilitate the maintenance of *Ruppia tuberosa* in the southern Coorong, resulting in its disappearance from the South Lagoon (Paton 2010). Essentially, each winter, some additional seeds within the diminishing seed bank were stimulated to germinate but were never replaced and eventually the seed bank was effectively exhausted. Modelling shows that sufficient water would have reached the Murray Mouth during the millennium drought to provide suitable conditions for *Ruppia tuberosa* to reproduce if water from the Murray Darling Basin was not being extracted. Thus, the loss of this submerged aquatic plant from the southern Coorong during the 2000s was due to extraction of water from the Murray Darling Basin and not drought *per se*.

A key characteristic of the Coorong is a well-established gradient in salinity along its length, with salinities being highest at the southern end of the Coorong. In the years prior to the millennium drought, salinities in the southern Coorong ranged from around 30-60 gL^{-1} in winter, 60-80 gL^{-1} in spring and summer, and 70-110 gL^{-1} in autumn (e.g., Paton 2010), which were typical of salinities measured over the previous 30-40 years. In these years, *Ruppia tuberosa* was distributed along the length of the South Lagoon, indicative of the plant's capacity to cope with a wide range of salinities. Salinities, however, do affect rates of seed germination and sprouting of turions, with higher salinities up to 110 gL^{-1} delaying and dampening germination and sprouting (Paton *et al.* unpub; Kim *et al.* 2013). Given the plants re-establish during winter though, exposure to salinities approaching or exceeding 100 gL^{-1} should be rare. During the millennium drought, however, salinities in winter exceeded 100 gL^{-1} throughout most of the South Lagoon from 2003-2006 and exceeded 120 gL^{-1} from 2007-2010. These high salinities during the millennium drought were likely to have contributed to the loss of *Ruppia tuberosa* from the southern Coorong in the 2000s. However, the plants disappeared one or more years after the high salinities were reached, so high salinities did not necessarily drive the loss of *Ruppia tuberosa* from the southern Coorong. An alternative is that inappropriate water levels in spring were the major factor in the demise of *Ruppia tuberosa*. Throughout this period, little if any water was released over the barrages, so, year after year, populations of *Ruppia tuberosa* were left exposed in spring before they had reproduced. Consistent with this, a small isolated population of *Ruppia tuberosa* remained in a bay within the southern Coorong during the millennium drought despite the high salinities (up to 180 gL^{-1} in summer) because a natural sandbar across the entrance of the bay prevented water levels dropping in spring and so allowed these plants time to reproduce.

With the disappearance of *Ruppia tuberosa* from the southern Coorong during the millennium drought, *Ruppia tuberosa* gradually established mid-way along the North Lagoon in the vicinity of Noonameena. Plants first appeared in this area in winter 2005 and slowly established over the next five years. Colonisation of these areas was probably by small fragments of *Ruppia* (pieces of stolon) dispersed in the water column. By 2009 and 2010, *Ruppia tuberosa* was spread over a 25 km stretch of the North Lagoon, from Magrath Flat (where it already existed prior to the drought) to Long Point, with populations at Noonameena and Rob's Point approaching 90% cover in these years (e.g. Paton & Bailey 2011; Paton *et al.* 2015). Salinities at these sites in winter ranged from 40-120 gL^{-1}. Like their southern counterparts, these northern populations of *Ruppia tuberosa* also suffered falling water levels in spring, although not to the same extent because water levels do not change as much in the North Lagoon. Thus, not all of the plants growing in the North Lagoon were exposed to desiccation. However, when extensive River Murray flows returned to the Murray Mouth in late 2010, the salinities in the middle sections of the North Lagoon quickly dropped and the extensive *Ruppia tuberosa* beds that had established were swamped during summer by filamentous green algae (*Enteromorpha* sp.). This effectively eliminated *Ruppia tuberosa* from the middle sections of the North Lagoon and, few, if any, plants were detected at sites within this region by winter 2011 or subsequently (e.g. Paton & Bailey 2012; Paton *et al.* 2015).

Even since the re-establishment of suitable salinities in the southern Coorong, the recovery of populations of *Ruppia tuberosa* since the breaking of the millennium drought has been slow because of the absence of an effective seed bank. Five years on, the species has not recovered to any extent except at the northernmost sites in the southern Coorong, with even these sites unable to replenish their seed banks. This is not surprising given that the volumes of water released over the barrages during spring have been limited in at least four of the last five years and consequently reproductive outputs continue to be disrupted by falling water levels in spring. A further burden on the re-establishment of *Ruppia tuberosa* has been the appearance of filamentous green algae during spring and summer throughout much of the South Lagoon, particularly in the last couple of years and particularly in the vicinity of Salt Creek, where large volumes of water that have been drained from the Upper South-East have been released. These releases have dampened local salinities and may well have facilitated the establishment of filamentous green algae in the southern Coorong. As with populations of *Ruppia tuberosa* at Noonameena, the *Ruppia tuberosa* that survived the millennium drought in a secluded bay in the South Lagoon was also swamped by filamentous green algae over spring 2014 and has been eliminated. The extent to which salinities are freshened in the southern Coorong may now need to be limited to reduce the extent of interference from filamentous green algae.

Ecological Character Description for *Ruppia tuberosa*

There have been dramatic changes in the distribution and abundance of *Ruppia tuberosa* in the Coorong over the last 10-15 years (outlined above). Overall, the species has declined, shifted its distribution back and forth, and been slow to recover from the impacts of the millennium drought. Although the performance of *Ruppia tuberosa* was likely to be slowly declining at the time the Coorong was listed as a wetland of international importance in the mid-1980s, the perturbations that occurred during the millennium drought hastened the declines and drew attention to the underlying causes. Changes in water levels and salinities that are linked to management and use of water by humans have been the underlying causes that have challenged *Ruppia tuberosa*. That the species still exists is testament to its resilience and capacity to cope to an extent with changes in salinity and water level fluctuations.

Ruppia tuberosa is a critical component of the Ecological Character of the Coorong for the following reasons. *Ruppia tuberosa*: (1) provides habitat and food for other species; (2) dampens wave action and hence erosion of mudflats; (3) is the only plant of its ilk that can tolerate the conditions in the southern Coorong and if lost there are no alternative species that could be substituted to provide the same ecological services; and (4) is the last representative of a suite of submerged aquatic plants that once existed in and defined the ecological character of the Coorong; albeit the red algae *Gracilaria chilensis,* which may now provide some of these ecological services in estuarine parts of the northern Coorong. Given this, the Ecological Character Description for the Coorong needs to include *Ruppia tuberosa* as a key component.

The following ecological character description for *Ruppia tuberosa* is based on (1) the historical distribution and abundance that existed for approximately 20 years prior to the millennium drought (i.e. since the mid-1980s) and (2) the expected current distribution and abundance had the perturbations over the last decade not been as severe. Furthermore, given the tenet of the Murray Basin Plan, the description aims to define an ecosystem that is healthy and resilient, rather than one in a state of collapse.

For a healthy, productive and resilient southern Coorong, *Ruppia tuberosa* should occupy the ephemeral mudflats of the southern Coorong from approximately the Needles in the southern parts of the North Lagoon to the southernmost parts of the South Lagoon, a spread of over 50 km. Within this range, most locations on either side of the Coorong should support the species. However, the width of the beds will vary from location to location, depending on the actual bathymetry and water levels, and the extent to which bays are protected from prevailing winds in winter and spring. Protected bays with shallow bathymetries generally support more plants. In every year, plants should be detected in winter at 80% of sites (at least), with at least 50% of these sites having healthy populations of *Ruppia tuberosa*.

Healthy populations of *Ruppia tuberosa* have at least 30% cover at the optimum water depths (water depths in the range of 0.5-0.8 m) in winter, with a density of at least 10 shoots per 75 mm diameter core (2260 shoots per m^2) where plants are present in the cores. In addition, 50% of cores should have seeds present in winter, as this provides an indication of some ongoing resilience (i.e. a potential reserve of seeds should the plants fail to reproduce and replenish the seed bank in the current year). At least 50% of sites with *Ruppia tuberosa* should also produce flowers in spring with densities of at least 50 flower-heads per m^2 over at least half the area occupied by plants. By the end of summer, and as water levels recede, healthy populations of *Ruppia tuberosa* should have produced turions such that at least 50% of 75 mm diameter cores taken across the *Ruppia* beds contain at least type II turions. Furthermore, the accumulated seed banks should exceed 2,000 seeds per m^2.

The available data during the 1980s and 1990s, and prior to the millennium drought, although sometimes limited in extent, indicate that *Ruppia tuberosa* would have met these targets during this period. These targets, however, are not being met at the moment. Only two of 11 sites (18%) monitored in July 2014 were healthy, and only one of the sites had more than 50% of cores containing seeds. Furthermore, the prospect of re-establishing healthy and resilient populations of *Ruppia tuberosa* across the southern Coorong remains unlikely for the foreseeable future. This is because of the current inability to solve water level issues in spring and to deal with interference from filamentous green algae.

Limits of Acceptable Change (LAC)

Given that *Ruppia tuberosa* is a key ecological feature of the southern Coorong, the loss of the species from the whole of the South Lagoon for several years and up to 10 years at some of the southernmost sites is unacceptable. The slow rate of recovery following the millennium drought suggests that the limits of acceptable change were breached during this malevolent period. The capacity to recover quickly is related to the cover of plants and the salinity and water level conditions that are provided during recovery. Once the cover of plants is around 1%, it typically takes at least 2-3 years for the cover to reach 30% and longer if inappropriate conditions for *Ruppia tuberosa* recur. *Ruppia tuberosa* plants were not detected back on sites across the southern half of the South Lagoon until 3-4 years after the breaking of the millennium drought, and then only small numbers of plants were detected, suggesting that, to reach a minimum 30% cover, populations of *Ruppia tuberosa* may require a further two or more years. To maintain some semblance of the ecological character of the southern Coorong, such absences need to be avoided in the future. Consequently, a conservative approach should be used. In setting a limit to the level of change that can be tolerated, a key consideration should be the likely capacity for speedy recovery without the need for intervention (e.g. translocations from other sites), while still maintaining the presence of *Ruppia tuberosa* across at least a reasonable portion of the South Lagoon. When populations fall below 10% cover in winter, there is a risk that these populations will disappear in the subsequent year, and at best recovery to 30% is likely to take at least a year with suitable conditions. A simple Limit of Acceptable Change for *Ruppia tuberosa* would be when the cover has fallen to 10% or less for at least half of the populations (or sites) being monitored across the southern Coorong. In July 2014, *Ruppia tuberosa* was still beyond this Limit of Acceptable Change.

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