



Short communication

An evaluation of the impact of *Melaleuca quinquenervia* invasion and management on plant community structure after fireMelissa R. Martin ^{a,*}, Philip W. Tipping ^b, K.R. Reddy ^a, Paul T. Madeira ^b, Danyelle Fitzgerald ^b^a University of Florida, Department of Soil and Water Science, 106 Newell Hall, PO Box 110510, Gainesville, FL 32611, United States^b United States Department of Agriculture, Agricultural Research Service, Invasive Plant Research Laboratory, 3225 College Avenue, Fort Lauderdale, FL 33314, United States

ARTICLE INFO

Article history:

Received 4 February 2011

Received in revised form 17 August 2011

Accepted 18 August 2011

Available online 26 August 2011

Keywords:

Fire

Invasion

Management

Melaleuca quinquenervia

Richness

ABSTRACT

Two questions were asked in this study: after a fire, does the choice of invasive plant management strategy, namely herbicidal or biological, alter (1) plant community assemblages and (2) the re-invasion potential of the Australian tree *Melaleuca quinquenervia*? Plant species richness was highest in the non-invaded and herbicide sites compared to the biological site with 10.5, 10.8, and 8.25 species m⁻² found in each site, respectively. Although the total count of live and dead seedlings was highest in the biologically controlled site at 22.8 and 13.6 plants m⁻², respectively, *M. quinquenervia* seedlings were recruited in all sites. While the ultimate goal of management programs is to restore ecosystem integrity, this work provides evidence that passive restoration may not be enough to restore plant community structure in this system.

Published by Elsevier B.V.

1. Introduction

Populations of invasive exotic plants reproduce quickly and spread into new habitats causing substantial economic and environmental harm (Richardson et al., 2000). Herbicidal and biological management programs in natural areas aim to reduce the size and spread of invasive plant populations in order to reduce the harmful ecological effects and allow native plant communities to recover. However, the impact of various treatment methods on plant community structure and re-invasion potential of target species often remain unexamined. Reid et al. (2009) found that, while biodiversity conservation was a goal of 76% of the management plans targeting Australian "Weeds of National Significance", only 18 of 95 published papers reported on post-treatment plant community structure. Similarly, D'Antonio and Meyerson (2002) concluded that the development of monitoring programs is often overlooked after management, but is vital to restoration efforts as treatment may actually facilitate the spread of invasive plants in disturbed ecosystems.

The successful management of invasive species can be particularly difficult in natural areas that depend on disturbances such as fire to maintain community structure and function. In these systems, fire-adapted invasive species may disproportionately benefit from post-fire resource availability, increasing in coverage and abundance (Ehrenfeld, 2003; Hobbs and Huenneke, 1992; D'Antonio and Vitousek, 1992). Keeley (2006) found that the restoration of "natural" fire regimes in forests of the Western United States may increase the abundance of exotic plants with the potential for ecosystem invasion. These species may then further complicate management programs by altering the basic patterns and influence of fire in natural communities (Mack and D'Antonio, 1998; Brookes et al., 2004).

The Australian tree *Melaleuca quinquenervia* (Cav.) Blake, otherwise known as the paper-bark tree, has successfully colonized and invaded most of the freshwater ecosystems in South Florida, including the fire-regulated *Pinus elliottii* Engelm–*Taxodium distichum* (L.) L.C. Rich var. *nutans* (Ait.) Sweet ecotone forest (Myers, 1984). High concentrations of the essential oils found in this invasive plant promote canopy fires which kill native vegetation and trigger the massive release of its seed, resulting in the establishment of widespread monotypic stands (Serbesoff-King, 2003). This fire induced sequence was repeated for decades allowing *M. quinquenervia* to colonize approximately 400,000 ha in the State of Florida (LaRoche, 1998). Studies have shown that *M. quinquenervia* invasion can alter the abundance of native plant species, wildlife habitats, and ecosystem nutrient storages (Serbesoff-King, 2003; Martin et al., 2009).

* Corresponding author. Present address: United States Fish and Wildlife Service, A.R.M. Loxahatchee National Wildlife Refuge, 10218 Lee Road; Boynton Beach, FL 33473, United States. Tel.: +1 561 735 6006; fax: +1 561 735 6008.

E-mail addresses: melissa.martin@fws.gov (M.R. Martin), Philip.Tipping@ars.usda.gov (P.W. Tipping), krr@ufl.edu (K.R. Reddy), Paul.Madeira@ars.usda.gov (P.T. Madeira), Danyelle.Fitzgerald@ars.usda.gov (D. Fitzgerald).

In the 1980s an integrated, interagency program was created to suppress the plant using mechanical, chemical, and biological controls (Van Driesche et al., 2010). Two of the intentionally introduced, specialized insect herbivores, *Oxyops vitiosa* Pascoe (Coleoptera: Curculionidae) and *Boreioglycaspis melaleucae* Moore (Hemiptera: Psyllidae) have been shown to reduce both the growth and reproductive capacities of *M. quinquenervia* (Tipping et al., 2008). Two additional species have recently been released so information on their impact is unavailable. Both *O. vitiosa* and *B. melaleucae* have established and spread throughout South Florida (Center et al., 2006; Tipping et al., 2008). Rayamajhi et al. (2009) reported that in addition to reducing the density and canopy cover of *M. quinquenervia*, two biological control agents resulted in a two to four fold increase in plant diversity in a Florida forest. Limited information is available, however, on how management programs interact with natural disturbances such as fire to affect plant community structure in invaded landscapes (D'Antonio and Meyerson, 2002; Denslow and D'Antonio, 2005).

The objective of this work was to elucidate changes in plant community structure in a *P. elliottii*–*T. distichum* wetland forest after the invasion and subsequent management of *M. quinquenervia*. Two questions were asked in this study: after a fire, does the choice of invasive plant management strategy, namely herbicidal or biological, alter (1) plant community assemblages and (2) the re-invasion potential of *M. quinquenervia*?

2. Materials and methods

2.1. Site description

The study sites are located in what was historically a mixed *T. distichum*–*P. elliottii* forest with a hardwood under-story in the Belle Meade Tract of the Picayune Strand State Forest in Collier County, Florida. Invaded portions of this landscape are now comprised of sparse populations of mature *M. quinquenervia* trees with dense understories of saplings that can exceed densities of 100 plants m^{-2} . A more detailed description of the study site is available in Martin et al. (2010).

2.2. Experimental design

In order to assure the proper assignment of treatment causality in experiments several fundamental assumptions must be met including the random assignment of treatments across experimental units and treatment replication (Beyers, 1998). The most rigorous field studies utilize randomly assigned, replicated experimental treatments. Often, however, land managers manipulate natural areas to restore function, provide habitat, or mitigate anthropogenic disturbance without regard for experimental design. As a result, large tracts of land are treated as needed or as resources allow. The resulting landscapes are complex and provide a statistical challenge to empirical studies. Despite this, evaluating large-scale field treatments can provide unique opportunities to gain insight on the outcomes of adaptive management of ecosystems.

The current study evaluated the results of a multi-agency, integrated management strategy that has taken place over the course of several decades. As large tracts of the native forest became infested with *M. quinquenervia*, the two biological control agents mentioned above were released: *O. vitiosa* in 1998 and *B. melaleucae* in 2002. These two agents quickly spread and became common throughout the entire landscape. Later, in 2003, a limited amount of state funding became available to aerially treat a single tract of reproductive *M. quinquenervia* with the

herbicide Velpar® (Hexazinone, 3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione). The end result of these two management strategies is a complex landscape of large, contiguous, un-replicated blocks of native, invaded, and managed vegetation. In early May of 2007 the Great Balsa fire burned approximately 8000 ha in southwest Florida and all of the field sites described below. The fire was unplanned so no direct measurements were taken of fire intensity.

This study began after the fire, with the establishment of twenty-five, 1 m^2 plots (replicates) arranged five plots per transect with five transects in each of three contiguous study sites (15 transects and 75 plots in total). The sites (treatment) sampled were: site #1: reproductive *M. quinquenervia* managed with a herbicide application in the summer of 2003 (hereafter referred to as "herbicide site"), site #2: reproductive *M. quinquenervia* managed with the two biological control agents (hereafter referred to as "biological control site"), and site #3: native forest with no history of *M. quinquenervia* invasion (hereafter referred to as "non-invaded site").

The total number of plant species was measured in each plot (no. of 25 per site) on February 12–14, 2008. The percentage of each species present was calculated as the total count of live plants divided by the total count of all plants in each m^{-2} plot, averaged per site. The percentage of the Florida Exotic Plant Pest Council's (FLEPPC), Category I invasive plant species was calculated as the total count of live *M. quinquenervia* and *Panicum repens* L. plants divided by the total count of all plants in each m^{-2} plot averaged per sites. Species richness in each site was the average total number of species in each plot. Species diversity was derived from the number of individuals of each species and was calculated using Simpson's Reciprocal Index (D^{-1}), where $D = \sum (n \times N^{-1})^2$, where n is the total number of individuals of a particular species and where N is the total number of individuals of all species. Additionally, four, 100 m^2 plots were established between the five transects in each of the sites and the total count of mature woody species was measured in each of these larger plots (no. of 4 per site) and averaged per site.

When possible, plants were identified to species level in the field. Samples of unknown species were taken from outside the plot and preserved for identification to genus level by the University of Florida Herbarium. Preserved samples of all species are available at the United States Department of Agriculture, Agricultural Research Service, Invasive Plant Research Laboratory in Fort Lauderdale, Florida.

2.3. Statistical analyses

Diversity indices and species abundances were calculated as a mean for each site. ANOVA and Tukey means separation tests were used to detect any differences among the sites. Differences are reported as significant for tests with p values ≤ 0.05 . The percentages of *M. quinquenervia* and FLEPPC Category I invasive plants datasets varied from the normal distribution and were transformed with square root(x) function. All statistical analyses were performed using JMP 9 software (SAS Institute, NC, USA).

3. Results

Full models were run for the main effect of management strategy/site (treatment). There were no consistent transect effects for any of the measured variables. A total of 50 plant species were found across the three study sites with 39 species in the non-invaded site, 37 in the biological control site, and 28 species in the herbicide site (Supplementary item 1). There was considerable overlap in species between the biological control site and non-invaded sites with 74% of all plant species found in both sites. The herbicide site had fewer plants in common with the non-invaded site at 62%.

Table 1

Diversity indices and the percentages of *M. quinquenervia* and Category I invasive plants (\pm S.E.) in the non-invaded, herbicide, and biologically controlled sites (lower case letters within columns indicate significant differences at P values ≤ 0.05).

Site	Richness species (m^{-2})	Simpson index (D^{-1})	<i>M. quinquenervia</i> (%)	Category I (%)
Non-invaded	10.5 \pm 0.65 a	4.55 \pm 0.33 a	10.3 \pm 1.82 b	10.5 \pm 1.83 b
Herbicide	10.8 \pm 0.57 a	2.54 \pm 0.18 b	1.39 \pm 0.30 c	1.50 \pm 0.33 c
Biological control	8.25 \pm 0.55 b	2.84 \pm 0.28 b	23.4 \pm 4.38 a	23.5 \pm 4.38 a
<i>P</i>	0.007	<0.0001	<0.0001	<0.0001

Table 2

Woody species abundance (\pm S.E.) for the non-invaded, herbicide, and biologically controlled sites. All *M. quinquenervia* individuals measured in the non-invaded site germinated after the 2007 fire (lower case letters within columns indicate significant differences at P values ≤ 0.05).

Woody species abundance plants (m^{-2})	<i>Melaleuca quinquenervia</i>	<i>Taxodium distichum</i>	<i>Pinus elliottii</i>
Live seedling (<15 cm)			
Non-invaded	5.2 \pm 0.93 b	0.20 \pm 0.08 a	0.20 \pm 0.13
Herbicide	2.58 \pm 0.47 b	0.00 \pm 0.00 b	0.04 \pm 0.04
Biological control	22.8 \pm 4.64 a	0.00 \pm 0.00 b	0.25 \pm 0.12
<i>P</i>	<0.001	0.005	0.36
Dead seedling (<15 cm)			
Non-invaded	0.28 \pm 0.15 b	*	*
Herbicide	0.00 \pm 0.00 b	*	*
Biological control	13.6 \pm 5.87 a	*	*
<i>P</i>	0.007		
Mature (>15 cm)			
Non-invaded	1.78 \pm 0.98	0.53 \pm 0.04 a	0.06 \pm 0.01 a
Herbicide	2.27 \pm 0.29	0.00 \pm 0.00 c	0.00 \pm 0.00 b
Biological control	3.79 \pm 0.94	0.13 \pm 0.01 b	0.003 \pm 0.003 b
<i>P</i>	0.24	<0.001	<0.001

* No seedlings found.

Overall, the plant species richness was highest in the non-invaded and herbicide sites compared to the biological control site (Table 1). The Simpson's diversity index was highest in the non-invaded compared to the herbicide and biological control sites. *Pluchea* sp. 1 was the most common plant in the herbicide, non-invaded, and biological control sites comprising on average 55.9 ± 0.60 , 13.3 ± 2.45 , and 24.3 ± 4.34 percent of the total number of plants counted in each m^{-2} plot, respectively.

The biological control site had the highest percentage of *M. quinquenervia* and FLEPPC Category I invasive plants, followed by the native and then the herbicide sites (Table 1). The abundance of *M. quinquenervia* live and dead seedlings was highest in the biological control compared to the non-invaded and herbicide sites (Table 2). Out of the total number of *M. quinquenervia* seedlings (live + dead) measured in the biological control, 37% were dead followed by 5% in the non-invaded site and 0% in the herbicide site. The non-invaded site had highest abundance of *T. distichum* and *P. elliottii* mature trees compared to the herbicide and biological control sites.

4. Discussion

4.1. Plant community structure

Approaches to restoring plant communities following management programs for invasive species can run the gamut from passive to active. The most passive approach relies on native plant communities recovering on their own, while more active methods involve directed efforts like replanting natives. Selecting the best approach depends on multiple factors including cost and the impact of the management itself on the native plant community. However, there has been little evaluation of the effects of these management programs on native community recovery in disturbed ecosystems.

In this study, the herbicidal and biological management of *M. quinquenervia* resulted in lower levels of plant diversity after a fire when compared to an unmanaged, non-invaded site, although the herbicide site contained levels of species richness comparable to

the non-invaded site. Despite this, the herbicide site shared only 64% of plant species in common with the non-invaded site and had no *T. distichum* and fewer *P. elliottii* plants present. Similarly, Mason and French (2007) found that despite significant post-treatment reductions of *Chrysanthemoides monilifera* (L.) T. Nord., dune systems were unable to passively return to pre-invasion levels of native plant diversity. They attributed this deficit to collateral damage from aerial herbicide applications which prevented recovery of dune communities. It is possible that the herbicide treatment may have further damaged remnant populations of native woody species already weakened by the invasion of *M. quinquenervia*. Martin et al. (2010) found that the herbicidal treatment of *M. quinquenervia* reduced the above- and below-ground storage of nutrients compared to the non-invaded and biological control sites. Such a fundamental ecosystem change may result in decreased native plant community productivity and stability over the long-term.

Rayamajhi et al. (2009) found that as *M. quinquenervia* populations in South Florida declined over an eight-year period because of insect biological control, the abundance of native plants increased. While no pre-treatment data existed for this study site, we anticipate that damage from herbivores will likewise open the forest canopy and eventually improve conditions for native plants in the managed sites. While this study demonstrates how foundational ecosystem components were affected by the management of invasive plants in conjunction with a natural fire event, the challenges involved in the statistical analysis of large-scale treatment designs limit the extrapolation of these results without further experimentation. Additional research in multiple sites under varied resource conditions is needed to evaluate the consequences of the treatment of *M. quinquenervia* on native plant community recruitment and stability.

4.2. Plant community re-invasion

Arguably the effort to control *M. quinquenervia* in South Florida has been one of the most successful integrated pest management

projects on record. Mechanical and chemical control programs have suppressed existing stands and biological agents have largely eliminated the invasive potential of existing *M. quinquevnia* populations (Van Driesche et al., 2010). In this study, post-fire recruitment of *M. quinquevnia* was highest in the biological control site compared to the non-invaded and herbicide sites. This finding is not surprising considering that before the fire the biologically controlled site was dominated by reproductively mature *M. quinquevnia* trees. It should be noted, however, that all of the rates of *M. quinquevnia* re-invasion after this 2007 fire were significantly lower than experienced after a 1998 fire that took place in the same area. After the 1998 fire, 591 *M. quinquevnia* seedlings m⁻² were recruited in the invaded sites (Tipping et al., unpublished data) compared to the 22.8 seedlings in this study. The lower recruitment rates in all sites are most likely the result of herbivory from the aforementioned biological agents, which have been shown to reduce the seed production of *M. quinquevnia* trees by 99% (Tipping et al., 2008).

Although *Pluchea* sp. 1 was the most common plant found, there was no difference in percentage of this species and percentage of *M. quinquevnia* seedlings present in the non-invaded and biologically controlled sites. The *M. quinquevnia* seedling in these two sites, however, experienced a higher level of seedling mortality compared to the herbicide site. The higher mortality levels observed in the biologically controlled and non-invaded sites are most likely the result of attack from the biological control agents and shading effects from the re-growth of trees that survived the fire. Additional work is needed to investigate how integrated management programs will affect existing populations of *M. quinquevnia* considering future disturbances and the ecosystem-level changes caused by past management activities. Management-induced alterations in soil resources could prevent the re-establishment of native plant communities and further promote the lower level of species diversity measured in the herbicide site.

In addition to the challenges of restoring diversity to levels comparable to non-invaded areas, controlling one species often leads to invasion by other species. Ogden and Rejmanek (2005) found that, although the use of fire and herbicides did significantly decrease the cover of the invasive fennel *Foeniculum vulgare* Mill., it was replaced by exotic Mediterranean annual grasses. Riparian systems invaded by *Impatiens glandulifera* Royle showed an overall increase in plant invasions after management (Hulme and Bremner, 2006). Similarly, populations of exotic grasses were replaced after treatment by the exotic forb *Erodium L'Hér. ex Aiton* in coastal sage scrub ecosystems (Cox and Allen, 2008).

In 2009 the FLEPPC released a list of 73 Category I invasive plants found in Florida (FLEPPC, 2011). The Category I designation indicates that these species are “[i]nvasive exotics that...[alter] native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives.” Two Category I species were found in the three study sites, *M. quinquevnia* and *P. repens*. The invasive grass *P. repens* or torpedo grass is a serious pest in the State of Florida and may eventually out-compete natives in these sites (David, 1999). The potential for re-invasion following management reveals a need for a more active management approach that considers site specific environmental conditions (Bay and Sher, 2008; MacDougall and Turkington, 2007). Such analyses should include both above- and belowground alterations to ecosystem function caused by exotics and the tactics used to manage them. While the ultimate goal of management programs is to restore ecosystem integrity, this work has shown that passive restoration after management may

not be enough to restore plant community structure in these systems.

Acknowledgements

We are especially appreciative of the invaluable insights and long hours of field support of the staff of the USDA-ARS Invasive Plant Research Laboratory, including Eileen Pokorny, Kayla Nimmo, Susan Keusch, Elizabeth Mattison, and Elizabeth Bolton. We also thank Gavin Wilson, Yu Wang, and Vivana Nadal for laboratory and technical support. This work was partially funded by the National Science Foundation under Grant No. (0504422), the Florida Exotic Pest Plant Council, the Sam Polston Memorial Fellowship at the University of Florida, and the Everglades Foundation Graduate Fellowship Program.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.aquabot.2011.08.004.

References

- Bay, R.F., Sher, A.A., 2008. Success of active revegetation after *Tamarix* removal in riparian ecosystems of the southwestern United States. A quantitative assessment of past restoration projects. *Restor. Ecol.* 16, 113–128.
- Behers, D.W., 1998. Causal inference in environmental impact studies. *J. N. Am. Benthol. Soc.* 17, 367–373.
- Brookes, M.L., D'Antonio, C.M., Richardson, D.M., Grace, J.B., Keeley, J.E., DiTomaso, J.M., Hobbs, R.J., Pellatt, M., Pyke, D., 2004. Effects of invasive alien plants on fire regimes. *BioScience* 53, 677–688.
- Center, T.D., Pratt, P.D., Tipping, P.W., Rayamajhi, M.B., Van, T.K., Wineriter, S.A., Dray, F.A., Purcell, M., 2006. Field colonization, population growth, and dispersal of *Boreioglycaspis melaleucae* Moore, a biological control agent of the invasive tree *Melaleuca quinquevnia* (Cav.) Blake. *Biol. Biol. Control* 39, 363–374.
- Cox, R.D., Allen, E.B., 2008. Stability of exotic annual grasses following restoration efforts in Southern California coastal sage scrub. *J. Appl. Ecol.* 45, 495–504.
- D'Antonio, C., Meyerson, L.A., 2002. Exotic plant species as problems and solutions in ecological restoration: a synthesis. *Restor. Ecol.* 10, 703–713.
- D'Antonio, C.M., Vitousek, P.M., 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. *Annu. Rev. Ecol. Syst.* 23, 63–87.
- David, P.G., 1999. Response of exotics to restored hydroperiod at Dupuis Reserve, Florida. *Restor. Ecol.* 7, 407–410.
- Denslow, J.S., D'Antonio, C.M., 2005. After biocontrol: assessing indirect effects of insect releases. *Biol. Control* 35, 307–318.
- Ehrenfeld, J.C., 2003. Effects of exotic plant invasions on soil nutrient cycling processes. *Ecosystems* 6, 503–523.
- FLEPPC, 2011. The Florida Exotic Pest Plant Council's 2009 invasive plant species list, <http://www.fleppc.org/list/09list.htm> (last accessed 12.08.11).
- Hobbs, R.J., Huenneke, L.F., 1992. Disturbance, diversity, and invasion: implications for conservation. *Conserv. Biol.* 6, 324–337.
- Hulme, P.E., Bremner, E.T., 2006. Assessing the impact of *Impatiens glandulifera* – on riparian habitats: partitioning diversity components following species removal. *J. Appl. Ecol.* 43, 43–50.
- Keeley, J.E., 2006. Fire management impacts on invasive plants in the western United States. *Conserv. Biol.* 20, 375–384.
- LaRoche, F.B., 1998. Managing melaleuca (*Melaleuca quinquevnia*) in the Everglades. *Weed Technol.* 12, 726–732.
- MacDougall, A.S., Turkington, R., 2007. Does the type of disturbance matter when restoring disturbance-dependent grasslands? *Restor. Ecol.* 15, 263–272.
- Mack, M.C., D'Antonio, C.M., 1998. Impacts of biological invasions on disturbance regimes. *Trends Ecol. Evol.* 13, 195–198.
- Martin, M.R., Tipping, P.W., Sickman, J.O., 2009. Invasion by an exotic tree alters above and belowground ecosystem components. *Biol. Invasions* 11 (8), 1883–1894.
- Martin, M.R., Tipping, P.W., Reddy, K.R., Daroub, S.M., Roberts, K.M., 2010. Interactions of biological and herbicidal management of *Melaleuca quinquevnia* with fire: consequences for ecosystem services. *Biol. Control* 54 (3), 307–315.
- Mason, T.J., French, K., 2007. Management regimes for a plant invader differentially impact resident communities. *Biol. Conserv.* 136, 246–259.
- Myers, R.L., 1984. Ecological compression of *Taxodium distichum* var. *nutans* by *Melaleuca quinquevnia* in Southern Florida. In: Ewel, K.C., Odum, H.T. (Eds.), *Cypress Swamps*. University Presses of Florida, Gainesville, FL, pp. 358–364.
- Ogden, J.A.E., Rejmanek, M., 2005. Recovery of native plant communities after the control of a dominant invasive plant species, *Foeniculum vulgare*: implications for management. *Biol. Conserv.* 125, 427–439.

Rayamajhi, M.B., Pratt, P.D., Center, T.D., Tipping, P.W., Van, T.K., 2009. Decline in exotic tree density facilitates increased plant diversity: the experience from *Melaleuca quinquenervia* invaded wetlands. *Wet. Ecol. Manage.* 17, 455–467.

Reid, A.M., Morin, L., Downy, P.O., French, K., Virture, J.G., 2009. Does invasive plant management aid the restoration of natural ecosystems? *Biol. Conserv.* 142 (10), 2342–2349.

Richardson, D.M., Pysek, P., Rejmanek, M., Barbour, M.G., Panetta, F.D., West, C.J., 2000. Naturalization and invasion of alien plants: concepts and definitions. *Divers. Distrib.* 6, 93–107.

Serbesoff-King, K., 2003. Melaleuca in Florida: a literature review on the taxonomy, distribution, biology, ecology, economic importance and control measures. *J. Aquat. Plant Manage.* 41, 98–112.

Tipping, P.W., Martin, M.R., Pratt, P.D., Center, T.D., Rayamajhi, M.B., 2008. Suppression of growth and reproduction of an exotic invasive tree by two introduced insects. *Biol. Control* 44, 235–241.

Van Driesche, R.G., Carruthers, R.I., Center, T.D., Hoddle, M.S., Hough-Goldstein, J., Morin, L., Smith, L., Wagner, D.L., Blossey, B., Brancatini, V., Casagrande, R., Causton, C.E., Coetzee, J.A., Cuda, J., Ding, J., Fowler, S.V., Frank, J.H., Fuester, R., Goolsby, J., Grodowitz, M., Heard, T.A., Hill, M.P., Hoffmann, J.H., Huber, J., Julien, M., Kairo, M.T.K., Kenis, M., Mason, P., Medal, J., Messing, R., Miller, R., Moore, A., Neuenschwander, P., Newman, R., Norambuena, H., Palmer, W.A., Pemberton, R., Perez Panduro, A., Pratt, P.D., Rayamajhi, M., Salom, S., Sands, D., Schooler, S., Sheppard, A., Shaw, R., Schwarzländer, M., Tipping, P.W., Van Klinken, R.D., 2010. Classical biological control for the protection of natural ecosystems. *Biol. Control* 54, S2–S33.