Status of Insect Biocontrol Against Hydrilla and Eurasian Watermilfoil

by

Alfred F. Cofrancesco[1] *and Michael J. Grodowitz*[1]

The development of biocontrol technology for aquatic plant management began in 1959 when the U.S. Army Corps of Engineers (CE) and the U.S. Department of Agriculture (USDA) entered into cooperative research efforts. In the first attempt, classical biological approaches were used. Researchers traveled to the country of origin of the plant and looked for natural enemies.

In general, biological control is the introduction by man of parasites, predators, and/or pathogenic microorganisms to suppress populations of plant or animal pests. Many exotic organisms that are introduced into a new habitat expand rapidly and occupy all available resources. Although populations of these organisms often fluctuate seasonally, they often expand and occupy the maximum-carrying capacity of the system (Figure 1). Biological control agents are used to attempt to reduce these populations to below a problem state (Figure 2).

At the onset of joint CE and USDA research activities 35 years ago, there was skepticism about the ability of biocontrol agents to impact aquatic vegetation, particularly submersed aquatic plant problems. As we have developed potential agents, we realized that these agents are not really tools, but they are resources that are subject to abiotic and biotic factors that need to be managed.

Biological agents can be influenced by climate, weather, geographic barriers, and other abiotic factors. These influences need to be considered when utilizing the agents. In addition, biotic factors, such as predation and various forms of competition, also regulate how potential agents perform.

Biocontrol research on submersed aquatic plants has been conducted using both insects and pathogens to manage hydrilla and Eurasian watermilfoil. Hydrilla is a submersed aquatic plant that clogs waterways and impedes

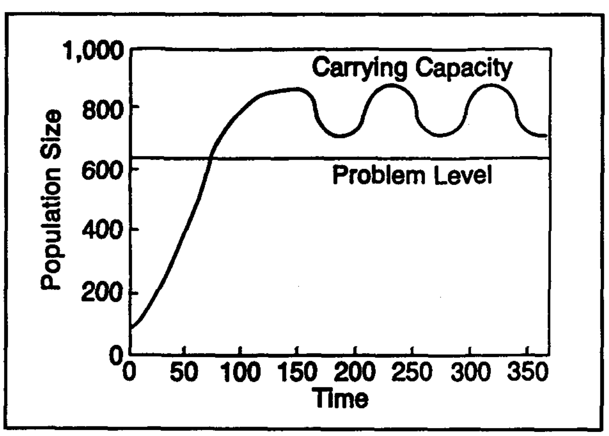

Figure 1. Logistic growth curve of exotic organisms before use of biocontrol agent

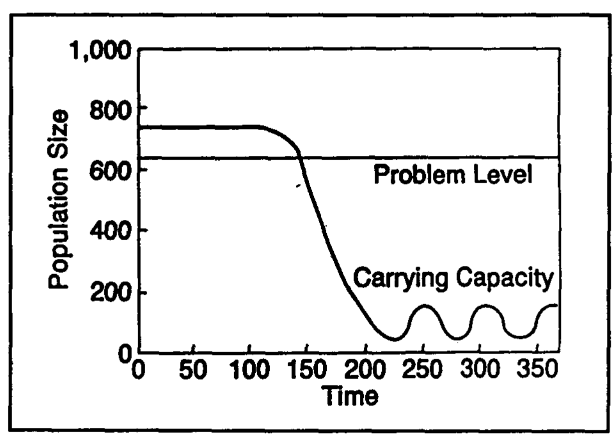

Figure 2. Logistic growth curve of exotic organisms after use of biocontrol agent

[1] U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

navigation (Schardt and Schmidtz 1989). The plant was introduced into the United States by business, as a plant for fish aquariums. The plant has spread rapidly throughout the southern United States and along the east coast as far north as Delaware. In addition, populations of the plant are found in California.

Hydrilla verticillata L. infested 40,000 to 60,000 acres in Florida alone during the period between 1982 to 1989 (Schardt and Schmitz 1989) and was rapidly expanding into northern regions. Expensive herbicidal control methods were only temporarily effective. Partial treatment with herbicides of an infestation at one lake (Lake Istokpoga) during 1989, for example, cost $1.2 million, an amount equivalent to 20 percent of Florida's total statewide nuisance aquatic plant control budget for that year. Clearly, widespread herbicidal control of hydrilla exceeded the resources of most public agencies, and alternatives were desperately needed. As a result, when the USDA and CE considered collaborative projects for biological control of new target species, *H. verticillata* was positioned as the top priority by both agencies.

Research began in 1980 to determine the area of origin for this problem plant. Surveys were conducted throughout Africa, Australia, and parts of Asia (Balciunas 1982, 1983, 1984, 1985, 1987; Balciunas and Dray 1985). Biocontrol agents were most abundant in India and Australia. In 1984, the USDA established a research facility in Australia with the support of the CE.

The two first insect species selected were from India, a tuber-feeding weevil (*Bagous affinis*) and leaf-mining fly (*Hydrellia pakistanae*). These had originally been discovered in Pakistan during the early 1970s as part of an excess foreign currency (PL-480) project (Baloch and Sana-Ullah 1974; Baloch, Sana-Ullah, and Ghani 1980). Host range tests conducted in the Gainesville, FL, quarantine facility proved that both of these species thrived only on hydrilla (Buckingham 1988a,b, 1989, 1990). Both were released in Florida during 1987 (Center 1989, 1992). *Bagous affinis* failed to establish because of its need for dry conditions, such as a distinct dry season or a prolonged lake drawdown, both atypical occurrences in the Southeast (Bennett and Buckingham 1991; Baloch, Sana-Ullah, and Ghani 1980). Conversely, *H. pakistanae* populations did establish throughout the region.

Faunal surveys were succeeded in Australia by more specific studies. Six candidate Australian species were eventually recognized (Balciunas 1987; Balciunas and Center 1988; Balciunas et al. 1989). Two of these, the leaf-mining fly *Hydrellia balciunasi* and the stem-boring weevil *Bagous hydrillae*, were later imported to the Gainesville, FL, quarantine facility for supplemental testing (Balciunas 1987; Balciunas and Center 1988; Buckingham 1990). Both proved acceptable for field use and were released in 1989 and 1991, respectively. Additionally, four stream-dwelling species of moths were found. These were of interest for their perceived potential to control hydrilla in flowing-water systems, a habitat in which other control measures were particularly ineffective. One species, *Strepsinoma repititalis* (now *Margarosticha repititalis*?), was eliminated from further consideration when it was found that its diet was not restricted to hydrilla (Balciunas, Center, and Dray 1989). A second species, *Nymphula dicentra*, may be conspecific with *Parapoynx diminutalis,* an Asian species already present in the United States, so studies were deferred until its taxonomic status could be ascertained. *Aulacodes siennata* (now *Theila siennata*?) seemed a promising candidate, but the Australian project terminated before evaluations could be completed. A fourth species, *Nymphula eromenalis* (now *Ambia ptolycusalis*?), also had not been evaluated prior to cessation of the project. Dr. Dale Habeck later spent a few months in Australia during 1992 to study these species further. As a result, *A. siennata* was imported into the quarantine facility for host-specificity testing. However, the feeding range exhibited under laboratory conditions proved too broad to risk field release, so it has been dropped from consideration (see Buckingham 1994).

Additional research is continuing in China to study biological control agents that might be useful in temperate regions. As a result, a temperate strain of *H. pakistanae* from northern China was released in 1992. Also, the silver-faced *Hydrellia* species, now named *Hydrellia sarahae*, was imported to United States quarantine, and preliminary testing has begun (see Buckingham 1994). Also, midges similar to the African species presumed to be the causal agent of severe tip damage and stunting of hydrilla plants in Lake Tanganyika (Pemberton 1980) have been found in the Far East (see Buckingham 1994). Additional searches for a stem-boring weevil earlier reported from central China proved fruitless. This bagoine species, unlike the similar *B. hydrillae*, purportedly completes its entire developmental cycle under submersed conditions and would therefore probably be a superior biological control agent. A donaciine beetle was also found associated with hydrilla. Dr. Buckingham observed larvae of these chrysomelid beetles feeding within the root zone of hydrilla beds. The resultant damage caused the plants to appear stressed and generally unhealthy.

Hydrellia pakistanae and *H. balciunasi* are small (about 3 mm) leaf-mining flies that were introduced into the United States from India and Australia, respectively, for the management of hydrilla. *Hydrellia pakistanae* was first released into Lake Patrick, a small south-central Florida lake in 1987 (Table 1). The first releases of *H. balciunasi* occurred in 1989 in a small pond located on the Orangebrook Golf Course in southern Florida and at Lake Patrick in central Florida. Since then, over 4 million *H. pakistanae* and >200,000 *H. balciunasi* have been released in many areas of the southeastern United States.

For *H. pakistanae*, successful establishments have been high. Currently, *H. pakistanae* is apparently permanently established throughout the entire peninsula of Florida from the extreme southern portions to as far north as Gainesville, FL. This indicates that *H. pakistanae* populations are flourishing, and their range is expanding rapidly with little outside help by way of supplementary large-scale releases. In addition, populations of *H. pakistanae* are surviving and expanding in the more northern range of hydrilla. For example, small but persistent populations have been observed in certain sections of Lake Seminole, FL. The most northern established population is found in Muscle Shoals, AL, where high population levels of *H. pakistanae* have occurred since 1992. *Hydrellia pakistanae* is occasionally collected as far west as Sheldon Reservoir near Houston, TX, where it was accidentally released as a contaminant with releases of *H. balciunasi. Hydrellia pakistanae* has also been released in considerable numbers in southern Louisiana on Lake Boeuf; recent collections do not reveal the presence of *H. pakistanae*. We are planning to continue to survey the southern Louisiana region for the presence or absence of *H. pakistanae*.

Hydrellia balciunasi is not as widespread as that observed for *H. pakistanae*. While the number and distribution of releases for *H. balciunasi* is considerably less than attempted for *H. pakistanae* (Table 1), releases have been more than adequate in many of the areas. However, the only permanently established population of *H. balciunasi* in the United

Table 1
Total Releases for *Hydrellia pakistanae*, Both the Pakistan and Chinese Strains, and for *H. balciunasi* Since the First Release of *H. pakistanae* in 1987

Species	Number of States	States	Number of Release Sites	Number Released	Date of First Release
H. pakistanae (India strain)	5	FL, GA, AL, LA, TX	27	4,178,223	1987
H. pakistanae (Chinese strain)	3	AL, LA, TX	3	35,800	1993
H. balciunasi	2	FL, TX	9	208,045	1989
Total	5		39	4,422,068	

States occurs in Sheldon Reservoir near Houston, TX, where a consistent but low population has been found since 1992.

Reasons why *H. balciunasi* has not established at more locations are not clear. For example, with numerous release attempts in southern Florida, no established populations can be found. At many Florida sites, establishment appears to be successful at first, but subsequent sampling reveals no *H. balciunasi.* In many of these sites, relative high numbers of *H. pakistanae* are found instead. Such preliminary information may indicate some sort of competitive exclusion between the species, but more information is needed. Similarly, releases of *H. balciunasi* have been accomplished at several sites in the south Texas area; but, to date, no confirmed reports of establishment have been reported except at Sheldon Reservoir. We are currently continuing our release efforts with *H. balciunasi* at several Texas locations, including the Huntsville State Park site and on Choke Canyon Reservoir, where releases were made as recently as fall of 1993 and winter of 1993/1994, respectively.

There is increasing evidence, both qualitative and quantitative, that indicates that the introduced *Hydrellia* sp. cause significant damage to hydrilla infestations. For example, qualitative observations on lakes and ponds since 1987 have indicated that 75 percent had significant declines in the status of the hydrilla infestation after the introduction of *H. pakistanae*. An excellent example is a pond on Orangebrook Golf Course near Fort Lauderdale, FL, where a year after establishment of *H. pakistanae*, a majority of the hydrilla was declining. This decline was correlated with qualitative observations of increases in *H. pakistanae* population levels. Similar declines after the introduction of *H. pakistanae* have been observed at sites in Louisiana and Alabama. For 28 sites that were observed periodically since the initial introductions of *H. pakistanae*, 39 percent had significant reductions in hydrilla after confirmed establishment, and 35 percent had declines even though establishment was weak or not confirmed. In a majority of cases, the introduction of *H. pakistanae* is apparently having significant impact on the hydrilla. However, simple qualitative observations are not sufficient to critically examine the impact of *Hydrellia* on hydrilla infestations. More frequent observations taken more quantitatively are needed for adequately examining the effects of *Hydrellia* on hydrilla infestations.

Myriophyllum spicatum is a submersed aquatic plant native to Eurasia (Godfrey and Wooten 1981). It is believed that the plant was introduced into North America in the early 1800s (Reed 1977); however, other individuals feel it was not introduced until the 1940s (Couch and Nelson 1986). Since its introduction, it has been widely distributed throughout the United States. The plant causes major problems in the northern lakes where extensive monocultures of the vegetation develop and restrict the use of the habitat and outcompete the native vegetation.

Investigations have been conducted of Eurasian watermilfoil declines in North America, and herbivorous insects have been observed associated with these declining watermilfoil populations (Painter and McCabe 1988; MacRae, Winchester, and Ring 1990; Creed and Sheldon 1991). How much impact that these herbivores may have contributed to these declines remains to be determined. Laboratory studies have been conducted which indicate various aquatic insects feed on and damage Eurasian watermilfoil (e.g., Batra 1977; Buckingham and Bennett 1981; Buckingham and Ross 1981; Painter and McCabe 1988; MacRae, Winchester, and Ring 1990; Creed and Sheldon 1991).

Herbivores appear to have a strong effect on watermilfoil buoyancy. The exposure of stem vascular tissue caused by feeding may result in a reduction in buoyancy of the plant. Creed and Sheldon (1991) have observed adult and larval weevils feeding and streams of bubbles emerging from the damaged portion of the stem. This type of impact on a larger scale could result in the collapse of the upper portion of a watermilfoil bed. If herbivores were reducing the flotation capability of the plant, then removal of considerable amounts of stem and leaf tissue would not be required for the insects to have a strong negative effect on watermilfoil. The reduction in the floating capability of Eurasian watermilfoil may have a secondary impact of dropping plants below the optimal photo zone, reducing the plant ability to photosynthesis, compounding the impact to plant population. The effect becomes even more pronounced if damaged plants can drag down healthy ones. Loss of buoyancy may prove to be one of the major mechanisms of watermilfoil bed destruction by herbivores.

In addition to studies examining the impact of native herbivores on Eurasian watermilfoil, classical biological control research is also being conducted. These research efforts are being based out of the Sino-American Biological Control Laboratory in Beijing, China. Overseas surveys in China began in 1989 to locate insect biocontrol agents of Eurasian watermilfoil. Surveys have been conducted in over 10 provinces in China, and a number of agents have been identified. Two of the most promising candidates, both weevils, are already in United States quarantine facilities in Florida. Presently, inquarantine host specificity studies are being conducted on the *Bagous* sp. and the *Phytobius* sp. of weevils, while studies in China are being conducted on a donaciine leaf beetle larvae that attaches to the roots of Eurasian watermilfoil (Bennett 1994).

All aspects of classical biological control research will continue to examine agents for management of hydrilla and Eurasian watermilfoil. It is believed that the potential exists for effective biocontrol agents to be identified from the native range of these plants because in their native range these plants do not form expensive monocultures of plants that cause problems. It is apparent that some type of control mechanisms is regulating these plant populations.

References

Balciunas, J. K. (1982). "Overseas searches for insects for control of aquatic plants." *Proceedings, 16th Annual Aquatic Plant Control Research Program Planning and Operations Review.* Miscellaneous Paper A-82-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 141-154.

________. (1983). "Overseas searches for insects on hydrilla in Southeast Asia and Australia." *Proceedings, 17th Annual Aquatic Plant Control Research Program. Miscellaneous Paper A-83-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 104-154.*

________. (1984). "Overseas searches of biocontrol agents for hydrilla." *Proceedings, 18th Annual Aquatic Plant Control Research Program.* Miscellaneous Paper A-84-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 78-84.

________. (1985). "Final report on the overseas survey (1981-1983) for insects to control hydrilla," Technical Report A-85-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

________. (1987). "Australian insects to control hydrilla." *Proceedings, 21st Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-87-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 57-66.

Balciunas, J. K., and Center, T. D. (1988). "Australian insects to control hydrilla." *Proceedings, 22nd Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-88-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 312-319.

Balciunas, J. K., Center, T. D., and Dray, F. A. (1989). "Testing suitability of Australian bioagents for control of *Hydrilla verticillata.*" *Proceedings, 23rd Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-89-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 24-27.

Balciunas, J. K., and Dray, F. A. (1985). "The search for insects to control U.S. hydrilla populations." *Proceedings, 19th Annual Meeting, Aquatic Plant Control*

Research Program. Miscellaneous Paper A-85-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 75-78.

Baloch, G. M., and Sana-Ullah. (1974). "Insects and other organisms associated with *Hydrilla verticillata* (L.f.) L.C. (Hydrocharitacea) in Pakistan." *Proc. III Int. Symp. Biol. Contr. Weeds, 10-14 September 1973, Montpellier, France.* A. J. Wapshere, ed., Miscellaneous Publication No. 8, Commonw. Inst. Biol. Contr., 61-66.

Baloch, G. M., Sana-Ullah, and Ghani, M. A. (1980). "Some promising insects for the biological control of *Hydrilla verticillata* in Pakistan," *Trop. Pest Manage.* 26, 194-200.

Bennett, C. A. (1994). "Overseas Research." *Proceedings, 28th Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-94-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 172-175.

Bennett, C. A., and Buckingham, G. R. (1991). "Laboratory biologies of *Bagous affinis* and *B. laevigatus* (Coleoptera: Curculionidae) attacking tubers of *Hydrilla verticillata* (Hydrocharitaceae)," *Ann. Entomol. Soc. Am.* 84(4), 420-438.

Buckingham, G. R. (1988a). "Reunion in Florida: Hydrilla, a weevil, and a fly," *Aquatics* 10, 19-25.

________. (1988b). "Quarantine research program - hydrilla insects." *Proceedings, 22nd Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-88-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 307-311.

________. (1989). "Quarantine work - insect biocontrol for hydrilla." *Proceedings, 23rd Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-89-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 28-33.

________. (1990). "Quarantine laboratory: Research for hydrilla control." *Proceedings, 24th Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-90-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 34-38.

________. (1994). "Quarantine research: Florida hydrilla midges." *Proceedings, 28th Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-94-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 176-180.

Center, T. D. (1989). "Release and establishment of insect biocontrol on Hydrilla." *Proceedings, 23rd Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-89-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 34-40.

________. (1992). "Release and field colonization of new biocontrol agents of *Hydrilla verticillata.*" *Proceedings, 26th Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-92-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 205-221.

Couch, R., and Nelson, E. (1986). "*Myriophyllum spicatum* in North America." *Proceedings of the First International Symposium on watermilfoil (Myriophyllum spicatum) and related Haloragaceae species.* L. W. J. Anderson, ed., Aquat. Plant. Manage. Soc., Washington, DC, 8-18.

Creed, R. P., Jr., and Sheldon, S. P. (1991). "The potential for biological control of Eurasian watermilfoil (*Myriophyllum spicatum*): Results of Brownington Pond, Vermont, study and multi-state lake survey." *Proceedings, 25th Annual Meeting, Aquatic Plant Control Research Program.* Miscellaneous Paper A-91-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 183-193.

Godfrey, R. K., and Wooten, J. W. (1981). *Aquatic and wetland plants of the southeastern United States.* The University of Georgia Press, Athens, GA.

MacRae, I. V., Winchester, N. N., and Ring, R. A. (1990). "Feeding activity and host preference of the milfoil midge, *Cricotopus myriophylli* Oliver (Diptera: Chironomidae)," *J. Aquat. Plant Manage.* 28, 89-92.

Painter, D. S., and McCabe, K. J. (1988). "Investigation into the disappearance of Eurasian watermilfoil from the Kawartha Lakes, Canada," *J. Aquat. Plant Manage.* 26, 3-12.

Reed, C. F. (1977). "History and distribution of Eurasian watermilfoil in United States and Canada," *Phytologia* 36, 417-436.

Schardt, J. D., and Schmitz, D. C. (1989). "1989 Florida aquatic plant survey," Technical Report 90-CGA, Florida Department of Natural Resources, Tallahassee, FL.