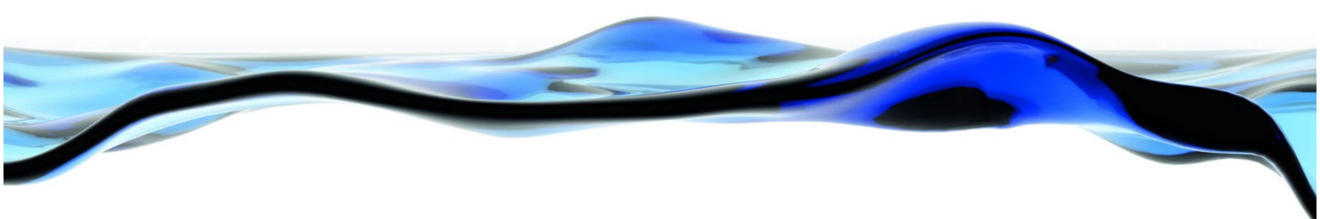
Using recent wetting events to detect salinity thresholds for aquatic plants in the South-East of South Australia

Aldridge K, Goodman A, Nicol J, Gehrig S and Ganf G



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Enquires should be addressed to:

Goyder Institute for Water Research
Level 1, Torrens Building
220 Victoria Square, Adelaide, SA, 5000

tel: 08-8110 9994
e-mail: goyder@csiro.au

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Executive summary

Aquatic plants (macrophytes) are essential components of wetland ecosystems; they provide habitat and food for higher trophic organisms and are considered to be indicators of the condition of wetland ecosystems. Historical data for macrophyte communities in the South-East of South Australia indicates a shift from macrophyte communities suited to wet, low salinity conditions to drier, more saline conditions. In order to optimise management of water resources in the South-East it is imperative to identify salinity threshold values for the condition of wetland ecosystems. The aim of this project was to produce a database that could be used to characterise relationships between salinity and the abundance and distribution of key aquatic plant species and communities in the South-East.

A survey of the macrophyte communities in wetlands of the South-East was conducted in November-December 2010. This included 80 transects in 28 wetland/wetland complexes, which contained 76 species of macrophytes, including three exotics and four species listed as rare in South Australia. The survey also incorporated water quality and sediment character gradients, with electrical conductivity varying between 200 and 70263 µS cm^{-1}.

Preliminary findings from this study showed that there were four distinct macrophyte community groups found within wetlands of the South-East. Electrical conductivity was found to be the primary driver of macrophyte community composition. Groups 1 and 2 are freshwater wetlands dominated by freshwater macrophytes and euryhaline species. Group 1 wetlands are clear, groundwater fed systems only present in the south of the region. Group 2 wetlands have larger surface water contributions (although groundwater is important) and are generally located in the east of the region. Group 4 wetlands are brackish to saline systems in the north or along the coast of the region.

Although electrical conductivity appeared to be the primary driver of macrophyte communities, increases in dissolved organic carbon, total phosphorus, total nitrogen, dissolved oxygen, turbidity and chlorophyll *a* were associated with Group 3 wetlands, which were considered to be degraded sites located in the north of the region. The cause of this degradation requires further investigation, but it is likely to be associated with internal and

external inputs of nutrients and dissolved organic carbon creating conditions that allow phytoplankton and epiphytic algae to displace macrophytes.

The surveys resulted in the production of a database, which could be used in several ways to assist in the management of wetlands, drainage networks and land-use in the South-East. In particular, the information will be used in current and proposed research projects for the Goyder Institute. It will provide input data for a decision support system; be used to establish salinity threshold values for management of wetlands and drainage networks; and used to understand the likely impacts of alternative management actions. The collection of this important information would not have been possible without approval of the project being fast-tracked by the Goyder Institute. This is particularly important given there is much interest in research and management of wetlands in the South-East, but there are no guarantees of sufficient water availability in future years to enable this type of data collection.

Introduction

The South-East of South Australia (herein referred to as the South-East) is a region of high biodiversity, much of which is dependent upon wetlands (Taylor 2006). Prior to European settlement wetland ecosystems are believed to have covered 55% of the lower South-East. However, land clearance and drainage of the landscape has meant that now only 10% of the region is covered by wetlands, much of which is considered to be degraded (Taylor 2006).

Due to the extensive drainage network and groundwater use that now exists in the South-East, there have been large modifications to the hydrological cycle, which have impacted the salinity regimes of the wetlands. Historical data for aquatic macrophyte communities in the South-East indicates a shift from communities suited to wet, low salinity conditions to drier, more saline conditions (Ganf *et al.* 2010). As salinity increases, macrophytes become increasingly stressed resulting in reduced growth and reproduction and ultimately death, leading to a decline in species richness (Hart *et al.* 1991; Nielsen *et al.* 2003).

Future management actions, including groundwater use and the movement of drainage water, will impact upon the hydrological and salinity regimes of wetlands. This will impact upon the ecological condition of these wetlands. In order to optimise management of water resources in the South-East, it is therefore imperative to identify salinity threshold values for the condition of wetland ecosystems. Macrophytes play an integral role in wetland ecosystems, providing both energy and habitat for higher trophic organisms, including fish and birds. Consequently, they are considered good indicators of wetland condition (Spencer *et al.* 1998).

In 2010, rainfall of 600-800 mm in the South-East (Bureau of Meteorology, unpublished data) meant that there was sufficient water within many wetlands to examine the ecological response, for only the second time in the past 10 years. The aim of this project was to utilise this wet period and establish a relationship between salinity and the abundance and distribution of key aquatic plant species and communities in the South-East. This information will be used to produce salinity response models in future research projects in the South-East. These objectives were achieved by utilising the natural north-south salinity gradient that exists in the South-East. The response of the macrophyte community to this salinity gradient was examined. The influence of additional physicochemical conditions upon macrophyte communities was also examined, to determine whether other factors may need to be considered for future management of these wetlands.

Methods

Wetland surveys

In November-December 2010, 28 wetlands (including wetland complexes greater than one wetland basin) were visited in order to assess the macrophyte community and physico-chemical conditions (Figure 1 and Table 1). Where a salinity gradient was present within a wetland or there existed obvious spatial differences in the macrophyte community within the wetland, multiple sites within the wetland were surveyed.

Macrophyte frequency of occurrence

Twenty metre transects (dimensions: 20 x 1 m) were selected for surveys of the macrophyte community, consisting of twenty 1 m x 1 m cells. In each cell, the presence of individual macrophyte species were identified and recorded. The number of transects varied between sites to allow spatial variation in the macrophyte community to be incorporated. For each species, the number of cells in each transect containing that species was calculated as a frequency of occurrence (e.g. 4 of 20).

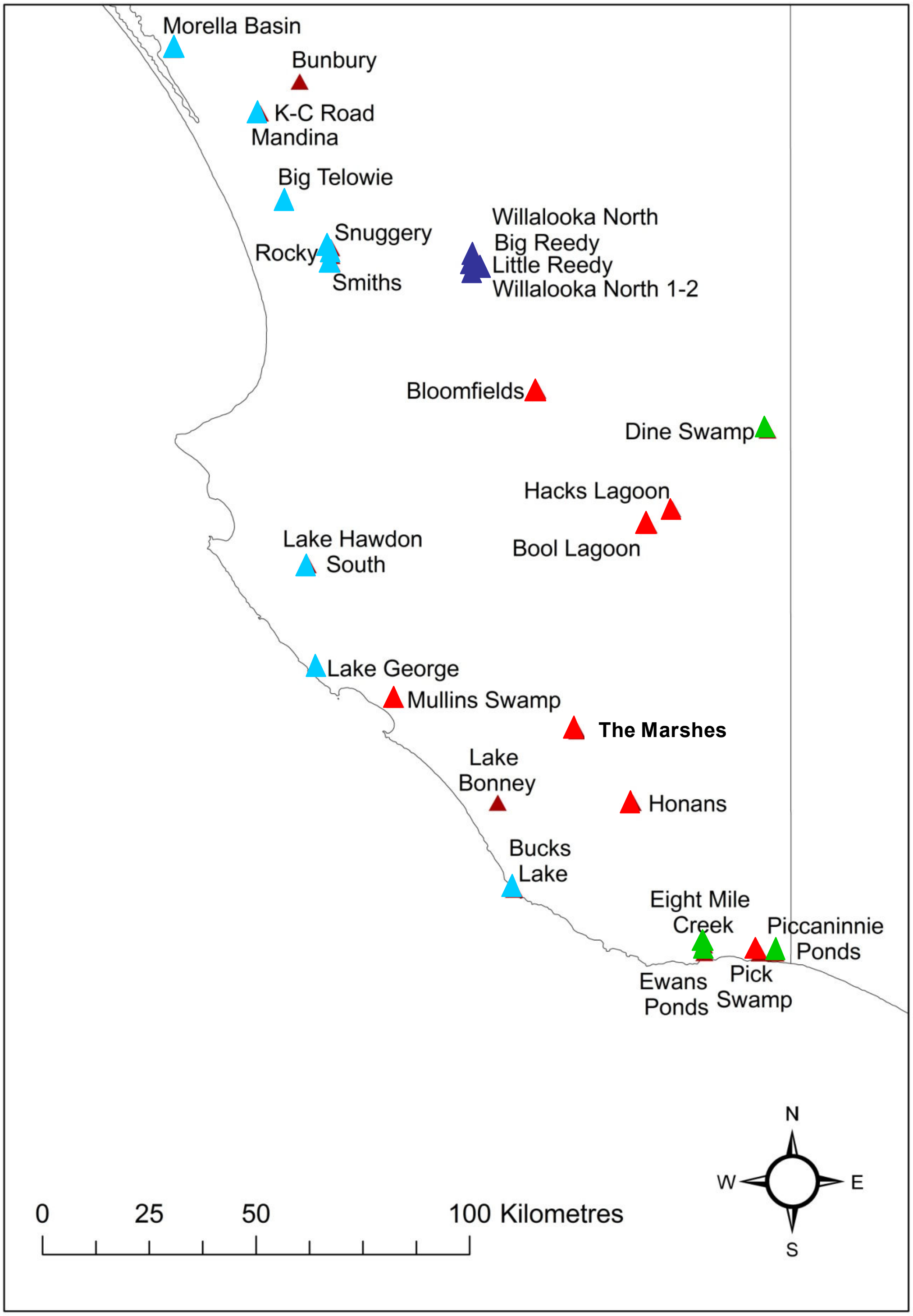

Figure 1. Locations of wetlands and wetland complexes surveyed November-December, 2010. Different coloured labels show macrophyte community groups identified from data analysis (green=group1, red=group 2, dark blue=group 3 and light blue=group 4; Figure 2 and Figure 3). Bunbury and Lake Bonney were not included in the data analysis due to missing physicochemical data.

Table 1. Wetlands surveyed in south-east South Australia, November-December 2010.

Wetland/wetland complexes	Date sampled
Bunbury	29/11/2010
K-C Road	30/11/2010
Mandina Marshes	30/11/2010
Morella Basin	30/11/2010
Big Telowie	1/12/2010
Rocky	1/12/2010
Smiths	1/12/2010
Snuggery	1/12/2010
Bloomfield	2/12/2010
Bool Lagoon	2/12/2010
Dine Swamp	2/12/2010
Hacks Lagoon	2/12/2010
Big Reedy	3/12/2010
Little Reedy	3/12/2010
Willalooka North	3/12/2010
Willalooka South 1	3/12/2010
Willalooka South 2	3/12/2010
Lake Hawdon South	6/12/2010
Honans	7/12/2010
The Marshes	7/12/2010
Eight Mile Creek	8/12/2010
Ewans Ponds	8/12/2010
Lake George	8/12/2010
Piccaninnie Ponds	8/12/2010
Pick Swamp	8/12/2010
Bucks Lake	9/12/2010
Lake Bonney	9/12/2010
Mullins Swamp	9/12/2010

Sediment character

At each end and in the middle of each transect, sediment samples were collected with a trowel to a depth of 5 cm. Samples were stored below 3°C in the dark and returned to the laboratory at The University of Adelaide. Samples were dried at 70°C to a constant weight. Sediments from transects were pooled to give 3 replicate sediment samples for each wetland. The replicates were then ground with a mortar and pestle to <2mm and analysed for organic matter content, texture and electrical conductivity.

Organic matter content was analysed following APHA method 2540-E (Eaton *et al.* 2005), whereby a subsample of sediment of a known dry weight was ignited to 550°C for 1 hr and the combusted weight was measured. The difference between combusted and dry weights was calculated as the organic matter content. The electrical conductivity was determined following methods of Slavich and Petterson (1993), whereby soil was overlain with deionised water to 1:5 soil:water ratio. After 24 hr on an orbital shaker the electrical conductivity was measured ($EC_{1:5}$), which was then used to calculate the electrical conductivity of soil water (ECe) by:

$$ECe = f \times EC1{:}5$$

where *f* is a conversion factor based on broad soil texture grades (Slavich and Petterson 1993). Soil texture was determined flowing methods of McDonald *et al*. (1998), which involves determining the behaviour of moist bolus and ribbon length of soil.

Water quality

At each site, a calibrated Hydrolab DS-5X (Hach) multiprobe was lowered through the water column. At approximately 0.25 m intervals spot measurements were made (between 10:00 am and 5:00 pm depending on when the wetland was surveyed) for water temperature, specific electrical conductivity, dissolved oxygen (concentration and saturation), pH, turbidity and chlorophyll *a* upon equilibration. This was repeated multiple times within each site to incorporate spatial differences. Chlorophyll *a* measurements made with the Hydrolab DS-5X were corrected for laboratory measurements of collected depth-integrated water samples and analysed using methods described below.

Depth-integrated water samples were collected from three locations within each site and pooled as a composite sample. Approximately 1 L of unfiltered water was collected and approximately 100 mL of this was immediately filtered through a Millex® AP 20 GF prefilter and a Millex ® 0.45µm PES Membrane filter. Filters were not pre-rinsed as they were found not to leach detectable levels of nutrients; however, the first 5 mL of filtered sample was not dispensed into the sample bottle. All samples were immediately stored in the dark below 3°C until analysis.

Unfiltered water samples were analysed for total phosphorus (TP), total Kjeldahl nitrogen (TN) and chlorophyll *a*. Nutrient analyses were conducted by the South Australian Research and Development Institute. Chlorophyll *a* was measured following Golterman *et al*. (1978). This involved concentrating suspended particulate material onto Whatman International GF-C filters, extracting chlorophyll in 99.8% methanol and measuring absorbance at 750 and 665 nm using a Hitachi U-2000 spectrophotometer (Hitachi Ltd., Tokyo, Japan), with a path length of 10 mm. Filtered samples were analysed for dissolved organic carbon (DOC) by the Australian Water Quality Centre, a NATA (National Association of Testing Authorities) accredited laboratory, following standard methods.

<u>Preliminary data analysis</u>

Data from 25 of the 28 wetlands was analysed, using only wetlands with a full suite of physicochemical parameters. Transects from individual wetlands were pooled and converted to presence-absence for all analyses. The plant community between the 25 wetlands was compared by group average clustering using the package PRIMER version 6.1.12 (Clarke and Gorley 2006). At a similarity of 23%, cluster analysis identified four distinct groups and the differences between the groups were analysed by indicator species analysis (Dufrene and Legendre 1997) using the package PCOrd version 5.12 (McCune and Mefford 2006). Relationships between the plant community and physicochemical conditions were analysed by NMS ordination (using the package PRIMER version 6.1.12 (Clarke and Gorley 2006) with standardised environmental variables overlayed on the ordination using Spearman rank correlation. Bray-Curtis (1957) similarities were used to calculate the similarity matrix for the cluster and ordination analyses.

Indicator species analysis

Dufrene and Legendre’s (1997) indicator species analysis combines information on the concentration of species abundance in a particular group (survey date) and the faithfulness of occurrence of a species in a particular group (McCune *et al.* 2002). A perfect indicator of a particular group should be faithful to that group (always present) and exclusive to that group (never occurring in other groups) (McCune *et al.* 2002). This test produces indicator values for each species in each group based on the standards of the prefect indicator. Statistical significance of each indicator value is tested by using a Monte Carlo (randomisation) technique, where the real data is compared against 10,000 runs of randomised data (Dufrene and Legendre 1997). For this study, the groups were assigned according to cluster groups. A species that is deemed not to be a significant indicator of a particular group is either uncommon or widespread. An uncommon species is only found in one group but in low numbers and a widespread species is found in more than one group in similar numbers (Dufrene and Legendre 1997). Whether a species was classed as a widespread or uncommon non-significant species was determined by examination of the relative abundance table produced by PCOrd.

Results and outputs

<u>Macrophyte survey along a salinity and physicochemical gradient</u>

A survey of the macrophyte communities in wetlands of the South-East was conducted in November-December 2010. This included 80 transects in 28 wetland/wetland complexes, which contained 76 species of macrophytes including three exotics and four species listed as rare in South Australia. The survey also incorporated water quality and sediment character gradients. The gradients are important in determining macrophyte responses to physicochemical conditions and identifying threshold values. Electrical conductivity varied between 200 (Honans) and 70,263 µS cm^{-1} (Bunbury). Similarly, gradients were observed for dissolved oxygen (1.06-15.34 mg L^{-1}), pH (5.13-10.58), dissolved organic carbon (1.1-99.7 mg L^{-1}), total nitrogen (0.902-7.560 mg L^{-1}) total phosphorus (0.009-1.200 mg L^{-1}), sediment ECe (1693-230632 µS cm^{-1}) and sediment organic matter content (0.024-0.486 g g^{-1} dry weight).

Production of the database

The surveys resulted in a production of a database including macrophyte frequency of occurrence in each transect, water quality parameters in each wetland and sediment characteristics for each replicate of each wetland. The database includes 4 worksheets: site description, macrophyte frequency of occurrence, water quality and sediment character. Samples of these worksheets are shown below as Image 1, Image 2 and Image 3. To facilitate future use of the database metadata was also included in a separate file, a sample of which is shown in Image 4.

Image 1. Sample of the macrophyte frequency of occurrence worksheet from the database.

Wetland	Transect	*Alisma lanceolatum*	*Batrachium trichophyllum*	*Baumea arthrophylla*	*Baumea articulata*	*Baumea juncea*
8 Mile Creek	1					
8 Mile Creek	2					
Big Reedy	1					
Big Reedy	2					
Big Telowie	1					
Big Telowie	2					
Big Telowie	3					
Big Telowie	4					
Bloomfield	1					
Bloomfield	2					
Bloomfield	3					
Bloomfield	4					
Bool - Drain	1			20		
Bool - Drain	2			13		
Bool - Drain	3			1		
Bool - Yards	1	19		19		7
Bool - Yards	2	20		18		1
Bucks	1					
Bucks	2					
Bucks	3			9		*
Bunbury	1					
Dine	1					

Image 2. Sample of the water quality worksheet from the database.

Wetland	Transects	Electrical conductivity (uS/cm)	Dissolved organic carbon (mg/L)	Total nitrogen (mg/L)
Big Reedy	1-2	1384.9	33.4	7.560
Big Telowie	1-4	8861.8	10.3	1.320
Bloomfield	1-4	481.6	35.5	3.160
Bool Drain	1-2	1580.0	32.2	4.130
Bool Drain Outlet	3	2779.7	30.8	4.230
Bucks	1-3	4954.7	63.6	5.600
Bunbury	1	70263.3	39.6	3.050
Dine	1	244.3	34.7	3.630
Ewans Ponds	1-2	739.7	1.1	6.370
Hacks	1-4	1360.3	38.2	3.050
Honans	1-2	200.1	21.6	1.460
Honans	4-5	364.6	16.2	2.070
K-C Road	1-5	16509.4	20.0	1.700
Lake Bonney	1-3	9850.0	99.7	6.490
Lake George	1	58990.0	41.4	5.030
Lake George	2	62236.5	44.1	4.960
Lake Hawdon South	1-3	2751.7	10.7	1.260
Little Reedy	1	1027.0	26.3	4.030

Image 3. Sample of the sediment character worksheet from database.

Wetland	Replicate	Sediment texture	Electrical conductivity of soil water (uS/cm)	Organic Matter (g/g DW)
8 Mile Creek	1	Loamy Sand	23381.0	0.209
8 Mile Creek	2	Loamy Sand	24674.9	0.191
8 Mile Creek	3	Loamy Sand	21179.1	0.169
Big Reedy	1	Loam	7780.5	0.173
Big Reedy	3	Loam	6469.5	0.126
Big Reedy	2	Loam	5443.5	0.122
Bloomfield	1	Loam	3163.5	0.154
Bloomfield	3	Loam	3211.0	0.091
Bloomfield	2	Clayey Sand	6038.2	0.162
Bool - Drain	1	Sand Clay Loam	11257.5	0.267
Bool - Drain	2	Sandy Clay	6716.6	0.151
Bool - Drain	3	Sandy Clay	7387.4	0.069
Bucks	1	Sandy Loam	20134.2	0.059
Bucks	2	Loamy Sand	27807.5	0.078
Bucks	3	Sandy Loam	19057.8	0.092
Bunbury	1	Medium Clay	96600.0	0.269
Bunbury	2	Medium Clay	100650.0	0.252
Bunbury	3	Medium Clay	98475.0	0.259

Image 4. Sample of the metadata spreadsheet for the database. Metadata fields are based on fields used by the Department of Environment and Natural Resources.

Metadata Field	Details
Dataset Name/Project/Title	Macrophyte and physico-chemistry database for wetlands in south-east South Australia_Nov-Dec 2010
Description/Abstract	A survey of macrophyte communities, water quality and sediment character was conducted in the wetlands of south-east South Australia. Measurments were made at multiple locations in 28 wetland/wetland complexes. Field surveys were conducted between 29/11/10 and 10/12/10.
Methodology/Lineage	At each site 20 m transects containing 20 1 x 1m cells were surveyed for macrophyte presence. At each end of the transects and in the middle, sediment samples were collected and anlysed for texture, organic matter content and salinity. At each site, physico-chemical parameters (water temperature, electrical conductivity, dissolved oxygen, pH, turbidity and chlorophyll) were measured with a hydrolab at approximately 0.25 m intervals through the water column at multiple sites. Integrated water samples were collected from 3 locations within each site and pooled as a composite sample. Samples were analysed in the laboratory for chlorophyll, total nitrogen, total phosphorus and dissolved organic carbon. Depth profiles of chlorophyll were calibrated *post hoc* using integrated samples analysed in the laboratory.
Dataset Use	The data can be used to assess changes in macrophyte abundance and distribution in wetlands of south-east South Australia. In addition, factors controlling the abundance and distribution can be investigated. Compaison to previously collected data will allow an understanding of the influence of successive wetting events on macrophyte communities.
Restrictions on Use	Permission required from owners (The University of Adelaide) for use of the data by external organisations. Acknowledgement of the source of the data must always be made.
Start date	29/11/2010
End date	10/12/2010
Category	Biodiversity
Theme	Flora populations and distributions
Accuracy/Validation	Field and laboratory personnel are highly experienced. The hydrolab for physico-chemical measurements was calibrated prior to sampling. Chlorophyll analyses conducted in the field were calibrated with laboratory analyses *post hoc*. Nutreint analyses were conducted by the South Australian Research and Development Institute. Dissolved orgnaic carbon analyses were conudcted by Australian Water Quality Centre, a NATA (National Association of Testing Authorities) accredited laboratory.
Positional Accuracy	The coordinates are based on GPS readings, which have an accuracy of <20m.
Geographic Extent	Surveys were conducted in south-east South Australia, between Salt Creek-Tintinara-Naracoorte-South Australian/Victorian Border east of Naracoorte-South Australian/Victorian border west of Nelson
Status	Complete
Maintenance	Data supplied and entered in database is complete.
Completion date	28/02/2010
Data format	Source data is stored in excel spreadsheets
Organisation	The University of Adelaide
Contact Name	Kane Aldridge
Contact Details	Postal: The University of Adelaide, Adelaide, South Australia, 5005. Email: kane.aldridge@adelaide.edu.au
Reference/Citation	Goodman A., Gehrig S., Nicol J., Ganf G. and Aldridge K. (2011). Drivers of macrophyte communities in south-east South Australia, November-December 2010.

Preliminary findings

Cluster analysis identified four groups at a similarity of 23% (Figure 2). Wetlands in Group 1 were dominated by freshwater emergent (*Phragmites australis, Carex fasicularis, Hydrocotyle verticillata* and *Ranunculus sessiflorus*), floating (*Lemna minor*) and submergent (*Isolepis inundata*) species (Table 2). Furthermore, *Myriophyllum salsugineum* and *Persicaria* sp. were only present in Group 1 wetlands but not sufficiently widespread within the group to be significant indicators (Table 2). Finally there were several species that were widespread between groups also present in Group 1 wetlands (Table 2). The majority of the aforementioned species were freshwater emergent (*Typha domingensis, Baumea articulata* and *Eleocharis acuta*), floating (*Wolfia* sp.), or submergent (*Lepilaena australis* and *Potamogeton ochreatus*) species (Table 2). Physicochemical conditions in Group 1 wetlands were characterised by low surface water electrical conductivity and high sediment organic carbon content (Figure 3).

Similar to Group 1 wetlands, physicochemical conditions in Group 2 wetlands were also characterised by low surface water electrical conductivity and high sediment organic carbon content (Figure 3). However, the plant community was dominated by freshwater emergent (*Cyperus fasicularis, Juncus pallidus* and *Triglochin procerum*), amphibious herbland (*Crassula helmsii, Myriophyllum simulans/varifolium* and *Villarsia reniformis*) and submergent (*Potamogeton tricarinatus*) taxa (Table 2). In addition, all of the uncommon species present only in Group 2 (except *Ficinia nodosa* and *Gahnia filum*) were freshwater species with low salinity thresholds (Table 2). The widespread species between Groups 1 and 2 were freshwater species with low salinity tolerance; however, the widespread species between Group 2 and Groups 3 and/or 4 were euryhaline species that are found over wide salinity ranges (Table 2).

Group 3 wetlands were characterised by intermediate to high surface water electrical conductivity, were eutrophic (high TN and TP), had high turbidity, DOC, dissolved oxygen and chlorophyll *a* (Figure 3). The plant community was dominated by emergent species (*Cyperus gymnocaulos* and *Distichlis distichophylla*) and the tree *Melaleuca halmaturorum* (Table 2). There were no uncommon species present in Group 3 and the widespread species were species found over wide salinity ranges (Table 2).

Group 4 wetlands were characterised with intermediate to high surface water salinity (Figure 3) and the plant community was dominated by halophytes (*Ruppia tuberosa, Sarcocornia quinqueflora* and *Lepilaena cylindrocarpa*) and euryhaline species (*Wilsonia rotundifolia, Myriophyllum muelleri, Selliera radicans* and *Triglochin striatum*) (Table 2). Uncommon species only found in group 4 wetlands were halophytic (*Lepilaena preissii*) euryhaline (*Gahnia trifida, Lobelia* sp., *Schoenoplectus pungens, Wilsonia backhousei* and *Wilsonia humilis*) or coastal terrestrial (*Lepidosperma laterale*) taxa (Table 2).

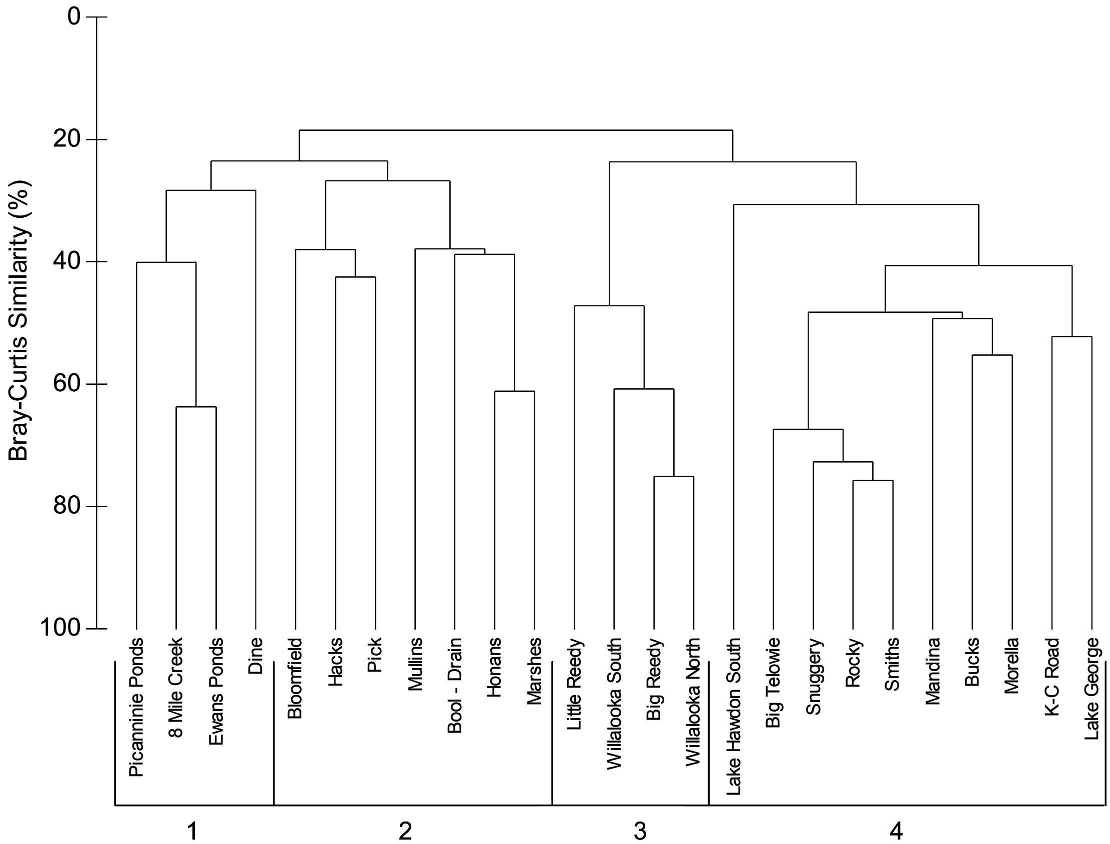

Figure 2. Group average cluster analysis comparing the plant communities of 25 South-East wetlands.

Table 2. Indicator species analysis results (and functional classification) comparing the four groups identified from the cluster dendrogram comparing plant communities of 25 South-East wetlands (yellow highlighted denotes significant indicator α=0.05, *denotes exotic species, #denotes listed as rare in South Australia).

Species	Group	*P*	Reason species is not a significant indicator	Functional classification
*Alisma lanceolatum**	2	0.604	Uncommon	Freshwater emergent
Apodasmia brownii	2	1.000	Widespread between groups 2 and 4	
*Aster subulatus**	2	0.597	Widespread between groups 2 and 3	Fresh-brackish emergent
Azolla sp.	2	0.604	Uncommon	Freshwater floating
*Batrachium trichophyllum**	2	0.604	Uncommon	Freshwater amphibious
Baumea arthrophylla	2	0.231	Widespread between groups 1, 2 and 4	Fresh-brackish emergent
Baumea articulata	1	0.710	Widespread between groups 1 and 2	Freshwater emergent
Baumea juncea	4	0.172	Widespread between groups 2 and 4	Fresh-brackish emergent
Bolboschoenus caldwellii	2	0.604	Uncommon	Euryhaline emergent
Carex fasicularis	1	0.042		Freshwater emergent
Carex tereticaulis	2	0.112	Uncommon	Freshwater emergent
Ceratophyllum demersum#	2	0.113	Uncommon	Freshwater submergent
Cotula coronopifolia	2	0.838	Widespread between groups 2, 3 and 4	Euryhaline amphibious
Crassula helmsii	2	0.004		Freshwater amphibious
Cyperus fasicularis	2	0.019		Freshwater emergent
Cyperus gymnocaulos	3	0.004		Fresh-brackish emergent
Distichlis distichophylla	3	0.045		Euryhaline emergent
Eleocharis acuta	1	0.111	Widespread between groups 1 and 2	Freshwater emergent
Epilobium pallidiflorum.	2	0.107	Uncommon	Fresh-brackish emergent
Eucalyptus camaldulensis	4	0.921	Widespread between all groups	Fresh-brackish tree
Ficinia nodosa	2	1.000	Uncommon	Euryhaline emergent
Gahnia filum	2	0.110	Uncommon	Euryhaline emergent
Gahnia trifida	4	1.000	Uncommon	Euryhaline emergent
Hydrocotyle plebeya	2	0.608	Uncommon	Freshwater emergent
Hydrocotyle verticillata	1	0.042		Freshwater emergent
Isolepis fluitans	2	0.268	Widespread between groups 2 and 4	Freshwater submergent
Isolepis platycarpa	4	0.115	Widespread between groups 1 and 4	Euryhaline emergent
Isolepis inundata	1	0.040		Freshwater submergent
Juncus holoschoenus	2	0.115	Uncommon	Freshwater emergent
Juncus kraussii	4	0.178	Widespread between groups 2 and 4	Euryhaline emergent
Juncus pallidus	2	0.012		Freshwater emergent
Lemna minor	1	0.018		Freshwater floating
Lepidosperma laterale	4	1.000	Uncommon	Terrestrial
Lepilaena australis	1	0.708	Widespread between groups 1 and 2	Freshwater submergent
Lepilaena cylindrocarpa	4	0.003		Halophyte-submergent
Lepilaena patentifolia	4	0.180	Widespread between groups 2 and 4	Euryhaline submergent
Lepilaena preissii	4	1.000	Uncommon	Halophyte-submergent
Lilaeopsis polyantha	1	0.177	Widespread between groups 1, 2 and 4	Euryhaline amphibious

Species	Group	*P*	Reason species is not a significant indicator	Functional classification
Lobelia sp.	4	0.881	Uncommon	Euryhaline amphibious
Melaleuca halmaturorum	3	0.016		Euryhaline tree
Mimulus repens	4	0.818	Widespread between groups 2, 3 and 4	Euryhaline amphibious
Myriophyllum muelleri	4	0.004		Euryhaline amphibious
Myriophyllum papillosum#	2	0.112	Uncommon	Freshwater amphibious
Myriophyllum salsugenium	1	0.310	Uncommon	Freshwater amphibious
Myriophyllum simulans/varifolium#	2	0.012		Freshwater amphibious
Myriophyllum triphyllum	2	0.112	Uncommon	Freshwater amphibious
Persicaria sp.	1	0.322	Uncommon	Freshwater emergent
Phragmites australis	1	0.021		Freshwater emergent
Potamogeton ochreatus#	1	0.713	Widespread between groups 1 and 2	Freshwater submergent
Potamogeton pectinatus	4	0.288	Widespread between groups 2 and 4	Euryhaline submergent
Potamogeton tricarinatus	2	0.014		Freshwater submergent
Ranunculus inundatus	2	0.112	Uncommon	Freshwater emergent
Ranunculus papulentus	1	0.322	Uncommon	Freshwater emergent
Ranunculus pentandrus var. *pentandrus*	1	0.193	Widespread between groups 1 and 2	Freshwater emergent
Ranunculus sessiflorus	1	0.042		Freshwater emergent
Ricciocarpus natans	2	0.608	Uncommon	Freshwater amphibious
Rorippa eustylis	2	0.112	Uncommon	Freshwater emergent
Ruppia megacarpa	4	0.347	Widespread between groups 2 and 4	Euryhaline submergent
Ruppia polycarpa	2	0.420	Widespread between groups 2 and 4	Euryhaline submergent
Ruppia tuberosa	4	0.002		Halophyte-submergent
Samolus repens	4	0.660	Widespread between groups 1, 2 and 4	Euryhaline emergent
Sarcocornia quinqueflora	4	0.005		Halophyte-emergent
Schoenoplectus pungens	4	0.186	Uncommon	Euryhaline emergent
Schoenoplectus validus	2	0.596	Uncommon	Freshwater emergent
Selliera radicans	4	0.015		Euryhaline amphibious
Spirodela sp.	1	0.718	Widespread between groups 1 and 2	Freshwater floating
Triglochin procerum	2	0.046		Freshwater emergent
Triglochin striatum	4	<0.001		Euryhaline emergent
Triglochin trichophorum	2	0.597	Uncommon	Freshwater emergent
Typha domingensis	2	0.115	Widespread between groups 1 and 2	Freshwater emergent
Villarsia reniformis	2	0.047		Freshwater amphibious
Wilsonia backhousei	4	1.000	Uncommon	Euryhaline emergent
Wilsonia humilis	4	1.000	Uncommon	Euryhaline emergent
Wilsonia rotundifolia	4	0.003		Euryhaline emergent
Wolfia sp.	2	0.339	Widespread between groups 1 and 2	Freshwater floating
Pasture grass*	3	0.101	Widespread between all groups	Terrestrial
Decaying pasture grass	2	0.420	Widespread between groups 2 and 4	
Filamentous algae	4	0.334	Widespread between groups 2 and 3	

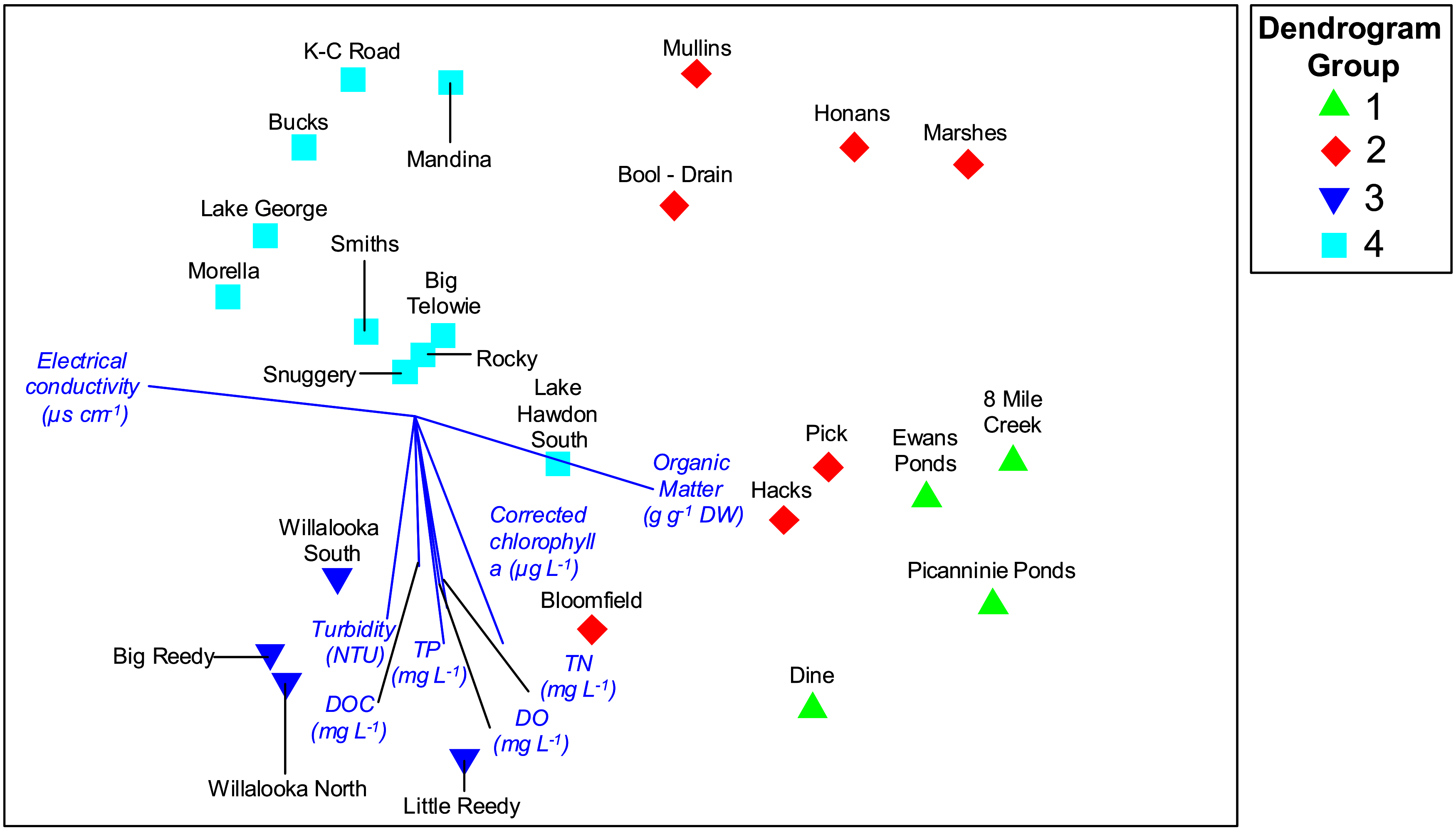

Figure 3. NMS ordination (stress=0.15) comparing the plant community of 25 South-East wetlands with environmental variables overlayed as vectors (TN is total nitrogen, TP is total phosphorus, DOC is dissolved organic carbon and DO is dissolved oxygen).

Discussion

Drivers of macrophyte communities in the South-East

Preliminary findings from this study showed that there are distinct macrophyte community groups found within wetlands of the South-East. Electrical conductivity was found to be the primary driver of macrophyte community composition (Figure 3). As electrical conductivity increased, the organic matter content of the sediments decreased, presumably due to decreased macrophyte abundance and organic material. Groups 1 and 2 are freshwater wetlands dominated by freshwater macrophytes and euryhaline species. Group 1 wetlands, with the exception of Dine Swamp, are clear groundwater fed systems only present in the south of the region (Figure 1). Group 2 wetlands have larger surface water contributions (although groundwater is important) and are located in the east of the region (Figure 1). Group 4 wetlands are brackish to saline systems in the north or along the coast of the region. Lake Hawdon South is the exception but was present in Group 4 due to the presence of several euryhaline species (e.g. *Juncus kraussii, Schoenoplectus pungens*).

Additional physicochemical conditions were correlated with the macrophyte community composition. In particular, DOC, TP, TN, dissolved oxygen, turbidity and chlorophyll *a* appeared to be important determinants of the macrophyte community composition. Increasing DOC, TP, TN, dissolved oxygen, turbidity and chlorophyll *a* were associated with Group 3 wetlands, which were considered to be degraded sites located in the north of the region (Figure 1). These sites had been dry for an extended period and terrestrial vegetation (predominantly agricultural weeds) had recruited on the wetland bed (A. Goodman unpublished data). It is thought that when inundated in spring 2009 the terrestrial vegetation died with decomposition releasing nitrogen and phosphorus (there were probably also significant external inputs from surrounding land-use) causing a phytoplankton bloom. Furthermore, decomposition released dissolved organic carbon which (in conjunction with phytoplankton) has resulted in high turbidity and conditions unfavourable for recruitment and growth of submergent macrophytes (*sensu* Morris *et al.* 2003; Scheffer and van Nes 2007; Viaroli *et al.* 2008). The high dissolved oxygen observed in Group 3 wetlands was due to high phytoplankton abundance and it is expected that during the night the wetlands would become anoxic. Some wetlands within Group 4 were previously dominated by *Triglochin procerum* (A. Goodman unpublished data). In 2010 the *T. procerum* beds were present but the plants had been top-flooded and the leaves were rotting and covered in epiphytic algae. Dine Swamp was identified within Group 1, which was due to the presence of floating species. Dine Swamp was considered to be degraded, with low abundance of rooted macrophytes and high DOC, TN, TP and chlorophyll *a*.

Based on the snapshot of the plant community in spring 2010 four broad wetland types can be identified in the South-East; freshwater open water wetlands (group 1), freshwater vegetated wetlands (group 2), degraded eutrophic wetlands (group 3) and brackish to saline wetlands (group 4). However, application of these groups requires caution because they were based on a single snapshot of the plant community at a point in time and do not take into consideration the dynamic nature of these systems. They provide a starting point for the hydrological, physicochemical and ecological classification of South-East wetlands but further research is required to define such a framework.

<u>Value of the information</u>

The primary output of this project is a database, which will be able to be used in several ways to assist management of wetlands, drainage networks and land-use in the south-east. This will include current (*a decision support system for the South-East*) and proposed (*sustainable water management in the South-Eas*t) research projects for the Goyder Institute. Application of the database within these and other projects will include:

- Development of salinity response curves for a range of macrophyte species and communities
- Determination of salinity threshold values of a range of macrophyte species and communities (including germination thresholds)
- Determination of secondary drivers of macrophytes communities and threshold values for those drivers identified to be important
- Providing input data for a decision support system

- Ground-truthing remote sensing analysis of wetland condition, a landscape ecological model and high resolution aerial monitoring flights

- Validation of the use of wetland vegetation components for management purposes

- An understanding of the resilience of wetland ecosystems to prolonged drought

When coupled with hydrological information, this database will be able to be used to establish salinity trigger values for management of wetlands and drainage networks and understand the likely impacts of alternative management actions. The collection of this important information would not have been possible without approval of the project being fast-tracked by the Goyder Institute. This is particularly important given there is much interest in research and management of wetlands in the South-East, but there are no guarantees of sufficient water availability in future years for this type of data collection.

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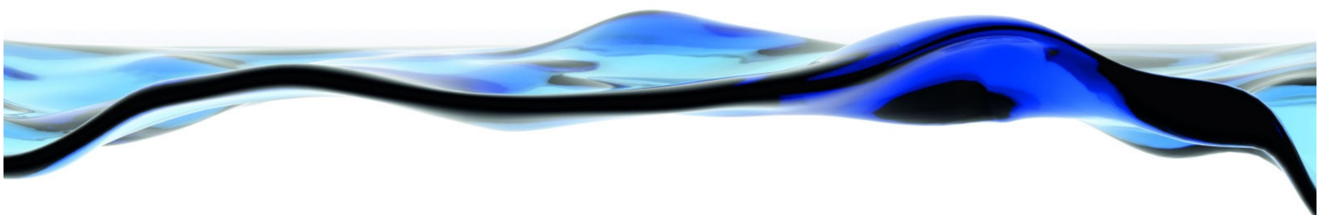

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