

NOTES

Population Dynamics of *Cyrtobagous salviniae* on Common Salvinia in South Florida

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INTRODUCTION

Common salvinia (*Salvinia minima* Baker) is an exotic floating fern that has been in the U.S. from at least 1928 (Small 1931). It colonizes lentic or slow moving, fresh water bodies like ponds, lake, swamps, and marshes. The native range of this species encompasses Central and South America (Mickel and Beitel 1988, Stoltze 1983, Palacios-Rios and Cortes 1990). It is adventive in Bermuda (Weatherby 1937), Puerto Rico (Proctor 1989), and Spain (Lawalree 1964). Jacono et al. (2001) documented multiple introductions of this species in North America where it now occurs in at least 7 states and 69 drainages. Madeira et al. (2003) analyzed the genetic variation of common salvinia and found relatively close similarity among North American populations with the exception of a recent introduction in Mississippi.

This species has become an increasing problem in parts of the United States, especially Texas and Louisiana. It often dominates fresh water systems, replacing native vegetation like duckweed (*Lemna* sp.), which is valued as waterfowl food. The pest status is less clear in Florida where it seems less aggressive and unable to form persistent mats, in contrast to its status in Texas and Louisiana. The less aggressive nature of this plant in Florida may be due to the presence of the specialized herbivore *Cyrtobagous salviniae* (Coleoptera: Curculionidae) which did not occur in the mid-South until its recent introduction (P. W. T., unpubl. data). This weevil was found widely distributed throughout Florida in 68% of all drainages containing common salvinia (Jacono 2001). This species has been used worldwide as an effective biological control agent for giant salvinia (*Salvinia molesta* Mitchell), a close relative of common salvinia (Room et al. 1981). The *C. salviniae* widely used to control giant salvinia originated in Brazil, so we refer to them as the Brazil population while we refer to those naturalized in Florida as the Florida population. There has been some question of the identity of the Florida population because of minor genetic differences between the two populations (Goolsby et al. 2000). However, the most recent molecular work indicates that Brazil and Florida populations of *C. salviniae* are very similar when compared to the closely related *C. singularis* (P. Madeira, unpubl. data).

Our objective was to sample populations of adult *C. salviniae* in south Florida in order to assess temporal abundance and estimate density on common salvinia.

MATERIALS AND METHODS

Sampling Method. We sampled six sites in south Florida every 2 to 3 weeks from October 1999 through October 2001 for the presence of *C. salviniae* adults. We used a stratified sampling approach to identify suitable locations within a site which were then sampled with a fine mesh net to collect common salvinia. In preliminary studies, we collected separate samples from three locations within the site and processed them using a Berlese funnel. Our initial results found extremely large variability in the number of weevils among locations from within a site leading us to increase the number of locations to five and then twenty with no appreciable reduction in variances. In order to reduce sampling and processing costs while maximizing our chances of detecting this species, we elected to take a composite sample from 5 locations within each site and to sample more frequently. Plant material was bulked within site and date and returned to the lab where it was placed in a Berlese funnel to extract adults. The collection vial was filled with tap water and 1 to 2 plants of common salvinia were placed inside as 'trap plants' to attract and provide food for adults. The samples were held in the Berlese funnels for 72 h and vials were changed every 24 h. The plant material was removed from the Berlese funnels, dried at 32 C for 7 d then weighed to obtain dry weight biomass.

The data were examined in two ways: 1) the number of *C. salviniae* per g of dry weight biomass of common salvinia and, 2) the estimated mean number of *C. salviniae* per square meter of common salvinia on the water. The first number was generated by dividing the number of weevils in each sample by the dry weight biomass of common salvinia. This value corrected for sample differences in the weight of plant material collected in the field.

The same dry weight biomass of each sample was used to estimate the area occupied by common salvinia on the surface of the water. The first step was obtain an representative estimate of fresh weight biomass per square meter by floating five 0.1 m² pvc frames in a water-filled tank. Living primary and secondary growth form, common salvinia plants were placed in a frame until it was completely filled without crowding, i.e. fronds laid flat and completely covering water surface. This is the most typical condition for the plants in

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south Florida where the larger growth form (tertiary) formed by crowding is rarely if ever present. Although mats are very dynamic and irregular, this estimate targeted a solid mat of a square meter which does exist regularly, if temporarily, at many sites. Plants were then removed, blotted dry with paper towels and weighed. Through extrapolation, the mean of these measurements provided a realistic estimate of the average fresh biomass of common salvinia per square meter at sites in south Florida. We compared these values with numerous field collected samples of contiguous mats of common salvinia in the primary and secondary growth form from another study and found them not significantly different. We determined the area sampled by converting dry weight to fresh weight biomass (divide dry weight by mean percent moisture [4%]), then dividing the estimated fresh weight of the sample by the estimate (mean \pm SE) for mean fresh weight per square meter (1010.7 \pm 9.51 g). The mean number of *C. salviniae* adults per square meter of common salvinia was estimated by multiplying the area of the sample by the number of weevils collected in that sample. This estimate was generated to provide some context for relative comparison to other studies.

Site Descriptions. Sample sites differed in water and light conditions, as well as associated vegetation, and included river, canal, slough, and ditch habitats. The Hiatus site (N26°05.101, W81°17.663) was a ditch in a residential area in full sun that also contained populations of giant duckweed (*Spirodela polyrhiza* [L.] Schleiden), water penny (*Hydrocotyle umbellata* L.), and cattail (*Typha latifolia* L.). The Keri Rd. (N26°35.826, W81°24.774) site was situated in a canal in full sun in Glades County with waterhyacinth (*Eichhornia crassipes* [Mart.] Solms), water lettuce (*Pistia stratiotes* L.), and mosquito fern (*Azolla caroliniana* Willdenow) growing within. Rt. 29 (N26°48.956, W81°24.596) was a full sun site in a slough in Hendry County colonized with torpedo grass (*Panicum littorale* Morhr ex Vasey), primrose willow (*Ludwigia peruviana* [L.] Hara, and various sedges. Fish Eating Creek (N26°55.845, W81°18.877) was a shaded site in an oxbow in Glades County with waterhyacinth as the predominate vegetation besides common salvinia. Fakahatchee Strand (N25°58.941, W81°24.213) was a roadside drainage ditch in partial shade in a cypress swamp in Collier County with a variety of emergent vegetation in close association. The Turner river site (N25°53.265, W81°16.254) was located on the Turner River just south of the Tamiami Trail bridge in Collier County. Sampling at this site was conducted from boats around emergent vegetation on both banks. These last two sites were not sampled as often as the first four sites.

RESULTS AND DISCUSSION

A floating plant like common salvinia is completely dependent on water conditions, especially water levels, and there were multiple occasions where sites dried up or were flushed out by high water levels (Figure 1). Despite these perturbations, *C. salviniae* populations were present throughout the course of the study as long as common salvinia was present. Although the relationship between common salvinia density and *C. salviniae* populations at the site level was not quantified implicitly in this study, it was rare that weevils were

not collected from the plants. The most intensively sampled site, Hiatus, showed somewhat regular peaks in *C. salviniae* densities that generally corresponded with fall and winter seasons in the first two years. However, during 2001, a peak in population density was evident during the spring and summer. Similar trends were visible at the Keri Rd., Rt. 29, and Fish Eating creek sites (Figure 1).

Populations of *C. salviniae* rebounded quickly following drought events when the site dried up and later rehydrated. This indicates that local extinction events can be ameliorated by the metapopulation dynamics of this species, which is capable of flight dispersal to new sites. Sites like Keri Road, Fakahatchee Strand, and Fish Eating Creek experienced regular local extinctions of the host plant because of drought, yet were quickly recolonized by weevils after water levels rose and common salvinia reappeared (Fakahatchee Strand data not shown). A site like Turner River, which was less stagnant than the other sites and experienced regular flushing events, supported smaller and more fugitive populations of common salvinia. Despite this, *C. salviniae* was found regularly as long as the plant was present, albeit at lower densities (data not shown).

During the course of this survey there appeared to be a least one major peak of adult density each year at the less dynamic sites, with the highest numbers occurring more often during late fall and early winter, but sometimes during the summer. Populations of *C. salviniae* can build up to high levels on common salvinia mats and such densities may have a suppressive effect on populations of the plant, rendering it less aggressive as suggested by Jacono (2001). It is noteworthy that during this survey we never saw common salvinia in the tertiary growth stage. This growth form typifies sites in Texas and Louisiana where unrestricted growth by the plant occurs (P. W. T., pers. observ.). This may be a result of nutrification or other environmental factors but may also reflect the absence of herbivory by *C. salviniae*. The overall mean (\pm SE) for the estimate of weevils per square meter of common salvinia ranged from 40.6 \pm 5.0 at Keri Rd. to 11.0 \pm 3.1 at Turner River. This estimate approached or exceeded 100 at some dates and sites in this study. Although Room (1988) and Room and Thomas (1985) estimated that 300 adults and 900 larvae of *C. salviniae* per square meter were necessary to control giant salvinia, a larger plant, recent work in the U.S. on giant salvinia found that less than 100 adults of *C. salviniae* per square meter would suffice (P. W. T., unpubl. data). Accordingly, a lesser number would presumably be sufficient to control the smaller common salvinia.

Two additional herbivores were commonly found during this survey: *Samea multiplicalis* (Guenée) (Lepidoptera: Pyralidae) and *Synclita oblitalis* (Walker) (Lepidoptera: Pyralidae). Both species are generalists and feed on a variety of aquatic plants throughout the southeastern U.S. (Knopf and Habeck 1976, Habeck et al. 1986). *Samea multiplicalis* was released in Australia on giant salvinia with no significant effect (Forno 1987). It is present in both common and giant salvinia infestations in Texas and Louisiana where the impact appears to be negligible (P. W. Tipping, unpubl. data).

These data indicate that *C. salviniae* is present throughout the year in south Florida on common salvinia. It can build up to densities estimated to exceed 100 adults per square meter

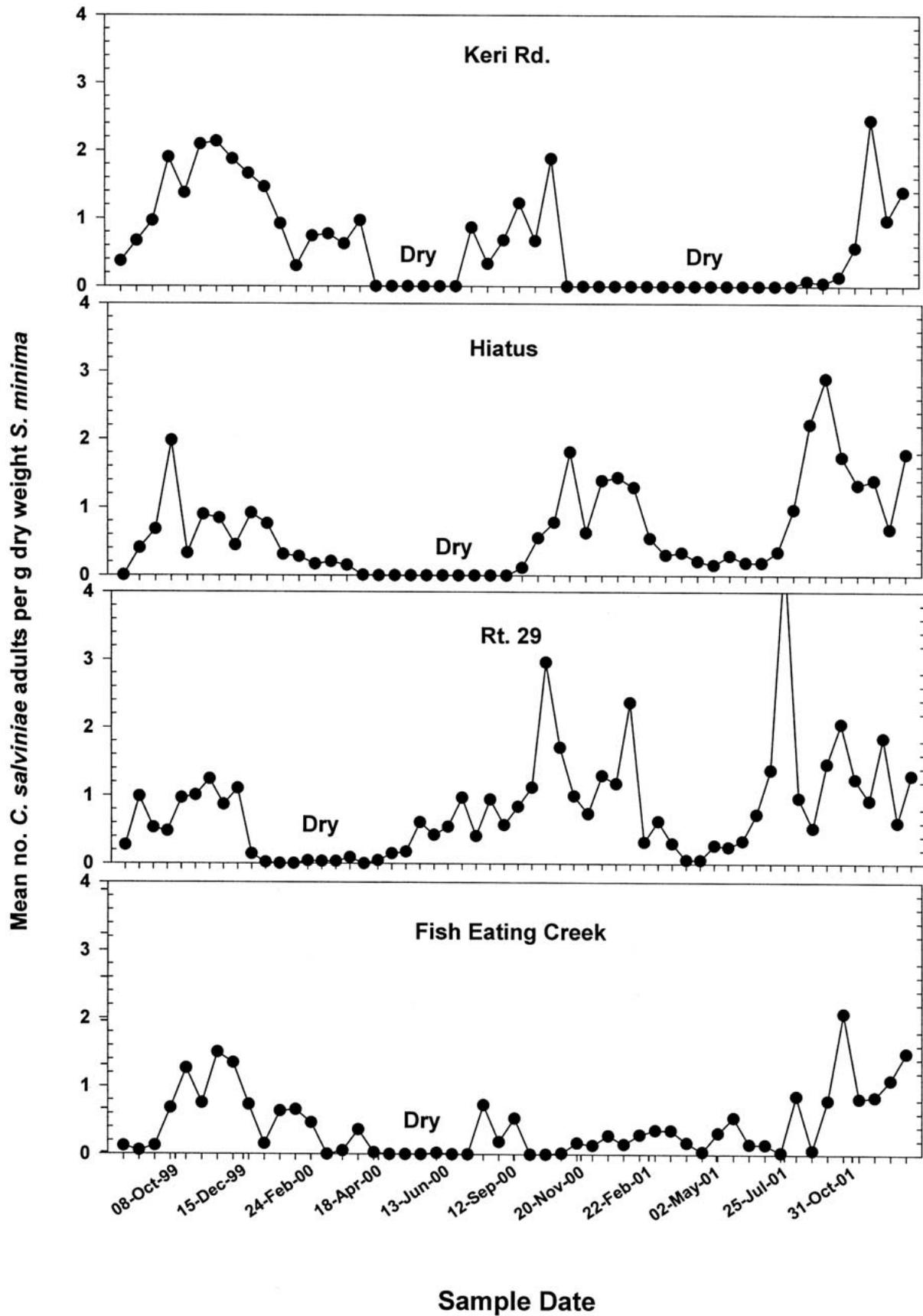


Figure 1. Mean number of *C. salviniae* adults collected per g of common salvinia in various sites in south Florida during 1999 to 2001.

at sites where common salvinia populations are relatively stable. At these higher densities, we suggest that *C. salviniae* may regulate populations of common salvinia in south Florida.

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LITERATURE CITED

- Forno, I. W. 1987. Biological control of the floating fern *Salvinia molesta* in north-eastern Australia: plant-herbivore interaction. *Bull. Entomol. Res.* 77:9-17.
- Goolsby, J. A., P. W. Tipping, T. D. Center and F. Driver. Evidence of a new *Cyrtobagous* species (Coleoptera: Curculionidae) on *Salvinia minima* Baker in Florida. *Southwest. Entomol.* 25:299-301.
- Habeck, D. H., K. Haag and G. Buckingham. 1986. Native insect enemies of aquatic macrophytes-moths. *Aquatics* 8:17-19, 22.
- Jacono, C. C., T. R. Davern and T. D. Center. 2001. The adventive status of *Salvinia minima* and *S. molesta* in the southern United States and the related distribution of the weevil *Cyrtobagous salviniae*. *Castanea* 66:214-226.
- Knopf, K. W. and D. H. Habeck. 1976. Life history and biology of *Samea multiplicalis*. *Envir. Entomol.* 5:539-542.
- Lawalree, A. 1964. Salviniaceae, pp. 24-25. *In*: T. G. Tutin and others (eds.) with the assistance of P. W. Ball and A. O. Chater. *Flora Europaea*. Vol. 1. University Press, Cambridge.
- Madeira, P. T., C. C. Jacono, P. W. Tipping, T. K. Van and T. D. Center. 2003. A genetic survey of *Salvinia minima* in the southern United States. *Aquatic Bot.* 76:127-139.
- Mickel, J. T. and J. M. Beitel. 1988. Pteridophyte flora of Oaxaca, Mexico. *Mem. New York Bot. Gard.* 46:328-329.
- Palacios-Rios, M. and G. Cortes. 1990. New pteridophyte records for the state of Quintana Roo, Mexico. *Brittonia* 42:241-243.
- Proctor, G. R. 1989. Ferns of Puerto Rico and the Virgin Island. *Mem. New York Bot. Gar.* 53. Bronx, New York.
- Room, P. M. 1988. Effects of temperature, nutrients and a beetle on branch architecture of the floating weed *Salvinia molesta* and simulations of biological control. *J. Ecology* 76:826-848.
- Room, P. M., K. L. S. Harley, I. W. Forno and D. P. A. Sands. 1981. Successful biological control of the floating weed *salvinia*. *Nature* 294:78-80.
- Room, P. M. and P. A. Thomas. 1985. Nitrogen and establishment of a beetle for biological control of the floating weed salvinia in Papua New Guinea. *J. Applied Ecology* 22:139-156.
- Small, J. K. 1931. Ferns of Florida: being descriptions of an notes on the fern-plants growing naturally in Florida (illustrated). The Science Press, New York. pp. 190-193.
- Stoltze, R. G. 1983. Ferns and fern allies of Guatemala. Part III. Marsileaceae, Salviniaceae, and the fern allies. *Fieldiana Bot.* 12:10-13.
- Weatherby, C. A. 1937. A further note on *Salvinia*. *Am. Fern J.* 27:98-102.