Incorporating indicator species into predictions of watertable depth and soilsalinity levels for land capability assessment

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Introduction

Salt-affected land varies considerably spatially across the landscape and over the year in both levels of soil salinity and watertable depth (Bennett *et al.* 2008). Water-table depths are closest to the surface in winter and soil salinity levels are lowest at this time (Smith 1962). Water-tables start to fall in spring and soil salinity levels to rise, reaching a maximum during summer and autumn. Therefore the value of taking measurements at a particular place and point in time is questionable, with a requirement for a number of measurements to be taken over the year and across the site to accurately determine the site conditions.

Saltland pastures often fail because pasture plants have been placed into inappropriate parts of the landscape. Attempts have been made to determine the best location for current pasture options for saltland in terms of both salinity and waterlogging (Barrett-Lennard *et al.* 2003). However, limited quality data have been available from which to make these assessments. A wide range of native and introduced annual and perennial plants grow on salt-affected land. Can these 'indicator' species be used, along with other recorded information about a site, to improve the location of sown/ planted pasture species on salt-affected land? To date there has been little work on the position of indicator species on a salinity/ waterlogging matrix (Barrett-Lennard *et al.* 2003; Malcolm 1986), with no work available on the potential of using indicator species to predict saltland capability.

As part of the Sustainable Grazing on Saline Land (SGSL) Initiative, research sites were set up in all of the southern Australian states. Although research activities at each site were independent, some common recordings were taken including the occurrence of native and naturalised species across the various landscapes. This paper will present the results of the variation in native and naturalized species occurring at three sites in Western Australia (WA) in relation to salinity and depth to groundwater, showing how these species can be used as 'indicator species' to predict saltland capability and therefore, the best and most productive method of managing saline landscapes in WA. A subsequent paper will expand this work to include data collected in Victoria and NSW, allowing predictions to be made across southern Australia.

Materials and methods

At each of the three SGSL research sites in WA, percentage cover of native and naturalised species was recorded in 5m x 5m quadrats along a salinity/ waterlogging gradient in spring in 2004 and 2005. The research sites were located in the low - medium rainfall wheatbelt zone of WA. Rainfall over the study period showed a typical mediterranean pattern with rainfall over the winter months ranging from 121 to 169 mm and over the summer months from 2 to 62 mm, although in subsequent years summer rainfall has been greater. The associated soil surface salinity was recorded on four occasions using an EM38 and these values were converted to average ECe values using calibrations derived on the day of sampling. Watertable depth was interpolated for each quadrat from bores located across each of the research sites. The depth used for all analysis was an averaged spring/ summer watertable depth, averaged from approximately monthly readings. For more information on the research sites see Barrett-Lennard et al. (2008).

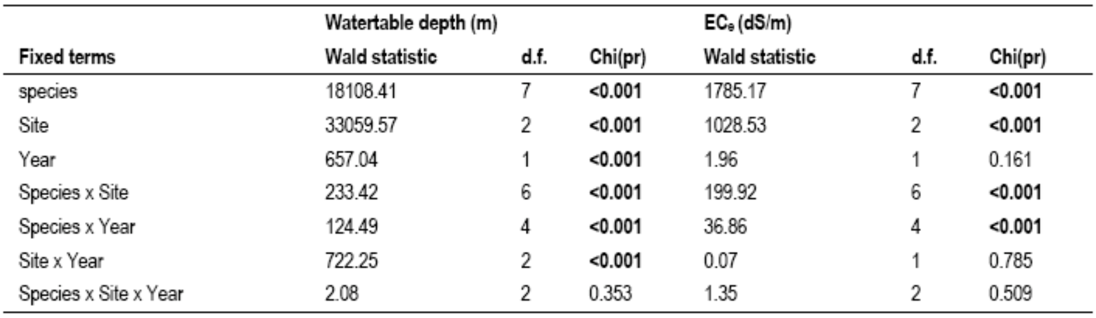
An irregular grid (REML) spatial analysis was conducted on the indictor species recorded as 40% or more cover at the three research sites using Genstat v.8.2, with species recorded, year and site all as fixed levels within the analysis. Row and column position were both taken to be random levels in the analysis. Watertable depth showed a normal distribution, however soil salinity level was not normal and so was transformed using a square-root transformation prior to the spatial analysis.

For each species recorded, a plot was made of where it was recorded at 80% cover, 40-75% cover, below 40% cover and where it did not occur across the range of soil salinity levels and watertable depths recorded. A weighted mean and standard deviation was calculated across the range of salinity levels and watertable depths at which each species was recorded at 40% or more cover. From this information 99% confidence intervals could be identified to predict where each species may occur at 40% or greater cover.

Results and discussion

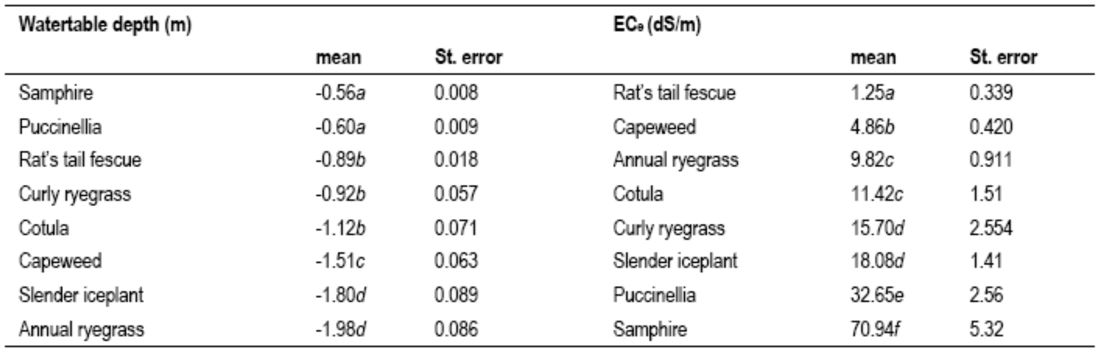
The results of the spatial analysis on the three sites showed that there were significant differences in both salinity and watertable depths between species recorded, sites and years (Table 1). Variation between sites is due to their position in the landscape, and also to the soil type at each site and how it is affected by rainfall events. Variation between years in watertable depth is due to annual rainfall and the pattern of rainfall events, particularly out of season rainfall events. Salinity levels did not show the same level of interaction between factors, partly because the levels recorded for each quadrat were averaged over each year, and partly because of the spatial variability that is present at each site (Barrett-Lennard *et al.* 2008).

Table 1 Wald statistic results from the irregular grid spatial analysis of watertable depth and salinity levels of the recorded native and naturalised species on three research sites. Wald statistics (Chi-squared probabilities) significant to 0.05 or greater are shown in bold.



	Watertable depth (m)			EC_e (dS/m)		
Fixed terms	**Wald statistic**	**d.f.**	**Chi(pr)**	**Wald statistic**	**d.f.**	**Chi(pr)**
species	18108.41	7	**<0.001**	1785.17	7	**<0.001**
Site	33059.57	2	**<0.001**	1028.53	2	**<0.001**
Year	657.04	1	**<0.001**	1.96	1	0.161
Species x Site	233.42	6	**<0.001**	199.92	6	**<0.001**
Species x Year	124.49	4	**<0.001**	36.86	4	**<0.001**
Site x Year	722.25	2	**<0.001**	0.07	1	0.785
Species x Site x Year	2.08	2	0.353	1.35	2	0.509

Table 2 Mean salinity and watertable depths where species occur at 40% or greater cover across the three sites. Multiple comparisons show the groupings of the species in relation to the standard errors of differences of means (watertable depth = 0.2766. ECe = 3.498)



Watertable depth (m)			**EC_e (dS/m)**		
	mean	**St. error**		**mean**	**St. error**
Samphire	-0.56*a*	0.008	Rat's tail fescue	1.25*a*	0.339
Puccinellia	-0.60*a*	0.009	Capeweed	4.86*b*	0.420
Rat's tail fescue	-0.89*b*	0.018	Annual ryegrass	9.82*c*	0.911
Curly ryegrass	-0.92*b*	0.057	Cotula	11.42*c*	1.51
Cotula	-1.12*b*	0.071	Curly ryegrass	15.70*d*	2.554
Capeweed	-1.51*c*	0.063	Slender iceplant	18.08*d*	1.41
Slender iceplant	-1.80*d*	0.089	Puccinellia	32.65*e*	2.56
Annual ryegrass	-1.98*d*	0.086	Samphire	70.94*f*	5.32

The mean and standard error of each species position in the landscape in relation to watertable depth and salinity of the soil is shown in Table 2. Samphire (*Halosarcia* sp.) showed little overlap with other species, requiring a shallow watertable and extreme soil salinity levels (Figure 1b). Puccinellia (*Puccinellia ciliata* Bor) also showed a preference for shallow watertables and high to extreme soil salinity levels. The soil salinity levels are higher than expected for this species as it has previously been reported to show best growth at levels of 16-32 dS/m (Semple *et al.* 2003), and it is suggested that ecotypic adaptation may have occurred in the naturalised population of puccinellia occurring at this site. Further investigation is required to determine whether this is the case. Rat's tail fescue (*Vulpia myuros* (L.) C.C. Gmel.) and curly ryegrass (*Parapholis incurva* (L.) C.E. Hubb.) also required a shallow watertable with a mean depth of less than 1 m. Capeweed (*Arctotheca calendula* (L.) Levyns), slender iceplant (*Mesembryanthemum nodiflorum* L.) and annual ryegrass (*Lolium rigidum* L.) showed a preference for the deepest watertables (Figure 1a). Soil salinity levels are also clearly differentiated between the species recorded, with rat's tail fescue and capeweed both showing a preference for low soil salinity levels, ryegrass, cotula (*Cotula coronopifolia* L.) and curly ryegrass occurring at moderate soil salinity levels, and slender iceplant occurring at high soil salinity levels (Figure 1).

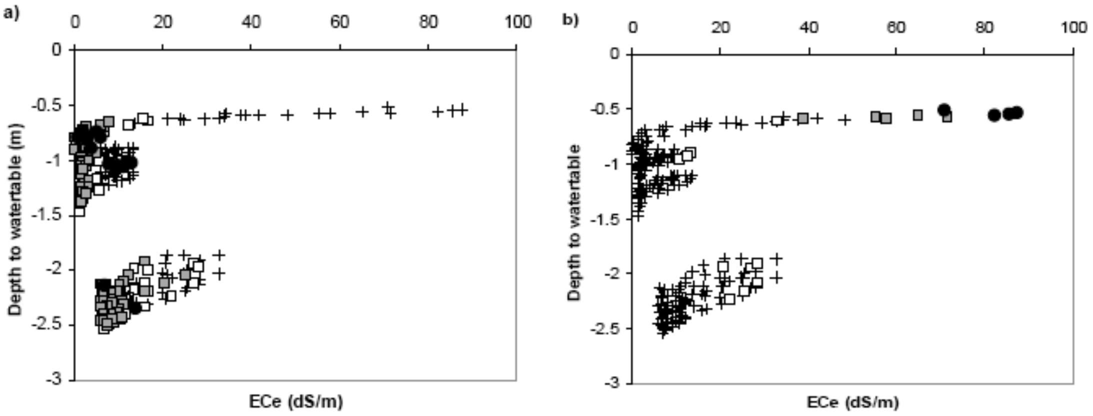


Figure 1 Percentage cover of a) capeweed and b) samphire in quadrats across the SGSL WA2 transect trials. ● – 80% or more of cover, ▨ - 40 – 79% of cover, ☐ - 1 – 39% of cover, + - not present.

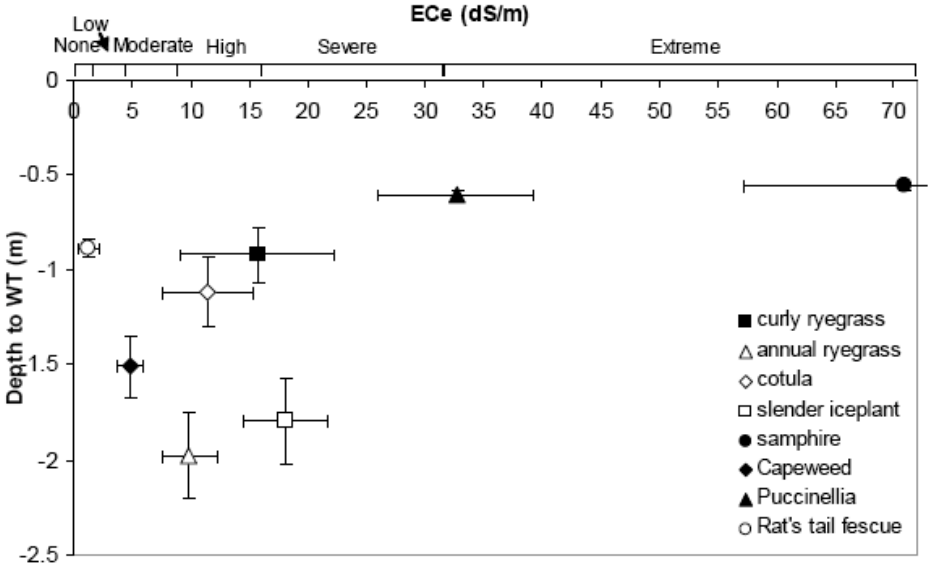


Figure 2 99.9% confidence intervals around the weighted means of indicator species where they were present in 40% or more of the quadrat (EC$_e$ averaged over 2 years).

Figure 2 shows the position of each of the recorded species in the landscape in relation to their preferred watertable depth and soil salinity level. The weighted mean of each species, where cover is greater than 40%, has been plotted. The error bars associated with each weighted mean are the 99% confidence interval for both watertable depth and soil salinity level. The confidence intervals highlight the range of watertable depth and soil salinity levels that each species are able to tolerate. For example, capeweed has a narrow soil salinity range where it can successfully grow, but a greater range of watertable depths. This compares to puccinellia and in particular samphire which have a narrower range of watertable depths where they can persist, but a greater range of soil salinity levels.

The performance of perennial plants on saltland graphs shown in Barrett-Lennard et al. (2008) can be overlaid on Figure 2 to give an indication of which indicator species occur as the dominant cover where the different saltland species show the best performance. There is some overlap in the options available with Rhodes grass and saltwater couch having similar preferences, and as do river saltbush and small-leaf bluebush. However, the following conclusions can be drawn on which species will successfully grow where, depending on the presence of the certain indicator species. For example a dominance of rat's tail fescue would be indicative of ideal conditions for lucerne, whereas the presence of curly ryegrass and cotula suggests the conditions are more saline and that saltwater couch or Rhodes grass would grow more successfully. The presence of capeweed annual ryegrass and slender iceplant suggests deeper watertables which would be more suited to the growth of bluebush or river saltbush. Where samphire is the dominant plant species then it is suggested that the best option will be to fence off the area, exclude grazing and allow natural revegetation to occur (Barrett-Lennard 2000).

Conclusions

Zonation in native and naturalised indicator species is a reflection of soil salinity and depth to watertable. Their presence in saline landscapes has the potential to assist in locating the best performing saltland pasture species on saltland of various capabilities. Most of the species recorded have either a wide tolerance to soil salinity or to watertable depth, but when more than one species is present, accurate identification of the potential soil salinity and watertable depth increases. The use of indicator species is thus a powerful tool to be used in combination with other site characterization methods to predict saltland capability and thus potential production of salt-affected land.

Determination of the responses of indicator species to salinity and depth to watertable has been based, to a substantial degree, on the plants that occurred naturally on the three research sites. Choice of species was therefore substantially dictated by chance. Not surprisingly, the range of species considered here has some obvious omissions. Further work is required to expand this range of species.

Acknowledgments

This work was supported by the Sustainable Grazing on Saline Lands initiative, an activity within the Land, Water and Wool Program, funded by Australian Wool Innovation Limited, Land and Water Australia and the Cooperative Research Centre for Plant-based Management of Dryland Salinity. Thanks to the host farmers - Keith Cater (Wubin), Colin Pearce (Meckering) and Michael Lloyd (Pingaring).

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