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Current levels of suppression of waterhyacinth in Florida USA by classical biological control agents

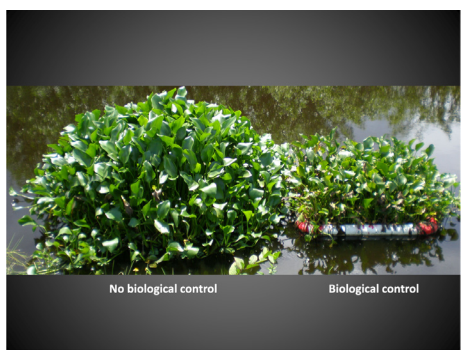
Philip W. Tipping [a,*], Melissa R. Martin [b], Eileen N. Pokorny [a], Kayla R. Nimmo [c], Danyelle L. Fitzgerald [d], F. Allen Dray Jr. [a], Ted D. Center [a]

[a] *USDA-ARS, Invasive Plant Management Laboratory, Ft. Lauderdale, FL, USA*
[b] *US Fish and Wildlife, ARM Loxahatchee Wildlife Refuge, Delray Beach, FL, USA*
[c] *Dry Tortugas National Park, Key West, FL, USA*
[d] *Nova University, Ft. Lauderdale, FL, USA*

HIGHLIGHTS

- No integration of herbicides and biocontrol for waterhyacinth control in Florida.
- Biocontrol agents markedly reduced biomass and flowering.
- Surface coverage reduction of 16.8% by biocontrol unacceptable to most managers.
- Additional agents which reduce surface coverage more likely to promote integration.

GRAPHICAL ABSTRACT



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ABSTRACT

Waterhyacinth, *Eichhornia crassipes* (Mart.) Solms (Pontederiaceae), has been a global target for classical biological control efforts for decades. In Florida, herbicidal application is the primary control method employed, usually without regard for the activities of the three biological control agents introduced intentionally during the 1970s, namely *Neochetina eichhorniae* Warner, *Neochetina bruchi*, Hustache (Coleoptera: Curculionidae), and *Niphograpta albiguttalis* Warren (Lepidoptera: Crambidae). A series of field experiments from 2008 to 2010 was conducted at four Florida sites using an insecticide-check approach to quantify the current levels of suppression provided by these agents. In the field *N. albiguttalis* was rarely found while more than 99% of all *Neochetina* sp. adults were *N. eichhorniae*. Although it was not possible to disentangle the relative impacts of *Neochetina* sp. adults from larvae on individual plant variables, the larvae played a major role in reducing plant biomass and the number of inflorescences. Plots exposed to unrestricted herbivory contained 58.2% less biomass and produced 97.3% fewer inflorescences at the end of the experiments. Despite these large reductions, herbivory decreased waterhyacinth coverage by only 16.8% and most of this was attributed to a low-nutrient site where coverage was reduced disproportionately. Overall, coverage trended upwards during the course of the experiments and was always close to 100% when the plots were harvested. Although coverage is a somewhat arbitrary metric, especially for floating plants subject to compression and dispersion, it influences the perception of biological control efficacy which, in turn, directly influences herbicide management decisions in Florida. Despite waterhyacinth populations that now produce less than half as much biomass and up to 98% fewer seeds than before the deployment of biological control agents, the overall approach used to achieve

* Corresponding author. Address: USDA-ARS, Invasive Plant Research Laboratory, 3225 College Ave., Ft. Lauderdale, FL 33314, USA. Fax: +1 954 476 9169.
E-mail address: philip.tipping@ars.usda.gov (P.W. Tipping).

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maintenance control of the plant in Florida will probably not change unless new biological control agents, such as *Megamelus scutellaris* Berg (Hemiptera: Delphacidae), can reduce coverage significantly.

1. Introduction

Waterhyacinth, *Eichhornia crassipes* (Mart.) Solms, remains one of the world's worst aquatic weeds despite an array of chemical, mechanical, and biological management options (Holm et al., 1977). In Florida, herbicides remain the control option of choice because of their efficacy, relatively low cost, and consistent support by public funding. In the fiscal year 2012, federal and state programs in Florida spent about $3.4 million to control the floating macrophytes *E. crassipes* and waterlettuce, *Pistia stratiotes* L. (Araceae), on more than 11,000 ha (FWCC, 2012). Managers typically employ maintenance control, a term loosely defined as 'techniques that are used in a coordinated manner, on a continuous or periodic basis, in order to maintain the target plant population at the lowest feasible level as permitted by the availability of funding and technology' (FWCC, 2013). The 2008 economic downturn reduced public funding in Florida for weed control efforts which, in some cases, allowed infestations to rebound and expand, thereby highlighting the crucial linkage between the sustainability of budgets and weed maintenance control programs.

Classical biological control agents, including those developed for *E. crassipes*, are not susceptible to such economic fluctuations; ideally after its release and establishment, an agent propagates and disperses of its own accord, finds the targeted weed and attacks it without further inputs (McFadyen, 1998). Developing these agents can be expensive initially and, because they rarely completely control the target weed, traditional methods are often still required, albeit to a lesser degree (Müller-Scharer and Schäffner, 2008). Despite these facts, biological control is often ignored by some land managers as an asset for cutting costs, in part because of the difficulty or lack of information on integrating biological control into existing management programs. This is typified in Florida where, despite the widespread presence of damaging insect biological control agents on *E. crassipes*, there is no intentional integration with herbicides because many managers find it easier and simpler to follow routine and regular spray programs against aquatic weed populations (Center et al., 1999). Integrated control is technically feasible against *E. crassipes* as demonstrated by Haag et al. (1988) and Haag and Habeck (1991) who designed and evaluated an integrated approach for *E. crassipes* using herbicides and biological control. A significant commercial industry exists in Florida for applying herbicides to aquatic plants and this may complicate efforts to promote integration with biological control agents because of perceived concerns about the potential loss of revenue if spraying is reduced as part of an integrated program. Most of these contractors are hired by public agencies that provide standard operating practices and routinely supervise and evaluate their results. In an era of general belt-tightening, this may be an opportune time to re-explore practical methods of integrating biological control with herbicidal control in order to reduce overall costs.

Classical biological control projects in Florida developed three insects, namely *Neochetina eichhorniae* Warner (Coleoptera: Curculionidae), *Neochetina bruchi* Hustache (Coleoptera: Curculionidae), and *Niphograpta albiguttalis* (Warren) (Lepidoptera: Crambidae), which were released against waterhyacinth in 1972, 1974, and 1977, respectively (Perkins, 1973; Center et al., 2002). In addition, the gallery-forming mite *Orthogalumna terebrantis* Wallwork (Acarina: Galumnidae) was accidentally introduced and is also widespread (Cordo and DeLoach, 1976). *Samea multiplicalis* (Guenée) (Lepidoptera: Crambidae) and *Synclita obliteratis* (Walker) (Lepidoptera: Crambidae) are two abundant generalist herbivores whose host range includes *E. crassipes* (Knopf and Habeck, 1976; Habeck et al., 1986). Evaluation studies have focused primarily on *N. eichhorniae* and *N. bruchi* using before and after release field studies with no- or non-persistent controls, or caged-tank studies with controls (Center and Durden, 1986; Center et al., 1999). It is difficult to maintain controls under field conditions because of agent dispersal and the presence of considerable biotic and abiotic environmental variation among sites. Recently, there has been a renewal of biological control programs in the USA that target *E. crassipes* which makes the evaluation of new agents problematic because of the presence of the existing agents. For example, and although observations of this insect are not presented here, a new agent, *Megamelus scutellaris* Berg (Hemiptera: Delphacidae), has been developed and was released in Florida in 2010 with the goal of increasing the suppression on the weed (Tipping et al., 2011). Conducting realistic field evaluations of the current agents would provide insight into the performance of newly released agents by disentangling their impacts from their successors.

Thus, the objective of the present studies conducted from 2008-2010 was to quantify the current level of suppression in the field in Florida provided by previously established agents and to provide a practical assessment of the degree to which these biological control agents are contributing, in aggregate, to the suppression of waterhyacinth in the field.

2. Materials and methods

Experiments were conducted over various intervals from 1 to 3 years in lakes, ponds, and canals with varying levels of nutrient availability at sites from north-central Florida to south Florida (Table 1). A randomized complete block design was used with 2 treatments and 4 replications (blocks). The treatments were: (1) an insecticide control where regular applications (acephate 0.07% ai or bifenthrin 0.01% ai) were applied until runoff; and (2) a herbivore treatment where only water was applied in the same manner. Neither of the insecticides used inhibited or promoted *E. crassipes* growth in experimental tanks and both were equally effective against herbivores attacking *E. crassipes*. Eight floating frames (made from polyvinyl chloride tubes, 7.6 cm in diameter) which enclosed 1 square meter were placed at each site, anchored with a rope and cinderblock, and assigned to a treatment. Plastic mesh bags were attached to the underside of each frame to enclose the area to a depth of 1 m in order to prevent plants from washing out from under the frames.

Experimental plant populations were initiated with five similarly- sized *E. crassipes* plants from greenhouse colonies that were free of herbivores. The fresh weight biomass of each starting population was recorded and converted to dry weight (DW) biomass by assuming a live plant moisture content of 96%. The experimental plant populations were evaluated every 4–6 weeks for percent coverage (to the nearest 10%) within the frame using mean visual estimates by two observers. Five plants were chosen without bias from the center of the square, carefully removed, and the following data were recorded: the number of leaves damaged by feeding from *Neochetina* adults, an estimate of the percentage of the adaxial leaf surfaces of the youngest and oldest leaves that were removed by *Neochetina* adults ('defoliation') (mean of two