3.6.1 Insects for Biocontrol of Aquatic Weeds

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Introduction

Biocontrol of aquatic weeds with insects has resulted in the successful establishment of many potential biocontrol insects since it was first attempted in the US against alligatorweed in 1964. Aquatic weeds have historically been a more serious problem in the southern US due to the moderate climate and shallow lakes in these regions where weeds often cover large areas. Consequently, the greatest body of research on biocontrol has focused on weeds of the southern US. The following section describes in detail the relationship of particular biocontrol insects introduced into the US and their target weeds.

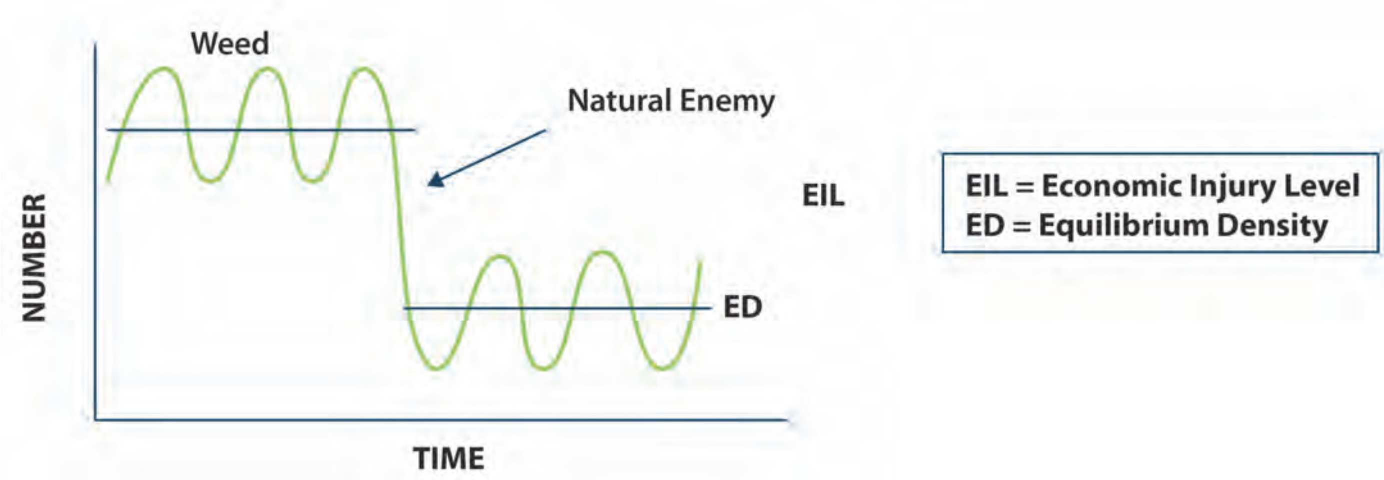
Alligatorweed (*Alternanthera philoxeroides*)

Enemy	Type	Origin (date)	Success	Comments
Agasicles hygrophila	Beetle	Argentina (1964)	Complete (south); negligible (north)	Found throughout the southern 2/3 of the range of alligatorweed in the US where it provides almost complete control
Amynothrips andersoni	Thrips	Argentina (1967)	Minimal	Attacks terrestrial alligatorweed more than the other species
Arcola (=Vogtia) malloi	Moth	Argentina (1971)	Moderate	Most important control agent in the upper Mississippi valley

If this manual had been written in the 1960s and 1970s, alligatorweed (introduced in the late 1800s) would have been included in Section 2 as one of the worst weeds in the US. The alligatorweed flea beetle (*Agasicles hygrophila*) was introduced in 1964 and has provided excellent control of the floating form of alligatorweed from southern Florida along the Gulf Coast to southern Texas. Unfortunately, the alligatorweed flea beetle is not as cold-tolerant as alligatorweed and insect populations die out during severe winters in the central and northern parts of the Gulf states. There are two growth forms of alligatorweed: plants that form floating mats along shallow shorelines and “terrestrial” plants that grow in intermittent wet/dry areas. The thrips feeds on terrestrial alligatorweed in northern areas especially in North Carolina. The beetle that is so effective in the southern range does not attack the terrestrial growth form.

Alligatorweed remains a problem in areas such as central and northern Texas, Mississippi, Alabama, Georgia and the Carolinas. The alligatorweed flea beetle is self-sustaining in its southern range but not in the north. The US Army Corps of Engineers periodically collects and re-releases the beetle in northern areas during spring to reestablish northern populations. This is an example of combining augmentation with classical biocontrol. The alligatorweed flea beetle has eliminated the need for other forms of control in natural areas when it is well-established. The *Amynothrips* and *Arcola* insects also are established on alligatorweed; the *Amynothrips* attacks the terrestrial alligatorweed plants more than do the other species. However, control of alligatorweed is largely attributed to the alligatorweed flea beetle. Alligatorweed provides a good example of how a biocontrol agent controls its weedy host plant without completely eradicating the population of the weed.

Alligatorweed grows quickly in spring and populations of the alligatorweed flea beetle increase as well, but lag behind development of the host plant. By the time alligatorweed has grown enough to become problematic, the population of the alligatorweed flea beetle reaches a density sufficient to destroy most of the alligatorweed. The number of alligatorweed flea beetles then decreases, alligatorweed growth resumes and this density-dependent cycle begins anew.



This is a nearly perfect example of a highly successful insect biocontrol program that adequately controls an invasive aquatic plant. Furthermore, 40 to 50 years after their introduction, none of the three insects released to control alligatorweed have been found feeding on, reproducing on or otherwise affecting nontarget native species.

Waterhyacinth (Section 2.11)

Enemy	Type	Origin (date)	Success	Comments
Neochetina bruchi	Weevil	Argentina (1974)	Substantial	Widely distributed throughout the range of waterhyacinth in the US
Neochetina eichhorniae	Weevil	Argentina (1972)	Substantial	Adults produce characteristic feeding scars on the leaves
Niphograpta albiguttalis	Moth	Argentina (1977)	Negligible	Prefers plants with short bulbous petioles
Orthogalumna terebrantis	Mite	USA (native)	Negligible	Produces characteristic dark stripes in the leaves; also attacks pickerelweed
Megamelus scutellaris	Bug	South America (2010)	Established	Damaged leaves and stems exhibit chlorosis

Two *Neochetina* weevils, the *Niphograpta* stem-boring caterpillar and the *Megamelus* planthopper have been released as biocontrol agents of waterhyacinth. The life cycle of the *Neochetina* weevils requires about 2 to 3 months to complete and is dependent on temperature. These weevils act on waterhyacinth by causing feeding damage that reduces the plant's ability to regenerate. Adult weevils produce characteristic rectangular feeding scars on the leaves, whereas larvae tunnel inside the leaf petioles to the crown or meristem where they damage new growth. Feeding damage also allows plant pathogens to invade the feeding scars and larval tunnels, which further weakens the plant. The life cycle of the *Niphograpta* caterpillar is completed in about 4 to 5 weeks. This insect prefers to attack smaller plants with bulbous petioles; petioles that are attacked often become waterlogged and die. However, the impact of the *Niphograpta* caterpillar has been difficult to evaluate because it causes tremendous damage for only a brief period and then disappears. The life cycle of the *Megamelus* planthopper from egg to adult takes about 25

days. Both the adults and nymphs cause extensive feeding damage that leads to chlorosis (yellowing) of the leaves and stems. Unlike the *Neochetina* weevils and *Niphograpta* caterpillar, *Megamelus* planthopper adults and nymphs feed externally and can disperse from waterhyacinth mats following chemical or mechanical control. The *Neochetina* weevils and the *Niphograpta* stem-boring caterpillar are established and occur almost everywhere waterhyacinth is distributed throughout the southern US. Growth of waterhyacinth is suppressed and vegetative reproduction is reduced, but other means of control are necessary in most areas. The *Megamelus* planthopper is currently at low densities due to weak dispersal behavior, interspecific competition with the weevils and egg parasitism.

Hydrilla (Section 2.2)

Enemy	Type	Origin (date)	Success	Comments
Bagous affinis	Weevil	India (1987)	Not established	
Bagous hydrillae	Weevil	Australia (1991)	Negligible	Adults recovered in 2009 from southern Louisiana See https://edis.ifas.ufl.edu/in1036
Cricotopus lebetis	Midge	Unknown (adventive)	Minimal?	Damages growing tips of hydrilla Also see http://edis.ifas.ufl.edu/IN211
Hydrellia balciunasi	Fly	Australia (1989)	Negligible	Found primarily in Texas See https://edis.ifas.ufl.edu/in1034
Hydrellia pakistanae	Fly	India (1987)	Minimal?	Widely distributed on dioecious hydrilla in the southeastern and south-central US
Parapoynx diminutalis	Moth	Asia (adventive)	Negligible	Causes localized heavy damage to hydrilla See https://edis.ifas.ufl.edu/in1024
Ctenopharyngodon idella	Fish	China (1963)	Substantial	Throughout the US by permit (Section 3.6.2) See http://plants.ifas.ufl.edu/guide/grasscarp.html

Two *Bagous* weevils (one from India that attacks tubers and one from Australia that mines stems) have been introduced as biocontrol agents for hydrilla. Only the Australian species has established but does not suppress hydrilla. The two introduced *Hydrellia* flies (one from India and one from Australia) have become established. The fly *H. pakistanae* is widespread in the southern US, whereas *H. balciunasi* is localized in distribution. Populations of *Hydrellia* flies have not reached densities high enough to control hydrilla, possibly due to parasitism of the pupae by a native wasp or perhaps other environmental factors. The entire life cycle for both flies is completed in about 3 to 4 weeks, which should allow development of high insect populations. The adventive *Parapoynx* moth from Asia probably entered the US via the aquarium trade and was discovered in Florida feeding on hydrilla in 1976. The life cycle of *Parapoynx* is completed in 4 to 5 weeks. The moth was never studied or approved for release, but large populations of hydrilla are occasionally completely defoliated by the moth. The adventive naturalized nonnative *Cricotopus* midge has been associated with hydrilla declines in several Florida locations since 1992. The life cycle of *Cricotopus* is completed in 1 to 2 weeks and developing larvae of the midge mine the shoot tips of hydrilla, which severely injures or kills the plant's growing tips. Feeding damage changes the plant's structure or architecture by preventing new hydrilla stems from reaching the surface of the water column. Despite localized and occasionally severe impacts on hydrilla, none of these insects can cause damage significant enough to provide adequate control when used alone. Research to identify biocontrol agents for hydrilla continues due

to the increasing spread of the species throughout the US, its development of resistance to the herbicides fluridone and endothall and the relatively high costs associated with other methods employed to control this weed.

Purple loosestrife (Section 2.18)

Enemy	Type	Origin (date)	Success	Comments
Galerucella calmariensis	Beetle	Germany (1992)	Substantial	Widely distributed throughout the range of purple loosestrife in the US
Galerucella pusilla	Beetle	Germany (1992)	Substantial	
Hylobius transversovittatus	Weevil	Germany (1992)	Substantial	
Nanophyes marmoratus	Weevil	France, Germany (1994)	Negligible?	

Two nearly identical *Galerucella* leaf beetles are responsible for most biocontrol of purple loosestrife; in fact, these beetles have reduced purple loosestrife infestations by 90% in several states, especially Oregon and Washington. Larvae feed on buds, leaves and stems of the plants and heavily defoliated plants are often killed by the feeding insects. The life cycle of the beetles is completed in about 6 weeks but there is only one generation per year, with pupation occurring in the soil if it is not continuously flooded. This low rate of reproduction is responsible for the lag time between introduction of the beetles and noticeable effects on the plants. Two weevils – the root-attacking *Hylobius* shown here and seed-attacking *Nanophyes* – also contribute to the successful biocontrol of purple loosestrife. Larvae of *Hylobius* feed and develop in the tap roots and pupation occurs in the upper part of the root. Larvae require 1 to 2 years to complete their development and adults can live for several years. Adults of *Nanophyes* feed on young leaves or flowers and lay their eggs in flower buds. Pupation occurs inside the bud and larvae consume the flower buds; buds then fail to open and drop prematurely from the plant. Although the entire life cycle is completed in about 1 month, there is only 1 generation per year. Leaf-eating *Galerucella* beetles, root-attacking *Hylobius* weevils and seed-attacking *Nanophyes* weevils have only recently been introduced as biocontrol agents on purple loosestrife but appear to be very successful in reducing the growth, occurrence and competitiveness of this emergent weed.

Eurasian watermilfoil (Section 2.3)

Enemy	Type	Origin (date)	Success	Comments
Acentria ephemerella	Moth	Europe (adventive)	Negligible?	All can cause declines to populations of Eurasian watermilfoil in localized areas of lakes. Results are difficult to predict.
Cricotopus myriophylli	Midge	China (adventive)	Negligible?	
Eurychiopsis lecontei	Weevil	US (native)	Substantial?	

Several insects have been found attacking Eurasian watermilfoil during overseas surveys, but none have been introduced to the US thus far. Recent declines in the abundance of Eurasian watermilfoil in some northern lakes have been attributed to the adventive *Acentria* moth and *Cricotopus* midge, as well as the native *Eurychiopsis* weevil. These insects are widely distributed throughout the range of Eurasian watermilfoil in North America and are found in all areas infested by the weed; as a result, it is difficult to assess their effectiveness as biocontrol agents. Larvae of the *Acentria* moth feed both in and on stems and leaves, which causes the leaves to drop off the plant. Females have reduced wings and are usually flightless and mating occurs in or on the water surface. Two generations are produced annually and pupae form on the stems. Larvae also feed on a variety of native plants in the absence of Eurasian watermilfoil, so the *Acentria* moth is not a typical biocontrol agent. The *Cricotopus* midge is widely distributed and has been shown to reduce the growth and biomass of Eurasian watermilfoil in laboratory experiments. This midge is not the same species of *Cricotopus* that attacks hydrilla, which suggests these insects may be host specific. It is worth noting that midges rarely feed on living plant tissue and most species typically feed on decaying organic matter. The *Eurychiopsis* weevil is generally considered to be the most important biocontrol agent of Eurasian watermilfoil from an operational perspective. Even though it is a native insect, this weevil prefers Eurasian watermilfoil over its native natural host. The life cycle of the weevil is completed in about 30 days; adults feed on leaves and stems, whereas larvae are stem borers that consume apical meristems. Feeding damage causes the stems to break apart and heavy feeding by the insects prevents the formation of surface mats. High populations of the *Eurychiopsis* weevil have been associated with declines of populations of Eurasian watermilfoil in some northeastern and midwestern states but fish predation may prevent this weevil from reaching its full biocontrol potential. The *Eurychiopsis* weevil is commercially available and can be purchased to augment existing weevil populations. However, research studying the value of augmenting existing populations with purchased insects has been inconclusive.

Waterlettuce (Section 2.12)

Enemy	Type	Origin (date)	Success	Comments
Spodoptera pectinicornis	Moth	Thailand (1990)	Not established	May be affected by predation by other insects
Neohydronomus affinis	Weevil	Brazil (1987)	Negligible?	

Waterlettuce is a tropical species that is believed to be native to North America and was extirpated (died out) during the Ice Ages but was reintroduced into Florida in the 16th century. It forms large floating mats similar to those of waterhyacinth in the extreme southern US and populations of waterlettuce often increase as waterhyacinth populations decline. Waterlettuce is a public health issue in Florida, where larvae of disease-causing *Mansonia* mosquitoes (Section 1.5) attach to the extensive feathery roots to obtain oxygen. Two insects have been released as biocontrol agents of waterlettuce but only the *Neohydronomus* weevil has become established.

Adults and larvae of the *Neohydronomus* weevil feed on the leaves, crown and newly emerging shoots of waterlettuce and the characteristic “shot hole” appearance of leaves indicates high weevil densities. Feeding by multiple larvae destroys the spongy leaf bases, which causes plants to lose buoyancy. The life cycle of the *Neohydronomus* weevil is completed in 3 to 4 weeks. The weevil has not contributed to long-term suppression of the plant in the US but has provided successful biocontrol of waterlettuce in other countries. It is thought that the *Neohydronomus* weevil is heavily preyed upon by imported fire ants in Florida; if true, this provides an interesting example of an exotic invader controlling a valuable potential biocontrol agent.

Giant salvinia (Section 2.13)

Enemy	Type	Origin (date)	Success	Comments
Cyrtobagous salviniae	Weevil	Brazil? (adventive)	Negligible, substantial	Provides good control of common salvinia in Florida and Louisiana. Effects of 2001 introduction on giant salvinia are dramatic at some sites
Cyrtobagous salviniae	Weevil	Brazil (2001)	Substantial	

The *Cyrtobagous* weevil is the only insect that has been released as a biocontrol agent of giant salvinia. Adventive weevils that were discovered in Florida in 1960 control common salvinia (*Salvinia minima*), whereas weevils released in 2001 from a Brazilian population are used as biocontrol agents for giant salvinia. The entire life cycle of the *Cyrtobagous* weevil takes about 46 days. Adults feed on leaf buds and leaves and larvae tunnel inside the plant, killing leaves and rhizomes. Attacked plants turn brown and eventually lose buoyancy. *Cyrtobagous* weevils are currently of great interest to aquatic plant managers worldwide due to their ability to effectively control giant salvinia.

Melaleuca (*Melaleuca quinquenerva*)

Enemy	Type	Origin (date)	Success	Comments
Oxyops vitiosa	Weevil	Australia (1997)	Substantial	Not established in permanently flooded sites due to inability to complete life cycle. See http://edis.ifas.ufl.edu/document_in172
Boreioglycaspis melaleucae	Psyllid	Australia (2002)	Substantial	
Fergusonina turneri	Fly	Australia (2005)	Not established	
Lophodiplosis trifida	Fly	Australia (2008)	Substantial	Feeding damage can kill melaleuca seedlings and saplings. See https://edis.ifas.ufl.edu/in1140

Melaleuca is a locally invasive plant that occurs only in south Florida and the Everglades and was introduced multiple times during the early 1900s. The species was used as an ornamental tree and was planted in marshes to drain wetlands. Melaleuca typically grows in dense, impenetrable stands and can attain a height over 50 feet. Four insects have been released as biocontrol agents of melaleuca but only three have become established.

The *Oxyops* weevil and the *Boreioglycaspis* psyllid were released in 1997 and 2002, respectively, and are widely established on melaleuca in south Florida. Damage to the tree is caused primarily by the immature stages of these insects. The slug-like weevil larvae feed on newly expanding leaves; psyllid nymphs attack older leaves and woody stems in addition to new leaves and the psyllid can kill newly emerged seedlings as well. These two insects complement each other well; the psyllid is able to complete its development entirely in the tree canopy under flooded conditions that prevent establishment of the weevil, which must pupate in the soil. Extensive leaf damage from both insects causes melaleuca to divert resources to the production of new foliage instead of flowers. The life cycle of the weevil is completed in about 3 months, whereas a new psyllid generation is produced in 6 weeks. The *Oxyops* weevil and the *Boreioglycaspis* psyllid have contributed to the substantial biocontrol of melaleuca. The *Lophodiplosis* gall-forming fly was released in 2008. It takes about six weeks from the time that the larva emerges from the egg until the midge becomes an adult. Gall formation diverts the tree's resources from normal growth and reproduction, and enhances the effects of other biological, chemical, and mechanical controls.

Summary

The use of insects as biological control agents for aquatic weeds has yielded mixed results, which is typical and expected of biocontrol programs. A number of aquatic weeds – including alligatorweed, purple loosestrife, melaleuca and salvinia – are being successfully controlled by insects released as biocontrol agents for these species. Control of other aquatic weeds – including waterhyacinth, hydrilla, Eurasian watermilfoil and waterlettuce – has been less successful. Multiple factors play a role in the failure of some biocontrol agents to reach their full potential. For example, the *Neohydronomus* weevil has provided successful biocontrol of waterlettuce in other countries, but has failed to control waterlettuce in Florida, possibly due to predation of the weevil by imported fire ants. Biocontrol can be an effective tool in the aquatic weed manager's arsenal since host-specific biocontrol agents allow management of populations of weedy species while leaving nontarget native plants unharmed. Therefore, it is important that researchers continue to identify and evaluate biocontrol agents so that the successes realized in the control of alligatorweed, purple loosestrife, salvinia and melaleuca can be duplicated in other weedy aquatic species. A major factor that limits the utility of biocontrol is that unless a potential biocontrol agent is species-specific, it cannot be introduced into the US. Therefore, it is unlikely that biocontrol alone can control all the invasive aquatic weeds in the US.

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Page 145: Alligatorweed flea beetle; Gary Buckingham, USDA-ARS
Page 146 upper: Graph; from Harley and Forno, 1992
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Page 147 upper: *Megamelus scutellaris*; Philip Tipping, USDA ARS IPRL
Page 147 lower: *Hydrilla verticillata*; William Haller, University of Florida
Page 148: Adult root-boring weevil *Hylobius transversovittatus*; Bernd Blossey
Page 149: *Cyrtobagous salviniae* on giant salvinia frond; Scott Bauer, bugwood.org