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THE EFFECTIVENESS OF MANAGEMENT OPTIONS USED FOR THE CONTROL OF SPARTINA SPECIES

REVIEW REPORT

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Cover Sheet

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SYSTEMATIC REVIEW SUMMARY

Background

Spartina spp. (cordgrasses) have been introduced to the estuaries around Europe, U.S.A., Australia, New Zealand and Asia as a coastal management tool to stabilise mud banks and through accidental introductions. These non-native *Spartina* species are highly aggressive in their new environment, and frequently become the dominant plant species in areas they invade displacing native flora and fauna. Over the past decade coastal management priorities have changed, with control of non-native species becoming important.

ObjectiveS

To investigate the effectiveness of management interventions used to control the abundance or completely eradicate invasive *Spartina* species and to analyse, when possible, the effects that potential sources of heterogeneity (e.g. substrate type) have on the results

Search Strategy

Electronic databases searched

ISI Web of Knowledge (incl. ISI Web of Science and ISI Proceedings), Science Direct, Blackwell Synergy, IngentaConnect, Directory of Open Access Journals, COPAC, Scirus (All journal sources), Scopus, Index to Theses Online, Digital Dissertations Online, Agricola, CAB Abstracts, English Nature's "Wildlink", CEH online database (Centre for Ecology and Hydrology), JSTOR, www.ConservationEvidence.com, and Conserve Online.

Search Terms Used

Spartina, Spartina AND (control OR eradication), Spartina alterniflora, Spartina anglica, Spartina densiflora, Spartina patens, Spartina x townsendii, Cordgrass, and Ricegrass.

Other Searches

In addition further internet searches using www.alltheweb.com, and http://scholar.google.com (Google Scholar Beta), including searches for specific file types (pdf, doc and xls) were undertaken. The following statutory bodies and NGOs websites were searched: English Nature, Scottish Natural Heritage, Countrywide Council for Wales, Joint Nature Conservation Committee, Defra, National Trust, Environment & Heritage Service Northern Ireland, US Fish & Wildlife Service & various state environment departments in USA and Australia. All searches were conducted during the first quarter of 2006.

Study Selection Criteria

Studies were included if they fulfilled the following selection criteria:

Subject

The following Spartina sp.: *S. alternifolia* (Smooth or "Atlantic" Smooth Cordgrass) *+ hybrids, S. anglica* (Common or "English" Cordgrass)*, S. densiflora* (Chilean Cordgrass)*, S. patens* (Saltmeadow Cordgrass), *S. x* townsendii (Townsend's Cordgrass).

Interventions of Interest

Hand Pulling & Manual Excavation, Mechanical Excavation & Dredging, Mowing, Crushing & Mechanical Smothering, Covering or Blanketing, Flooding or Draining,

Salinity Adjustments and Herbicide (aerial, boat or ground application methods) and any combination of the above methods.

Outcome Measures
Change in cover, density, frequency or biomass, or a measure of change in any plant characteristic.

Types of Study (Comparator)
Any randomised block design, control trial, site comparison or before and after time series experiment.

Data Collection and Analysis
A three phase study inclusion assessment was preformed and the observed agreement between two independent reviewers was calculated to be "substantially good". Cohen's D effect sizes were calculated for each data point where the mean, number of replicates and standard deviation were known for both a treatment (management intervention) and control (untreated) plot. Standardized mean difference, DerSimonian-Laird (*random effects*) pooled *d*+ meta-analysis was used to combine the effect sizes across all studies and test their level of significance. In addition datasets with only the means of the treatment and control recorded where analysed along with meta-analysable data of similar type to calculate the mean percentage decline ± standard deviation of that *Spartina* due that that specific management intervention.

Main Results
Control of *S. alterniflora* densities with glyphosate was highly effective with significant results from the meta-analysis of ground sprayed glyphosate (d+ = -3.065; 95% CI= -4.144 to -1.986; $p < 0.0001$). With June/July applications of 38 kg ae/ha being more effective than either similar concentrations at different times of the year or lower active ingredient concentrations. Multiple years of application only marginally increased the herbicides effectiveness, however if a years application is missed then reduction in density drops below 50%. The use of 1-5% wetter or surfactant with the glyphosate application improved the impact of the (d+ = -6.240; 95% CI = -8.988 to -3.492; $p < 0.0001$). Control of *S. anglica* densities with glyphosate was not as effective as those achieved against *S. alterniflora.* (43% and 58% decline respectively, Fig 2a), however the highest concentration of glyphosate active ingredient was 1.8 kg ae/ha, which was also not significant at decreasing *S. alterniflora* densities.

Imazapyr application had the greatest impact in controlling *S. alterniflora* densities (d+ = -3.208; 95% CI = -3.889 to -2.527; $p < 0.0001$), with lower concentrations of active ingredient (1.7kg ae/ha) required to achieve superior density reductions (0.85) reductions than glyphosate (0.58). The addition of a surfactant/wetting agent increased imazapyr effectiveness (d+ = -5.768; 95% CI = -7.354 to -4.181; $p < 0.0001$).

Control by cutting only, significantly reduced the density of *S. alterniflora* (d+ = -4.853; 95% CI = -9.093 to -0.614; p = 0.0248) with the mean decline of 68.1% ± 35.4sd. However, *S. anglica* densities actually increased over a years follow-up (d+ = 0.594; 95% CI = -0.765 to 1.952; p = 0.3918) with a mean proportional decline of = -0.428 ± 0.487sd, therefore increasing the mean density of *S. anglica* by 42.8%. Cutting and then smothering was only used against *S. anglica*, but was highly significant at reducing its density (d+ = -4.307; 95% CI = -5.799 to -2.814; $p < 0.0001$) with the greatest mean decline of 97.9% achieved by any management intervention within this systematic review against this species.

The use of mechanical tracked vehicles or specially adapted rollers to crush *S. alterniflora* provided significant declines in densities (d+ = -1.951; 95% CI = -3.033 to -0.870; $p < 0.0004$), with a mean decline of 61.2%. The addition of glyphosate, applied up to six weeks after the crushing event provides a highly significant reduction in crush *S. alterniflora* densities (d+ = -3.806; 95% CI = -5.967 to -1.645; $p < 0.0006$), with a mean percentage decline of 91.1%. Tilling, to work the substrate to improve its structure and drainage achieved the best control of *S. alterniflora* densities of all mechanical control methods (d+ = -5.108; 95% CI = -9.804 to -0.413; $p < 0.033$) with the greatest mean declines in densities of all management interventions undertaken to control *S. alterniflora* (96.5%).

The use of ungulates (hoofed grazing animals) was not effective at reducing the densities of *S. alterniflora* (d+ = -0.702; 95% CI = -2.679 to 1.275; $p < 0.4865$) with a mean percentage decrease of 24.4%. The use of *Prokelisia* spp. (planthoppers) was effective at reducing *S. anglica* densities by a mean percentage decrease of 92.5. However, they were required in large numbers (>2,000 per $0.5m^2$). But, *Prokelisia* spp. were not very effective against *S. alterniflora* with only a 18.4% density decline.

Conclusions

Due to the lack of reporting of key methodological and environmental variables only a partial investigation of the possible sources of heterogeneity could be completed, for example not all studies reported information such as the month that control was undertaken, the number of hours before tidal immersion after a herbicide was applied, or the substrate of the site. This limitation of both in-house monitoring and of contractors, employed to undertake large scale control programmes, has been noted previously by Patten (2002; 2004).

Implications for Policy Makers and Practitioners

The available evidence (summarised in Table 3) suggests that to achieve a successful control programme, management interventions should be specifically targeted in regards to the species that are to be targeted. For example bio-control was found to be highly effective (92.5%) against *S. anglica*, but its effectiveness was remarkably reduced against *S. alterniflora* (18.4%).

Imazapyr and glyphosate were by far the most commonly used management intervention by practitioners. Imazapyr achieved 85.1% density reductions of *S. alterniflora* while not assessed against *S. anglica*, and glyphosate achieved 57.9% density reductions against *S. alterniflora* and 42.8% against *S. anglica*. The addition of a surfactant/ wetting agent increased the effectiveness of both herbicides by an additional 8-12%. In addition, of these two herbicides, imazapyr provides greater control of *S. alterniflora* at lower concentrations with a smaller drying time required than glyphosate. The most effective herbicides against *S. anglica* were fenuron (88.2%) and aminote-T (75.8%), but both had small datasets and require further trials prior to extensive use.

Cutting alone is not an effective control intervention of *S. anglica*, produced an overall increase in stem density of 42.8%. However when cutting is combined with a smothering element such as industrial black plastic sheeting then this control methodology was highly significant, achieving declines of on average 98% (Table 3). In addition Hammond & Cooper (2003) reported that cutting and smothering was also the only management intervention which caused a decline in dry root weight. For the control of *S. alterniflora* both cutting only and cutting with glyphosate were effective at controlling densities (68% and 91% decline in density respectively).

Spartina management programmes, with the purchase of an amphibious tiller (~ £150,000), and is slow to implement (~0.25 ha/hr reported by Patten 2004). Crushing is less expensive than (~ £50,000), and in addition is quicker than tilling (1-2hr/ha), but for more effective control two or more treatments are required in one year (see Table 3).

Herbivory of *Spartina* spp. by ungulates (e.g. horses/cattle/deer) has been carried out for decades with little impact. However the use of a species such as *Prokelisia marginata* (a planthopper) as a classic biological control agent is still in its infancy and due to the limited number of datasets, further research into their use in controlling *S. alterniflora* and more promisingly against *S. anglica* should be investigated.

The Implications for Further Research

There are numerous confounding variables which operate within an estuarine environment. The majority of experiments captured had an insufficient number of replicated to assess the impact of many of these sources of heterogeneity in a robust manner. The length of experimental follow-up should be standardised. The majority of practitioners aren't concerned whether or not a control intervention has worked within the first couple of months, but instead require medium (10-12 months) and long term evaluations (2+ years) after control to assess whether a repeat treatment should be undertaken or a different control intervention be considered.

Further experimental evidence is required to fully establish the efficacy of a number of control interventions. These include the herbicides (paraquat, 2,2-DPA, aminote-T, fenuron, and diuron) cut and glyphosate, cut and smother and the herbivorous planthoppers (*Prokelisia* spp.). Experiments investigating the control of *S. townsendii* and *S. patens* were sparse, further research into control of these species is required as outside of their native range they pose very similar problems to the more dominant *S. alterniflora* and *S. anglica*.

In addition to the above, the basic reporting of the site characteristics and methodology of experimental trials should be improved to include at the very least the month that the management intervention was undertaken. For herbicide trials the drying time before immersion is also an important variable for a practitioner to know, as small drying times significantly reduce the efficacy of glyphosate. For mechanical control the substrate of the site is also important as considerable affect to the effectiveness of the management intervention. If these potential reasons for heterogeneity are not reported within papers and/or reports then the practitioner could waste limited resources undertaking a management intervention that is not optimised to their particular situation.