CENTRE FOR EVIDENCE-BASED CONSERVATION

REVIEW PROTOCOL FOR SYSTEMATIC REVIEW N$^{O.}$ 22

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

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REVIEW PROTOCOL

1. BACKGROUND

Estuarine environments support ecologically important expanses of tidal mudflats and salt marshes. These environments support a diverse array of plants and animals many specialised and native to their particular location. Due to increased global trade over recent decades, many non-native species of plants and animals have been introduced to the estuarine environments e.g. via. ship ballast water exchange (CSCC, 2003). Some species now threaten to cause fundamental shifts in the structure and function of major estuarine tidal lands. Among these hostile invaders are several species of salt marsh cordgrass (genus *Spartina*). In recent decades, populations of non-native *Spartina* have been introduced to the estuaries around Europe, U.S.A. and Australia and began to spread rapidly. Though important in their native settings, and in the past used in extensive coastal protection and land reclamation projects (Allan, 1930; Chung, 1993), these non-native *Spartina* species are highly aggressive in their new environment, and frequently become the dominant plant species in areas they invade.

Spartina anglica (common or "English" cordgrass) and *Spartina x townsendii* (Townsend's cordgrass) first originated in the U.K. at Hythe, Southampton water in the nineteenth century (Hubbard, 1957; Goodman *et al.* 1969; Gray *et al.* 1991). *S. anglica* was the resulting fertile hybrid produced by the chromosome doubling of *S. x townsendii*, (the sterile hybrid of the European native, *S. maritima*) and the introduced *S. alterniflora*. Within a century of its origin, common cordgrass has become the dominant salt marsh grass in Britain (Gray *et al.* 1991). It is shorter and more greyish than *S. alterniflora*, with vigorously spreading rhizomes and can transform mudflats into vast stands of low marsh vegetation. It dominates the marsh and displaces the associated plant species. This species has spread around Europe, USA and Australasia.

Spartina alterniflora (smooth or "Atlantic" smooth cordgrass) is closely related to *S. foliosa*. In Northern America it occurs along both the eastern and western coastlines and the Gulf Coast nations (Gleason & Cronquist, 1991). It is one of the most aggressive *Spartina* species (in USA) and has massive growth potential and ecological breadth, and is the parent species of the other most invasive cordgrass species *S. anglica* (the more aggressive in Europe). It spreads both by seed dispersal and by rhizomes forming extensive clonal colonies in a circular layout if viewed from overhead. In areas of the San Francisco estuary, the rate of lateral spread by rhizomes averages annually between 1 to 2 metres (3.3 to 6.6 feet), in contrast to the native *S. foliosa*, which had an annual spread of between 0.2 to 0.7 metres (0.6 to 2.4 feet) per year at the same locations (Josselyn *et al* 1993; CSCC, 2003) with a highly variable height range, depending upon its local environment and genetics. In the tidal salt marshes of the Atlantic coastline of Northern America *S. alterniflora* is dominant over most of the intertidal zone, even growing below mean low water in some areas (McKee & Patrick, 1988), and occupying, sometimes dominating the marsh plain and the low marsh. It is highly resilient, tolerating salinity of 45+ parts per thousand (greater than ocean salinity), and also thriving in brackish water. It can be buried and regenerate from 0.3m of deposited sediment (Zaremba, 1978).

Hybridization has occurred between *S. alterniflora* with *S. foliosa* in North America. Within the San Francisco Estuary population of *S. alterniflora* a rapid evolution of an aggressively expanding hybrid, formed by cross pollination with the native *S. foliosa* of the area (Daehler and Strong 1997). Both species act as pollen-parent and seed parent to the new hybrid form. The hybrids form produces a greater quantity of pollen (21 times greater) and has a higher fertility than the parent *S. foliosa*. Pollen swamping of the native *S. foliosa* occurs frequently so that the native stands produce predominantly hybrid introgressant seeds, and fail to sexually reproduce the species (Ayres et al. 1999, Antilla et al. 2000). This process, called "hybrid assimilation", can singularly result in the extinction of the native species (Levin et al. 1996, Rhymer and Simberloff 1996). Genetic analysis of *S. alterniflora* in San Francisco estuary has exposed that the majority of populations presumed to be "pure", are principally hybrid or introgressant stands with "pure" *S. alterniflora* in the minority. This trend implies that hybrids will in due course replace both parent species, as *S. anglica* did in the U.K.

Non-native invasive *Spartina* can have long-term effects on the coastal environments causing: extensive regional losses of tidal mud flats; elimination of foraging habitat for waders; alteration of natural sedimentation processes (incl. estuarine beaches and beach forming processes); loss of tidal sloughs and channels; an increase in dredging and flood control works and genetic assimilation local flora and extinction of native flora and fauna (Hammond, 2001; CSCC, 2003).

Various methods have or are being tested to be used to control and/or eradicate invasive *Spartina* species. These include a number of manual, mechanical and chemical methods. Some are designed to total eradicate target *Spartina* populations, while other methods are to provide a temporary control of the species or designed to aid the implementation of a removal method.

Using systematic review methodology, the different methods used to control or eradicate *Spartina* will be critically appraised. The review will consider all available evidence of the different control and eradication methods (Table 1). Bias will be limited through comprehensive searching of both published and unpublished "grey" literature), specific study inclusion criteria, and formal assessment of the quality and reliability of the studies retrieved. Subsequent quantitative and qualitative data synthesis will be utilised to summarise the available evidence, guiding our recommendations to land managers while also highlighting any gaps in the research evidence found to direct future research programmes.

2. Objective of the Review

2.1. Primary objective

To investigate the effectiveness of management interventions to control the abundance or completely eradicate invasive *Spartina* species (Table 1) and to analyse the effects that the various sources of potential heterogeneity (see 3.2) have on the results.

2.2. Secondary objective

Establish the timeframe required and how many treatments are required for each of the management interventions to eradicate invasive *Spartina* species.

2.3. Tertiary objective

To summarise the changes in vegetation type reported by comparing before control of *Spartina* species with the community assemblage afterwards.

Table 1. The components of the primary & secondary systematic review questions

Subject	Intervention	Outcome		
		Primary	**Secondary**	**Tertiary**
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)	1). Hand Pulling & Manual Excavation 2). Mechanical Excavation & Dredging 3). Mowing or Pruning or Flaming 4). Burning 5). Crushing & Mechanical Smothering 6). Covering or Blanketing 7). Flooding or Draining 8). Herbicide (aerial, boat or ground application methods) + any combination or other method + method of disposal of *Spartina* from the area	Changes in the abundance of: Cover, density, frequency, biomass.	Time taken to eradicate infestation + N$^{o.}$ treatments required	Changes in vegetation type (compare before control of *Spartina* sp. with the community assemblage afterwards).

3. METHODS
3.1. Search strategy

The following general computerised/web databases will be searched:

1) ISI Web of Knowledge (incl. ISI Web of Science and ISI Proceedings)
2) Science Direct
3) Blackwell Synergy
4) IngentaConnect
5) Directory of Open Access Journals
6) COPAC
7) Scirus (All journal sources)
8) Scopus
9) Index to Theses Online
10) Digital Dissertations Online
11) Agricola
12) CAB Abstracts
13) English Nature's "Wildlink"
14) CEH online database (Centre for Ecology and Hydrology)
15) JSTOR
16) ConservationEvidence.com
17) ConserveOnline

Other specific or specialised databases, such as important conservation organisation libraries and websites will be searched once identified or recommended by experts within the field.

In addition web searches will also be performed using the search engines: www.alltheweb.com, http://scholar.google.com. The first 50 hits (.doc, .txt, .xls & .pdf documents where this can be separated) from each data source will be examined for appropriate data, no further links from the captured website will be followed unless to a document/pdf file. Searches of publications from U.K., American and Australasian statutory and non-statutory organisations will be undertaken.

The following search terms will be utilised on each of the database and web searches:

1) ***Spartina***
2) ***Spartina*** **AND (control OR eradication)**
3) ***Spartina alterniflora***
4) ***Spartina anglica***
5) ***Spartina densiflora***
6) ***Spartina patens***
7) ***Spartina x townsendii***
8) **Cordgrass** (common name used in Europe and U.S.A.)
9) **Ricegrass** (common name used in Australasia)

Bibliographies (reference lists) of all articles accepted for assessment at full text will be searched for further relevant articles missed by previous searches. Authors, recognised experts and practitioners will be contacted for further recommendations, and for provision of any unpublished material or missing data that may be relevant to the review.

A single reviewer will search all electronic sources, recording the number of citations retrieved and entering all reference into an EndNote™ reference manager database.

3.2. Study inclusion criteria

The inclusion and exclusion criteria will be applied by one reviewer to all potential studies at a title & abstract level. Where there is insufficient information to make an informed decision regarding a studies inclusion, then relevance to the next stage of the review process (full text assessment) will be assumed. A second reviewer will examine a random subset of at least 25% of the reference list (up to a maximum of 2000 references) to assess repeatability of the selection criteria. Kappa analysis will be performed, with a rating of 'substantial' (0.6 or above) being required to pass the assessment. Disagreement regarding inclusion or exclusion of studies will be resolved by consensus, or following assessment by a third reviewer. If the Kappa value is low, the reference list will be reassessed against adjusted inclusion and exclusion criteria. The same subset of references will be re-assessed by a second reviewer with Kappa analysis. Reviewers will then consider articles viewed at full text for relevance, either excluding them from, or admitting them to, the review.

Relevant subjects, interventions & outcomes

For details of the *Spartina* spp., interventions and outcomes that are deemed relevant for inclusion within the review, see table 1 (above).

Types of comparator:

No article will be rejected due to lacking a comparator. However, for inclusion within formal meta-analysis a comparator (e.g. a control plot or alternative intervention) is required. Those articles lacking a comparator will be included within qualitative analysis and summarised within tables.

Types of study:

All articles whether published peer reviewed papers, articles in press or unpublished (grey) literature will be considered for inclusion within the review. All languages will be considered and included within sensitivity analyses.

Potential reasons for heterogeneity within the results that will be extracted from each paper and investigated:

Salinity; Longitude/Latitude; Age of stand; Height of stand; Density of *Spartina* (e.g. cover, stand density, frequency, and biomass); Size of controlled area; Duration, effort (frequency of control) and timing (i.e. season) of control program; Mechanical aspects of control methods (e.g. cutting and digging /excavation techniques); Chemical aspects of control methods (e.g. herbicide type, herbicide application method, concentration of herbicide, number of herbicide applications, weather during and within 48hrs application)

3.3. Study quality assessment

Reviewers will assess the methodologies used by all articles accepted at full text. Study quality will be scored according to a hierarchy of evidence adapted from systematic review guidelines used in medicine and public health (Stevens & Milne 1997) and conservation (Pullin & Knight 2003); e.g. a randomised control trial would be weighed higher than a site comparison study. A second reviewer will examine a random subset of at least 25% of the selected studies to assess repeatability of study quality. Disagreement regarding study quality will be resolved by consensus, or following assessment by a third reviewer.

3.4. Data extraction strategy

Data will be extracted by one reviewer, and a random subset of at least 25% of the selected studies will be checked by another reviewer to verify repeatability and accuracy. Data regarding the study characteristics, quality, design and results will be recorded using electronic data extraction forms. Where information regarding the reasons for heterogeneity is presented in the studies, it will also be recorded.

3.5. Data synthesis

Methods of data synthesis depend upon the type of data presented in the accepted studies. At a minimum, all studies that are accepted for inclusion, will be summarised qualitatively. Primary data will be collected from the author/organisation if it is not presented in the study write up. Summary tables of study characteristics, study quality and results will be presented, accompanied by a narrative synthesis.

Quantitative analysis will be undertaken on any data suitable for formal statistical analysis. If possible, meta-analyses for each of the interventions will be carried out with reasons for heterogeneity assessed by meta-regression (univariate or multivariate). If meta-analysis is not possible, then other appropriate statistical techniques may be performed.

4. POTENTIAL CONFLICTS OF INTEREST AND SOURCES OF SUPPORT

No conflicts of interest – funding for this review is via ongoing stipend from NERC.

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