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NOTE

The Runaway Weed: Costs and Failures of *Phragmites australis* Management in the USA

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Abstract While public funding of invasive species management has increased substantially in the past decade, there have been few cross-institutional assessments of management programs. We assessed management of *Phragmites australis*, a problematic invader of coastal habitats, through a cross-institutional economic survey of 285 land managers from US public and private conservation organizations. We found that from 2005 to 2009, these organizations spent >$4.6 million per year on *P. australis* management, and that 94 % used herbicide to treat a total area of ~80,000 ha. Despite these high expenditures, few organizations accomplished their management objectives. There was no relationship between resources invested in management and management success, and those organizations that endorsed a particular objective were no more likely to achieve it. Our results question the efficacy of current *P. australis* management strategies and call for future monitoring of biological management outcomes.

Keywords Invasive species · Management · *Phragmites australis* · Restoration · Economic survey

Introduction

Invasive species are considered among the greatest threats to native biodiversity (Mooney and Hobbs 2000; CBD 2010; GISP 2010). In the USA alone, over 4,300 non-native plants are naturalized, and thousands more are sold, grown, and cared for in nurseries and gardens despite the risk of escape (US OTA 1993). The sheer number of potential invaders, coupled with their occurrence in diverse habitats, has led conservation organizations to consistently increase the resources they direct towards invasive species management (D'Antonio et al. 2004; Pullin and Knight 2005); for example, the US federal budget for invasive species increased by $400 million between 2002 and 2006 (US NISC 2006).

However, increasing investment is rarely matched with evidence of accruing economic or ecological benefits (Reid et al. 2009). Little data exists on cross-institutional invasive species management practices or outcomes. There are a few reasons for this. First, a suite of disparate organizations—local, state, federal, and private—and individual landowners are involved in the management of any one species. (At the US federal level alone, invasive species management falls under the purview of at least 16 agencies.) This makes auditing difficult. Second, much of the funding for invasive species management comes from decentralized general resource funds rather than specific appropriations (US GAO 2005). Third, funding for treatment and assessment are often decoupled, so that many organizations only report extent of areas treated or resources used (Blossey 1999; Panetta and Lawes 2005).

Limited data suggests that organizations rarely meet their invasive species management objectives (Denslow and D'Antonio 2005). A recent survey of Australian land managers indicates that undesired species invade recently managed areas over 50 % of the time (Reid et al. 2009). In another survey, only 3 of 78 forest managers in the north-eastern USA reported successful elimination of invasive plants from their management areas (Acharya 2009). In coastal habitats, invasive species management efforts may be most successful when introduced populations are small and restricted, financial resources are abundant, and early action is taken (Williams and Grosholz 2008)—three criteria for management success predicted elsewhere (Myers et al. 2000).

In order to assess invasive species management practices across institutions, and to quantify the relationship between management expenditures and success, we conducted an

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economic survey of organizations involved in *Phragmites australis* (common reed) management. Focusing on a single species allowed us to develop a targeted questionnaire that we distributed to land managers in federal, state, municipal, and private organizations across the USA.

The genus *Phragmites*, a group of clonal wetland grasses, has existed in North America for at least 40,000 years (Orson 1999) with endemic North American populations recognized as a unique subspecies, *Phragmites australis americanus* (Saltonstall et al. 2004). In the late 1800s, Eurasian genotypes were introduced to the East Coast and have since spread across much of the continent (Saltonstall 2002). This invasion has spurred widespread aggressive attempts to reduce populations. To achieve these ends, managers use chemical, mechanical, and physical control methods (Marks et al. 1994). Failure to achieve long-term *P. australis* suppression using these techniques has led researchers to explore alternative control methods, including biocontrol (Tewksbury et al. 2002).

Attempts to manage invasive *P. australis* have come under recent critique. Some challenge the assumption that *P. australis* invasion negatively affects ecosystems (Hershner and Havens 2008; Martin and Blossey 2009). For example, while some studies indicate that introduced *P. australis* invasion alters invertebrate assemblages (Angradi et al. 2001; Robertson and Weis 2005), others suggest that some or many invertebrate taxa are unaffected (Fell et al. 1998; Warren et al. 2001; Gratton and Denno 2005). Other evidence suggests that significant ecological differences exist among *P. australis* populations (Park and Blossey 2008; Mozdzer and Zieman 2010) but that these differences do not always align by native status (Maerz et al. 2010; Cohen et al. 2012). Despite this ongoing debate, many organizations continue to attempt to reduce non-native *P. australis* while protecting native *P. australis americanus*.

In this survey, we asked organizations to report on their management objectives, expenditures, control methods, and management outcomes as well as attitudes towards potential implementation of a biocontrol program. We anticipated that using a high-profile, easily identifiable, and widely targeted invader would allow us to test for quantitative differences among organizations in management approaches, intensities, and success rates. Because so few organizations monitor biological variables before, during, and after management, such economic data are the only available means of assessing management practices.

Methods

In spring 2009, we conducted pilot interviews with managers from the US Fish and Wildlife Service, The Nature Conservancy, and the New York State Department of Transportation that we used to develop a draft survey. We tested this draft survey with two focus groups of federal and state land managers in New York State and Virginia. We incorporated focus groups' suggestions into the final survey.

In order to generate a contact list, we adapted a systematic sampling strategy from Dillman's (2007) discussion of email and web-based survey design, compiling contacts from a *P. australis* management Listserv managed since 1998. The final contact list included managers from federal, state, municipal, and private conservation organizations (N=520). We distributed the survey instrument to these contacts via email in October 2009, asking them to further distribute to appropriate colleagues. After 2 weeks, we sent an email reminder, and we closed our data collection in December 2009.

Our communications with participants emphasized the survey's usefulness and the importance of a response from each person in the sample. After a respondent indicated her affiliation, she answered a series of questions that addressed her organization's management expenditures (for both *P. australis* and all invasive plants), management objectives, management practices, management outcomes, and perceived management constraints as well as attitudes towards potential implementation of a biocontrol program. Questions on objectives, outcomes, and constraints were divided into series of sub-questions which respondents rated on a 5-point Likert scale (1=strongly disagree; 5=strongly agree).

Statistical Methods

In order to test for differences among responses by affiliation (federal, state, municipal, land trust, and other private), we conducted ANOVAs on the following dependent variables: "area *P. australis* managed in the past 5 years," "*P. australis* management expenditures (hours per ha per year and USD per ha per year)," and "percent total invasive plant budget and time spent on *P. australis* management," testing post hoc contrasts with Tukey–Kramer HSD. To calculate aggregate expenditure, we multiplied management hours per year by the median annual wage of a conservation scientist, \$29/h (US BLS 2010), and added this to USD per year. To test for agreement between ordinal measures of (1) respondent agreement with an objective and (2) perceived success at achieving that objective, we used the Kendall's tau-b statistic (1=perfect agreement, −1=perfect inversion, 0=no relationship; Agresti 1984). In order to determine which ordinal logistic regression models best explained the relationship between expenditure (area, dollars, or time) and success sub-question rations, we used an information theoretic approach, comparing models with corrected Akaike's Information Criterion (AICc) and considering all models within 2 AIC of the top model (Burnham and Anderson 2002). When necessary, data were log transformed to meet

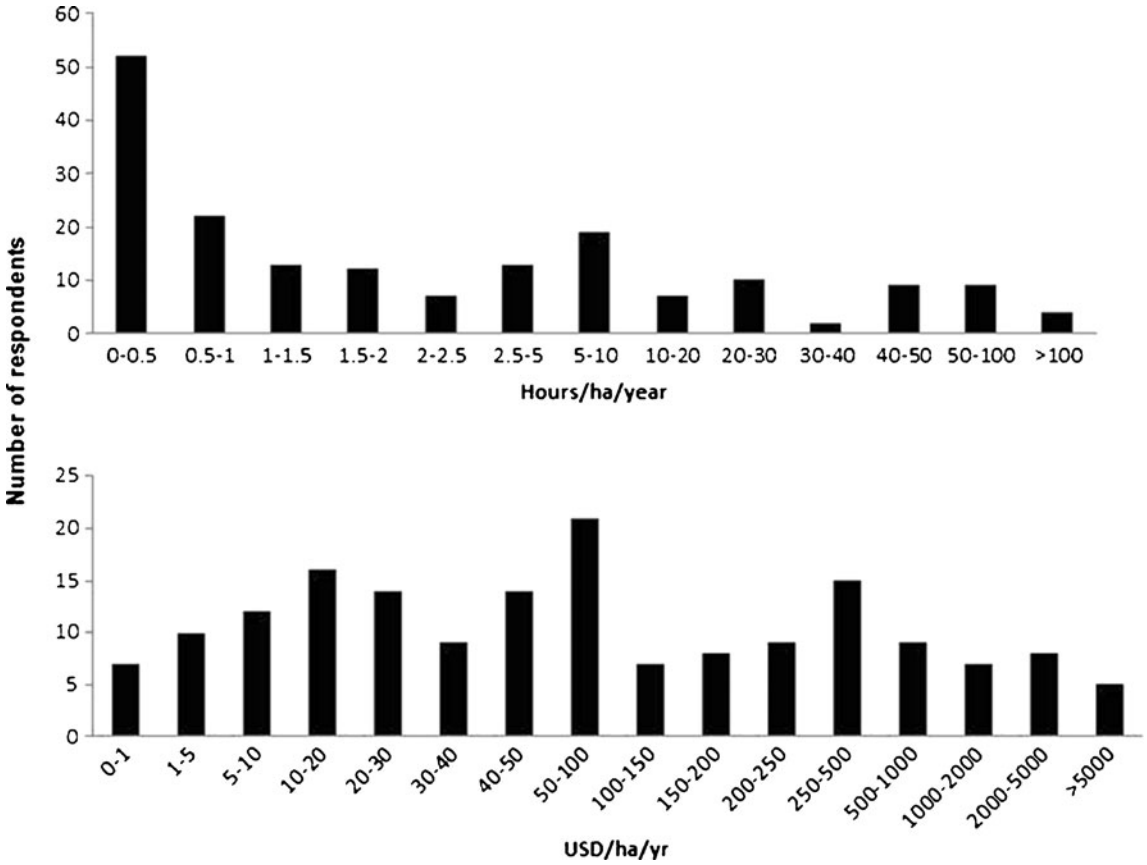

Fig. 1 Number of respondent organizations (N=196) in each level of expenditure on *Phragmites australis* management in time (hours per hectare per year, *top*) and dollars (USD per hectare per year, *bottom*)

the assumption of normality. We performed all statistical tests in JMP 8.0 (SAS Institute Inc., Cary, NC, USA).

Results

Participants

We received responses from 285 managers located in 425 counties in 40 states. Meanwhile, *P. australis* has been reported in 859 counties in 45 states (USDA 2010); we therefore believe that our survey captures a significant cross-section of organizations that manage *P. australis*. We received the greatest number of responses from managers working for private organizations (39 %), followed by federal (24 %), state (23 %), municipal (8 %), and land trust (6 %) organizations.

Organizations managed invasive species on areas that ranged from 0.4 ha to 22.5 million ha (median=2,145 ha); combined, they managed ~81 million ha, or 12.3 % of the

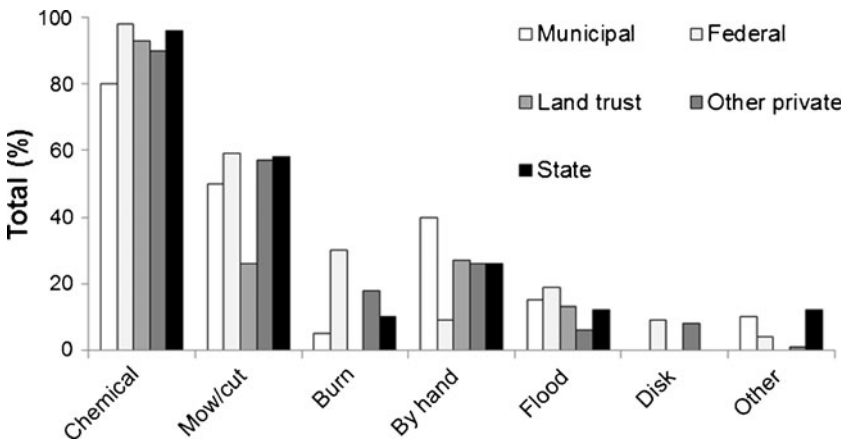

Fig. 2 *Phragmites australis* control methods (percent) used in the past 5 years by respondents in different organizations

Table 1 Land managers' ratings of nine management objectives by those whose organizations actively managed *Phragmites australis* between 2005 and 2009

Organizational objective	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Response avg.
Improve transportation	7.6 % (14)	3.8 % (7)	10.3 % (19)	23.2 % (43)	55.1 % (102)	1.85
Improve tourism	4.3 % (8)	8.6 % (16)	14.6 % (27)	23.8 % (44)	48.6 % (90)	1.96
Improve water availability	7.0 % (13)	9.7 % (18)	14.5 % (27)	22.6 % (42)	46.2 % (86)	2.09
Restore historical view	11.2 % (21)	10.1 % (19)	26.1 % (49)	23.9 % (45)	28.7 % (54)	2.51
Restore aesthetic qualities	13.7 % (26)	20.5 % (39)	32.3 % (61)	20.0 % (38)	21.1 % (40)	2.86
Restore natural hydrology	27.0 % (51)	24.3 % (46)	18.1 % (35)	7.4 % (14)	9.0 % (17)	3.53
Restore native fauna	56.5 % (109)	17.1 % (33)	8.1 % (16)	2.6 % (5)	5.7 % (11)	4.16
Restore native flora	77.7 % (153)	13.2 % (26)	5.1 % (10)	0.5 % (1)	3.6 % (7)	4.61
Improve ecosystem functions	70.1 % (138)	17.3 % (34)	8.1 % (35)	2.5 % (5)	2.0 % (4)	4.51

Data presented on a Likert scale (1=strongly disagree; 5=strongly agree) as percent and total number of respondents per sub-question

area of the continental USA. This number may seem high, but the federal government alone owns ~21.4 % of the continental USA, and many respondents oversaw invasive species programs for entire regions.

Expenditures

Organizations managed up to 10,000 ha of native *P. australis* (median=0 ha) and 28,328 ha of non-native *P. australis* (median=40 ha), for combined total areas of 22,566 ha native *P. australis* and 89,900 ha non-native *P. australis*. Combined organizations spent 30,553 h/year and $3,752,800/year on non-native *P. australis* management, for an aggregate expenditure of ~$4,638,800/year. Both time and dollars spent varied among organizations (Fig. 1), with state organizations investing significantly less time than private organizations (state mean=10.6/h/ha/year, private mean=12.3/h/ha/year; $F_{4,172}$=2.94, P=0.022).

Control Methods

The vast majority of organizations used herbicide as their primary *P. australis* control method (94 %, N=185). Other methods were less common (Fig. 2). Combined, these organizations treated 83,000 ha with herbicide.

Objectives and Outcomes

The most highly rated management objective was restoration of native flora; some objectives were of little concern (Table 1). A number of respondents felt their organizations had been successful in temporary *P. australis* control, but success in long-term *P. australis* control was more elusive (Table 2). While some believed management had increased the abundance and richness of native plant species, few indicated that management resulted in restoration of pre-invasion plant communities (Table 2).

Table 2 Land managers' ratings of ten management outcomes by those whose organizations actively managed *Phragmites australis* between 2005 and 2009

Outcome	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Response avg.
Increase in tourism	3.3 % (6)	4.4 % (8)	23.2 % (42)	26.5 % (48)	42.5 % (77)	1.99
Restoration of pre-invasion hydrology	8.6 % (16)	17.8 % (33)	37.3 % (59)	24.3 % (45)	11.9 % (22)	2.87
Increase in number of native faunal spp.	9.3 % (17)	17.5 % (32)	36.6 % (67)	27.3 % (50)	9.3 % (17)	2.9
Increase in abundance of native faunal spp.	9.3 % (17)	17.5 % (32)	38.5 % (70)	25.8 % (47)	8.8 % (16)	2.93
Restoration of pre-invasion fauna	8.2 % (15)	17.9 % (33)	43.5 % (80)	22.3 % (41)	8.2 % (15)	2.96
Long-term control of *P. australis*	14.2 % (27)	24.7 % (47)	24.7 % (47)	22.1 % (42)	14.2 % (27)	3.03
Restoration of pre-invasion native plant spp.	13.1 % (25)	30.4 % (58)	30.4 % (58)	19.4 % (37)	6.8 % (13)	3.24
Increase in number of native plant spp.	20.6 % (39)	24.9 % (51)	27.0 % (51)	21.2 % (40)	6.3 % (12)	3.32
Increase in abundance of native plant spp.	27.9 % (53)	22.1 % (47)	24.7 % (47)	20.0 % (38)	5.3 % (10)	3.47
Temporary control of *P. australis*	45.8 % (88)	28.1 % (21)	10.9 % (21)	10.9 % (21)	4.2 % (8)	4.01

Data presented on a Likert scale (1=strongly disagree; 5=strongly agree) as percent and total number of respondents per sub-question

Constraints

Most organizations cited lack of personnel and monetary resources as the most significant constraints on their programs, with "re-invasion of *P. australis* after control" and "inaccessibility of target population" of intermediate importance. Interestingly, assessment of the importance of monetary constraints was not related to an organization's invasive plant management budget (F=1.492, P=0.207) or annual *P. australis* management expenditure (F=0.814, P=0.518; Fig. 3).

Organizations that gave a high rating to a particular objective were not more likely to achieve it: this was true for highly ranked objectives, such as restoration of native plant species (tau-b=0.159) and native fauna (tau-b=0.192), as well as lesser priority ones like restoration of hydrology (tau-b=0.313; Table 3). Logistic ordinal models indicated no relationships between organizational expenditure and any rating of management success.

The majority of respondents (91 %, N=260) indicated that they were comfortable with the use of biocontrol to manage *P. australis* populations if control agents were specific to non-native *P. australis* and there appeared to be no risk to native *P. australis*. Meanwhile 2 % of respondents (N=5) were unconditionally uncomfortable with the use of biocontrol, and 14 % (N=41) believed biocontrol should only be used if chemical, mechanical, and physical measures were unable to stop introduced *P. australis* invasion. A majority (57 %, N=162) would accept use of biocontrol if the agent attacked native *P. australis* in confinement, but not in the field (65 % of those who had managed *P. australis*; 40 % of those who had not), while 46 % (N=131) would accept attack of native *P. australis* in the field, but only if it did not lead to a significant decline (50 % of those who had managed *P. australis*; 35 % of those who had not). Surprisingly, 18 % (N=51) of respondents were willing to accept the use of biocontrol even if the agents were to cause a population-level decline of both the non-native and native types (21 % of those who had managed *P. australis*; 10 % of those who had not).

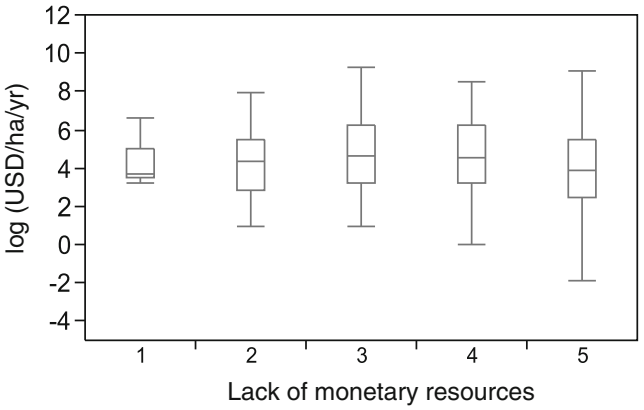

Fig. 3 The relationship between respondent agreement with the statement "lack of monetary resources constrains my organization's *Phragmites australis* management" (rated on a Likert scale where 1=strongly disagree, 5=strongly agree) and *P. australis* management budget [log (USD per hectare per year)]. Data are shown as *boxplots* displaying median, 25–75 percentiles, and range

Table 3 Contingency tables showing respondents' agreement with a particular organizational objective against their perception of whether their organization has achieved that objective (rated on a Likert scale, 1=strong disagreement, 5=strong agreement)

	Total % χ^2, P	1	2	3	4	5
Restoration of native plant spp.						
Success	1	0.5	1.6	1.1	0.0	0.5
		0.542, 1	0.069, 1	0.224, 1	0.224, 1	0.005, 1
	2	0.0	0.0	0.0	0.0	0.5
		2.026, 1	0.193, 1	6.16, 0.98	0.46, 1	0.38, 1
	3	0.5	2.7	1.1	0.5	0.0
		0.002, 1	0.294, 1	0.158, 1	2.652, 1	0.242, 1
	4	0.5	1.6	5.9	3.7	0.5
		2.17, 1	0.310, 1	1.150, 1	0.003, 1	0.426, 1
	5	5.3	13.4	21.4	26.7	11.8
		0.004, 1	5.61, 0.9	1.203, 1	1.400, 1	0.281, 1
Restoration of native fauna						
Success	1	1.1	0.0	1.7	2.2	3.4
		1.61, 1	0.42, 1	0.062, 1	0.65, 1	0.72, 1
	2	1.7	1.1	6.2	1.1	12.3
		0.26, 1	0.70, 1	2.39, 1	3.71, 1	0.02, 1
	3	1.7	1.1	8.4	11.2	20.1
		037, 1	0.007, 1	0.26, 1	3.03, 1	1.10, 1
	4	0.0	0.0	1.1	3.4	14.0
		1.84, 1	0.92, 1	2.42, 1	0.002, 1	2.19, 1
	5	1.1	0.6	0.0	0.0	6.7
		1.61, 1	0.80, 1	2.59, 1	2.68, 1	1.48, 1
Restoration of hydrology						
Success	1	4.0	2.3	2.8	1.7	0.6
		18.39, 0.30	3.64, 1	0.38, 1	0.73, 1	3.53, 1
	2	1.1	2.3	10.2	6.3	5.1
		0.64, 1	0.72, 1	0.85, 1	0.0058, 1	0.64, 1
	3	2.8	2.3	14.8	8.5	8.5
		0.0056, 1	0.27, 1	0.98, 1	0.049, 1	0.32, 1
	4	0.0	0.6	2.8	6.3	8.0
		2.46, 1	0.87, 1	2.66, 1	1.55, 1	3.95, 1
	5	0.0	0.6	2.3	1.7	4.6
		1.27, 1	0.058, 1	0.31, 1	0.21, 1	3.25, 1

Discussion

Our results suggest that efforts to control introduced *P. australis* have delivered few long-term ecological benefits despite their cost (>$4 million/year) and organizations' goals

of ecological restoration. Importantly, increased spending and effort did not increase long-term ecological benefits. These results call into question the efficacy of *P. australis* control programs nationwide.

For over 15 years, managers and researchers have suggested that invasive species management is hindered by the absence of frameworks for monitoring biological outcomes of management (Blossey 1999). As Hobbs and Humphries (1995) observe, invasive management programs often focus on the invader and, in doing so, lose sight of the invaded ecosystem—the real object of concern. Many organizations do not quantify management outcomes, and if they do, they tally dollars spent or areas treated. The prevalence of herbicide application is also troubling given the lack of evidence that such management is effective. Widespread use of herbicide for conservation is rarely scrutinized, even with its potential to damage non-target species (Hayes et al. 2002; Matarczyk et al. 2002; Rinella et al. 2009). Our economic data suggest that managers are not observing substantial ecological improvements in response to control measures. It is imperative to quantify effects of large-scale herbicide use, as well as other intensive control techniques, on species other than targeted plant invaders. Only quantitative evidence for beneficial effects of control efforts can justify continuation of such treatments. We therefore reiterate the call for biological monitoring.

Our results are consistent with those of Reid et al. (2009), and we suspect that poor long-term results are not unique to *P. australis*. As land management agencies have a responsibility towards land stewardship, land management organizations and funding bodies should require, support and enable continued assessments of management outcomes. In order to re-orient invasive plant management programs to focus on ecological restoration, we propose the following three guidelines. First, management objectives should be clearly defined and measurable and should go beyond invader abundance. Second, organizations should document that the invading species is responsible for ecosystem deterioration and is not a symptom of other stressors (MacDougall and Turkington 2005). Third, organizations should record (and make publicly available) data before, during, and after management. We understand and recognize that we are asking many organizations to fundamentally change their operating procedures, priorities, and philosophies at a time where conservation resources are extremely limited. Yet quantification of invasive plant program outcomes can only help in maintaining public support. At the same time, we are asking funders to hold organizations accountable and support assessments as part of management programs. Only through improvement of current management practices can we hope to arrive at a more ecologically and economically sustainable approach to land stewardship.

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References

Acharya, C. 2009. Forest invasive plant management: understanding and explaining management effects. Masters thesis. Ithaca: Cornell University.

Agresti, A. 1984. *Analysis of ordinal categorical data*. Hoboken: Wiley.

Angradi, T.R., S.M. Hagan, and K.W. Able. 2001. Vegetation type and the intertidal macroinvertebrate fauna of a brackish marsh: *Phragmites* vs. *Spartina*. *Wetlands* 21: 75–92.

Blossey, B. 1999. Before, during and after: The need for long-term monitoring in invasive plant species management. *Biological Invasions* 1: 301–311.

Burnham, K.P., and D.R. Anderson. 2002. *Model selection and multimodel inference: A practical information-theoretic approach*. New York: Springer.

Cohen, J., J. Maerz, and B. Blossey. 2012. Traits, not origin, explain impacts of plants on larval amphibians. *Ecological Applications* 22: 218–228.

Convention on Biological Diversity (CBD). 2010. Invasive alien species. http://www.cbd.int/invasive/ (accessed 10 November 2010).

D'Antonio, C.M., N.E. Jackson, C.C. Horvitz, and R. Hedberg. 2004. Invasive plants in wildland ecosystems: Merging the study of invasion processes with management needs. *Frontiers in Ecology and the Environment* 2: 513–521.

Denslow, J.S., and C.M. D'Antonio. 2005. After biocontrol: Assessing indirect effects of insect releases. *Biological Control* 35: 307–318.

Dillman, D.A. 2007. *Mail and internet surveys: The tailored design, second edition—2007 update*. Hoboken: Wiley.

Fell, P.E., S.P. Weissbach, D.A. Jones, M.A. Fallon, J.A. Zeppieri, E.K. Faison, K.A. Lennon, K.J. Newberry, and L.K. Reddington. 1998. Does invasion of oligohaline tidal marshes by reed grass, *Phragmites australis* (Cav) Trin ex Steud, affect the availability of prey resources for the mummichog, *Fundulus heteroclitus* L? *Journal of Experimental Marine Biology and Ecology* 222: 59–77.

Global Invasive Species Program (GISP). 2010. http://www.icsu-scope.org/projects/complete/gisp.htm (accessed 8 November 2010).

Gratton, C., and R.F. Denno. 2005. Restoration of arthropod assemblages in a *Spartina* salt marsh following removal of the invasive plant *Phragmites australis*. *Restoration Ecology* 13: 358–372.

Hayes, T.B., A. Collins, M. Lee, M. Mendoza, N. Noriega, A.A. Stuart, and A. Vonk. 2002. Hermaphroditic, demasculinized frogs after exposure to the herbicide atrazine at low ecologically relevant doses. *Proceedings of the National Academy of Sciences of the United States of America* 99: 5476–5480.

Hershner, C., and K.J. Havens. 2008. Managing invasive aquatic plants in a changing system: Strategic consideration of ecosystem services. *Conservation Biology* 22: 544–550.

Hobbs, R.J., and S.E. Humphries. 1995. An integrated approach to the ecology and management of plant invasions. *Conservation Biology* 9: 761–770.

MacDougall, A.S., and R. Turkington. 2005. Are invasive species the drivers or passengers of change in degraded ecosystems? *Ecology* 86: 42–55.

Maerz, J., J. Cohen, and B. Blossey. 2010. Does detritus quality predict the effect of native and non-native plants on the performance of larval amphibians? *Freshwater Biology* 55: 1694–1704.

Marks, M., B. Lapin, and J. Randall. 1994. *Phragmites australis* (*P. communis*)—Threats, management, and monitoring. *Natural Areas Journal* 14: 285–294.

Martin, L.J., and B. Blossey. 2009. A framework for ecosystem services valuation. *Conservation Biology* 23: 494–496.

Matarczyk, J.A., A.J. Willis, J.A. Vranjic, and J.E. Ash. 2002. Herbicides, weeds and endangered species: Management of bitou bush (*Chrysanthemoides monilifera* ssp *rotundata*) with glyphosate and impacts on the endangered shrub, *Pimelea spicata*. *Biological Conservation* 108: 133–141.

Mooney, H., and R. Hobbs. 2000. *Invasive species in a changing world*. Washington, D.C.: Island.

Mozdzer, T.J., and J.C. Zieman. 2010. Ecophysiological differences between genetic lineages facilitate the invasion of non-native *Phragmites australis* in North American Atlantic coast wetlands. *Journal of Ecology* 98: 451–458.

Myers, J.H., D. Simberloff, A.M. Kuris, and J.R. Carey. 2000. Eradication revisited: Dealing with exotic species. *Trends in Ecology and Evolution* 15: 316–320.

Orson, R.A. 1999. A paleoecological assessment of *Phragmites australis* in New England tidal marshes: Changes in plant community structure during the last few millennia. *Biological Invasions* 1: 149–158.

Panetta, F.D., and R. Lawes. 2005. Evaluation of weed eradication programs: The delimitation of extent. *Diversity and Distributions* 11: 435–442.

Park, M.G., and B. Blossey. 2008. Importance of plant traits and herbivory for invasiveness of *Phragmites australis* (Poaceae). *American Journal of Botany* 95: 1557–1568.

Pullin, A.S., and T.M. Knight. 2005. Assessing conservation management's evidence base: A survey of management-plan compilers in the United Kingdom and Australia. *Conservation Biology* 19: 1989–1996.

Reid, A.M., L. Morin, P.O. Downey, K. French, and J.G. Virtue. 2009. Does invasive plant management aid the restoration of natural ecosystems? *Biological Conservation* 142: 2342–2349.

Rinella, M.J., B.D. Maxwell, P.K. Fay, T. Weaver, and R.L. Sheley. 2009. Control effort exacerbates invasive-species problem. *Ecological Applications* 19: 155–162.

Robertson, T.L., and J.S. Weis. 2005. A comparison of epifaunal communities associated with the stems of salt marsh grasses *Phragmites australis* and *Spartina alterniflora*. *Wetlands* 25: 1–7.

Saltonstall, K. 2002. Cryptic invasion by a non-native genotype of the common reed, *Phragmites australis*, into North America. *Proceedings of the National Academy of Sciences of the United States of America* 99: 2445–2449.

Saltonstall, K., P.M. Peterson, and R.J. Soreng. 2004. Recognition of *Phragmites australis* subsp. *americanus* (Poaceae: Arundinoideae) in North America: Evidence from morphological and genetic analyses. *Sida Contributions to Botany* 21: 683–692.

Tewksbury, L., R. Casagrande, B. Blossey, P. Hafliger, and M. Schwarzlander. 2002. Potential for biological control of *Phragmites australis* in North America. *Biological Control* 23: 191–212.

US Bureau of Labor Statistics (BLS), US Department of Labor. 2010. Occupational outlook handbook, 2010–11 Edition, Conservation scientists and foresters. http://www.bls.gov/oco/ocos048.htm (accessed 11 January 2010).

US Department of Agriculture (USDA). 2010. Plants database: *Phragmites australis*. http://plants.usda.gov/java/profile?symbol=PHAU7 (accessed 2 January 2010).

US Government Accountability Office. 2005. Invasive species: Cooperation and coordination are important for effective management of invasive weeds. http://www.gao.gov/new.items/d05185.pdf (accessed 10 February 2010).

US National Invasive Species Council (NISC). 2006. Fiscal year 2006 interagency invasive species performance-based crosscut budget. http://www.invasivespeciesinfo.gov/docs/council/FY06budget.pdf (accessed 1 October 2009).

US Office of Technology Assessment (OTA). 1993. *Harmful non-indigenous species in the United States, OTA-F-565*. Washington, D.C.: US Government Printing Office.

Warren, R.S., P.E. Fell, J.L. Grimsby, E.L. Buck, G.C. Rilling, and R.A. Fertik. 2001. Rates, patterns, and impacts of *Phragmites australis* expansion and effects of experimental *Phragmites* control on vegetation, macroinvertebrates, and fish within tidelands of the lower Connecticut River. *Estuaries* 24: 90–107.

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