Yellow Starthistle Control Methods: Biological Control

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Introduction

Classical biological control of weeds works by reuniting an exotic weed species with its natural invertebrate or microbial enemies. This involves searching for and identifying the natural enemies that attack the weed in its area of origin, followed by extensive safety and host specificity testing of those natural enemies, and finally the release of those deemed safe on sites here in the United States.

For yellow starthistle, *Centaurea solstitialis,* the area of origin is believed to be 'southern Europe (France, Italy, and Greece) and Central Asia (Turkey, Armenia, and Iran) (Maddox 1981). Before a natural enemy is released in the United States, its host specificity is examined in quarantine for safety. Only those natural enemies that have a high degree of host specificity will be introduced into California. Thus, not all of the 42 or more species of insects and diseases that attack yellow starthistle in Europe (Clement 1990) will be released in North America, only those that attack yellow starthistle and possibly one or two other species in the genus *Centaurea*. Safety is evaluated through host specificity testing in which a series of plants are exposed to potential biological control agents and examined for feeding, oviposition, larval development and adult emergence. Host specificity testing follows standard protocols that assume that a plant's natural enemy is most likely to feed on close relatives to the target host, less likely to feed on distant relatives, and unlikely to feed on unrelated hosts. Thus, the selection of plants for testing is based on an ever-widening circle of relatedness. Much of the initial host specificity testing occurs in the target host's area of origin in outdoors gardens or in field cages. Testing of California native plants usually occurs in quarantine facilities in the United States to avoid the need to export and grow our natives in new regions where they might escape and become weeds themselves.

The advantages of biological control are that, when successful: a) It is able to suppress the targeted weed to very low levels and maintain this level of control indefinitely, b) it is highly specific to the target weed, and c) established biological control agents can move away from the initial release sites into neighboring infestations and bring these under control. The disadvantage of biological control is that an intense effort over several years is required both domestically and overseas. The cost for this effort can be high, but the cost-savings after control has been achieved far outweighs these initial costs.

The United States Department of Agriculture has performed most of the foreign exploration and quarantine screening of yellow starthistle natural enemies to date. The California Department of Food and Agriculture has arranged for release of approved biocontrol agents into field sites in California, and, in cooperation with the United States Department of Agriculture, monitored their establishment and initiated studies on the impacts of each natural enemy species released. A total of five insects have been approved for release against yellow starthistle in the United States (Table 1). All attack the flower heads and impact the plant by reducing seed production.

The California Department of Food and Agriculture's Biological Control Program has been involved in an extensive statewide distribution effort through the County Agricultural Commissioner Offices for 3 of the 5 species approved for release: *Bangasternus orientalis, Urophora sirunaseva,* and *Eustenopus villosus* (Villegas 1996). The California Department of Food and Agriculture puts on workshops to train county biologists and provide them with at least 200-300 specimens of a natural enemy species which they can use to start nursery colonies in each of the counties statewide. From these field nurseries, the county biologists

willharvest and distribute natural enemies to private and public land owners. Individual land owners can contact their county Agricultural Commissioners Office and request yellow starthistle natural enemies. There is no charge for these insects and they are limited only by their availability.

Table 1.

Natural enemies introduced into California for control of yellow starthistle (*Centaurea solstitialis*).

Scientific Name	Common Name	Generations/ Year	Present Status
Bangastemus ofientalls	Bud weevil	1	Widespread; common
Urophora sirunaseva	Gall fly	2	Widespread; common
Eustenopus vfflosus	Hairy weevil	1	Widespread; locally abundant
Larinus curtus	Flower weevil	1	Recovered in Sonoma and Sutter Counties, occurs in low numbers
Chaetorellia australis	Peacock fly	2	Recovered in Mariposa, Napa, Shasta, and Siskiyou Counties; occurs in low numbers

Biocontrol Agents Approved For Release

The bud weevil, *Bangastemus orientalis* (Coleoptera: Curculionidae), is a medium sized weevil, 4.5 - 6.0 mm in length and oblong in shape. It is dark brown to black with a reddish tinge and its back has some white and brown short hairs that are arranged in spots. This insect has one generation per year. Adult weevils emerge from their overwintering sites in May and are found active on yellow starthistle plants from late May through mid July. The eggs are deposited on the leaves or stems immediately below the upper-most young unopened buds on a plant. The eggs are covered with a black tar-like secretion from the female which adheres the egg to the leaf and prevents dessication. Upon hatching, the larva burrows into the leaf, then down into the stem and up to the developing bud. The larva mines the bracts of the green bud until shortly before the flower begins to open then burrows directly into the head and feeds on the developing seeds and disk tissue. Once in the flower head, development is rapid with the larva progressing through three molts. When its growth is complete, the fat larva (now approximately 6mm long) stops feeding, forms a pupal chamber within the flower head, and pupates. Adults exit the heads in August and overwinter in protected areas such as in debris at the base of trees and along fence rows.

Bangasternus orientalis has experienced higher than expected larval mortality in California which appears to prevent this natural enemy from building up to high population densities. The eggs are deposited on the outside of the flower head and are heavily preyed on by some unknown predaceous insects. Also, survivorship is low among the first instar larvae as they tunnel through the plant stems toward the flower buds, although once inside the flower head, larval survivorship is much higher. Usually 40-60% of the seeds in a head are consumed (Maddox et al. 1991), however, seed destruction can range from 30 to 100%, depending on the size of the head.

The bud weevil was first released in 1985. Field collections of adults from the initial release sites have resulted in releases at over 400 sites in 49 counties throughout California. It is now widespread and usually can be found wherever yellow starthistle is growing.

The gall fly, Urophora *sirunaseva* (Diptera: Tephritidae), is a small fly approximately 3-4 mm long (excluding the ovipositor). Its body color is dark, usually black, and its legs are pale yellow. The wings are clear with three black crossbands and a black band along the wingtip. Males are noticeably smaller than the females which have an ovipositor 1-2 mm long. Eggs are deposited in intermediate-aged closed buds with vertically oriented spines. After hatching, the larva moves to a position in the base of the flower head and initiates around itself the growth of a woody gall, which displaces any seeds that would have formed there. Usually 1-3 galls can be found in a single flower head, but as many as 12 have been found. The immature fly grows through three larval instars. This insect has two generations per year. The overwintering generation becomes active in the spring, usually April and May; the second generation is active from mid June through July. *U. sirunaseva* overwinters as a mature larva in the seed head. In the winter, yellow starthistle seed heads

lose their bracts and the white cottony knap is exposed. The overwintering gall fly is located in amongst the white knap. In the spring, the larva terminates diapause, pupates, then emerges to begin the cycle again.

The impact of *U. sirunaseva* on yellow starthistle is currently under evaluation. The formation of the gall may physically prevent seeds from being formed where the gall is located. However, the individual galls are small relative to the size of the seed head, so few seeds are displaced by a single gall. The presence of the galls may also be a drain on the overall plant resources, ultimately reducing the total number of seeds produced by the other uninfested seed heads of a plant. The presence of *U. sirunaseva* in a seed head can be checked by squeezing the head with your fingers (carefully avoiding the spines) and feeling for the hard nutlike gall among the softer parts of the head.

The gall fly was first introduced in 1984. Distribution efforts by CDFA have resulted in releases at over 180 sites in 38 counties throughout California. This insect is a good flyer and has moved several miles from release sites. It is now widespread and usually can be found wherever yellow starthistle grows.

The hairy weevil, *Eustenopus villosus* (Coleoptera: Curculionidae) is a brown weevil slightly larger than *B. orientalis*. It is 6-8 mm long and has a long snout approximately 2-3 mm in length. Its body is covered with a mixture of long and short hairs, the long hair giving it a fuzzy or hairy appearance. The short hairs are either white or brown and create wide white lines down the back and along the sides of the adult. This insect has one generation per year. The overwintering adults emerge in June and are active from mid-June through August. Unlike the previous two natural enemies, both the adult weevil and larva feed on yellow starthistle flower heads. When the adults first become active, they feed on the young closed flower buds by chewing into the base of the bud with their long snout. This feeding kills the developing bud and, in populations with high densities of *E. villosus*, most of the early season flowers are killed. This will cause yellow starthistle flowering to be delayed by several weeks. The plant, however, responds to this damage by producing mid to late season flowers on its lateral stems which gives it a stunted look. Young flower buds that are not killed by adult feeding are later used by female weevils to deposit their eggs. E. villosus deposits its eggs in the large swollen flower buds shortly before the flowers open. The adult female chews a hole in the side of the bud, deposits the egg, then covers the hole with a mucus plug which eventually hardens. The larva hatches, burrows deeper into the head and feeds on the developing seeds. Hairy weevil larvae grow through three instars. Larval feeding in a flower head causes a "wound" response by yellow starthistle. A dark hard callus tissue may be formed inside the head and plant sap may leak out over the entire flower head. In some populations, this sticky sap encourages the growth of sooty mold and gives the plants a black or dirty appearance. When ready, the larva stops feeding, forms a pupal chamber and pupates. The adults emerge in August through September and overwinter in protected areas such as the debris at the base of trees and along fence rows.

The hairy weevil appears to have the greatest impact on yellow starthistle among all of the bioagents released in California to date. Unpublished field studies suggest that 50% of the flower buds may be killed by adult feeding. Of the remaining buds, 50-60% may be infested with larvae and produce few or no seeds. *E. villosus* was first introduced in 1990. Unlike the previous two bioagents, however, this insect does not disperse well on its own, moving less than one mile in five years. It has, however, built up large populations at some release sites and collections from these sites have resulted in its distribution to over 400 sites in 48 counties.

The flower weevil, *Larinus curtus* (Coleoptera: Curculionidae), is a moderately sized weevil, similar to *E. villosus*. The adult is shiny black but, because it feeds in the open flowers, it is usually covered with bright yellow pollen. The flower weevil has one generation per year. Eggs are laid among the open flowers and the larvae feed on the developing seeds. Adult weevils emerge from the seed heads and overwinter away from their host plant. *L. curtus* was first introduced into California in 1992. It has been released at five sites in five counties but establishment has been confirmed at only two sites: one in Sutter County, the other in Sonoma County. Follow-up surveys at the Sutter County site have revealed that some weevils are infested with the protozoan, *Nosema* sp., a parasite located in its digestive system. The source of this parasite is unknown because a small subsample of the material was inspected and determined clean of parasites before release. It is suspected that this parasite will depress reproduction and shorten the life span of this weevil and may have been the cause of *L. curtus* failing to establish at three of the five release sites. Studies are underway to determine the impact of this parasite on the growth and reproduction of this weevil.

The peacock fly, *Chaetorellia australis* (Diptera: Tephritidae), is a moderate sized fly, approximately 45 mm long (excluding the ovipositor), making it slightly larger than the gall fly. The body of the peacock fly is pale orange-yellow. The wings are clear with a brown strip along the leading edge and three brown crossbands. The ovipositor of the adult female is 2-3 mm long. Eggs are deposited by inserting them between the bracts of the intermediate-aged closed buds. Upon hatching, the larvae burrow into the head and feed on the developing seeds. The peacock fly is different from *U. sirunaseva* in that its larvae do not form a gall, rather they are free living and actively search for seeds in the flower head. This fly has two generations per year. Peacock flies overwinter as mature larvae in the seed heads.

The peacock fly also attacks bachelor button, *Centaurea cyanus*, which, despite its value as an ornamental, is another invasive exotic weed, especially in the Pacific Northwest. The peacock fly emerges very early in the spring, before any yellow starthistle has started to bolt. As a result, the first generation occurs on bachelor button and the second generation occurs on yellow starthistle. It has been released at 27 sites in 21 counties since 1989 but has been recovered only from Mariposa, Napa, Shasta, and Siskiyou Counties where naturalized populations of bachelor button coexist with yellow starthistle. The impact of this bioagent on yellow starthistle is yet to be determined. It is unlikely that this natural enemy will play a significant role in controlling yellow starthistle in California as its distribution will be limited by the lack of bachelor button throughout the state. It may, however, have some impact on yellow starthistle in Oregon and Washington.

It is important to know that these bioagents have yet to cause a detectable decline in yellow starthistle abundance. The biological control effort against yellow starthistle is still in its early stages. To achieve control of this weed, it will likely be necessary to introduce natural enemies that attack all parts of the plant: the root, rosette, stems, and flower heads. While all of the current insects attack only the flower heads, their release is the beginning of a larger, long-term effort. Several new natural enemies of yellow starthistle are currently undergoing host specificity testing by the United States Department of Agriculture, Agricultural Research Service: *Ceratapion basicorne*, a weevil that feeds on the root and stem; *Terellia uncinata*, another seed head fly; and *Puccinia jaceae*, a rust fungus that attacks the stem and leaves (Bruckart 1989). Also, scientists at the California Department of Food and Agriculture are examining a new species of *Aschocyta*, which is a naturally occurring soil-borne fungus that attacks the roots of yellow starthistle seedlings (Woods 1995,1996).

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