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The rise and fall of an invasive estuarine grass

T. Riddin [a,*], E. van Wyk [b], J. Adams [a,1]

[a] Department of Botany, Nelson Mandela Metropolitan University, PO Box 7700, Port Elizabeth 6031, South Africa
[b] Invasive Species Programme, South African National Biodiversity Institute, Kirstenbosch Research Centre, Claremont 7735, South Africa

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ABSTRACT

Spartina alterniflora Loisel. is the only known halophyte that is invasive in intertidal salt marsh habitats in South Africa and it poses a considerable threat to the biodiversity of nearby estuaries. First detected in 2004, regular chemical treatment during the growing period from 2013 and adjustments to the recommended herbicide mix has almost completely removed the plant from the Great Brak Estuary. Part of the success of this treatment was due to the small area of infestation (~1 ha), which was not difficult to access. In 2009 there were 429 stems per m^2 but following herbicide treatment between 2013 and 2015, by November 2015 there were only 149 stems in the entire estuary (mean = 8 stems per m^2). Above-ground biomass had been reduced by 74% and below-ground biomass by 90%. Native salt marsh vegetation began to grow between the dead *S. alterniflora* shoots by October 2014 and increased to 95% cover by November 2015. The maximum total invaded area of 10,221 m^2 in 2011 was reduced to 10 m^2 by November 2015. Average annual costs for the control of *S. alterniflora* were ~ZAR 34, 349), or $ 2414. This study is important as it is one of a few examples of a national prospect of eradication of an invasive alien plant. However continuous monitoring is necessary, as this plant has been shown in other countries to regrow after chemical treatment.

1. Introduction

Spartina alterniflora Loisel. (Poaceae) is an aggressive ecosystem engineer that has been declared an alien invasive in ten countries (China, Canada, USA, Brazil, Uruguay, France, UK, Australia, New Zealand and South Africa) (http://www.cabi.org/isc/datasheet/107740). It invades open, intertidal mudflats of estuaries changing them to dense, monospecific marshes. This results in habitat loss, a change in benthic communities and a trophic shift from algal-based to a detritus-based food web (Simenstad and Thom, 1995; Daehler and Strong, 1997; Hedge et al., 2003; Levin et al., 2006; Neira et al., 2007). This is due to its rapid growth and large under-ground biomass, almost five times that of above-ground biomass (Ellison et al., 1986). Also known as smooth cordgrass, *S. alterniflora* naturally inhabits tidal salt marshes of the Atlantic and Gulf Coasts of North America, extending to South America as far as northern Argentina.

In South Africa, *Spartina alterniflora* was first observed in 2004 in the Great Brak Estuary (34°03′23″ S, 22°14′25 ″ E). At that time, only four patches occurred in the lower reaches of the estuary. When mapped in 2006 it covered an area of 2566 m^2 (Adams et al., 2012). It reached 24 patches in 2011 covering a total area of 10,221 m^2. In 2007 it was positively identified using genetic analysis and was the first record of the species in Africa, and the first time worldwide in an estuary that seasonally closes to the sea (Adams et al., 2012). This is indicative of its highly adaptive nature as in the Great Brak the intertidal area where it occurs can be flooded for up to eight months at a time. Chemical treatment of *S. alterniflora* in the Great Brak Estuary began in 2011 but due to delays, continuous treatment only started in January 2013 to present. Treatment occurred during summer (growing season) with two to three applications being made per summer. The final herbicide mix used was a foliar spray with glyphosate (700 g kg^{-1}) at an application rate of 10 kg per ha, together with an additional 0.5% imazapyr (100 g l^{-1} active ingredient). As the *S. alterniflora* population was reduced in size over time, knap-sack (16 L) herbicide application equipment was replaced with small (1 L) bottle spot-spraying from 2014 and onwards, further reducing the risk of non-target effects. Challenges to achieving persistent treatment from 2009 until 2013 were due to the short treatment season, delays in herbicide approval by the Department of Agriculture, Forestry and Fisheries, and funding and administrative delays. A further delay was that the mouth closed early 2015 and spraying could not commence due to *Spartina alterniflora* patches being inundated.

Only twelve alien plant species were identified by the Conservation of Agricultural Resources Act 43 of 1983 (CARA) in South African estuaries. These include aquatics like water hyacinth, water fern, parrot's feather and terrestrial examples such as *Sesbania punicea* (Fabaceae) (Adams et al., 1999). However new legislation (the National Environmental Management: Biodiversity Act [NEM:BA] (Act no.10 of 2004))

* Corresponding author. Tel.: +27 41 5 042 429; fax: +27 41 5 832 317.
E-mail address: taryn.riddin@live.co.za (T. Riddin).
[1] Tel.: +27 41 5 042 429; fax: +27 41 5 832 317.

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came into being which provides a framework for assessment, listing and management of invasive species. When the NEMBA regulations were passed in October 2014, *Spartina alterniflora* was declared a Category 1a invasive species, indicating that the species must be managed or eradicated where feasible. This research undertook a risk assessment which confirmed that *S. alterniflora* was a high risk Category 1a species.

The aim of this study was to document the rise and fall of *S. alterniflora* in the Great Brak Estuary; the results presented complement those found in Adams et al. (2016). That study characterized the plant and sediment conditions and the responses to control methods. Results from that study showed a significant decrease in stem density (50%), percentage live stems (decreased to less than 5%) and stem height by October 2014. *Spartina alterniflora* is able to regrow from underground biomass (Deng et al., 2008; Roberts and Pullin, 2008) and for this reason, the present study measured above- and below-ground biomass in order to compare with the data from Adams et al. (2012). The findings of this paper are of particular interest as they record the progression towards imminent eradication and they describe the passive recovery of the indigenous salt marsh vegetation in the dying *S. alterniflora* patches.

2. Materials and methods

Despite listing of *Spartina alterniflora* as a Category 1a species in South Africa (NEM:BA regulations of October 2014), a formal risk assessment had not been published for this species. The Australian Weed Risk Assessment Protocol developed by Pheloung et al. (1999) and refined by Gordon et al. (2008) was used to assess the risk of *S. alterniflora* in South Africa. This method takes into account information on the plant's biology, bioclimatic features and the evolutionary history which is then synthesized into a spreadsheet model that produces a score for invasiveness. This method has been shown to be highly accurate across a broad geographic range (Gordon et al., 2010). Questions are divided into aspects such as History, Biogeography, Biology and Ecology. The answers are combined into a scoring system and if the total is greater than 6, it means that the species has a high likelihood of becoming invasive (should not be introduced, or reject); a total of 1 to 6 indicates that further evaluation is needed before a regulatory decision is possible; and a total less than 1 suggests that it is unlikely that the species will be invasive.

Plant characteristics of the *S. alterniflora* patches have been assessed since 2009 prior to and after chemical treatment until 2014 (Adams et al., 2016). These were stem density (no. stems per m^2), stem height (cm), percentage live material, as well as total area covered (m^2). These characteristics were measured in five or more quadrats (0.35×0.35 m) in each of the *S. alterniflora* patches. The total number of quadrats assessed varied from between 65 to 40 depending on the patch size and their decrease in size over time. This paper reports on the above- and belowground biomass assessed in each quadrat in March 2015 and compared with available biomass data from 2009 and 2012 (Adams et al., 2012). All data were analysed using Minitab® 17.1.0. Kruskal Wallis H test of non-parametric data was used to determine significant differences between the data sets.

Salt marsh vegetation recovery following attempts to suppress *S. alterniflora* was also assessed in each of the quadrats in March and November 2015. This was done by recording the plant cover of indigenous species in each of the quadrats. Salt marsh in the Great Brak Estuary has been mapped by Nunes (2012) and Adams (2008). In both these studies three transects ranging from 215 to 370 m in length were assessed for plant cover of the salt marsh in duplicate quadrats (1 m^2) placed at 5 m intervals along the length of each transect. This approach generated baseline data for naturally occurring intertidal salt marsh for the estuary and allowed for a comparison of the change in salt marsh cover and species richness over time.

The size of the *S. alterniflora* patches was mapped using a GPS and Arcpad® (Version 7.0) software. An assessment of the sediment seed bank was done in 2011 but no seed was found in the sediment (Adams et al., 2012). The cost of management of *S. alterniflora* was assessed for the duration of the treatment and compared with other case studies.

3. Results

The Weed Risk Assessment score for *S. alterniflora* in South Africa was 23. The high score was mainly due to the fact that it is an aquatic grass that forms dense thickets, produces viable buoyant seed, reproduces vegetatively, hybridizes easily, has a history of repeated introductions to stop coastal erosion and it is dispersed unintentionally by people (Table 1).

Persistent summer chemical treatments resulted in the almost complete disappearance of *S. alterniflora* in the Great Brak Estuary (Plate 1). By November 2015 there were only 149 live stems in the whole study area, with *S. alterniflora* stem density at 30 stems per m^2 and the mean stem height of these remaining individuals at 32 ± 2 cm. The total area affected by the invasive grass in November 2015 was 10 m^2 (Fig. 1c) compared with the total area cover of 10,221 m^2 recorded in 2011 (Fig. 1b). The remaining individuals mainly occurred at sites where the original plants were found in 2006 (Fig. 1). In March 2015 dead patches of *S. alterniflora* were visible and some of these had disappeared completely (i.e. no sign of live or dead plants) by November 2015.

Both mean above- and below-ground biomass decreased significantly by March 2015 following three summer chemical treatments, compared to data collected prior to any treatment had begun. Above ground biomass decreased from 933.2 ± 81.3 g m^{-2} in 2009 to 240.2 ± 20.1 g m^{-2} in 2015, a 74% reduction ($H = 55.98$, $p < 0.001$). Similarly below ground biomass decreased from 3119.7 ± 299.8 g m^{-2} in 2009 to 313.1 ± 32.4 g m^{-2} in 2015 (a 90% reduction, $H = 80.99$ $p < 0.001$).

Native salt marsh vegetation began to appear by October 2014 at the edges of the *S. alterniflora* patches; one and a half years after chemical treatment began. These were seedlings of *Sarcocornia* spp. (Plate 2a). By March 2015 native salt marsh vegetation cover of up to 10% per m^2 was measured in a total of four *S. alterniflora* patches. The last assessment in November 2015 showed that 49 of the 60 patches assessed had salt marsh recovery with up to 95% plant cover in some patches (Plate 2b). Total plant cover (% per m^2) had increased to 74% compared to a mean cover prior to treatment of 63% (Fig. 2). Species richness had doubled from 6 (prior to treatment) to 7 species after removal of *S. alterniflora* (Fig. 2).

Total costs for the management of *S. alterniflora* in the Great Brak Estuary were ZAR 103 047 over the 3-year study period (2013–2015), with an annual average cost of ZAR 34 349 (Table 2). This equates to an average of R 11.08 m^{-2} (0.78 US$ m^{-2} or 7800 US$ per ha, using the invaded area at the start of treatment in January 2013 (i.e. 0.93 ha). Travel costs were initially high in 2013 as the contractor applying the herbicide had to travel 400 km to get to the study site. In subsequent years local contractors were employed. Costs also decreased over time as the total *S. alterniflora* area decreased and spot spraying became the method of application.

4. Discussion

This paper documents the near complete eradication of *Spartina alterniflora* in the Great Brak Estuary in South Africa. It describes the management approach which is an important case study for effective invasive plant control for the country. To date, the removal of the *S. alterniflora* population was successful because of the small contained area of infestation (maximum 10,221 m^2 over 24 patches), development on both banks of the estuary allowing for easy access and no viable seeds were produced by this population (Panetta, 2015). Although there were delays in initial control efforts, the threat posed by

Table 1
Weed Risk Assessment Score for *Spartina alterniflora* in South Africa following Pheloung et al. (1999) and Gordon et al. (2010).

Question	Answer	Reference	Score	Possible scores
Species suited to South African climates	Yes	Adams et al., 2012	2	0, 1 or 2
Quality of climate match data (0-low; 1-intermediate; 2-high)			2	0,1 or 2
Broad climate suitability (environmental versatility)	Yes	CABI	1	0 or 1
Does the species have a history of repeated introductions outside its natural range?	Yes	CABI	2	0, 1 or 2
Naturalized beyond native range	Yes	CABI	2	−2, −1, 0, 1, 2
Environmental weed	Yes	Daehler and Strong, 1997; Adams et al., 2012	2	0, 1, 2, 3, 4
Grows on infertile soils	Yes		1	0 or 1
Forms dense thickets	Yes	ISSG	1	0 or 1
Aquatic	Yes	CABI	5	0 or 5
Grass	Yes	CABI	1	0 or 1
Hybridizes naturally	Yes	Strong and Ayres, 2009	1	−1 or 1
Reproduction by vegetative propagation	Yes	Adams et al., 2012	1	−1 or 1
Minimum generative time (years)	1		1	0, 1, −1
Propagules likely to be dispersed unintentionally	Yes	Cohen and Carlton, 1995	1	−1 or 1
Propagules dispersed intentionally by people	Yes	Deng et al., 2009; CABI	1	−1 or 1
Propagules likely to disperse as a produce contaminant	No		−1	−1 or 1
Propagules buoyant	Yes	Adams et al., 2012	1	−1 or 1
Prolific seed production	No		−1	−1 or 1
Evidence that a persistent propagule bank is formed (>1 yr)	No	Adams et al., 2012	−1	−1 or 1
Well controlled by herbicides	Yes	This study	−1	−1 or 1
Tolerates or benefits from mutilation, cultivation or fire	Yes	This study; CABI	1	−1 or 1
Effective natural enemies present in South Africa	No		1	−1 or 1
		Total score	23	

S. alterniflora was clear. The goal of complete eradication was (and continues to be) tested in this study, and encouragement for eradication as a feasible management option was taken from management experiences with *S. alterniflora* in Washington State (Washington State Department of Agriculture (2011). In addition, progress was enhanced by enthusiastic and supportive local stakeholders, organized in the form of the local residents' association and Great Brak Estuary management forum. These stakeholders shared the perception of threat of *S. alterniflora* to the estuary and assisted with aspects such as accommodation for researchers, water for mixing herbicides and posting notes on project progress on the residents' association web site. They also provided valuable information about the tides and local situation prior to field workers travelling to the site. Furthermore and importantly, the SANBI Invasive Species Programme provided a responsible authority and resources to oversee the progress towards eradication (Wilson et al., 2013).

The Weed Risk Assessment (Pheloung et al., 1999; Gordon et al., 2010) confirmed a high potential risk posed by *Spartina alterniflora* to the Great Brak and potentially to other estuaries in South Africa. *Spartina alterniflora* was finally listed as a Category 1a invasive in the latest Alien and Invasive Species Regulations list (October 2014) for the National Environmental Management Biodiversity (NEMBA) Act 10 of 2004. This means that "... invasive species that may not be owned, imported into South Africa, grown, moved, sold, given as a gift or dumped in a waterway." These species require compulsory control and eradication where feasible. This study provides a systematic approach to affirm species risk and it provides empirical evidence that eradication of *S. alterniflora* from the Great Brak Estuary may be feasible. Invasive status of *S. alterniflora* should therefore remain 1a. The control and decline of the *S. alterniflora* population in the Great Brak Estuary is shown by the significant change in plant characteristics following a continuous and repeated chemical control approach. Stem density at the peak of invasion was 55 to 429 stems per m^2 (or 4,384,809 stems in total using a maximum area of 10,221 m^2) (Adams et al., 2012). By November 2015 only 149 stems were recorded in the estuary. *S. alterniflora* patch size has also decreased to only 10 m^2, above-ground biomass was reduced by 74% compared to that measured in 2009 and below-ground biomass by 90%. It also appeared that below-ground biomass was decomposing.

The efficacy of any treatment is typically determined by comparing the area before and after treatment (Hedge et al., 2003). However this also refers to the restoration of the habitat to native conditions after treatment. Hacker and Dethier (2009) suggest that this is not simple where the species is an "ecosystem engineer"; one which alters physical conditions of the habitat itself such as *S. alterniflora*. Habitat may be altered to such an extent that it is not conducive to recolonization of indigenous species. In addition, reversion back to open intertidal mudflats does not always result in restoration back to the original state (Levin et al., 2006; Kelly, 2014). It has been suggested that this is due to the long lasting effects of the roots and rhizomes which require many years to decompose (Neira et al., 2007; Hacker and Dethier, 2009). Benner et al. (1991) have shown that the below-ground biomass of *S. alterniflora* lost 55% of its organic matter after 18 months decomposition. The decay of below-ground biomass and the effects of sulphide

Plate 1. *Spartina alterniflora* in 2009 (left) and at the same site in October 2014 after chemical treatment (right).

Fig. 1. Location of *Spartina alterniflora* patches in the Great Brak Estuary over time. Left = 2006 (2566 m^2), middle = patches in 2011 (10,221 m^2), right = remaining individuals (10 m^2) in November 2015.

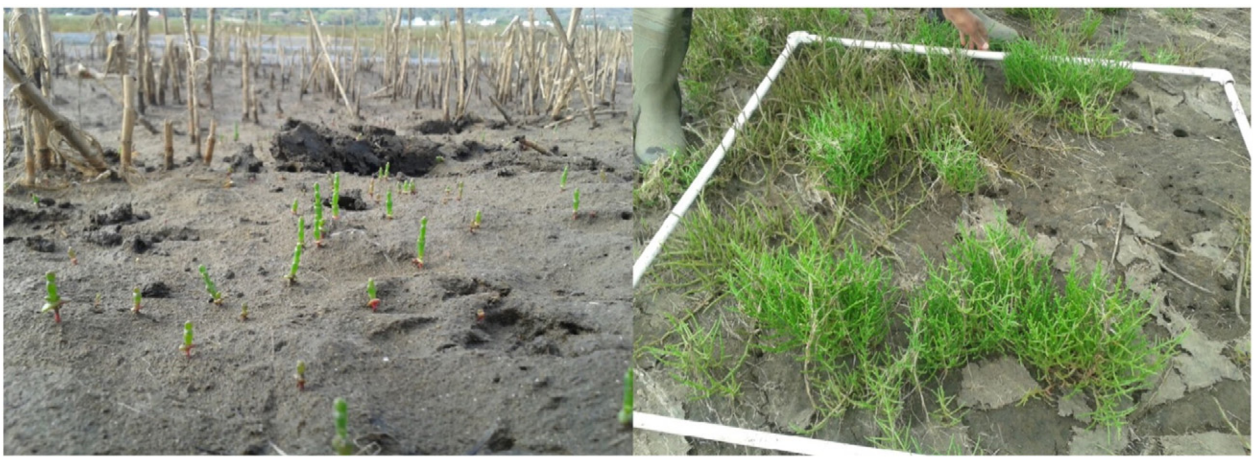

Plate 2. Regrowth of native salt marsh (*Sarcocornia decumbens*) in October 2014 (left) and November 2015 (right).

and anoxia could hamper the re-establishment of native plants and animals. Also, the increased elevation of the *S. alterniflora* stands through sediment accretion may result in colonization by supratidal salt marsh and not intertidal salt marsh, as was found in removal of *Spartina anglica* in Washington (Reeder and Hacker, 2004; Hacker and Dethier, 2009). In this study native salt marsh returned one and a half years after chemical treatment targeting *S. alterniflora* began in January 2013. By November 2015 some areas already showed 95% cover by intertidal salt marsh species. *Sarcocornia* spp. have large seed banks and are able to remain viable over a number of years allowing them to return when suitable habitat is available (Riddin and Adams, 2009). Seed germination appears to be unaffected by *Spartina alterniflora* invasion and subsequent management. This supports the findings of Patten and O'Casey (2007) who found that in areas where *Spartina* had not influenced elevation changes, *Triglochin maritimum* L. and *Salicornia virginica* L. returned within 1 to 2 years after successful *S. alterniflora* control.

In any alien invasive management practice, early detection and rapid response are key aspects for successful control (Rejmanek and Pitcairn, 2002). The cost implication of management and removal is also reduced when populations are small (<10 ha) (Rejmanek and Pitcairn, 2002). In systems where invasion is severe, eradication efforts are faced with either focusing on the centre of the invasion where plant density is greatest and are the source of future expansion through seeding, or the edges of patches where plant density is lower (Williams and Grosholz, 2008). When plant populations are small and growing exponentially any removal that exceeds population growth rate will achieve

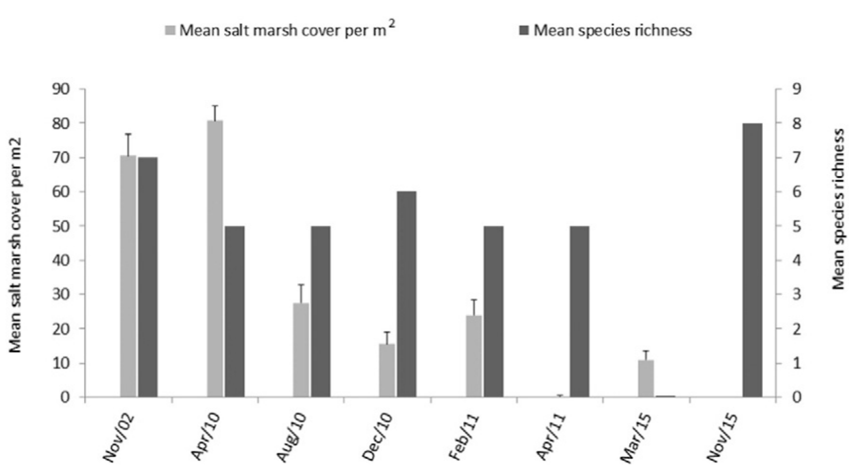

Fig. 2. Total native salt marsh cover (% per m^2) and species richness in the Great Brak Estuary over time.

Table 2
Summary of expenditure and time associated with management of *Spartina alterniflora* between 2013 and 2015 in the Great Brak Estuary.

Item	Late growth season 2013 (ZAR)	Growth season 2013–14 (ZAR)	Growth season 2014–15 (ZAR)	Total
Contractor cost	10,292	5022	3953	19,267 (18%)
Researcher cost	12,000	12,000	16,000	40,000 (39%)
Accommodation and travel	12,000	15,000	15,000	42,000 (41%)
Herbicide	300	1480	0	1780 (2%)
Total cost/year (ZAR)	34,592	33,502	34,953	103,047
Person days (contractor)	9	18	20	47 days
Person days (researchers)	12	12	16	40 days

eradication (Buhle et al., 2011). In this study the objective of complete eradication was pursued and control costs decreased over time as the area of invasion decreased. Control costs in the Great Brak Estuary across three treatment seasons were R 11.08 m^{-2} (0.78 US\$ m^{-2}). By comparison, Washington State spent approximately 90,372 US\$ per ha (9.04 US\$ m^{-2}) in 2010 for *S. alterniflora* eradication efforts across the State (Washington State Department of Agriculture, 2011). Those efforts involved 27 acres (10.93 ha) and that cost also included salaries. Cost of extirpating a 0.28 ha population of *Melaleuca quinquenervia* (across 6 years) in South Africa was estimated at a total of R661 802 (including salaries) which equates to R236.35 m^{-2} and 16.61 US\$ m^{-2} or 166,098 US\$ per ha, with salaries included in this cost (Van Wyk and Jacobs, 2015).

Invasive alien plant eradication occurs via two processes: (i) extirpation which is the elimination of the target in both space and time and (ii) containment, which is the prevention of further occupancy of space (i.e. reducing spread). Extirpation is not synonymous with eradication, as the latter refers to efforts being undertaken on the largest relevant scale, including the prevention of re-invasion (Panetta, 2015). This study has shown that the complete eradication of *S. alterniflora* in the Great Brak Estuary is within reach. But even though the extirpation of *S. alterniflora* from the Great Brak Estuary can be considered successful for now and the population has been contained, follow up monitoring is crucial not only in the Great Brak Estuary but in nearby systems to check for establishment. This is currently being done on a regular basis in estuaries close to the Great Brak by SANBI's Invasive Species Programme in partnership with relevant local authorities.

When then will *S. alterniflora* be considered eradicated in the Great Brak Estuary? There are a number of views on determining time to eradication. Some suggest taking an economic approach when the optimal stopping time is a tradeoff between the cost of management and the cost of escape and invasion elsewhere (Regan et al., 2006). Others suggest the time of seed persistence in the sediment or for as long as it takes for the seed bank to be depleted (Panetta, 2015). The seed of *S. alterniflora* can remain viable for up to one year (Xiao et al., 2009); however no viable seed was found at the Great Brak Estuary and therefore monitoring should continue until all below-ground biomass has decomposed and there are no living above-ground stems. It is suggested that a monitoring period (including the Great Brak and adjacent estuaries) of two years be necessary before eradication can be declared.

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References

Adams, J.B., 2008. Specialist Report: Macrophytes, Great Brak Catchment Ecological Water Requirements Study. NMMU Botany Department.
Adams, J.B., Bate, G.C., O'Callaghan, M., 1999. Primary producers. In: Allanson, B.R., Baird, D. (Eds.), Estuaries of South Africa. Cambridge University Press, Cambridge.
Adams, J.B., Grobler, A., Rowe, C., Riddin, T., Bornman, T.G., Ayres, D.R., 2012. Plant traits and spread of the invasive salt marsh grass, *Spartina alterniflora* Loisel., in the Great Brak Estuary, South Africa. African Journal of Marine Science 34, 313–322.
Adams, J.B., van Wyk, E., Riddin, T., 2016. First record of Spartina Alterniflora in southern Africa indicates adaptive potential of this saline grass. Biological Invasions 18 (8), 2153–2158.
Benner, R., Fogel, M.L., Sprague, E.K., 1991. Diagenesis of belowground biomass of *Spartina alterniflora* in salt-marsh sediments. Limnology and Oceanography 36, 1358–1374.
Buhle, E.R., Feist, B.E., Hilborn, R., 2011. Population dynamics and control of invasive *Spartina alterniflora*: inference and forecasting under uncertainty. Ecological Applications 22, 880–893.
CABI, d. http://www.cabi.org/isc/datasheet/107740 (19/09/2014).
Cohen, A.N., Carlton, J.T., 1995. Nonindigenous aquatic species in a United States estuary: a case study of the biological invasion of the San Francisco Bay and Delta, in: Report for the US Fish and Wildlife Service, W.D.C.a.t.N.S.G.C.P., Connecticut Sea Grant (Ed.).
Daehler, C.C., Strong, D.R., 1997. Reduced herbivore resistance in introduced Smooth Cordgrass (*Spartina alterniflora*) after a century of herbivore-free growth. Oecologia 110, 99–108.
Deng, Z., An, S., Wang, Z., Zhou, C., Zhi, Y., 2009. Spartina alterniflora: A review of its status, dynamics and management. Chapter 1. In: Wilcox, C.P., Turpin, R.B. (Eds.), Invasive Species: Detection, Impact and Control.
Deng, Z., An, S., Zhao, C., Chen, L., Zhou, C., Zhi, Y., Li, H., 2008. Sediment burial stimulates the growth and propagule production of *Spartina alterniflora* Loisel. Estuarine, Coastal and Shelf Science 76, 818–826.
Ellison, A.M., Bertness, M.D., Miller, T., 1986. Seasonal patterns in the belowground biomass of *Spartina alterniflora* (Gramineae) across a tidal gradient. American Journal of Botany 73, 1548–1554.
Gordon, D.R., Mitterdorfer, B., Pheloung, P.C., Ansari, S., Buddenhagen, C., Chimera, C., Daehler, C.C., Dawson, W., Denslow, J.S., LaRosa, A., Nishidal, T., Onderdonk, D.A., Panetta, F.D., Pyšek, P., Randall, R.P., Richardson, D.M., Tshidada, N.J., Virtue, J.G., Williams, P.A., 2010. Guidance for addressing the Australian Weed Risk Assessment questions. Plant Protection Quarterly 25, 56–74.
Gordon, D.R., Onderdonk, D.A., Fox, A.M., Stocker, R.K., 2008. Consistent accuracy of the Australian weed risk assessment system across varied geographies. Diversity and Distributions 14, 234–242.
Hacker, S.D., Dethier, M.N., 2009. Differing consequences of removing ecosystem-modifying invaders: significance of impact and community context to restoration potential. In: Rilov, G., Crooks, J.A. (Eds.), Biological Invasions in Marine EcosystemsEcological, Management and Geographic Perspectives. Springer, Springer-Verlag Berlin Heidelberg, pp. 375–388.
Hedge, P., Kriwoken, L.K., Patten, K., 2003. A review of Spartina management in Washington State, US. Journal of Aquatic Plant Management 41, 82–90.
ISSG, d. Global Invasive Species DatabaseAvailable from: http://www.issg.org/database/species/ecology.asp?si=792&fr=1&sts=sss&lang=EN (19/09/2014).
Kelly, B.P., 2014. The Impacts of Spartina Densiflora Removal on Benthic Macroinvertebrates in a Humbolt Bay Salt Marsh, Biology. The Faculty of Humbold State University, p. 63.
Levin, L.A., Neira, C., Grosholz, E.D.I., 2006. Invasive cordgrass modifies wetland trophic function. Ecology 87, 419–432.
Neira, C., Levin, L.A., Grosholz, E.D., Mendoza, G., 2007. The influence of invasive *Spartina* growth phases on associated macrofaunal communities. Biological Invasions 9, 975–996.
Nunes, M., 2012. Microalgae and Macrophytes as Indicators of Ecological Health in the Great Brak Estuary, Botany. Nelson Mandela Metropolitan University, p. 148.

Panetta, F.D., 2015. Weed eradication feasibility: lessons of the 21st century. Weed Research 55, 226–238.

Patten, K., O'Casey, C., 2007. Use of Willapa Bay, Washington, by shorebirds and waterfowl after Spartina control efforts. Journal of Field Ornithology 78, 395–400.

Pheloung, P.C., Williams, P.A., Halloy, S.R., 1999. A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. Journal of Environmental Management 57, 239–251.

Reeder, T., Hacker, S., 2004. Factors contributing to the removal of a marine grass invader (*Spartina anglica*) and subsequent potential for habitat restoration. Estuaries 27, 244–252.

Regan, T.J., McCarthy, M.A., Baxter, P.W.J., Panetta, D., Possingham, H.P., 2006. Optimal eradication: when to stop looking for an invasive plant. Ecology Letters 9, 759–766.

Rejmanek, M., Pitcairn, M.J., 2002. When is eradication of exotic pest plants a realistic goal? In: Veitch, C.R., Clout, M.N. (Eds.), Turning the Tide: the Eradication of Invasive Species, International Union for the Conservation of Nature (IUCN), Gland, Switzerland and Cambridge, U.K, pp. 249–253

Riddin, T., Adams, J.B., 2009. The seed banks of two temporarily open/closed estuaries in South Africa. Aquatic Botany 90, 328–332.

Roberts, P.D., Pullin, A.S., 2008. The effectiveness of management interventions for the control of Spartina species: a systematic review and meta-analysis. Aquatic Conservation: Marine and Freshwater Ecosystems 18, 592–618.

Simenstad, C.A., Thom, R.M., 1995. *Spartina alterniflora* (smooth cordgrass) as an invasive halophyte in Pacific Northwest estuaries. Hortus Northwest 6, 38–40.

Strong, D.R., Ayres, D.A., 2009. Spartina Introductions and Consequences in Salt Marshes: Arrive, Survive, Thrive, and Sometimes Hybridize.

Van Wyk, E., Jacobs, L.E.O., 2015. Prospects for extirpating small populations of the wetland invader *Melaleuca quinquenervia* from South Africa: a case study from the Western Cape region. African Journal of Aquatic Science 40, 299–306.

Washington, S.D.o.A., 2011. Spartina eradication program 2010 progress report. Washington State Department of Agriculture Report (N/1/11). January 2011. AGR PUB 850-323.

Williams, S., Grosholz, E., 2008. The invasive species challenge in estuarine and coastal environments: marrying management and science. Estuaries and Coasts 31, 3–20.

Wilson, J.R.U., Ivey, P., Manyama, P., Nänni, I., 2013. A new national unit for invasive species detection, assessment and eradication planning. South African Journal of Science 109, 13.

Xiao, D., Zhang, L., Zhu, Z., 2009. A study on seed characteristics and seed bank of *Spartina alterniflora* at saltmarshes in the Yangtze Estuary, China. Estuarine, Coastal and Shelf Science 83, 105–110.