Chapter 8: Introduction to Biological Control of Aquatic Weeds

James P. Cuda: University of Florida, Gainesville FL; jcuda@ufl.edu

Introduction

There are many herbivores or plant-eating animals in the aquatic environment, including moose, muskrat, turtles, fish, crayfish, snails and waterfowl. These animals are general herbivores and may prefer to eat certain types of plants, but do not rely on a single plant species as a primary food source. Although these animals do consume aquatic plants and therefore reduce the growth of some species, they generally do not have a significant impact on overall plant growth because they feed on many different plants and are not considered biological control agents. Biological control (also called biocontrol) is broadly defined as the planned use of one organism (for example, an insect) to control or suppress the growth of another organism such as a weedy plant species. Biocontrol of weeds is primarily the search for, and introduction of, species-specific organisms that selectively attack a single target species such as an exotic weed. These organisms may be insects, animals or pathogens that cause plant diseases, but most biocontrol agents are insects. Biocontrol has been studied and used for more than a century and has developed into a complicated and technical science based on a number of principles that will be discussed in this chapter. Two different approaches are currently used in the biocontrol of aquatic weeds: classical (importation) and non-classical (augmentation, conservation).

Classical biocontrol is by far the most common biological control method and typically involves the introduction of natural enemies from their native range to control a nonnative invasive plant. The excessive growth of a weed in its new habitat is due in part to the absence of natural enemies that normally limit or slow the growth, reproduction and spread of the weed in its native range. Classical biocontrol seeks to reunite an invasive plant with one or more of its coevolved natural enemies to provide selective control of the weed. Thus, classical biocontrol can be defined as the planned introduction and release of nonnative target-specific organisms (usually arthropods, nematodes or plant pathogens) from the weed's native range to reduce the vigor, reproductive capacity or density of the target weed in its adventive (new or introduced) range.

Classical biocontrol offers several advantages over other weed control methods. It is relatively inexpensive to develop and use compared to other methods of weed control. Classical biocontrol provides selective, long-term control of the target weed and because biocontrol agents reproduce, they will usually spread on their own throughout the infested area. Some of the strengths of classical biocontrol also contribute to its shortcomings. For example, it may not be possible to find a biocontrol agent that effectively controls a single weed and selectively attacks only that particular weed. When potential biocontrol agents are identified, their establishment and suppression of the target weed in the introduced area are not guaranteed. Even if biocontrol agents do successfully establish in their introduced areas, control is not immediate and agents may require many years to have a major impact on target weeds. Finally, once a biocontrol agent is established, it cannot be recalled if desirable nontarget species are affected by the agent.

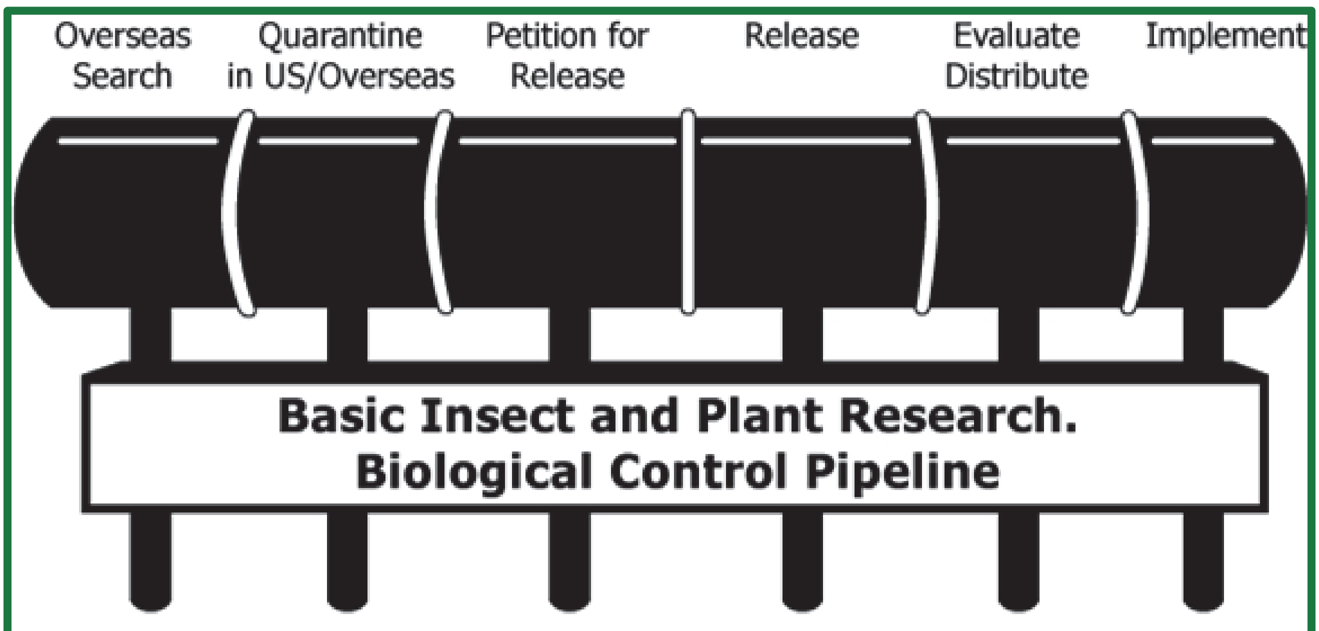
Non-classical biocontrol involves the mass rearing and periodic release of resident or naturalized nonnative aquatic weed biocontrol agents to increase their effectiveness. Savvy home gardeners employ this approach when they purchase ladybird beetles to control aphids (insects that are serious pests of fruits, vegetables and ornamentals) in their home gardens. Augmentative or repeated releases of native or naturalized insects have occasionally been used for suppression of alligatorweed, waterhyacinth (Chapter 15.7), hydrilla (Chapter 15.1) and Eurasian watermilfoil (Chapter 15.2).

The "new association" approach is a variation of classical biocontrol. **New association biocontrol** differs from classical biocontrol in that the natural enemies or biocontrol agents have not played a major role in the evolutionary history of the host plant and are therefore considered new associates. Because organisms used in the new association approach are not entirely host-specific, this approach is appropriate only in cases where the target weed has few or no closely related native relatives in the area of introduction.

A good example of the new association approach is the milfoil weevil (*Eurychiopsis lecontei*), which is native to North America and attacks native species of milfoil (*Myriophyllum* spp.) in the US and Canada. Recent studies have shown that milfoil weevils reared on the introduced weed Eurasian watermilfoil (*Myriophyllum spicatum*) not only develop faster and survive better on the exotic invasive milfoil, but also preferentially attack the nonnative weed species over the native northern watermilfoil (*M. sibiricum*), its natural host plant. This phenomenon was unexpected, unplanned and unusual. Many aquatic resource managers are currently evaluating this natural occurrence to determine how best to include this weevil in weed control programs.

Procedures in a Classical Weed Biocontrol Project

Weed biocontrol scientists (most of whom are entomologists or pathologists) develop and refine procedures for locating, screening, releasing and evaluating biocontrol agents. All countries



currently conducting weed biocontrol projects follow this protocol in one form or another to ensure that candidate organisms are safe to introduce. The normal process in a classical biocontrol program is often referred to as the "pipeline." The pipeline consists of the following series of well-defined steps:

•Step 1: Target selection. Ideal targets for biocontrol are invasive nonnative aquatic plants with no closely related native plants in their introduced ranges. Scientists read the literature associated with the target weed to learn where the weed came from (geographic origin), what desirable plants are closely related to the weed and to identify potential natural enemies.

•Step 2: Overseas and domestic surveys. Scientists visit the native range of the target weed to search for natural enemies that may affect and slow the growth of the weed. They evaluate how the target weed is damaged by organisms in its native range to determine if these organisms may be useful as biocontrol agents for the target weed in its introduced range. Another predictor of success is past performance; if a biocontrol agent has been successful in controlling a weed in some countries, there is a high probability that it will be successful in other countries as well. Scientists also conduct surveys in the weed's introduced range (domestic surveys) to avoid introducing biocontrol agents that are already established but ineffective.

•Step 3: Importation and quarantine studies. If an organism attacks only the exotic weed, and not desirable species, scientists request permission from the US Department of Agriculture to import the organism to the US for host range testing. Once permission for importation is granted, the potential biocontrol agent is brought to the US and placed in an approved quarantine laboratory where it cannot escape and is carefully studied to ensure it will not harm desirable species such as crops and native plants.

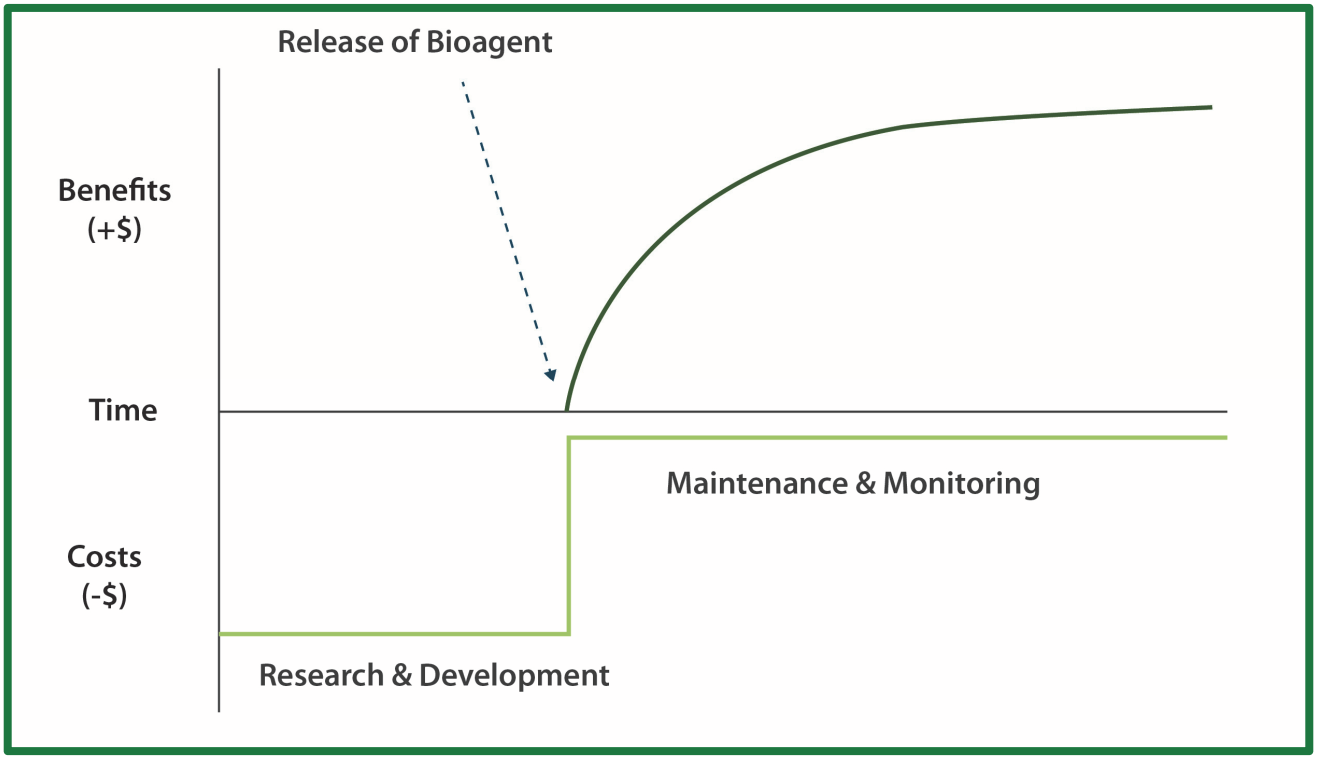
•Step 4: Approval for release. The results of quarantine studies are forwarded to the appropriate federal and state agencies, who determine whether the organism is safe to release. These independent agencies may request that additional testing be done to evaluate the effect of the organism on additional native plants, especially threatened or endangered species, as well as related plants not included in the original quarantine studies.

•Step 5: Release and establishment. Once the biocontrol agent is shown to pose minimal risks to desirable native, ornamental and crop plants, permits are issued and large numbers of the biocontrol agent are reared. This ensures that population densities will be high enough to allow breeding colonies of the agent to establish in the field. Scientists then release the biocontrol agent in multiple locations to increase the likelihood of successful establishment.

•Step 6: Evaluation. Scientists monitor all introduced biocontrol agents after field release to confirm establishment and dispersal of the agent. Multiple releases of the organism may be necessary initially to maintain populations that are adequate for control of the weed species. Studies are also conducted to determine the effect of the biocontrol agent on the target weed as well as on additional nontarget plants.

•Step 7: Technology transfer. Resource managers are trained in the identification and use of the biocontrol agent. Scientists also collaborate with those using the biocontrol agent to determine the best methods to integrate biocontrol with other weed control methods.

Successful biocontrol programs are expensive at the beginning and can take a long time to develop, but biocontrol can reduce the need for other weed control methods such as herbicides and mechanical harvesting. Because classical biocontrol can provide selective, long-term control of a target weed and biocontrol agents naturally spread by reproducing, the use of biocontrol results in the reduction or elimination of costs for other aquatic weed control methods.



Safety – what has to be done to introduce a biocontrol agent?

Host specificity is fundamental to biological weed control because it ensures that an introduced agent will not damage desirable plants. Host-specific, coevolved natural enemies are considered good candidates for use as biocontrol agents because they are unable to reproduce on plants other than their weedy hosts. In addition, these types of organisms have proven to be the safest to introduce because they are least likely to damage nontarget species. Because host-specific natural enemies reproduce only when they have access to their host plants, their populations are limited by availability and abundance of the target weed.

Potential biocontrol agents are first tested for effectiveness and host specificity in their native range, then promising candidates are brought to quarantine laboratories in the US for final host range testing to determine whether the organism can live and reproduce on native plants. Before scientists can release an agent into the US for classical biocontrol of an invasive aquatic plant, the potential agent must undergo rigorous testing in quarantine to ensure it will only survive on the weed species and will not harm nontarget species. The potential biocontrol agent is offered a series of carefully chosen plants in two different types of tests to determine if the agent is safe to release. In no-choice tests, the agent is given access only to a nontarget plant to determine if it will attack the nontarget plant if the agent's host plant (the target weed) is unavailable. In multiple-choice tests, the agent is offered the target weed and at least one nontarget plant to determine whether the agent damages only the target weed. Nonnative biocontrol agents can only be released if these tests show that the agent requires the host plant to survive and reproduce and that it will not attack desirable nontarget plants.

Selecting organisms as candidates for classical biocontrol is a complicated and lengthy process because scientists must identify natural enemies that have developed a high degree of specificity with their weedy host plants. According to established guidelines, no potential biocontrol agent can be introduced into a new environment before its host range is determined. Multiple screening tests are usually required to identify the host range of the agent and scientists must conduct a number of host range tests in the field and laboratory (egg laying, larval development and feeding by adults) to determine whether a biocontrol agent requires the presence of the weedy host plant to survive. Candidate organisms that are able to live and reproduce without access to their weedy host fail the host specificity requirement; they are then dropped from further consideration and quarantined populations are destroyed.

The review process – why does it take so long to release a biological control insect?

The US Department of Agriculture's Animal and Plant Health Inspection Service, Plant Protection Quarantine permitting unit (hereafter referred to as APHIS) is responsible for approving the release of any biocontrol agent in the US. The Plant Protection Act of 2000 gives APHIS the authority to regulate "any enemy, antagonist or competitor used to control a plant pest or noxious weed." Scientists must apply for a permit from APHIS before they can import a potential biocontrol agent into the US for host specificity testing and approved biocontrol agents must be sent directly to a high-security quarantine facility upon entry into the US. There are a number of secure quarantine facilities located throughout the US that are specifically designed and constructed for biocontrol research on aquatic and terrestrial weeds.

After host specificity testing is completed, a permit must be obtained from APHIS before the biocontrol agent is released in the field. A multi-agency Technical Advisory Group for Biological Control Agents of Weeds (TAG) reviews information submitted by the requesting scientist to APHIS. TAG members review test plant lists for weed biocontrol projects, advise weed biocontrol scientists, review petitions for field release of weed biocontrol agents and provide APHIS with recommendations on the proposed release.

In addition to submitting a release petition to TAG and APHIS, scientists contact the Department of the Interior to ensure that threatened and endangered species are included in their test plant list. Release of nonnative weed biocontrol agents also requires compliance with the Endangered Species Act (ESA) and the National Environmental Policy Act (NEPA). Scientists must complete an Environmental Assessment (EA) document that outlines the potential impact of the biocontrol agent on the environment in order to comply with the NEPA. The EA provides the public with possible positive and negative environmental impacts that might occur if the new biocontrol agent is released in the US. Scientists must also submit to the US Fish and Wildlife Service a Biological Assessment (BA) document in order to comply with the ESA. The review process is designed in this manner to ensure that there is little chance the introduced biocontrol agents will become pests themselves. Once a weed biocontrol agent is released, several years may be required for the organism to establish and impact the target weed. Scientists continually monitor dispersal of the agent, collect data on its effectiveness to the target weed and also monitor the agent's effect (if any) on nontarget plants during this time.

What is considered a success?

Successful biocontrol of an aquatic weed is a function of the biocontrol agent's capacity to reproduce on individual plants and to build populations large enough to damage the weed's population. However, high population densities of a biocontrol agent do not necessarily guarantee success and effective biocontrol may only occur when the weed is stressed concurrently by local climatic conditions, competing plants or other natural enemies.

In general, insect biocontrol of aquatic weeds in the US has been successful since it was first used to control alligatorweed in 1964. Insects have provided varying levels of control (from complete control to suppression of growth) of the aquatic form of alligatorweed and of waterhyacinth in most areas where insect biocontrol has been attempted. The high success rate achieved by these projects may be correlated with the growth form of the weeds, their susceptibility to disease-causing pathogens, the fluid nature of the aquatic environment, the organisms used as biocontrol agents, or a combination of these factors. For instance, waterhyacinth and the aquatic form of alligatorweed produce floating mats, a growth habit that makes them susceptible to wave action and currents that are unique to aquatic environments. Also, reproduction of these weeds is due primarily to rapid vegetative growth, which results in clonal populations with little or no genetic diversity. Since many plant defenses against diseases and insects (including biocontrol agents) are determined by the genetic composition of a plant, the entire population of a clonally reproducing species would likely react to a biocontrol agent in the same manner; that is, if one plant is damaged by the biocontrol agent, the entire population is likely to be damaged by the agent as well. Waterhyacinth and the aquatic form of alligatorweed also are highly susceptible to secondary infection, so plants that have been injured by insects or disease rot and disintegrate very rapidly. Finally, beetles – especially weevils – have been responsible for most successful biocontrol programs. Adults of these insects tend to remain above the water, which may reduce fish predation, whereas larvae often feed inside the plant. These habits allow them to maintain high density populations in the environment. A number of successful weed biocontrol programs have utilized members of the insect group *Coleoptera*; in fact, the majority (greater than 75%) of insects released thus far for biocontrol of aquatic plants are weevils and beetles.

Defining success in biocontrol of weeds is usually subjective and highly variable. A project may be considered successful in an ecological sense when a biocontrol agent successfully establishes in an area and reduces the target weed's population. However, the severity of damage inflicted by the biocontrol agent may not result in the level of control desired by lake managers, boaters and homeowners. Recently, a clear distinction has been made between "biological success" and "impact success." Biocontrol agents can be biologically successful (they establish and sustain high population densities on the target weed), but may not realize impact success (they do not provide the desired level of control or impact on the weed).

The use of terms that define success (such as complete, substantial or negligible) in a biocontrol program may not take into account variations in time and space. For example, in the southeastern United States where the alligatorweed flea beetle has been introduced, biocontrol success can range from complete to negligible depending on the season, geographic area and habitat (Chapter 9). However, these terms can be useful from an operational perspective since they describe the current success level of biocontrol efforts and help managers to determine which other control measures (e.g., harvesters, aquatic herbicides) must be used to achieve the desired level of weed control. The advantage of this system is that it describes success in practical terms that are more readily understood by aquatic plant managers and the public. For example, biocontrol is defined as complete when no other control method is required, substantial when other methods such as herbicides are still required but at reduced levels and negligible when other control methods must be used at pre-biocontrol levels to manage the weed problem.

Summary

Biocontrol historically has been a major component of integrated pest management programs for terrestrial insect and weed control and can be an effective tool in the aquatic weed manager's arsenal as well. Classical biocontrol, which relies on importation of natural enemies from a weed's native home, may be useful to control an exotic invasive species that thrives when introduced to an area that lacks the natural enemies responsible for keeping the weed in check in its native range. The use of host-specific biocontrol agents allows management of populations of weedy species while leaving nontarget native plants unharmed. Successful biocontrol programs are often expensive and time-consuming to develop, but if successful can provide selective, long-term control of a target weed. Although a number of types of organisms – including disease-causing plant pathogens, insects and grass carp – have been studied for potential use as biocontrol agents, the greatest successes in aquatic systems have been realized with insects (Chapter 9) and grass carp (Chapter 10).

For more information:

•Biological control for the public. http://everest.ento.vt.edu/~kok/Text_frame1.htm
•Biological control of weeds – it's a natural!
http://www.wssa.net/Weeds/Tools/Biological/BCBrochure.pdf
•Biological control of weeds: why does quarantine testing take so long?
http://ipm.ifas.ufl.edu/applying/methods/biocontrol/quarantinetest.shtml
•Harley KLS and IW Forno. 1992. Biological control of weeds: a handbook for practitioners and students. Inkata Press, Melbourne, Australia.
•How scientists obtain approval to release organisms for classical biological control of invasive weeds.
http://edis.ifas.ufl.edu/IN607
•Mentz KM. 1987. The role of economics in the selection of target pests for a biological control program in the South-west Pacific, pp. 69-85. In P Ferrer and DH Stechman (eds.), Biological control in the South-west Pacific. Report on an international workshop, Vaini, Tonga, 1985. Government Printing Office, Tonga.
• Plant management in Florida waters – biological control
http://plants.ifas.ufl.edu/guide/biocons.html.
•Smith RF and R van den Bosch. 1967. Integrated control, pp. 295-340. In WW Kilgore and RL Doutt (eds.). Pest control – biological, physical and selected chemical methods. Academic Press, New York.
•US Army Corps of Engineers Aquatic Plant Information System
http://el.erdc.usace.army.mil/aqua/APIS/apishelp.htm

Photo and illustration credits:

Page 52: Biocontrol pipeline; Joshua Huey, University of Florida Center for Aquatic and Invasive Plants
Page 54: Biocontrol graph; Harley and Forno, 1992