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Biological Control

Biology and Biological Control of Exotic True Thistles

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Forest Service
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FHTET-2007-05
September 2008

The Forest Health Technology Enterprise Team (FHTET) was created in 1995 by the Deputy Chief for State and Private Forestry, USDA, Forest Service, to develop and deliver technologies to protect and improve the health of American forests. This book was published by FHTET as part of the technology transfer series.

http://www.fs.fed.us/foresthealth/technology/

On the cover: Italian thistle. Photo: ©Saint Mary's College of California.

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Biology and Biological Control of Exotic Thistles

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Acknowledgments

We would like to thank all of the county weed superintendents and land managers that we have worked with through the years for encouraging us to develop our series of biology and biological control manuals.

We would like to thank Jennifer Andreas (Washington State University Extension), Richard Old (XID Services, Inc.), and other excellent photographers who contributed many of the photographs in this manual. We also wish to acknowledge Jennifer Andreas for her extensive help in gathering species distribution information.

Some of the material in this manual was adapted from the manual for the Biology and Biological Control of Leafy Spurge. We wish to acknowledge the authors of the adapted material (Drs. Rob Bourchier and Andrew Norton).

Finally, we would like to thank Mark Riffe, ITX/USDA Forest Service-Forest Health Technology Enterprise Team (FHTET), for editing, layout, and graphics; and Richard Reardon, FHTET, for producing this book.

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Chapter 1: Introduction

Carol Bell Randall and Rachel Winston

Overview

"Thistle" is an old English name for a large variety of weedy, prickly plants that grow throughout the world. The most notable characteristics of thistles are the prickly stems and leaves and the bracts around the flower head. While many different plants have "thistle" in their common name, only certain plant species fit the taxonomic requirements of being considered "true thistles." True thistle species fall within the family Asteraceae, the tribe Cardueae, and the subtribe Carduinae. Examples of plants that are not true thistles include yellow starthistle (subtribe Centaureinae), sow thistle (subtribe Sonchinae), and Russian thistle (family Chenopodiaceae). Only true thistles in the subtribe Carduinae are discussed in this manual.

The North American flora includes many true native thistles that are important components of healthy, natural ecosystems. In addition to native thistle species, there are true thistle species that are exotic and invasive in the United States and Canada (Figure 1-1.). This manual addresses the biological control of nine exotic thistles present in western North America (Table 1-1).

Figure 1-1. Exotic thistle infestations. Photos: left, Mark Schwarzländer (University of Idaho); right, Thurston County Noxious Weed Board.

Table 1-1. Exotic thistles discussed in this manual.

Scientific name	Common name	Duration
Carduus acanthoides	Plumeless thistle	Annual
Carduus nutans	Musk thistle	Biennial
Carduus pycnocephalus	Italian thistle	Annual
Carduus tenuiflorus	Slenderflower thistle	Annual
Cirsium arvense	Canada thistle	Perennial
Cirsium palustre	Marsh thistle	Biennial
Cirsium vulgare	Bull thistle	Biennial
Onopordum acanthium	Scotch thistle	Biennial
Silybum marianum	Milk thistle	Annual

Exotic thistles currently infest millions of acres across the United States, primarily occurring along roadways, waterways, agricultural fields, and in rangelands, pastures, forests, and disturbed areas. They are responsible for millions of dollars of damage annually in reduced agricultural yields and lowered forage value in grazing systems. Exotic invasive thistles can also displace native vegetation, negatively impacting wildlife and threatening the delicate ecological balance within many habitats.

Herbicides have traditionally been the most popular weed control method used to manage exotic thistles, and some long-term herbicide programs have been relatively successful. However, herbicides are not always the appropriate management tool due to their high costs, potential for environmental contamination, plant resistance, non-target effects, and prohibition in environmentally sensitive areas. Non-chemical weed control methods are becoming increasingly important component alternatives in integrated exotic thistle management programs, including the introduction of biological control agents.

Classical Biological Control of Weeds

Most invasive plants in North America are not native; they arrived with immigrants, through commerce, or by accident from different parts of the world. These non-native plants are generally introduced without their natural enemies, the complex of organisms that feed on the plant in its native range. The lack of natural enemies is one reason non-native plant species become invasive pests when introduced in areas outside of their native range.

Biological control (also called "biocontrol") of weeds is the deliberate use of living organisms to limit the abundance of a target weed. In this manual, "biological control" refers to "classical biological control," which reunites host-specific natural enemies from the weed's native range with the target weed. Biological control agents feed on a weed's flowers, seeds, roots, foliage, or stems. This damage may kill the weed outright, reduce its vigor and reproductive capability, or facilitate secondary infection from pathogens—all of which reduce the weed's ability to compete with other plants.

Natural enemies used in classical biological control of weeds include a variety of organisms, such as insects, mites, nematodes, and fungi. In the U.S., most weed biological control agents are plant-feeding insects. Beetles, flies, and moths are among the most commonly used insects. To be considered for release in the United States, biological control agents must feed and develop only on the target weed and, in some cases, on a few closely related plant species. A potential biological control agent's life cycle should be closely matched, or synchronized, with the development of the target weed. If properly synchronized, foliage-feeding insects would be in the feeding stage when the weeds are actively growing and seed-feeding insects would be in the feeding stage when the plant is actively developing seeds.

The most effective biological control agents tend to be those that damage the most vulnerable or most problematic and persistent parts of the host plant. Root- and stem-feeding biological control agents are usually more effective against perennial plants that primarily spread by root buds. Alternatively, flower- and seed-feeding biological control insects are typically more useful against annual or biennial species that only spread by seeds.

There are advantages and disadvantages to biological control of weeds. Some of these are listed in Table 1-2.

Table 1-2. Advantages and disadvantages of classical biological control as a weed management tool.

Advantages	Disadvantages
Target specificity	Protracted time until impact is likely
Continuous action	Unpredictable level of control
Long-term cost-effective	Uncertain "non-target" effects in the ecosystem
Gradual in effect	Irreversible
Generally environmentally benign	Not all exotic weeds are appropriate targets
Self dispersing, even into difficult terrain	Will not work on every weed in every setting

Host specificity is a crucial point of consideration for a natural enemy to be released as a biological control agent. Host specificity is the extent to which a biological control agent can survive only on the target weed. Potential biological control agents often undergo more than five years of rigorous testing to ensure that host specificity requirements are met. These tests are necessary in order to ensure that the biological control agents are effective and that they will damage only the target weed.

The United States Department of Agriculture's Animal and Plant Health Inspection Service -Plant Protection and Quarantine (USDA-APHIS-PPQ) is the federal agency responsible for authorizing the importation of biological control agents into the United States. The Canadian Food Inspection Agency (CFIA) serves the same role in Canada. Federal laws and regulations are in place to minimize the risks to native plant and animal communities associated with introduction of exotic organisms to manage weeds. The Technical Advisory

Group (TAG) for Biological Control Agents of Weeds is an expert committee with representatives from regulatory agencies, federal land management offices, and environmental protection agencies from the U.S. and representatives from Canada and Mexico. TAG reviews all petitions to import new biological control agents into the United States and makes recommendations to USDA-APHIS-PPQ about the safety and potential impact of prospective biological control agents. Weed biological control researchers work closely with USDA-APHIS-PPQ and TAG to accurately assess the environmental safety of potential weed biological control agents and programs. The Canadian counterpart to TAG is the Biological Control Review Committee (BCRC).

In addition, each state in the United States has its own approval process to permit field release of weed biological control agents.

International Code of Best Practices for Classical Biological Control of Weeds

Biological control practitioners have adopted the International Code of Best Practices for Biological Control of Weeds. The Code was developed by delegates and participants to the Tenth International Symposium for Biological Control of Weeds to reduce the potential for negative impacts from biological control of noxious weed activities By following the Code, practitioners reduce the potential for causing environmental damage through the use of biological control by voluntarily restricting biological control activities to those most likely to result in success.

International Code of Best Practices for Classical Biological Control of Weeds

1. Ensure that thetarget weed's potential impact justifies release of non-endemic agents
2. Obtain multi-agency approval for target
3. Select agents with potential to control target
4. Release safe and approved agents
5. Ensure that only the intended agent is released
6. Use appropriate protocols for release and documentation
7. Monitor impact on the target
8. Stop releases of ineffective agents or when control is achieved
9. Monitor impacts on potential non-targets
10. Encourage assessment of changes in plant and animal communities
11. Monitor interaction among agents
12. Communicate results to public

Although weed biological control is an effective and important weed management tool, it does not work in all cases and is not expected to eradicate or completely remove the target weed. Ideally, biological control should be integrated with other chemical, mechanical, or cultural methods of weed control to improve overall weed control success.

Biological Control of Exotic Thistles

Developing a biological control program for invasive thistles has a number of unique challenges. Thistles are a diverse group of plants exhibiting different life cycles (annual, biennial, and perennial) and occurring in many habitats.

One of the key characteristics of a successful biological control agent is host specificity. There are over 100 species and subspecies of closely related native thistles in the U.S. that may potentially be impacted by exotic thistle biological control agents. In order for a biological control agent to be approved for release in the United States or Canada, biological control researchers must demonstrate that the agent will not feed and develop on native thistles. Because of their large number, host specificity testing for native thistle species is complicated and time-consuming.

Seed-feeding insects are often chosen for biological control programs because, as a group, they often have relatively high levels of host specificity. The exotic thistles described in this manual are, for the most part, not seed-limited, so they are not particularly vulnerable to seed-feeding biological control agents. To increase the chances of success, researchers must identify biological control agents from other feeding guilds, such as stem-feeding or root-feeding organisms.

Some of the earliest biological control programs in the United States and Canada targeted exotic thistles. Many biological control agents have been intentionally and unintentionally released for exotic thistle control. In 1969, *Rhinocyllus conicus* (Figure 1-2) became the first approved exotic thistle biological control agent to successfully establish on musk thistle in Montana and Virginia. When this agent was approved, it was known to feed on some native North American thistles. Our understanding of the importance of native thistles to ecosystem function was not well-developed; many states and land management agencies even considered some native thistles to be weedy pests. Consequently, the non-target feeding was not considered to be a problem. In the 1990s, once scientists recognized that this weevil was causing unacceptable damage to native thistles and habitats, its release permits were revoked.

Figure 1-2. Thistle head seed weevil, *Rhinocyllus conicus*. Photo: Laura Parsons (University of Idaho).

Research is currently underway to assess the control level that individual biological control agents or combinations of biological control agents have on exotic thistles. As of 2008, a total of seven insect species have been approved for release in the United States and Canada as classical biological control agents of exotic thistles. The biology of these agents is presented in Chapter 3. It should be noted that although widely established, none of these approved exotic thistle biological control agents have yet built up to population levels that would be similar to those of a plant pest.

Integrated Weed Management

The successful management of noxious weeds usually incorporates several control methods and activities over a number of years in order to reach the land manager's weed management objectives. The use of multiple weed control methods is called Integrated Weed Management. A successful weed management program relies on realistic management objectives, accurate weed identification and mapping, and post-treatment monitoring to answer the question: "Are current weed management activities enabling me to meet my weed management objectives?" Most successful weed management programs incorporate the following weed control methods: chemical (herbicides), mechanical, and cultural treatments and biological control.

Land managers choose weed control methods that will enable them to achieve their goal in the most cost-effective manner. The control method(s) employed in a weed management strategy will depend on the size and location of the infested area, the target thistle species, and specific management goals (e.g., eradication vs. weed density reduction). Small patches of exotic thistles may be eliminated with a persistent herbicide program, but large areas will often require that managers employ additional control methods.

No single control method will enable managers to meet their exotic thistle management objectives in all environments. A combination of control methods, such as biological control with supplemental cultural practices or chemical controls, consistently applied through time is usually necessary to attain management objectives for exotic thistles, especially when they infest large acreages.

Is Biological Control of Exotic Thistles Right For You?

When biological control is successful, biological control agents behave like a pest species of the target weed: they increase in abundance until they suppress the target weed. As local weed populations are reduced, biological control agent populations decline with them due to starvation and/or dispersal.

Some factors to be aware of before starting biological control activities include the following:

- The efficacy of biological control agents cannot be guaranteed.
- Biological control will not work every time in every situation.
- Biological control will not eradicate the weed.
- Biological control may not, by itself, provide the desired level of control.
- It might take years before you can see biological control impacts.

For these reasons, we recommend that you develop an integrated weed management program in which biological control is one of many weed control methods used. Here are some questions you should ask before you begin a biological control program.

What are my weed management goals: to eradicate the weed or reduce weed abundance?

Biological control does not eradicate target weeds, so it is not a good fit with an eradication goal. Depending on the target weed, biological control agent used, and land use, biological control can be effective at reducing the abundance of a target weed. If your goal is to reduce weed abundance, then biological control may help you achieve it.

How soon do I need results: this season, one to two seasons, or within five to ten years?

Biological control takes time to work, so another weed management method may be a better choice if you need to show immediate results. Generally, it can take one to three years after release to confirm that biological control agents are established at a site, and even longer for agents to cause significant impacts to the target weed. Biological control may not be your best choice if you are looking for results within one to two seasons. In some weed infestations, more than five years may be needed for biological control to reach its weed-management goal.

What resources can I devote to my weed problem?

If you have a small weed problem (small infested area), weed control methods such as herbicides or hand pulling, followed by annual monitoring for re-growth, may be most effective in terms of reaching weed management goals with the lowest cover over time. These intensive control methods may allow you to achieve rapid control and prevent the weed from infesting more area. However, if an invasive weed is well-established over a large area, and resources are limited, biological control may be your most economical weed control option.

Is the weed the problem or a symptom of the problem?

Invasive plant infestations often occur where desirable plant communities have been disturbed. If the disturbance continues without restoration of a desirable, resilient plant community, biological control may not enable you to successfully deal with your weed problems.

The ideal biological control program:

1. is based upon an understanding of weed, habitat, and land use conditions,
2. is part of a broader integrated weed management program,
3. has considered all weed control methods and determined that biological control is the best option based on available resources and weed management objectives, and
4. has realistic goals and timetables and includes adequate monitoring.

About This Manual

This manual provides information on nine species of exotic thistles commonly found in western North America and each of their biological control agents. It also presents guidelines to establish and manage biological control agents as part of an exotic thistle management program.

Chapter 1: Introduction provides introductory information on exotic thistles, and biological control.

Chapter 2: Getting to Know Exotic Thistles provides detailed descriptions of taxonomy, growth characteristics and features, habitat, and occurrence in the United States of nine exotic thistles. It also presents general information on 19 native thistle species with which some of the exotic species may be confused. Photographs and drawings are provided.

Chapter 3: Biology of Thistle Biological Control Agents describes the biological control agents of exotic thistles. Included is information on each biological control agent's native range, original source of North American releases, part of plant attacked, life cycle, description, destructive stages, host specificity, known non-target effects, habitat preferences, and availability. This chapter is particularly useful for identifying biological control agents in the field.

Chapter 4: Elements of a Thistle Biological Control Program includes detailed information and guidelines on how to plan, implement, monitor, and evaluate an effective exotic thistle biological control program. Included are guidelines and methods for:

- Selecting and preparing release sites,
- Collecting, handling, transporting, shipping, and releasing biological control agents, and
- Monitoring biological control agents and vegetation.

Chapter 5: An Integrated Exotic Thistle Management Program discusses the role of exotic thistle biological control in the context of an integrated exotic thistle management plan.

The **Glossary** defines technical terms frequently used by those involved in exotic thistle biological control.

The **Appendices** are:

I Troubleshooting Guide: When Things Go Wrong
II PPQ Form 526: Interstate Transport Permit
II Sample Biological Control Agent Release Form
IV Idaho Statewide Thistle Biological Control Agent 2-Pagers and Monitoring Forms
V General Biological Control Agent Monitoring Form
VI Exotic Thistle Qualitative Monitoring Form
VII Exotic Thistle Biocontrol-Associated Vegetation Monitoring

Chapter 2: Getting to Know Exotic True Thistles

Rachel Winston and Eric Coombs

Exotic true thistles in North America are represented by a number of different genera, all of which are in the sunflower family (Asteraceae). This family is large and very diverse and includes dandelions, sunflowers, and daisies. There are 20 species (and additional subspecies and varieties) of exotic thistles in the United States. Nine species, occurring primarily in the western states, are described in detail within this manual. Under favorable conditions, all nine are capable of forming large infestations and having serious environmental impacts.

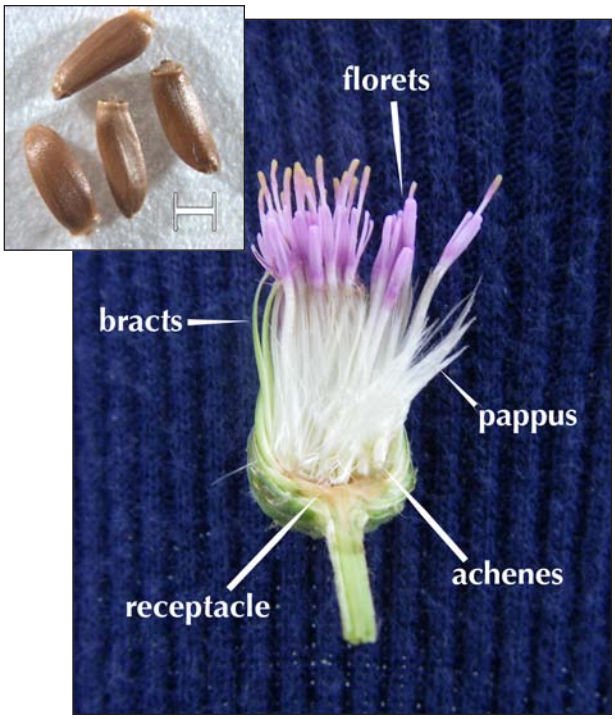
Plant Life Cycle

Thistles may be annuals, biennials, or perennials, which means they may take 1, 2, or more years, respectively, to complete their life cycle (Figure 2-1). The life cycle of all thistles begins as a seedling that develops into a rosette with 5 to 12 leaves. The leaves of all true thistles are characterized by sharp spines along the margins. Biennial and perennial thistles remain as rosettes their entire first year; annual thistles germinate and flower within the same growing season.

Like all other members of the sunflower family, thistles produce flower heads, or capitula, that are an aggregation of many individual flowers (Figure 2-2). These flowers, called florets, are clustered together and attached to a receptacle. Both the receptacle and florets are enclosed by modified leaves called involucral bracts. Each floret produces one seed (achene) from mid- to late-summer. Some species produce seeds with a tuft of whitish hairs (pappus) on one end, similar to those on seeds of dandelions.

Seeds are 4-5 mm long and dispersed primarily by wind. The seeds of most thistle species may remain viable for 20 years, though the majority of seeds germinate within one year. Flowering stems may be unbranched or branched and have one to many flower heads on each stem. The color, shape, and texture of thistle foliage, color of flowers, capitulum size, bract shape and texture, seed color and shape, and branching habit are important traits for distinguishing thistle species.

Figure 2-1. Generalized thistle life stages (Canada thistle): a. seedling, b. rosette, c. bolting, d. bud, e. flowering, f. senescence. Photos: a, d, and e, Richard Old (XID Services, Inc., www.xidservices.com); b, Jennifer Andreas (Washington State University Extension); c and f, Rachel Winston (MIA Consulting).



The taxonomic key depicted on the following pages can be used to differentiate the nine exotic true thistle species described in this manual. Following the key, each of the nine exotic true thistle species are described. Taxonomic classification and distribution information was taken from the USDA PLANTS database. (PLANTS is a collaborative effort of the USDA NRCS National Plant Data Center, the USDA NRCS Information Technology Center, and many other partners. See *www.plants.usda.gov*.)

Figure 2-2. Thistle flower head (capitulum) diagram and seeds. Photos: flower head, Rachel Winston (MIA Consulting); seeds, Richard Hansen (USDA-APHIS-PPQ-CPHST)..

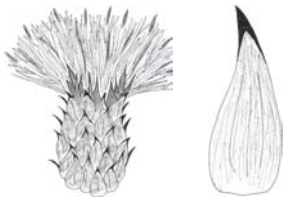
Simple Key to Nine Exotic True Thistle Species Commonly Found in Western North America

Rachel Winston (MIA Consulting)
Parts not drawn to scale.

1a) Spines extend along entire length of stems

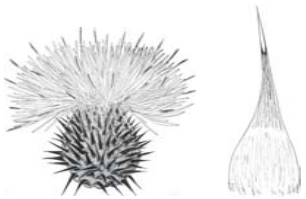
2a) Flower heads in clusters, each head measuring less than (or up to) 1 inch (2.5 cm) in diameter

3a) Bracts not spiny
Marsh thistle, *Cirsium palustre*



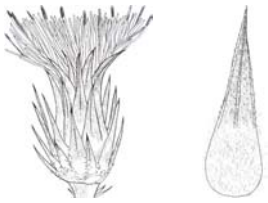
3b) Bracts spine-tipped

4a) Bracts needlelike, not broadly triangular in shape
Plumeless thistle, *Carduus acanthoides*

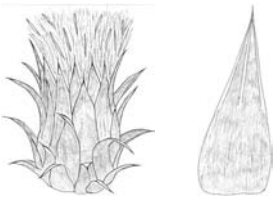


4b) Bracts not needlelike, broadly triangular

5a) Bracts with stiff, forward-pointing hairs
Italian thistle, *Carduus pycnocephalus*

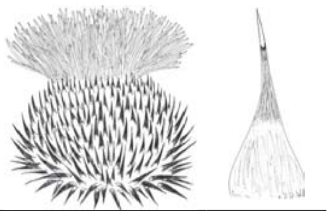


5b) Bracts without stiff, forward-pointing hairs
Slenderflower thistle, *Carduus tenuiflorus*

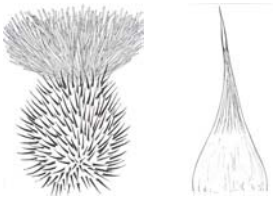


2b) Flower heads usually solitary, each head measuring greater than 1 inch (2.5 cm) in diameter

6a) Leaves and foliage gray in appearance, plant growing up to 12 feet (3.6 m) in height
Scotch thistle, *Onopordum acanthium*

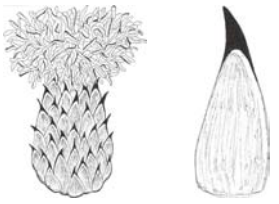


6b) Leaves and foliage not gray in appearance, plant never growing beyond 6 feet (1.8 m) in height
Bull thistle, *Cirsium vulgare*



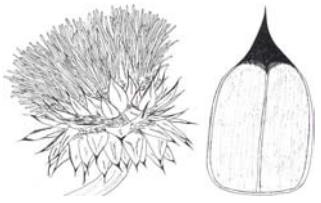
1b) Spines do not extend along the entire length of stems (there is a smooth expanse beneath flower heads at least) (Insert non spiny stem)

7a) Flower heads in clusters, each head measuring less than 1 inch (2.5 cm) in diameter
Canada thistle, *Cirsium arvense*

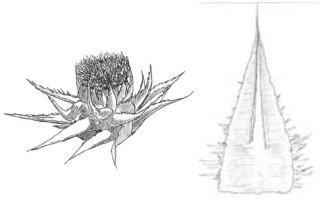


7b) Flower heads usually solitary, each head measuring greater than 1 inch (2.5 cm) in diameter

8a) Bracts not thick, less than ½ inch (1.25 cm) long, not fringed with smaller spines, purple at maturity
Musk thistle, *Carduus nutans*



8b) Bracts thick, greater than ½ inch (1.25 cm) long, fringed with smaller spines, green at maturity
Milk thistle, *Silybum marianum*



Taxonomic Classification of Exotic True Thistles

All exotic thistles described in this manual are true thistles. As such, they fall within the same Subtribe of the Asteraceae (Table 2-1). True thistles differ only in their classification at the level of Genus or Species.

Table 2-1. Taxonomic classification of exotic true thistles.

Superdivision	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Asteridae
Order	Asterales
Family	Asteraceae
Tribe	Cardueae
Subtribe	Carduinae

Species Descriptions of Exotic True Thistles

The following pages contain descriptions of the exotic thistles. The thistles are compared to each other in Table 2-2 on page 38.

Bull Thistle

Scientific name: *Cirsium vulgare* (Savi) Tenore
Synonyms: Spear thistle
Carduus lanceolatus L.
Carduus vulgaris Savi
Cirsium lanceolatum (L.) Scop., non Hill, Scop. var. *hypoleucum* DC

Bull thistle is native to Europe, western Asia, and northern Africa; it was introduced to the United States in the late 1800s. It is mostly a biennial but can also behave as an annual or very short-lived perennial. This species grows 3 to 4 feet (0.9 to 1.2 m) tall on average and reproduces only by seed. Seeds germinate and form rosettes whenever moisture is sufficient, but the majority of rosettes form during spring. Bolting occurs in May. Flowering occurs from June to July.

Leaves: Basal leaves are long (3 to 12 inches or 7.6 to 30 cm), lance-shaped, and lobed. Coarse hairs cover the upper surface of the leaf blade, while the lower surface is woolly. Long, yellow spines extend from the midrib and at each lobe, creating dagger-like tips. Terminal spines from the midrib grow longer than the others. Basal leaves form rosettes that grow up to 3 feet (0.9 m) in diameter. The bases of stem leaves attach to the stem in such a manner as to form long wings. Leaves grow alternately along the stems.

Stems: Stems are erect, stout, and hairy and can have many branches, though they sometimes appear solitary on the plant. Stems are spiny along their entire length.

Flowers: Bull thistle capitula are 1½ to 2 inches (3.8 to 5 cm) in diameter, 1 to 2 inches (2.5 to 5 cm) long, and are usually solitary at the ends of shoots and branches but may form small clusters at stem ends. Receptacles have rows of narrow, spiny bracts tipped in yellow. A single capitulum can produce more than 200 florets ranging from light pink to deep purple in color. All florets are hermaphroditic, having both male and female reproductive parts.

Figure 2-3. Bull thistle. a. plant (Marianna Szucs, University of Idaho), b. flower (Jennifer Andreas, Washington State University Extension), c. stem (Jennifer Andreas, Washington State University Extension), d. U.S. distribution.

Seeds: Achenes of bull thistle are 1/8 inch (3 mm) long and 1/16 inch (1.5 mm) wide. They are yellow in color, streaked with black, and have long white feathered pappus (¾ inch or 1.9 cm long) that aids in wind dispersal over long distances. Mature plants can produce up to 4,000 seeds per plant.

Roots: The root system consists of one long taproot that grows up to 28 inches (71 cm) long. This plant does not reproduce vegetatively.

Habitat and Ecology: Bull thistle grows best on neutral soils rich in nitrogen and with moderate moisture. It is not typically found in sand, pure clay, or in soils with high humus content, nor does it grow well in shade or drought conditions. It can be found in almost any type of disturbed area, including forest clearcuts, riparian areas, and pastures, where it can form dense thickets that displace other vegetation. Overgrazing pastures makes infestations worse.

Noxious Weed Status: This species is listed as noxious in nine states: Arkansas, Colorado, Iowa, Maryland, Minnesota, New Mexico, Oregon, Pennsylvania, and Washington.

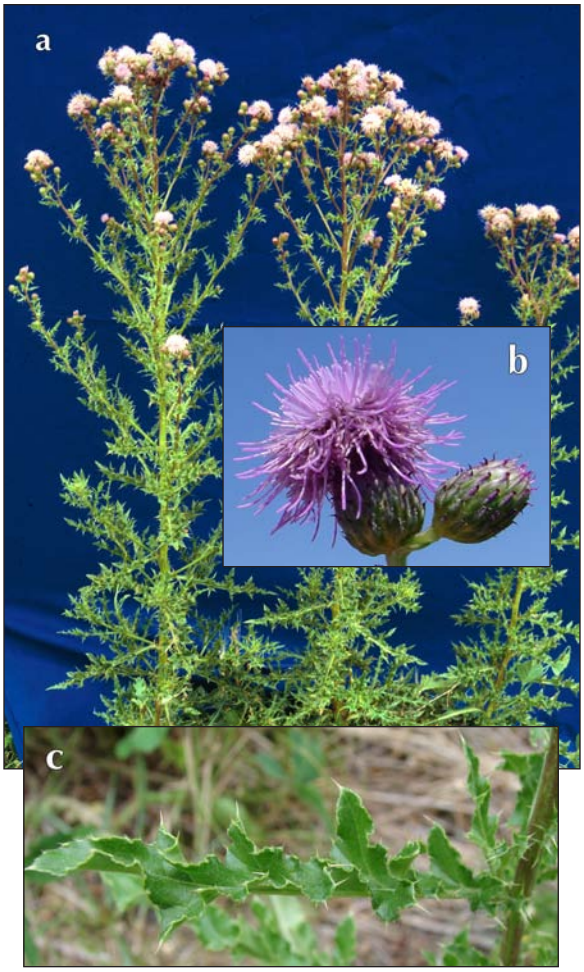
Notes: Phenolic acids produced by the thistle have allelopathic effects against competing plants and (along with spines) serve as a defense against herbivory.

Approved Biological Control Agents: Bull thistle is attacked by *Cheilosia corydon* (a fly), *Trichosirocalus horridus* (a weevil), and *Urophora stylata* (a fly).

Canada Thistle

Scientific name: *Cirsium arvense* (L.) Skopoli

Synonyms:
Creeping thistle
Field thistle
Breea arvensis Less.
Breea incana (Gmel.) W.A. Weber
Carduus arvensis (L.) Robson
Cirsium arvense (L.) Scop. varieties: *argenteum* (Vest) Fiori, *horridum* Wimmer & Grab., *integrifolium* Wimmer & Grab., *mite* Wimmer & Grab., *vestitum* Wimmer & Grab.
Cirsium incanum (Gmel.) Fisch.
Cirsium setosum (Willd.) Bess. ex Bieb.
Serratula arvensis L.



Canada thistle is native to Europe, parts of northern Africa, and Asia south to Afghanistan, Iran and Pakistan. It was introduced to the United States in the 1600s. It is a perennial that grows to 4 feet (1.2 m) tall on average and reproduces both vegetatively through its roots and by seed. Seeds germinate and form rosettes whenever moisture is sufficient, though the majority of rosettes are formed in spring. Flowering stems bolt in late spring. Flowering occurs from June to September.

Leaves: Leaves are irregularly lobed and have very prickly and ruffled margins. They are green on both sides and have a slightly downy lower surface. Basal leaves are less than 5 inches long. Along the stems, leaves grow alternately.

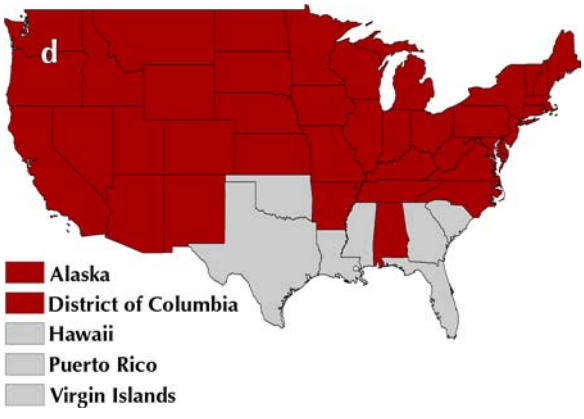


Figure 2-4. Canada thistle. a. plant (Steve Dewey, Utah State University, Bugwood.org) b. male flower (Richard Old, XID Services, Inc., www.xidservices.com), c. stem and leaf (Jennifer Andreas, Washington State University Extension), d. U.S. distribution.

Stems: Stems are slender and grooved and can be highly branched. They are slightly hairy when young but become covered with fine hair as the plant grows. Stems are not spiny. Stems die back in the fall and winter, with new shoots produced each spring from old stem bases or root buds. Because of its ability to vegetatively reproduce, what appear to be individual Canada thistle plants in fact may be individual flowering shoots (ramets) of the same plant.

Flowers: Canada thistle produces numerous small, compact (½ inch or 1.25 cm in diameter) capitula in clusters along upper stems. Bracts on the receptacle are not spiny. This species is dioecious: the florets on all flowering shoots of a single clonal plant are either male or female. This trait is unique among North American exotic thistles. At some sites, infestations consist of plants of only one sex. Florets vary in color from white to deep lavender.

Seeds: Achenes of Canada thistle are small (1/6 to 1/5 inches or 4 to 5 mm long), light brown, smooth, slightly tapered, and with a tuft of tan pappus loosely attached to the tip. A single flowering shoot produces 1,500 seeds on average. Male plants can produce copious amounts of pappus.

Roots: The root system of Canada thistle is rhizomatous, allowing for the vegetative reproduction of this species. It consists of a series of lateral shoots spreading horizontally from a central taproot and extending up to 3 feet (0.9 m) deep into the ground. New flowering shoots arise every 2 to 6 inches (5 to 15 cm) along the lateral roots. Root fragments ¼ inch (6 mm) long by 1/8 inch (3 mm) in diameter have enough stored energy to develop new plants and can survive at least 100 days without nutrient replenishment from photosynthesis.

Habitat and Ecology: Canada thistle grows best in disturbed, moist sites, including prairies, meadows, ditches, streambanks, lawns, and agricultural fields. It does not grow well in shade and is not common in undisturbed areas. Plowing, disking, or overgrazing pastures makes infestations worse.

Noxious Weed Status: This species is listed as noxious in 32 states: Alaska, Arkansas, Arizona, California, Colorado, Delaware, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Mexico, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Utah, Washington, Wisconsin, and Wyoming.

Notes: This plant has possible allelopathic effects against competing species. Because of its ability to regrow from very small root fragments, cultivation often exacerbates the problem in most areas, aiding infestations in spreading further.

Approved Biological Control Agents: Canada thistle is attacked by *Ceutorhynchus litura* (a weevil) and *Urophora cardui* (a fly) and less often by *Trichosirocalus horridus* (a weevil).

ITALIAN THISTLE

Scientific name: *Carduus pycnocephalus* L.

Figure 2-5. Italian thistle. a. plant (© 1995 Saint Mary's College of California), b. flower (Carol Witham), c. stem (© 1995 Saint Mary's College of California), d. U.S. distribution

Italian thistle is native to the Mediterranean region, southern Europe, northern Africa, and western Asia; it was introduced to the United States in the early 1900s. It is a winter annual that occasionally grows as a biennial. This species grows to 4 feet (1.2 m) tall on average and reproduces only by seed. Seeds germinate and form rosettes in the fall following autumn rains. Flowering stems bolt in early spring. Flowering occurs from April to July.

Leaves: Leaves are lance-shaped, green, and hairless above and covered with short matted hairs on the undersides. Basal leaves grow up to 5 inches (13 cm) long and 2½ inches (6.5 cm) wide and have four to eight lobes and spines on lobe tips. Terminal spines grow larger than the others. Stem leaves grow alternately and lightly clasp the stem.

Stems: Stems are slender, slightly winged, and spiny along their entire length. They may be branched or unbranched.

Flowers: Italian thistle produces numerous small, thimble-sized capitula (up to 1 inch or 2.5 cm long) in clusters of two to five at branch tips. Receptacles have very long, triangular bracts that partially cover the florets with their tips. Bracts have many tiny, firm, forward-pointing hairs, especially along the midrib. The bases of bracts are covered with cobwebby hair. Florets vary in color from pink to purple and are hermaphroditic, containing both male and female reproductive parts.

Seeds: Achenes of Italian thistle are small (1/5 inch or 5 mm long) and have bristly pappus measuring ½ inch (1.25 cm) long. Two different forms of seeds are produced: brown and silver. Outer brown achenes are covered in mucous and generally remain in the flower heads, falling with them to the ground at the end of the season. These seeds can germinate at lower temperatures than the inner silver achenes, which are dispersed by wind. Silver achenes can remain dormant in the soil longer than brown achenes.

Roots: The root system consists of one long taproot with several smaller lateral roots. This plant does not reproduce vegetatively.

Habitat and Ecology: Italian thistle grows best in warm, dry, Mediterranean climate areas in basalt soils or decomposing granitic soils with high nitrogen content and relatively high pH. It occurs in open areas such as pastures, rangelands, rights-of-way, and waste areas, capitalizing on disturbance of the soil. Overgrazing and annual burning of pastures infested with Italian thistle make the problem worse.

Noxious Weed Status: This species is listed as noxious in five states: Arkansas, California, Iowa, Oregon, and Washington.

Notes: This species is very similar in appearance to slenderflower thistle but is not as stout and has greener leaves.

Approved Biological Control Agents: Italian thistle is attacked by *Cheilosia corydon* (a fly), *Psylliodes chalcomera* (a beetle not established in the U.S.), and *Trichosirocalus horridus* (a weevil).

Marsh Thistle

Scientific name: *Cirsium palustre* (L.) Skopoli

Marsh thistle is native to Europe and western Asia; it was introduced to the United States in the early 1900s. It is a biennial that can sometimes grow as a short-lived perennial. This species grows to 4 feet (1.2 m) tall on average and reproduces by seed only. Seeds germinate and form rosettes during spring. Flowering stems bolt in spring. Flowering occurs from June to July.

Leaves: Leaves are deeply lobed, toothed, and have a strong midvein. The undersides of leaves are hairy while the upper surfaces only have scattered hairs. Prominent spines are found along margins but not on leaf surfaces. Basal leaves grow as long as 8 inches (20 cm). Stem leaves are smaller and grow alternately up the stem.

Stems: Stems are slender and have spiny wings along their entire length. They are generally unbranched until the very upper parts of the stem. Branches and stem tips nod occasionally as flower heads develop.

Flowers: Marsh thistle capitula are typically ½ inch (1.25 cm) in diameter and appear in clusters of 3 to 12 at the ends of shoots and branches. The receptacle has rows of purplish bracts that are not very spiny. Florets are usually purple in color and are hermaphroditic, having both male and female reproductive parts.

Seeds: Achenes of marsh thistle are small, hard, and elongated (1/6 inch or 4 mm long), with a pappus of feathery bristles.

Roots: The root system of marsh thistle is fibrous. This plant does not reproduce vegetatively.

Habitat and Ecology: Marsh thistle grows best in moist, acidic soils and is found along roadsides and ditches and in wetlands, forest edges, and fields. This plant tolerates shade and can be found in woodlands. Both disturbed and undisturbed soils are susceptible to marsh thistle invasion. Overgrazing of infested pastures makes the problem worse.

Figure 2-6. Marsh thistle. a. plant, b. flowers, c. stem (Malcolm Storey, www.bioimages.org.uk), d. U.S. distribution.

Noxious Weed Status: This species is listed as noxious in two states: Arkansas and Iowa.

Notes: This species currently does not occur in the western U.S.; however, it was included because of its presence in nearby British Columbia, Canada.

Approved Biological Control Agents: Marsh thistle is attacked only occasionally by *Cheilosia corydon* (a fly).

Milk Thistle

Scientific name: *Silybum marianum* (L.) Gaertn.

Synonyms: Blessed milkthistle
Carduus marianus L.
Mariana mariana (L.) Hill

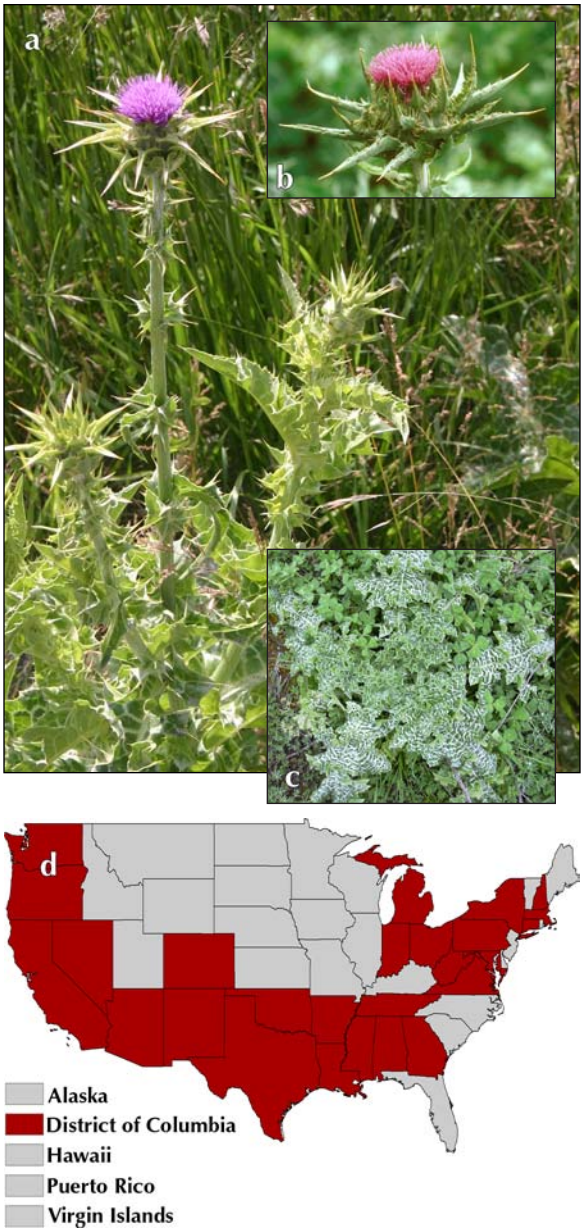


Figure 2-7. Milk thistle. a. plant (Eric Coombs Department of Agriculture), b. flower (Eric Coombs, Oregon Department of Agriculture), c. leaves (Thurston County Noxious Weed Board), d. U.S. distribution.

Milk thistle is native to southern Europe, the Mediterranean, and Northern Africa; it was introduced to the United States in the 1800s. It is a winter annual that occasionally grows as a biennial. This species grows 4 to 6 feet (1.2 to 1.8 m) tall on average and reproduces by seed only. Seeds germinate and form rosettes in the fall following autumn rains. Flowering stems bolt in early spring. Flowering occurs from May to August.

Leaves: Leaves are broad with yellowish margins tipped with woody spines that grow up to ½ inch (1.25 cm) long. Milk thistle leaves are easily distinguished by the white coloration (marbling) found along the veins of the dark green leaves, often resembling milk poured across their surfaces. Basal leaves are deeply lobed and can be 20 inches (51 cm) long and up to 10 inches (25 cm) wide. Stem leaves are smaller, not quite as lobed as basal leaves, and clasp the stem. They grow alternately up the stem.

Stems: Stems are stout, rigid, and not spiny along their length. They may be branched or unbranched.

Flowers: Milk thistle flower heads are up to 2 inches (5 cm) in diameter and are usually solitary at the ends of shoots and branches. Receptacles have rows of broad, leathery bracts that are tipped with very stiff spines ¾ to 2 inches (1.9 to 5 cm) long and fringed with smaller spines. A single capitulum can produce up to 200 florets ranging from magenta to purple. All florets are hermaphroditic, having both male and female reproductive parts.

Seeds: Achenes of milk thistle are heavy, 1/4 inch (6 mm) long, flat, smooth, and shiny and their color ranges from a mottled brown to black. They have a tuft of minutely barbed bristles that falls off in a ring when the seeds mature. A typical capitulum produces 150 achenes; a mature plant produces 6,000 achenes on average.

Roots: The root system consists of one long taproot. This plant does not reproduce vegetatively.

Habitat and Ecology: Milk thistle grows best in soils with high fertility and disturbance, including overgrazed pastures, roadsides, ditches, waste areas, and stockyards.

Noxious Weed Status: This species is listed as noxious in three states: Arkansas, Oregon, and Washington.

Notes: This plant is sometimes used in site remediation projects as it is capable of removing large amounts of lead, nitrates, and zinc from polluted soil. While all milk thistle plants are considered toxic to livestock, plants growing in polluted areas are especially toxic. Milk thistle is an ancient medicinal plant used in the treatment of liver disorders and is still sold by a number of garden seed suppliers in the U.S.

Approved Biological Control Agents: There are currently no biological control agents approved for use against milk thistle.

MUSK THISTLE

Scientific name: *Carduus nutans* L.

Synonyms: Nodding thistle
Carduus macrocephalus Desf.
Carduus macrolepis Peterm.
Carduus nutans L. subspecies: *leiophyllus* (Petrovic) Stojanov & Stef., *macrocephalus* (Desf.) Nyman, *macrolepis* (Peterm.) Kazmi, *nutans* L.
Carduus nutans L. varieties: *leiophyllus* (Petrovic) Arènes, *macrocephalus* (Desf.) Boivin, *vestitus* (Hallier) Boivin

Musk thistle is native to southern Europe, central Asia, and eastern Africa; it was introduced to the United States in the mid-1800s. It is a biennial that occasionally grows as a winter annual. This species grows 5 to 6 feet (1.5 to 1.8 m) tall on average and reproduces only by seed. Rosettes usually form in spring, though autumn rains stimulate germination as well. Bolting occurs in late spring. Flowering occurs from May to August.

Leaves: Leaves are dark green, hairless, and waxy and have characteristic white margins. They are coarsely lobed, with white spines along margins and at lobe tips. Basal leaves are up to 20 inches (51 cm) long and 6 inches (15 cm) wide. Stem leaves are smaller than basal leaves, grow alternately, and lightly clasp the stem.

Stems: Stems are stout and highly branched and have spiny wings along their lower sections but not on their upper portions.

Flowers: Musk thistle flower heads are up to 3 inches (7.5 cm) in diameter and are solitary at the ends of stems and branches. Receptacles have rows of wide, triangular bracts that end in small spines and are purple at maturity. A single capitulum can produce up to 1,500 magenta florets. When capitula mature, they nod (droop) at a 90-degree angle from the stem. All florets are hermaphroditic, having both male and female reproductive parts.

Figure 2-8. Musk thistle. a. plant (Eric Coombs, Oregon Department of Agriculture), b. flower (Becca Winston, MIA Consulting), c. leaf (Rachel Winston, MIA Consulting), d. stem (Richard Old, XID Services, Inc., www.xidservices.com), e. U.S. distribution.

Seeds: Achenes of musk thistle are yellowish-brown (1/8 inch or 3 mm long), with one edge straight and the other curved. The pappus consists of white bristles ¾ inch (1.9 cm) long. Capitula can produce up to 1,000 achenes each but produce only 250 on average. A mature plant can produce 10,000 achenes or more.

Roots: The root system consists of one large, fleshy taproot that is hollow near the root crown. This plant does not reproduce vegetatively.

Habitat and Ecology: Musk thistle grows best in neutral to acidic soils with moist conditions and a good deal of disturbance. It readily invades pastures, roadsides, ditches, and meadows. This species does not grow well in excessively dry, wet, or shady conditions. Overgrazing of infested pastures increases the problem.

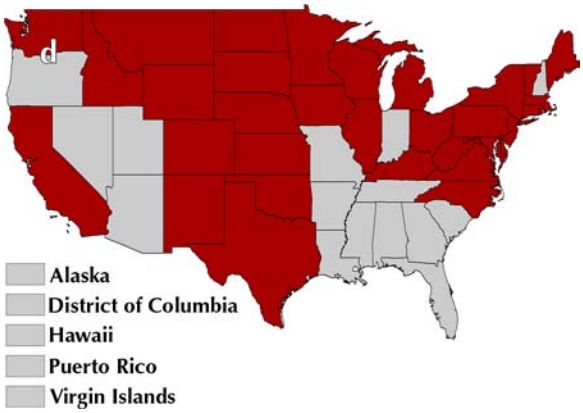
Noxious Weed Status: This species is listed as noxious in 25 states: Arkansas, California, Colorado, Idaho, Illinois, Iowa, Kansas, Kentucky, Maryland, Minnesota, Missouri, Nebraska, Nevada, New Mexico, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Utah, Washington, West Virginia, and Wyoming.

Notes: Musk thistle was the first thistle species targeted for biological control in the U.S.

Approved Biological Control Agents: Musk thistle is attacked by *Cheilosia corydon* (a fly), *Psylliodes chalcomera* (a beetle not established in the U.S.), *Trichosirocalus horridus*, (a weevil), and *Urophora solstitialis* (a fly not established in the U.S.).

Plumeless Thistle

Scientific name: *Carduus acanthoides* L.



Plumeless thistle is native to eastern Europe and Asia; it was introduced to the United States in the 1800s. It is an annual that occasionally grows as a biennial. This species grows 3 to 4 feet (0.9 to 1.2 m) tall on average and reproduces only by seed. Rosettes usually form in spring, though autumn rains stimulate germination as well. Bolting occurs in early summer.

Leaves: Leaves are hairy on the undersides, narrow, deeply lobed (almost to the midrib), and finely divided. Each lobe has one to three pointed spines on the margins that are short but very sharp. Basal leaves have white margins and are up to 8 inches (20 cm) long and 2 inches (5 cm) wide. Stem leaves are smaller than basal leaves and lightly clasp the stem. Flowering occurs from June to October.

Stems: Stems are highly branched but all stand erect. They have leaf-like spines that cover stems, extending along their entire length.

Flowers: Plumeless thistle capitula grow up to 1 inch (2.5 cm) in diameter and are either solitary or form small clusters of up to five capitula at the ends of stems and branches. Receptacles have rows of needlelike bracts tipped with sharp spines. A single capitulum can produce up to 100 pink or purple florets. All florets are hermaphroditic, having both male and female reproductive parts.

Seeds: Achenes of plumeless thistle are small, $^{1}/_{16}$ inch (1.5 mm) long, yellow to brown, slightly curved, and have a distinct light collar near the top. The pappus consists of small white bristles. Capitula can produce approximately 75 achenes each; a mature plant produces 3,750 achenes on average.

Roots: The root system consists of one large, fleshy taproot that is hollow near the root crown. This plant does not reproduce vegetatively.

Figure 2-9. Plumeless thistle. a. plant (Becca Schneiderhan, MIA Consulting), b. flower (Becca Schneiderhan, MIA Consulting) c. stem (Richard Old, XID Services, Inc., www.xidservices.com), d. U.S. distribution.

Habitat and Ecology: Plumeless thistle grows best in well-drained soil with moist conditions and a good deal of disturbance. It readily invades pastures, roadsides, ditches, and meadows.

Noxious Weed Status: This species is listed as noxious in 14 states: Arizona, Arkansas, California, Colorado, Iowa, Maryland, Minnesota, Nebraska, North Carolina, Oregon, South Dakota, Washington, West Virginia, and Wyoming.

Approved Biological Control Agents: Plumeless thistle is attacked by *Cheilosia corydon* (a fly), *Psylliodes chalcomera* (a beetle not established in the U.S.), *Trichosirocalus horridus* (a weevil), and *Urophora solstitialis* (a fly not established in the U.S.).

SCOTCH THISTLE

Scientific name: *Onopordum acanthium* L.
Synonyms: Scotch cottonthistle
Onopordum acanthium L. ssp. *acanthium* L.

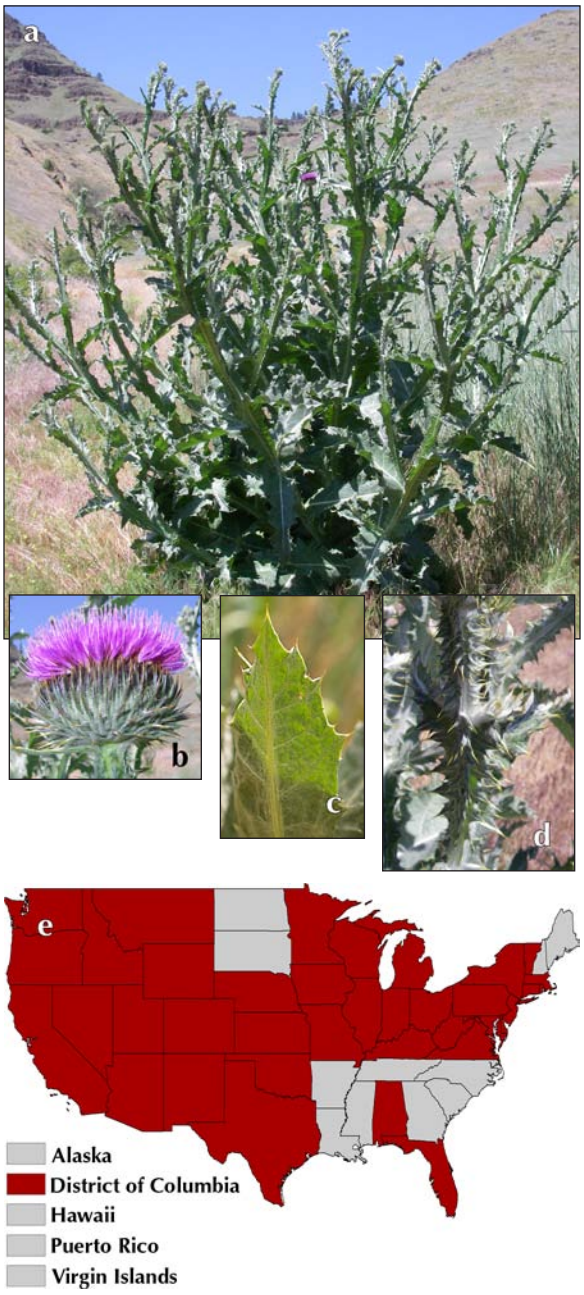


Figure 2-10. Scotch thistle. a. plant, b. flower, c. leaf, d. stem (all Rachel Winston, MIA Consulting), e. U.S. distribution

Scotch thistle is native to the Mediterranean region of Europe and western Asia; it was introduced to the United States in the 1800s. It is a biennial that occasionally grows as a short-lived perennial or even an annual. This species grows to 7 or 8 feet (2.1 to 2.4 m) tall and 4 feet (1.2 m) wide on average and reproduces only by seed. Rosettes usually form in spring and can grow on average to 3 feet (0.9 m) in diameter; autumn rains stimulate germination and rosette formation as well. Bolting occurs in early summer. Flowering occurs from July to October.

Leaves: Leaves are wider in the center than at the base and have wavy, toothed margins armed with sharp yellow spines. Upper and lower leaf surfaces are covered with a thick mat of woolly hairs that give the foliage a gray-green or silvery appearance. Basal leaves can grow up to 2 feet (61 cm) long and 1 foot (30 cm) wide. Stem leaves are smaller than basal leaves, grow in an alternate pattern, and extend onto the stems as wings.

Stems: Scotch thistle stems are robust, have numerous branches covered in woolly hair, and have spiny wings extending along their entire length.

Flowers: Scotch thistle capitula are globe-shaped and grow to 2 inches (5 cm) in diameter. They are usually solitary or form small groups of three capitula at the ends of stems and branches. The receptacle is honeycombed within and has rows of long, needlelike bracts tipped with orange-colored spines. A single capitulum can produce up to 150 pink or purple florets. All florets are hermaphroditic, having both male and female reproductive parts.

Seeds: Achenes of Scotch thistle are $^1/_5$ inch (5 mm) long, gray with dark mottling, and attached to a brown-colored pappus of toothed bristles that can be twice as long as the seed. Capitula can produce over 100 achenes each; a mature plant produces 10,000 achenes on average.

Roots: The root system consists of one large, fleshy taproot. This plant does not reproduce vegetatively.

Habitat and Ecology: Scotch thistle grows best in light, well-drained, and sandy or stony soils. It readily invades dry pastures, fields, and rangeland but is also found in waste places and along rivers, streams, canals, or other waterways. Heavy disturbance increases infestations.

Noxious Weed Status: This species is listed as noxious in 14 states: Arizona, Arkansas, California, Colorado, Connecticut, Idaho, Missouri, Nevada, New Mexico, Oklahoma, Oregon, Utah, Washington, and Wyoming.

Notes: Scotch thistle is the national emblem of Scotland. It is sometimes sold as an ornamental and has some medicinal and practical uses.

Illyrian and Taurian thistle (*Onopordum illyricum* and *Onopordum tauricum*, respectively) are closely related to Scotch thistle and are very similar in biology and suitability for biological control agents. They are not specifically addressed in this manual. These species are most problematic in California, though they are also becoming nuisances elsewhere.

Approved Biological Control Agents: There are currently no biological control agents approved for use against Scotch thistle.

Slenderflower Thistle

Scientific name: *Carduus tenuiflorus* W. Curtis

Figure 2-11. Slenderflower thistle. a. plant (Washington State Noxious Weed Control Board), b. flowers (Washington State Noxious Weed Control Board), c. leaf and stem (Thurston County Noxious Weed Board), d. U.S. distribution.

Slenderflower thistle is native to western and southern Europe and the Mediterranean region, northward to Scandinavia. It was introduced to the United States in the 1900s. It is a winter annual that occasionally grows as a biennial. This species grows 3 to 4 feet (0.9 to 1.2 m) tall and reproduces only by seed. Seeds germinate and form rosettes in the fall following autumn rains. Flowering stems bolt in early spring. Flowering occurs from April to June.

Leaves: Leaves are lance-shaped and gray-green with light colored veins. They are hairless and spiny above and covered with short matted hairs on the undersides. Basal leaves grow up to 5 inches (13 cm) long and 2 ½ inches (6 cm) wide, have 4 to 20 lobes, and spines on lobe tips. Stem leaves grow alternately along stems.

Stems: Stems are slender and may be branched or unbranched. They have triangular-shaped stem wings that are up to 1/3 inch (0.8 cm) wide and are tipped with spines; wings extend over the entire length of the stem.

Flowers: Slenderflower thistle produces numerous, small capitula less than 1 inch (2.5 cm) long. They grow in clusters of 5 to 20 at the ends of stems and branches. Receptacles have narrow, triangular bracts tipped with spines. Florets, averaging 20 per capitulum, vary in color from pink to purple and are hermaphroditic, having both male and female reproductive parts.

Seeds: Achenes of slenderflower thistle are small (1/6 inch or 4 mm long) and have bristly pappus measuring ½ inch (1.25 cm) long. Two different forms of seeds are produced: brown and silver. Outer brown achenes are covered in mucus and generally remain in the flower heads, falling with them to the ground at the end of the season. These seeds can germinate at lower temperatures than the inner silver achenes, which are dispersed by wind. Silver achenes can remain dormant in the soil longer than the brown achenes.

Roots: The root system consists of a shallow, branched, and slender taproot. This plant does not reproduce vegetatively.

Habitat and Ecology: Slenderflower thistle grows best in dry, open areas with highly fertile soils. It occurs in pastures, rangelands, rights-of-way, and waste areas, capitalizing on disturbance.

Noxious Weed Status: This species is listed as noxious in five states: Arkansas, California, Iowa, Oregon, and Washington.

Notes: Slenderflower thistle is very similar to Italian thistle but has lighter colored leaf veins and stouter, more strongly winged stems.

Approved Biological Control Agents: Slenderflower thistle is attacked by *Cheilosia corydon* (a fly) and *Trichosirocalus horridus* (a weevil).

Table 2-2. Trait comparisons of nine exotic thistles in western North America.

	Bull	Canada	Italian	Marsh	Milk	Musk	Plumeless	Scotch	Slenderflower
Life history	Biennial	Perennial	Winter annual/ biennial	Biennial	Winter annual/ biennial	Biennial	Annual/ biennial	Biennial/ short lived perennial	Winter annual
Repro-duction	Seed	Seed and rhizomatous roots	Seed	Seed	Seed	Seed	Seed	Seed	Seed
Average height	3 1/2′ 1 m	4′ 1.2 m	4′ 1.2 m	4′ 1.2 m	5 1.5 m′	5 1/2′ 1.7 m	3 1/2′ 1 m	7′ 2 m	3 1/2′ 1 m
Capitulum diameter	1 1/2 to 2″ 3.8 to 5 cm	1/2″ 1.25 cm	<1″ <2.5 cm	1/2″ 1.25 cm	2″ 5 cm	3″ 7.5 cm	Up to 1″ Up to 2.5 cm	2″ 5 cm	<1″ <2.5 cm
Capitula cluster #	1	1 to several	2 to 5	3 to 12	1	1	Up to 5	1	5 to 20
Bract description	Narrow; needlelike; tipped in yellow	Triangular; close to receptacle; not spiny	Triangular; cobwebby hairs; tiny, firm hairs on midrib	Triangular; close to receptacle; not spiny	Broad; leathery; up to 2″ long; fringed with smaller spines	Wide; triangular; purple at maturity	Needlelike; slightly triangular	Needlelike; tipped with orange colored spines	Triangular; not hairy
Stems spiny along entire length?	Yes	No	Yes	Yes	No	No: not upper portions	Yes	Yes	Yes
General leaf color	Green	Green	Green	Green	Green with white marbling	Green with white margins	Green	Gray green	Gray green

Native True Thistles

Even though the taxonomy of the group remains unsettled, there are at least 86 species (and numerous subspecies) of native true thistles in the U.S. All are in the genus Cirsium. This manual is focused on the northwestern United States and, more specifically, the states of Colorado, Idaho, Montana, Oregon, Utah, Washington, and Wyoming. Consequently, only the native thistle species (47 total) occurring in these regions are included in Table 2-3.

Table 2-3. Native true thistle species in the northwestern U.S.

Scientific Name (all *Cirsium*)	Common Name	Life Strategy	Distribution
C. altissimum	Tall thistle	Biennial	AL, AR, DC, DE, FL, GA, IA, IL, IN, KS, KY, LA, MI, MN, MO, MS, NC, ND, NE, NY, OH, OK, PA, SC, SD, TN, TX, VA, WI, WV
C. andersonii	Rose thistle	Biennial	CA, NE, OR
C. araneans	Jeweled thistle	Perennial	CO
C. aridum	Desert thistle	Perennial	WY
C. barnebyi	Barneby's thistle	Perennial	CO, UT, WY
C. brevifolium	Palouse thistle	Perennial	IH, OR, WA
C. brevistylum	Clustered, short-styled thistle	Annual Biennial Perennial	CA, IH, MT, OR, WA
C. calcareum	Cainville thistle	Biennial Perennial	CO, NM, UT
C. canescens	Prairie thistle	Biennial	CO, IA, ID, MO, MT, ND, NE, NM, OH, SD, WI, WY
C. canovirens	Gray-green thistle	Biennial Perennial	CA, ID, MT, NV, OR, UT, WY
C. centaureae	Fringed thistle	Perennial	CO, UT, WY
C. ciliolatum	Ashland thistle	Perennial	CA, OR
C. clavatum	Fish Lake thistle	Perennial	CO, UT
C. cymosum	Peregrine thistle	Perennial	CA, OR
C. douglasii	Douglas' thistle	Biennial Perennial	CA, NV, OR
C. drummondii	Dwarf thistle	Perennial	SD, WY
C. eatonii	Eaton's thistle	Biennial Perennial	CO, ID, MT, NV, UT, WY
C. edule	Edible thistle	Biennial Perennial	ID, OR, WA
C. flodmanii	Flodman's thistle	Perennial	CO, IA, ID, KS, MI, MN, MT, ND, NE, SD, UT, VT, WI, WY

C. foliosum	Elk thistle	Perennial	ID, MT, WA, WY
C. hookerianum	Hooker's, white thistle	Perennial	ID, MT, WA, WY
C. horridulum	Yellow thistle	Annual Biennial	AL, AR, CT, DE, FL, GA, LA, MA, MD, ME, MS, NC, NH, NJ, NY, OK, PA, RI, SC, TN, TX, VA
C. laterifolium	Porcupine thistle	Perennial	CO
C. longistylum	Longstyle thistle	Perennial	MT
C. modestum	Lacy thistle	Perennial	CO
C. murdockii	Murdock's thistle	Biennial Perennial	UT
C. neomexicanum	New Mexico thistle	Biennial Perennial	AZ, CA, CO, NM, NV, UT
C. occidentale	Cobwebby thistle	Biennial Perennial	CA, NV, OR
C. ochrocentrum	Yellowspine thistle	Biennial Perennial	AZ, CA, CO, KS, NE, NM, OK, SD, TX, UT, WI, WY
C. osterhoutii	Osterhout's thistle	Perennial	CO
C. ownbeyi	Ownbey's thistle	Perennial	CO, UT, WY
C. pallidum	Pale thistle	Perennial	CO, NM
C. peckii	Steen Mountain thistle	Perennial	OR
C. perplexans	Rocky Mounain thistle	Perennial	CO
C. pulcherrimum	Wyoming thistle	Perennial	CO, NE, UT, WY
C. pyrenaicum	Pyrenean thistle	Perennial	OR
C. remotifolium	Fewleaf thistle	Biennial Perennial	CA, OR, WA
C. rothrockii	Rothrock's thistle	Biennial	AZ, UT
C. rydbergii	Rydberg's thistle	Perennial	AZ, UT
C. scapanolepis	Mountain slope thistle	Perennial	CO
C. scariosum	Meadow thistle (previously Elk thistle)	Biennial Perennial	AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY
C. scopulorum	Mountain thistle	Biennial	CO, NM, UT
C. subniveum	Jackson Hole thistle	Perennial	CA, ID, MT, NE, OR, UT, WY
C. undulatum	Wavy-leaved thistle	Biennial Perennial	AZ, CA, CO, GA, IA, ID, IL, IN, KS, MI, MN, MO, MT, ND, NE, NM, NE, OK, OR, PA, SD, TX, UT, WA, WI, WY
C. vernale	Spring thistle	Perennial	CO
C. virginense	Virgin thistle	Perennial	AZ, NE, UT
C. wheeleri	Wheeler's thistle	Perennial	AZ, CO, NM, NE, UT

It is often difficult to differentiate exotic and native thistle species because of their similar appearance, growth traits, preferred habitat, and distribution. However, there are a few "rules of thumb" or questions that can aid in the identification process.

- Are the stems of the species in question covered in spines or sharp wings along their entire length?

  YES: The species is not native. Stems of native thistles are not spiny along their entire length, nor are they winged; they have bare or woolly (but not spiny) expanses between leaves, unless the leaves overlap profusely which does not occur on exotic species in this manual.
  NO: Refer to other characteristics to further differentiate.

- Are the bracts of the species in question spine-tipped, firm, and broad-triangular or wedge-shaped?

  YES: The species is not native. Bracts of native species are either firm and needle-shaped or soft and woolly.
  NO: Refer to other characteristics to further differentiate.

- Are the bracts of the species in question leathery and/or jagged along the margins?

  YES: The species is not native. Bracts of native species are either firm and needle-shaped or soft and woolly.
  NO: Refer to other characteristics to further differentiate.

- Is the root system of the species in question rhizomatous?

  YES: The species is not native. Native species are not rhizomatous.
  NO: Refer to other characteristics to further differentiate.

- Is the species in question dioecious (male and female florets are on separate plants)?

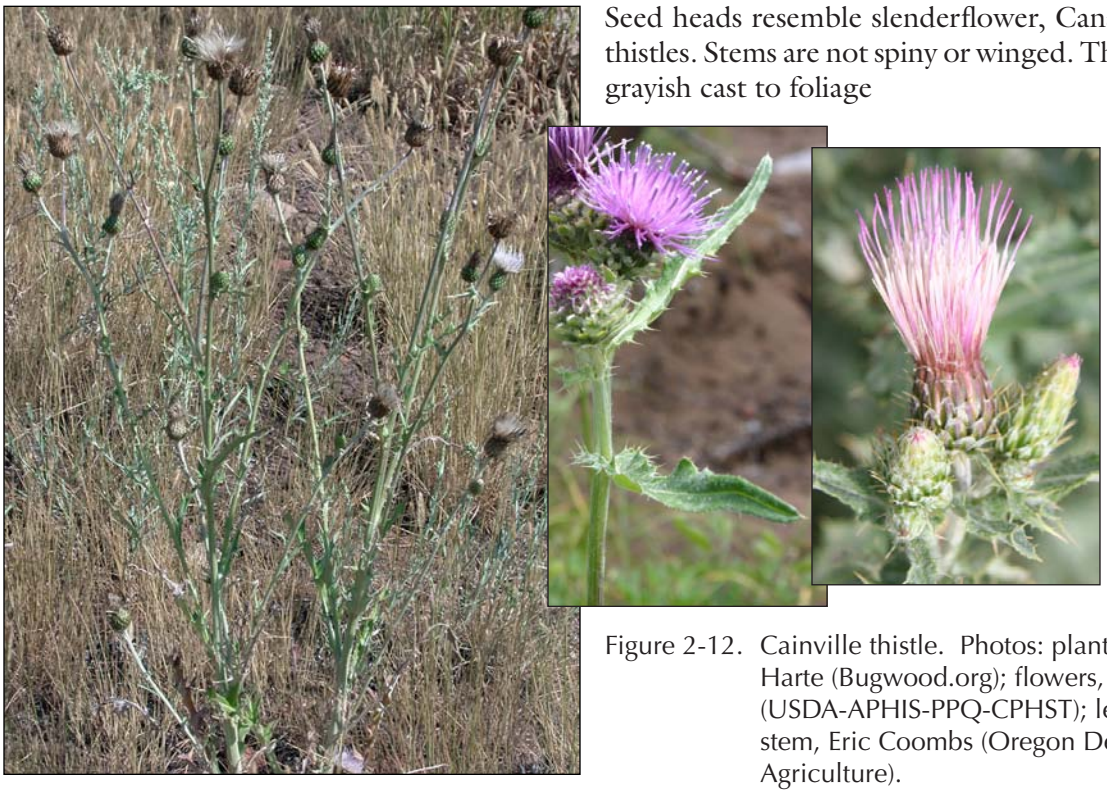
  YES: The species is not native. Native thistles are not dioecious.
  NO: Refer to other characteristics to further differentiate.

- Are the bracts of the species in question glandular (sticky and often aromatic)?

  YES: The species is native. None of the exotic thistles discussed in this manual have glandular bracts.
  NO: Refer to other characteristics to further differentiate.

Selected native species are highlighted on the following pages, with special emphasis placed on distinguishing each species from the exotic thistles targeted in this manual.

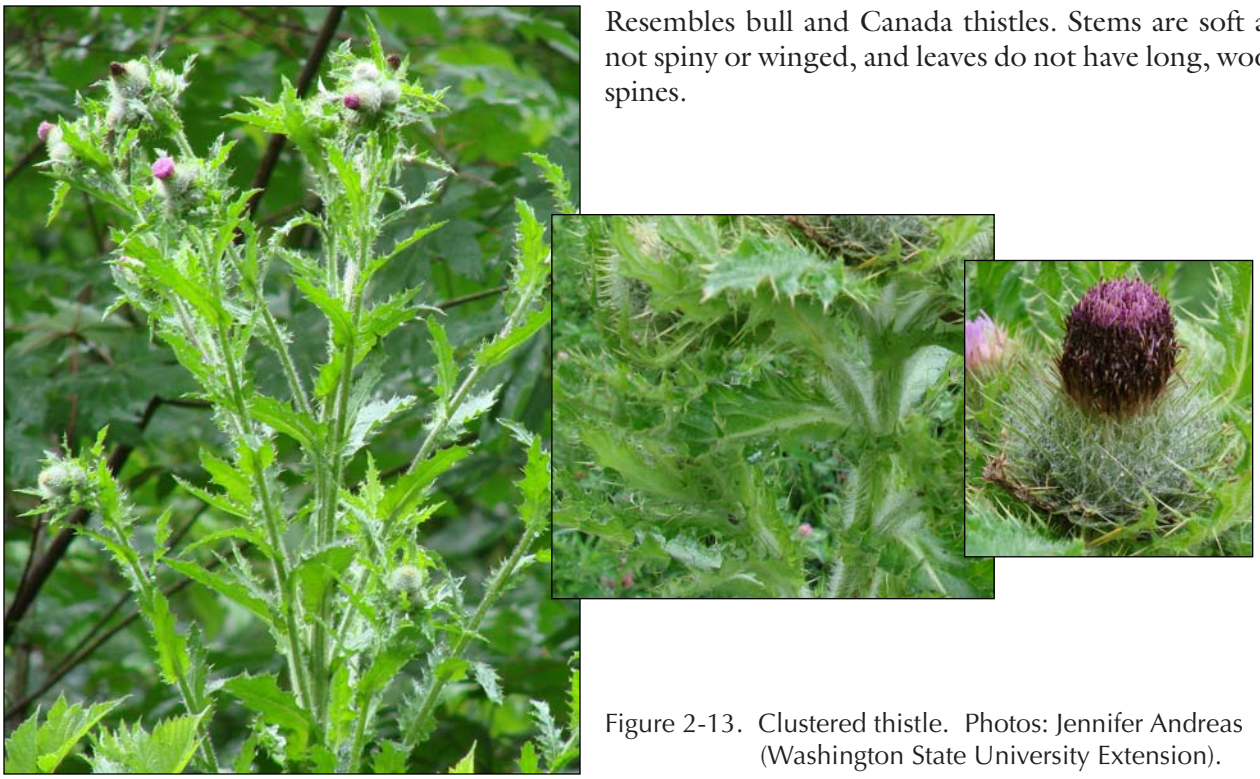
Cainville Thistle (*Cirsium calcareum*)



Seed heads resemble slenderflower, Canada, and Italian thistles. Stems are not spiny or winged. There is an overall grayish cast to foliage

Figure 2-12. Cainville thistle. Photos: plant, Mary Ellen Harte (Bugwood.org); flowers, Rich Hansen (USDA-APHIS-PPQ-CPHST); leaf and stem, Eric Coombs (Oregon Department of Agriculture).

Clustered Thistle (*Cirsium brevistylum*)



Resembles bull and Canada thistles. Stems are soft and not spiny or winged, and leaves do not have long, woody spines.

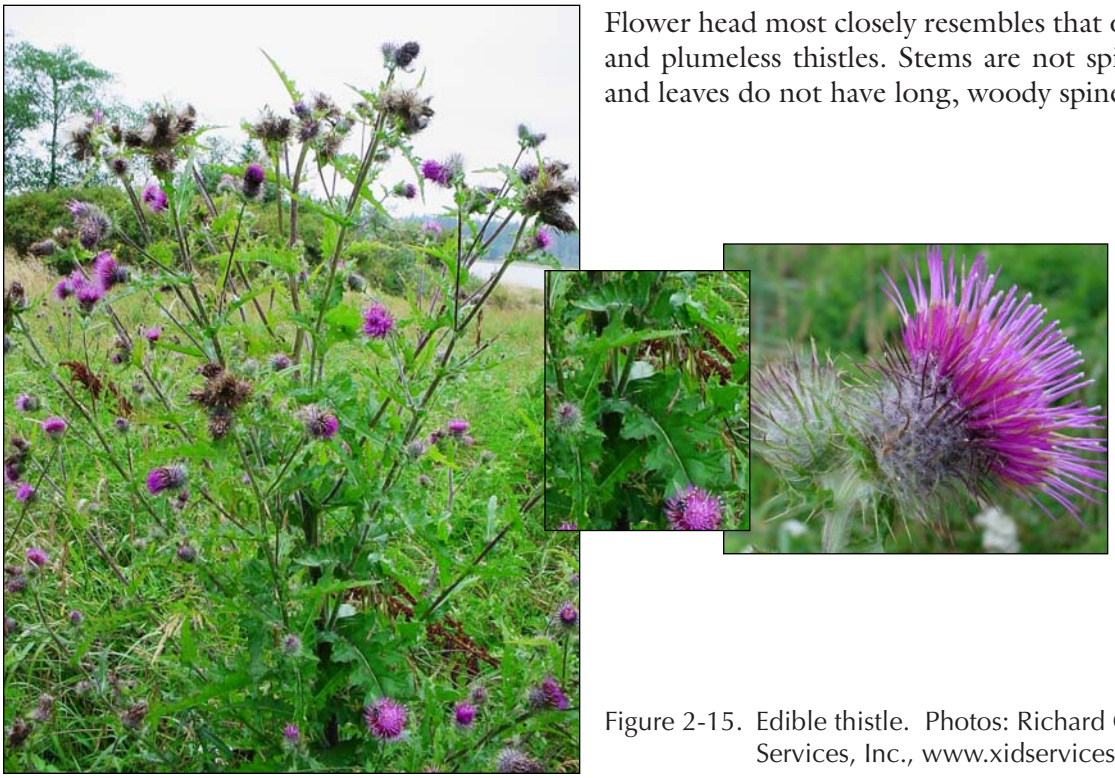
Figure 2-13. Clustered thistle. Photos: Jennifer Andreas (Washington State University Extension).

Cobwebby Thistle (*Cirsium occidentale* var. *venustum*)

Flower head most closely resembles that of Italian and slenderflower thistles but is much more cobwebby. Stems are not spiny or winged. Foliage has grayish cast.

Figure 2-14. Cobwebby thistle. Photos: plant and leaves, Mark Schwarländer (University of Idaho); flower head, Rich Hansen (USDA-APHIS-PPQ-CPHST).

Edible Thistle (*Cirsium edule*)



Flower head most closely resembles that of bull, Scotch, and plumeless thistles. Stems are not spiny or winged, and leaves do not have long, woody spines.

Figure 2-15. Edible thistle. Photos: Richard Old (XID Services, Inc., www.xidservices.com).

Eaton's Thistle (*Cirsium eatonii*)

Resembles marsh thistle with its erect and solitary form and cluster of flower heads subtended by leaves that extend beyond the cluster. Stems are soft, not spiny or winged.

Figure 2-16. Eaton's thistle. Photos: Mary Ellen Harte (Bugwood.org).

Flodman's Thistle (*Cirsium flodmanii*)

Flower head most closely resembles that of bull, Canada, and Scotch thistles, and overall grayish cast resembles Scotch thistle. Stems are not spiny or winged. Leaves are highly lobed and wavy-margined.

Figure 2-17. Flodman's thistle. Photos: Mark Schwarzländer (University of Idaho).

Jackson Hole Thistle (*Cirsium subniveum*)

Most closely resembles Canada thistle. Leaves are more slender and not as wavy. Plant has overall busy appearance with a gray-green hue.

Figure 2-18. Jackson Hole thistle. Photos: Eric Coombs (Oregon Department of Agriculture).

GRAY-GREEN THISTLE (*Cirsium canovirens*)

Most closely resembles white-flowered (uncommon) Canada thistle. Stems are not spiny or winged. Leaves are very spiny, and plant has overall grayish cast.

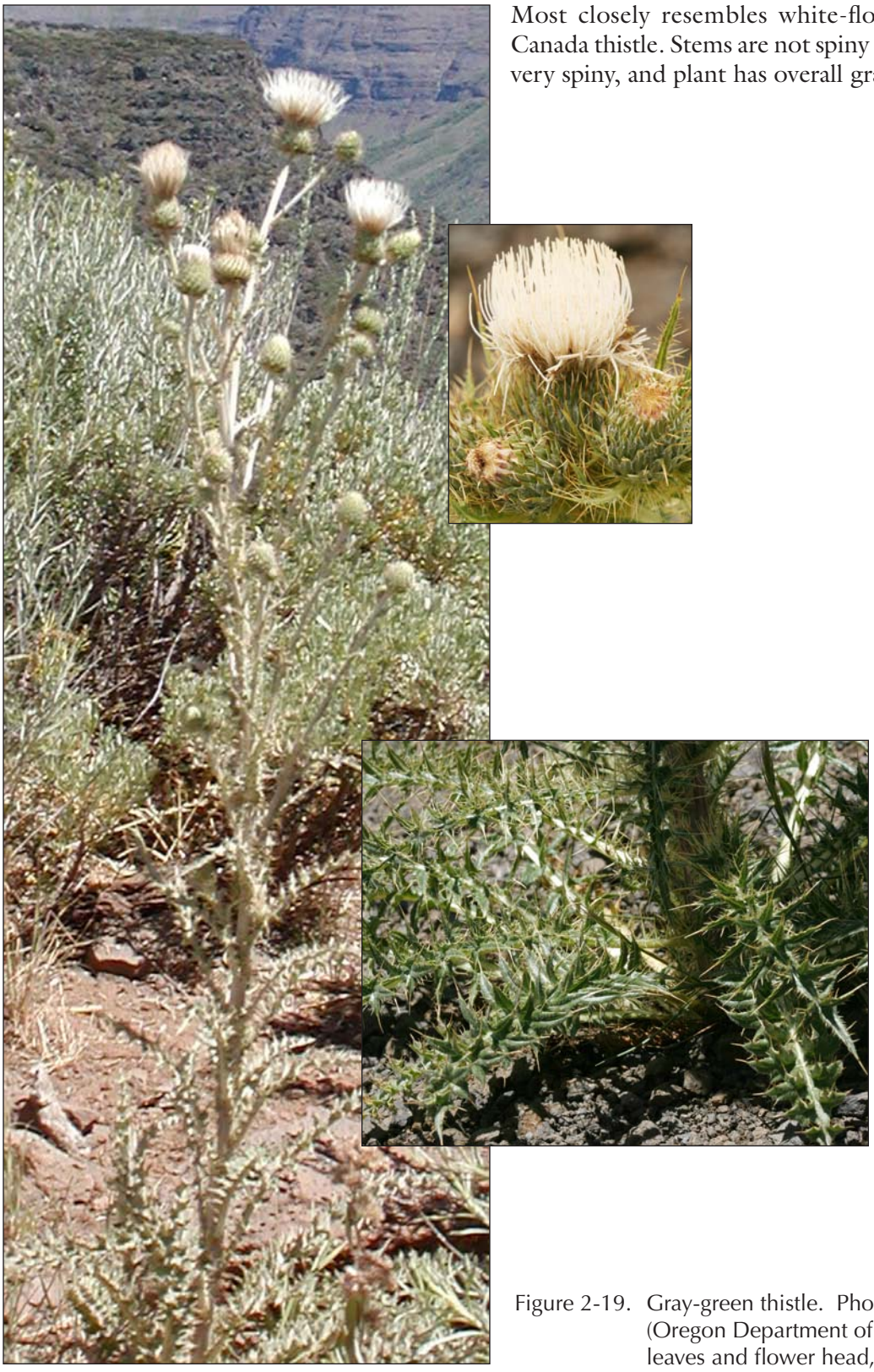


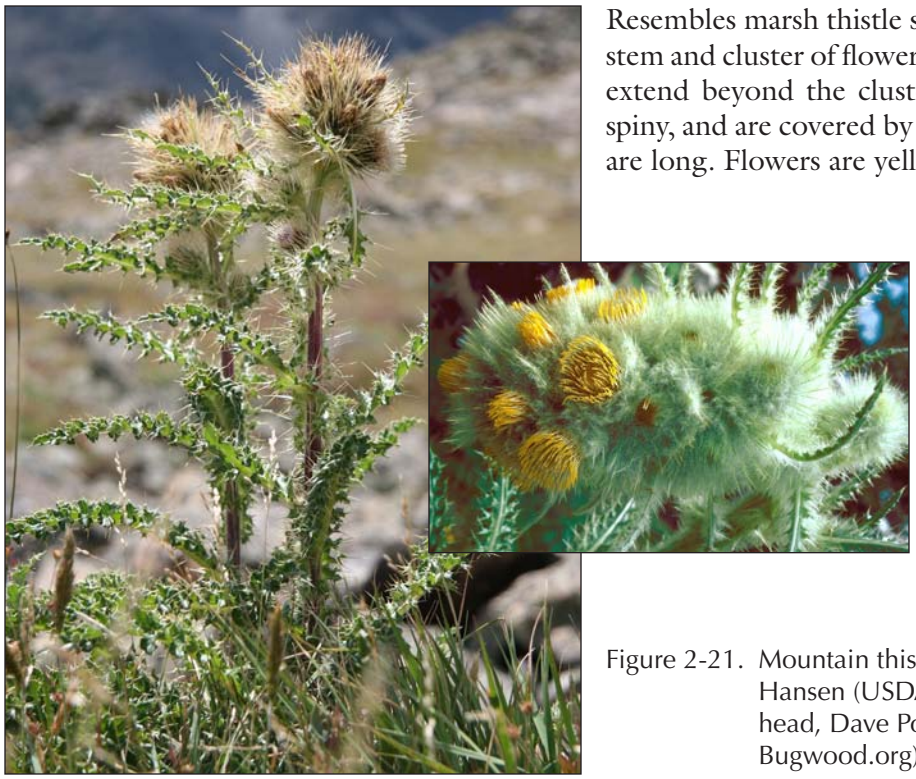
Figure 2-19. Gray-green thistle. Photos: plant, Eric Coombs (Oregon Department of Agriculture); stem/leaves and flower head, Steve Matson.

Meadow Thistle (*Cirsium scariosum*)

Resembles marsh thistle with its erect and solitary form and cluster of flower heads subtended by leaves that extend beyond the cluster. Stems are soft, not spiny, and are covered by overlapping leaves.

Figure 2-20. Meadow thistle. Photos: plant, Richard Old (XID Services, Inc., www.xidservices.com); leaves, Rachel Winston (MIA Consulting); flower head, Richard Hansen (USDA-APHIS-PPQ-CPHST).

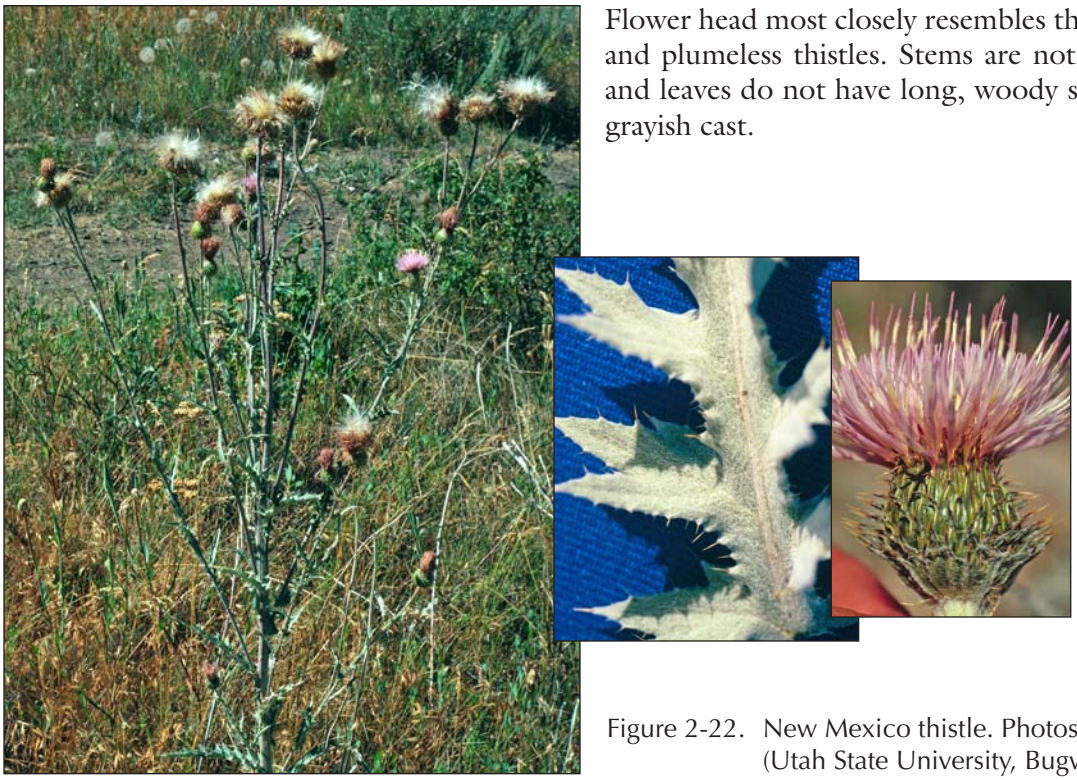
Mountain Thistle (*Cirsium scopulorum*)



Resembles marsh thistle somewhat with its solitary main stem and cluster of flower heads subtended by leaves that extend beyond the cluster. Stems are very woolly, not spiny, and are covered by overlapping leaves. Basal leaves are long. Flowers are yellow.

Figure 2-21. Mountain thistle. Photos: plant, Richard Hansen (USDA-APHIS-PPQ-CPHST); flower head, Dave Powell (USDA Forest Service, Bugwood.org).

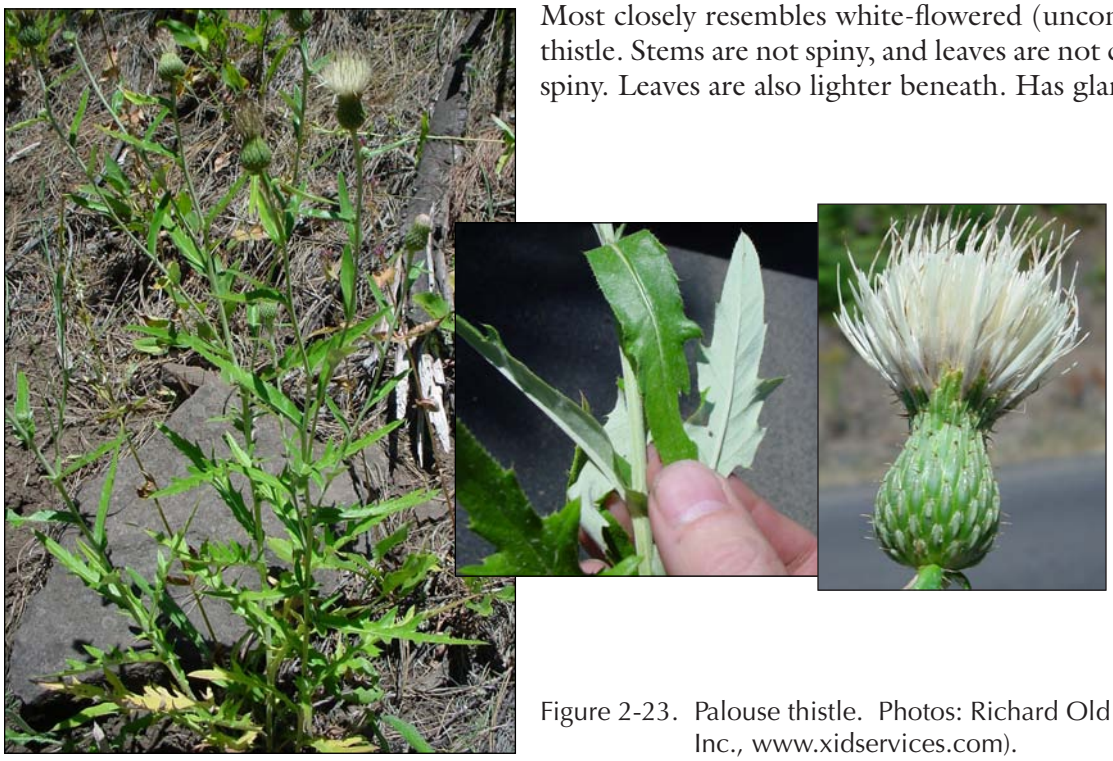
NEW MEXICO THISTLE (*Cirsium neomexicanum*)



Flower head most closely resembles that of bull, Scotch, and plumeless thistles. Stems are not spiny or winged, and leaves do not have long, woody spines. Foliage has grayish cast.

Figure 2-22. New Mexico thistle. Photos: Steve Dewey (Utah State University, Bugwood.org).

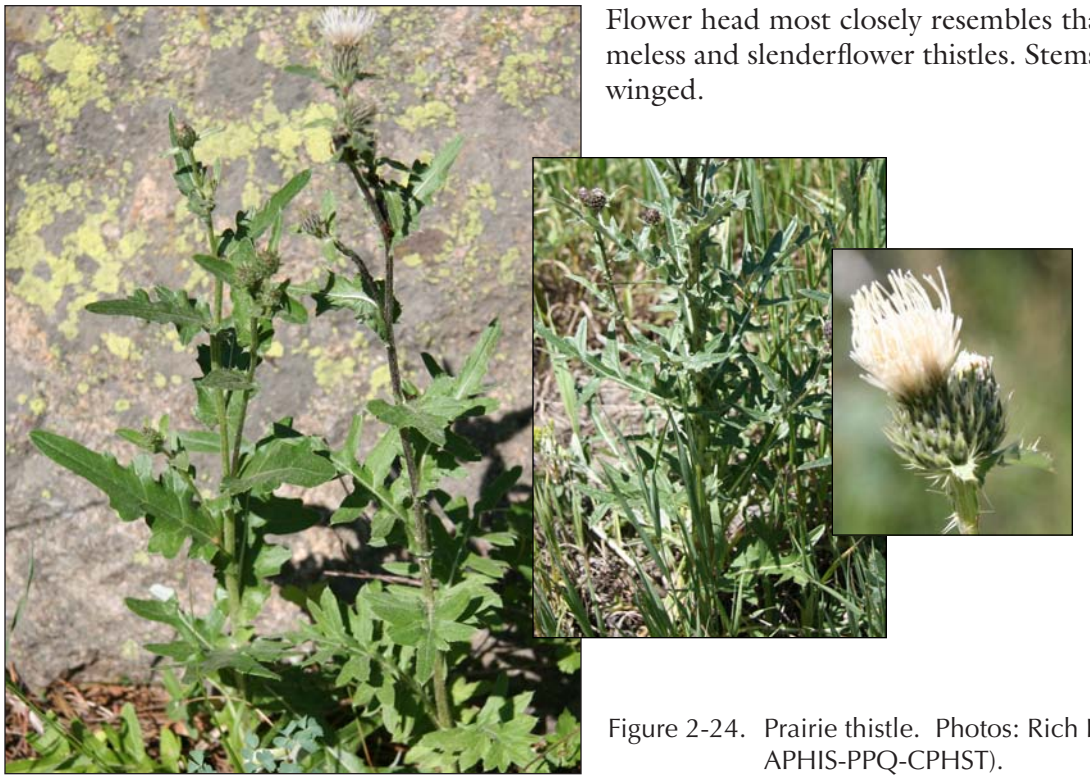
PALOUSE THISTLE (*Cirsium brevifolium*)



Most closely resembles white-flowered (uncommon) Canada thistle. Stems are not spiny, and leaves are not crinkled or very spiny. Leaves are also lighter beneath. Has glandular bracts.

Figure 2-23. Palouse thistle. Photos: Richard Old (XID Services, Inc., www.xidservices.com).

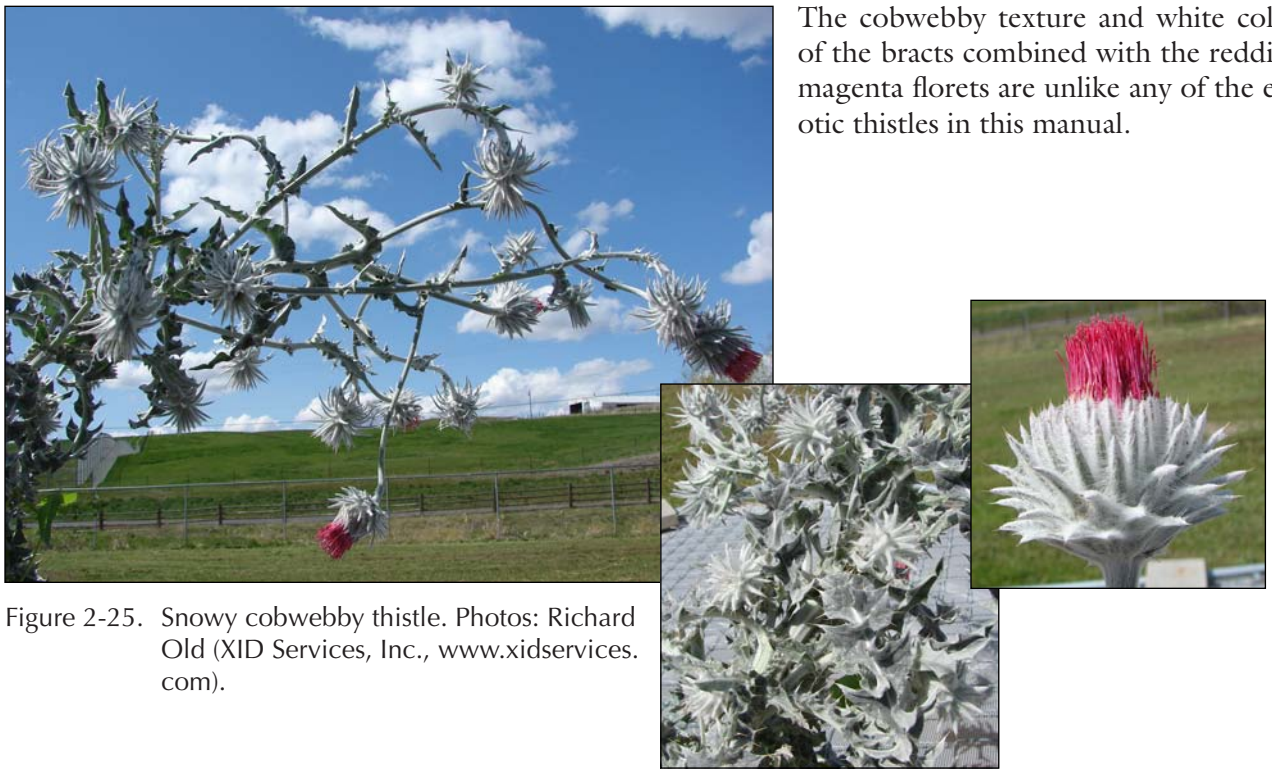
Prairie Thistle (*Cirsium canescens*)



Flower head most closely resembles that of Italian, plumeless and slenderflower thistles. Stems are not spiny or winged.

Figure 2-24. Prairie thistle. Photos: Rich Hansen (USDA-APHIS-PPQ-CPHST).

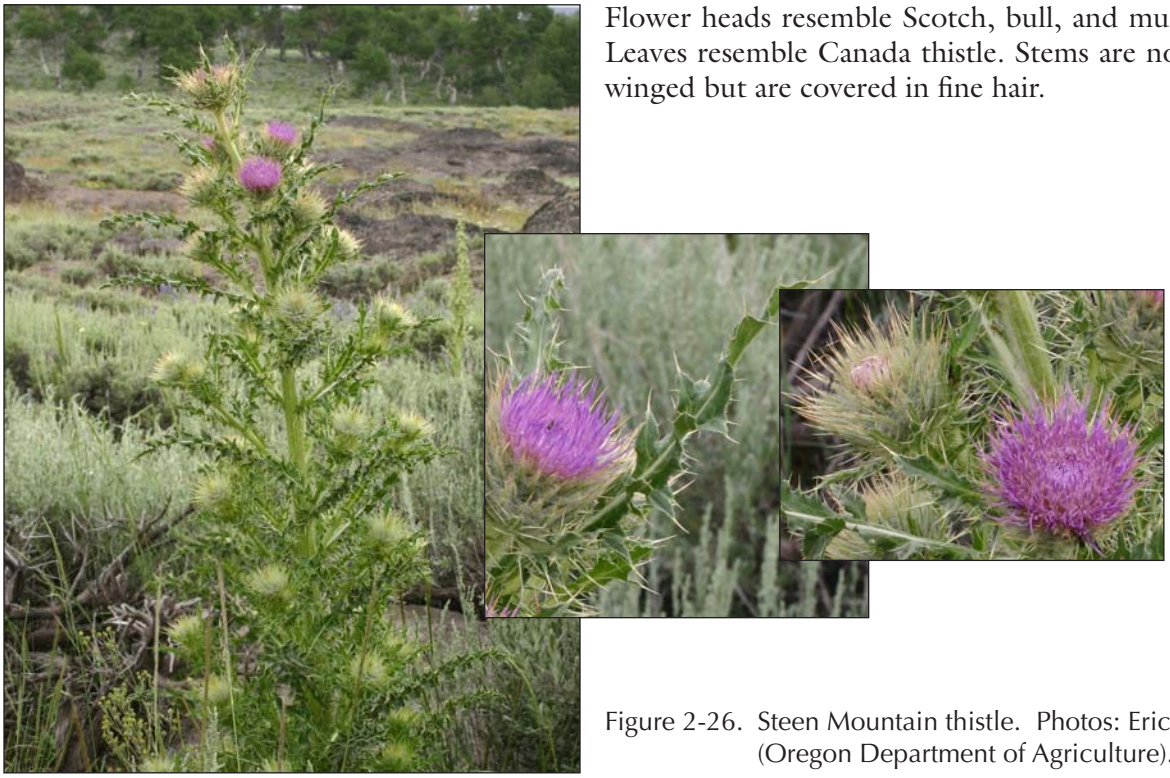
Snowy Cobwebby Thistle (*Cirsium occidentale* var. *candidissimum*)



The cobwebby texture and white color of the bracts combined with the reddish magenta florets are unlike any of the exotic thistles in this manual.

Figure 2-25. Snowy cobwebby thistle. Photos: Richard Old (XID Services, Inc., www.xidservices.com).

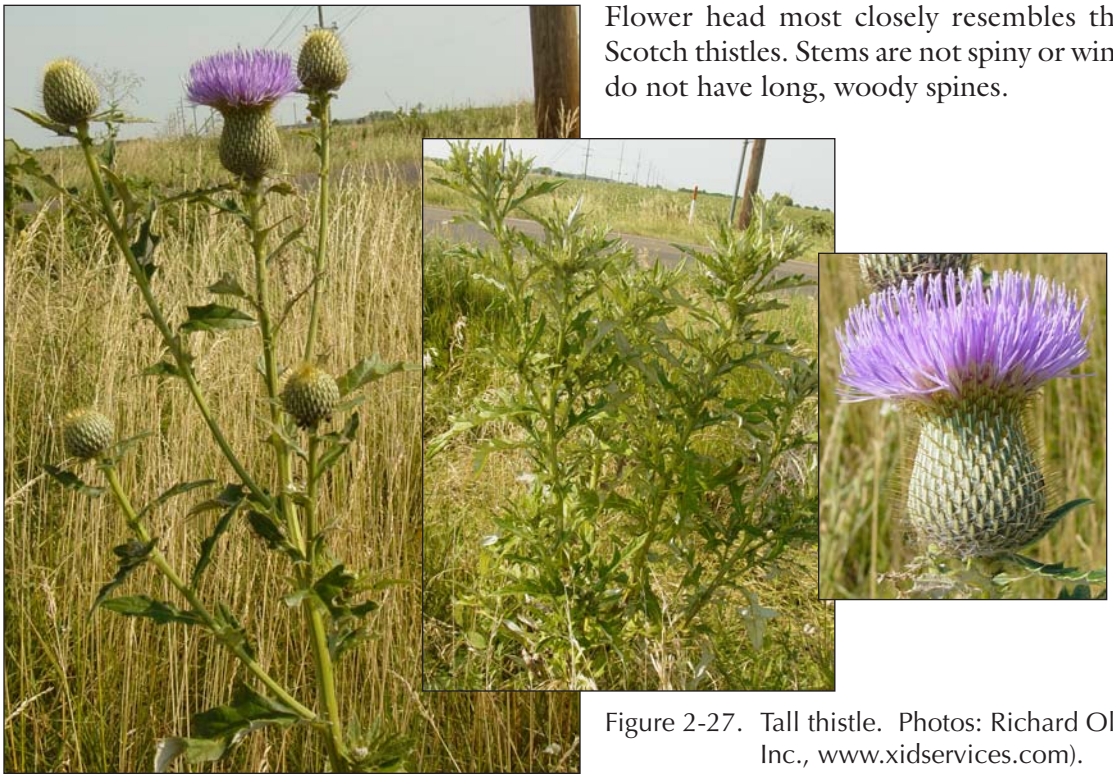
Steen Mountain Thistle (*Cirsium peckii*)



Flower heads resemble Scotch, bull, and musk thistles. Leaves resemble Canada thistle. Stems are not spiny or winged but are covered in fine hair.

Figure 2-26. Steen Mountain thistle. Photos: Eric Coombs (Oregon Department of Agriculture).

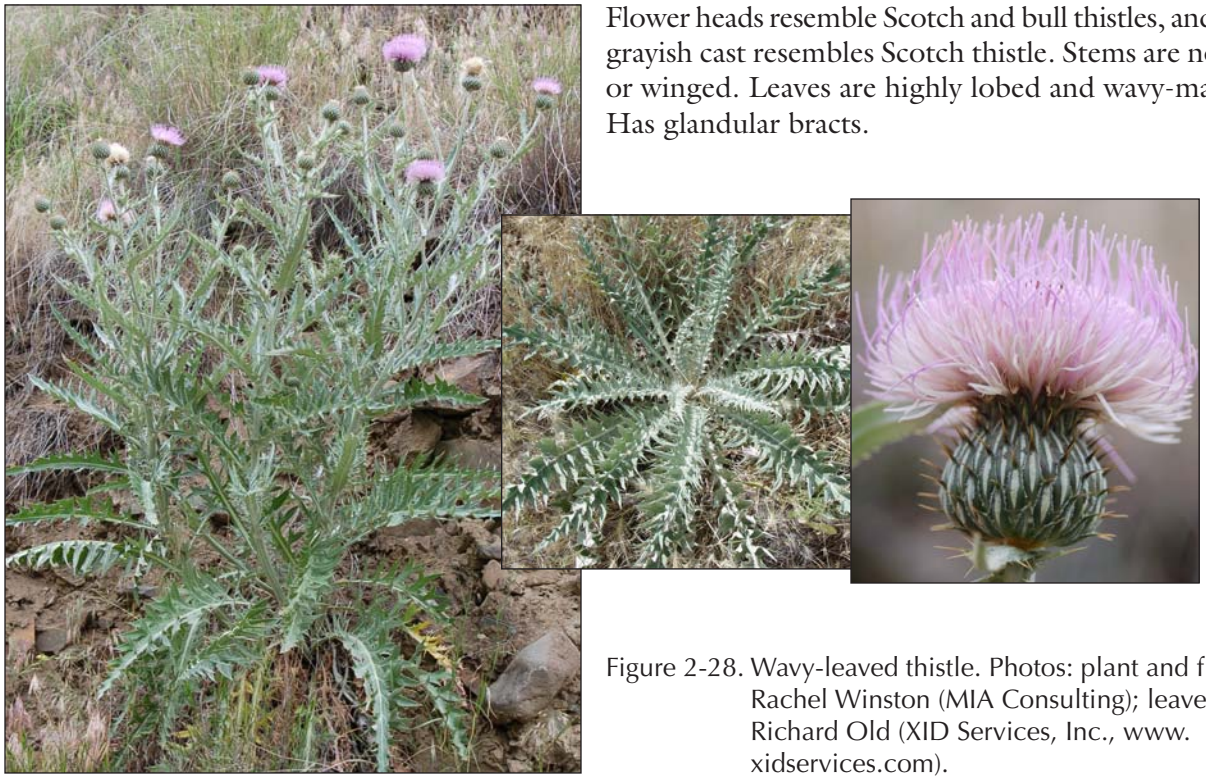
Tall Thistle (*Cirsium altissimum*)



Flower head most closely resembles that of bull and Scotch thistles. Stems are not spiny or winged, and leaves do not have long, woody spines.

Figure 2-27. Tall thistle. Photos: Richard Old (XID Services, Inc., www.xidservices.com).

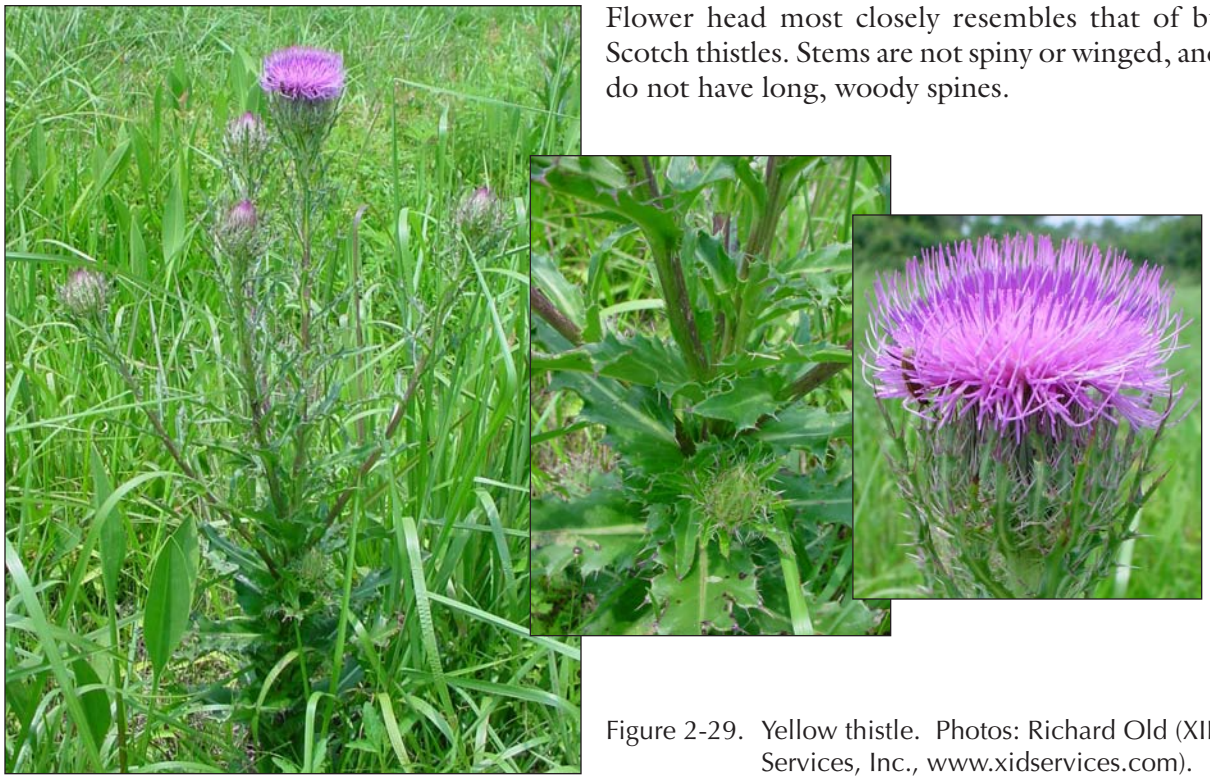
Wavy-Leaved Thistle (*Cirsium undulatum*)



Flower heads resemble Scotch and bull thistles, and overall grayish cast resembles Scotch thistle. Stems are not spiny or winged. Leaves are highly lobed and wavy-margined. Has glandular bracts.

Figure 2-28. Wavy-leaved thistle. Photos: plant and flower, Rachel Winston (MIA Consulting); leaves, Richard Old (XID Services, Inc., www.xidservices.com).

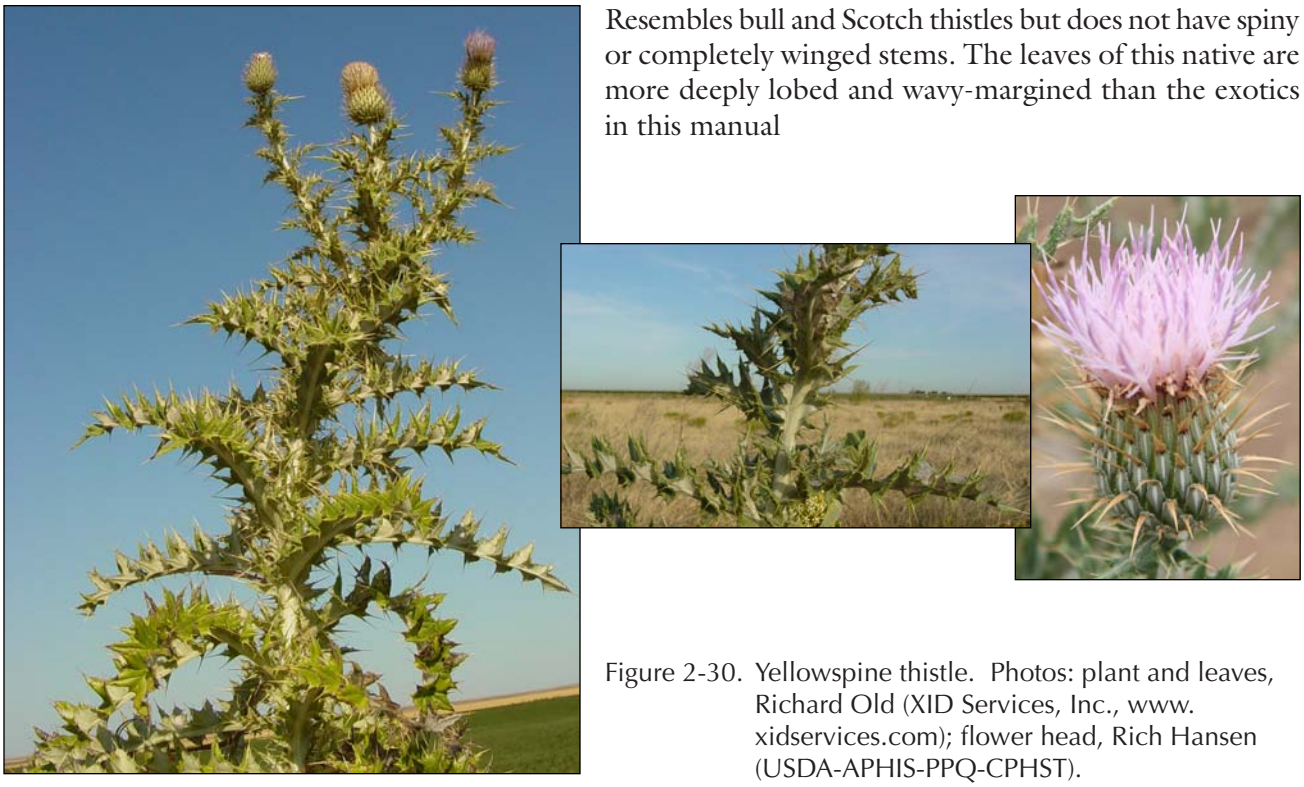
Yellow Thistle (*Cirsium horridulum*)



Flower head most closely resembles that of bull and Scotch thistles. Stems are not spiny or winged, and leaves do not have long, woody spines.

Figure 2-29. Yellow thistle. Photos: Richard Old (XID Services, Inc., www.xidservices.com).

YELLOWSPINE THISTLE (*Cirsium ochrocentrum*)



Resembles bull and Scotch thistles but does not have spiny or completely winged stems. The leaves of this native are more deeply lobed and wavy-margined than the exotics in this manual

Figure 2-30. Yellowspine thistle. Photos: plant and leaves, Richard Old (XID Services, Inc., www.xidservices.com); flower head, Rich Hansen (USDA-APHIS-PPQ-CPHST).

Chapter 3: Biology of Exotic True Thistle Biological Control Agents

Rachel Winston, Eric Coombs, Carol Bell Randall, and Rich Hansen

Biological control of exotic true thistles is one of the oldest classical biological control programs in the United States and Canada. It began in 1969 with the approval and release of the seed head weevil *Rhinocyllus conicus* in Montana and Virginia. Unfortunately, this weevil was later found to attack native thistle species, and its release permit was revoked in the late 1990s. To date, a total of seven insect species are approved for release in the United States and Canada as classical biological control agents of exotic thistles. These include three beetles and four flies. In addition, there are two species of native butterflies (not approved biological control agents) that feed on exotic thistles and a number of accidentally introduced and/or unapproved natural enemies. It is unlikely that any one of the currently established species could successfully control exotic thistles alone. Many exotic true thistle biological control programs use a combination of approved biological control agents that together may sometimes put severe stress on the plant and have a greater chance of contributing to weed suppression.

Basic Insect Biology

Insects are the largest and most diverse class of animals. An understanding of basic insect biology and anatomy will help land managers recognize and identify the insects used as biological control agents of exotic true thistles.

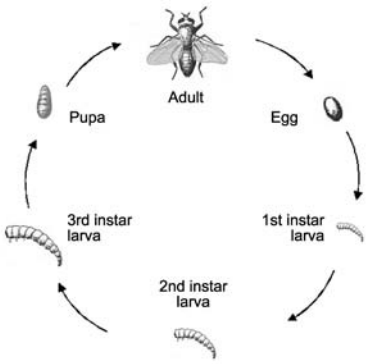


Figure 3-1. Complete metamorphosis. Image: Bugwood.org.

The insects used as biological control agents of thistles have complete metamorphosis, which means they exhibit a life cycle with four distinct stages: egg, larva, pupa, and adult (Figure 3-1). Adult insects have an exoskeleton (a hard external skeleton), a segmented body divided into three regions (head, thorax, and abdomen), three pairs of segmented legs, and one or two pairs of wings (Figure 3-2). The head of the adult insect has one pair each of compound eyes and antennae.

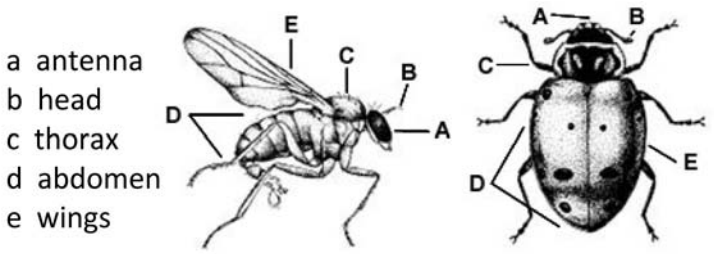


Figure 3-2. Generalized adult insect anatomy. Image: Bugwood.org.

Immature insects have an exoskeleton that must be shed for immature insects to grow to the next stage. The process of an insect shedding its "skin" in order to grow is called molting, and larval stages between molts are called "instars." Larvae generally complete three to five instars before they molt into the pupal stage (Figure 3-3). During the pupal stage, the insect changes from a larva to an adult. Insects do not feed during the pupal stage.

Beetles (Order Coleoptera)

Most adult beetles are hard-bodied with tough exoskeletons. They have two pairs of wings. The two front wings, called elytra, are thickened and meet in a straight line down the abdomen of the adult insect, forming a hard, shell-like, protective covering. The two hind wings are membranous and used for flight. These are larger than the elytra and are folded under the elytra when not in use. Beetle larvae are grub or wormlike with three small pairs of legs. Most are pale white with a brown or black head.

Flies (Order Diptera)

Many insects have the word "fly" in their common name though they may not be true flies. In the common names of true flies, "fly" is written as a separate word (e.g., house fly) to distinguish them from other orders of insects that use "fly" in their common name (e.g., butterfly in the order Lepidoptera and mayfly in the order Ephemeroptera). Adult true flies are easily distinguished from other groups of insects by their single pair of membranous wings and typically small, soft-bodies. Larvae of most true flies are legless and wormlike and are called maggots.

Butterflies and Moths (Order Lepidoptera)

Adult Lepidoptera have two pair of membranous wings, covered (usually completely) by minute powderlike scales. Antennae are prominent. The larvae (caterpillars) have a toughened head capsule, chewing mouthparts, and a soft body that may have hair-like or other projections, three pairs of true legs, and up to five pairs of additional prolegs. The pupal stage is known as a chrysalis or cocoon.

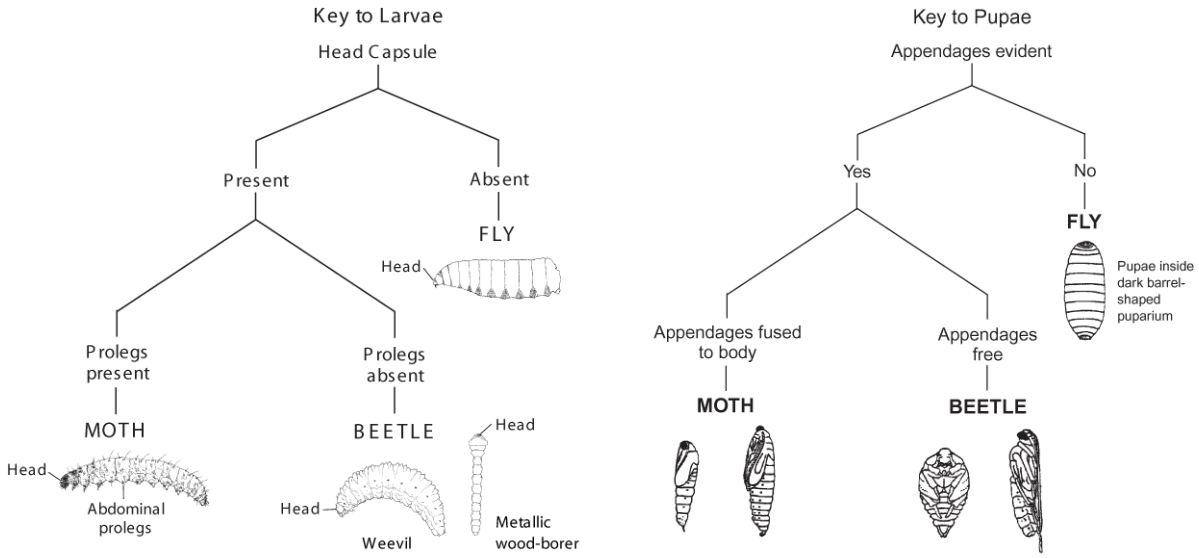


Figure 3-3. Keys to identification of insect larvae (left) and insect pupae (right). Image: Bugwood.org.

Basic Rust Biology (Order Uredinales)

Rusts are plant diseases caused by fungi. Rust diseases typically attack leaves and stems of the host plant. Rust infections usually appear as numerous rusty, orange, yellow, or even white colored spots that rupture the leaf surface. Most rust infections are local spots but some may spread internally through the plant. Rusts spread from plant to plant mostly by windblown spores, although insects, rain, and animals may aide in the transmission and infection process.

The life cycle of rust fungi can be very complicated: the following is a simplified description. Rust fungi produce four distinctive spores: teliospores, basidiospores, aeciospores, and urediospores. Teliospores serve as the overwintering stage of rust fungi; these germinate in spring and, following a number of steps, produce basidiospores. Basidiospores eventually give rise to aeciospores, which in turn give rise to urediospores. Urediospores are frequently the most recognizable stage of rust diseases and are easily blown to other plants to repeat the active cycle or produce teliospores for overwintering. Basidiospores, aeciospores, and urediospores can all attack and infect host plants.

Approved Thistle Biological Control Agents

Seven exotic true thistle biological control species (three beetles and four flies) are permitted for release in the U.S. (Table 3-1). These insects attack six of the nine species of exotic true thistles described in this manual. The remaining three exotic thistles within this manual have no approved biological control agents.

The seven approved biological control agents attack four distinct parts of thistle plants: two of the biological control agents are stem/root miners and gallers, two are seed feeders, one is a bud/leaf feeder, and one is a root crown feeder (Figure 3-4).

Table 3-1. Biological control agents approved for release in the U.S. against exotic thistles. PL= Plumeless thistle, SF= Slenderflower thistle.

Type of Insect	Scientific Name	Established	Thistle Species Attacked						
			Bull	Canada	Italian	Marsh	Musk	PL	SF
Beetle	*Ceutrorhynchus litura*	X		X					
	Psylliodes chalcomera				X		X	X	
	Trichosirocalus horridus	X	X	X	X		X	X	X
Fly	*Cheilosia corydon*	X	X		X	X	X	X	X
	Urophora cardui	X		X					
	Urophora soltitialis						X	X	
	Urophora stylata	X	X						

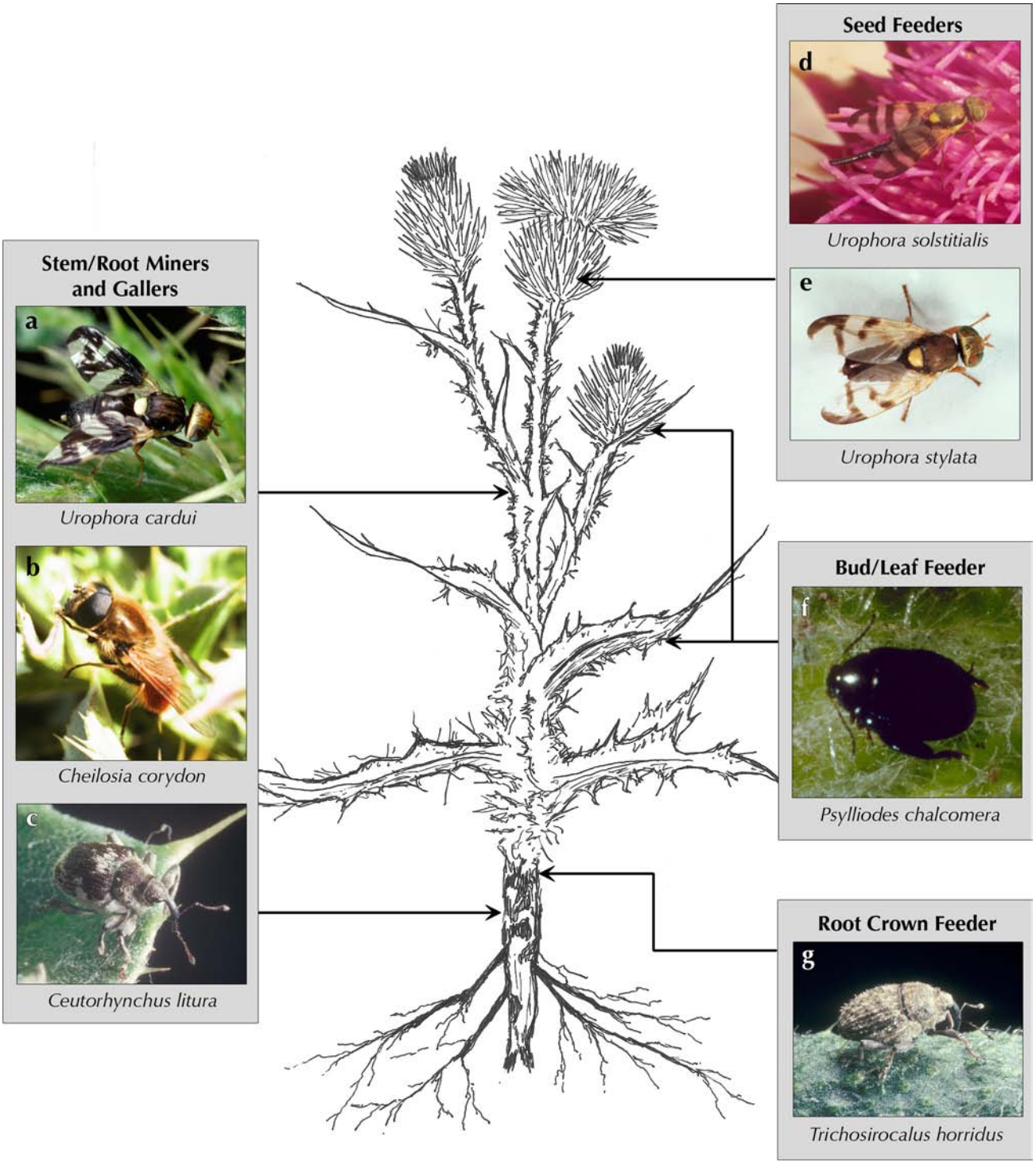


Figure 3-4. General location of attack for approved biological control agents for exotic thistle insects on a thistle plant. Plant drawing: Rachel Winston (MIA Consulting). Photos: a, c, and g, Laura Parsons (University of Idaho); b and d, Eric Coombs (Oregon Department of Agriculture); e, Peter Harris (Agriculture and Agri-Food Canada, Bugwood.org); f, USDA-APHIS, Bugwood.org.

CEUTORHYNCHUS LITURA

Canada thistle stem weevil

Figure 3-5. *Ceutorhynchus litura* adult. Photo: Laura Parsons (University of Idaho).

Order	Coleoptera
Family	Curculionidae
Native distribution	Europe
Original sources	Germany
First U.S. release	1972: Montana
Species attacked	Canada thistle
Nontarget effects	None reported
Establishment	ID, MT, NE, ND, OR, SK, UT, VA, WA, WY

Description

Larvae are white, grub-like, and are pointed in the front end. They complete three instars and measure up to 3 mm (1/8 inch) long at maturity. Adults are mottled black and white with a 'T'-shaped marking on their back. Adults have long snouts and are up to 4 mm (1/6 inch) long.

Life Cycle

Overwintering adults emerge from soil litter and feed on leaf and stem tissue in early spring. Eggs are laid in spring in the mid-vein on the underside of a new rosette leaf. Emerging larvae mine leaf veins, stems, and root crowns of target plants throughout spring and summer. Pupation occurs in the soil; emerging adults overwinter in soil litter. There is one generation per year.

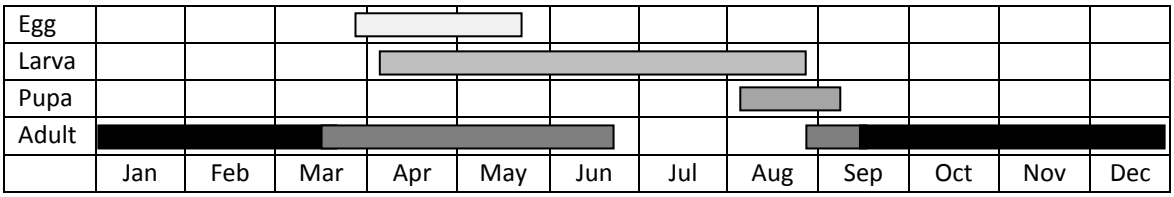


Figure 3-6. Life cycle of *C. litura*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period.

Impact

Larval and adult feeding usually does not significantly impact populations of Canada thistle directly, though some stunting of and stand reduction has been observed in eastern Oregon. Feeding does cause secondary damage as pathogens and other organisms enter the stems of Canada thistle via holes made by exiting larvae. Canada thistle is difficult to control given its ability to reproduce both vegetatively through its roots and by seed. Studies conducted to determine the effectiveness of this insect have shown varying results. Most conclude that impacts on Canada thistle would be greatest if this species were used in conjunction with other biological control agents.

Figure 3-7. *Ceutorhynchus litura* larvae and damage. Photo: Eric Coombs (Oregon Department of Agriculture).

Habitat Preference

This species does well in moist, disturbed areas where Canada thistle is dense and not stressed by drought, grazing, or other control methods.

Availability

This insect is readily available for collection in many states. It is best collected in the adult stage using a sweep net and aspirator during spring when host plants are beginning to bolt.

PSYLLIODES CHALCOMERA

Musk thistle leaf beetle

Figure 3-8. *Psylliodes chalcomera* adult. Photo: USDA-ARS, Bugwood.org.

Order	Coleoptera
Family	Chrysomelidae
Native distribution	Europe and Asia
Original sources	Italy
First U.S. release	1997: Kansas, Maryland, Texas
Species attacked	Italian, musk, and plumeless thistles
Nontarget effects	None reported
Establishment	Not established

Description

Larvae are slender, grub-like, and white with brown head plates. They complete three instars and are up to 3 mm ($1/8$ inch) long at maturity. Adults are small (up to 3 mm or $1/8$ inch long), shiny dark, and with a metallic blue-green sheen.

Life Cycle

Overwintering adults emerge in spring and oviposit at the bases of plants when host plants are bolting or in the soil near host plants. Emerging larvae feed on leaves, buds, and flowers throughout the growing season. Pupation occurs in the soil litter; emerging adults overwinter in soil litter as well. There is one generation per year.

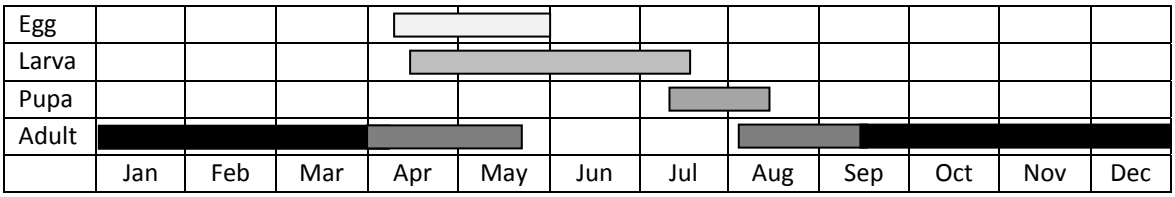


Figure 3-9. Life cycle of *P. chalcomera*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period.

Impact

Larval feeding stunts the growth and reduces the seed production of Italian, musk, and plumeless thistles, decreasing their rates of spread.

Habitat Preference

Little is known about the habitat preferences of *P. chalcomera* beyond the observation that it survives both cold and hot temperatures.

Availability

This species is currently not established in North America despite attempted introductions. Consequently, it is unavailable for redistribution.

Comments

Psylliodes chalcomera is not widespread in its native range; as a result, it has been difficult to collect large enough populations for release and establishment in North America.

TRICHOSIROCALUS HORRIDUS

Musk thistle crown weevil

Figure 3-10. *Trichosirocalus horridus* adult. Photo: Laura Parsons (University of Idaho).

Order	Coleoptera
Family	Curculionidae
Native distribution	Europe
Original sources	Italy
First U.S. release	1974: Virginia
Species attacked	bull, Canada, Italian, musk, plumeless, and slenderflower thistles
Nontarget effects	Other species in the tribe Cardueae might be marginal hosts
Establishment	CO, ID, KS, MD, MO, MT, OR, VA, WA,WY

Description

Larvae are white with dark brown head capsules. They complete three instars and reach up to 3 mm (1/8 inch) at maturity. Adults are small (approximately 4 mm or 1/6 inch long), round, brown with white mottling, have obvious spines on their thorax, and have long snouts.

Life Cycle

Overwintering adults emerge in spring and feed on rosettes of host plants. Eggs are deposited on the undersides of leaves along the midrib and primary veins of young plants. Hatching larvae move down and feed on the tissue at the root-stem junction. Pupation occurs in the soil in early summer. Adults emerge over the summer but are inactive until fall, when they feed superficially on host plant foliage. Adults overwinter in soil litter, emerging again in spring and often living until the next generation of adults begins to emerge. There is only one generation per year.

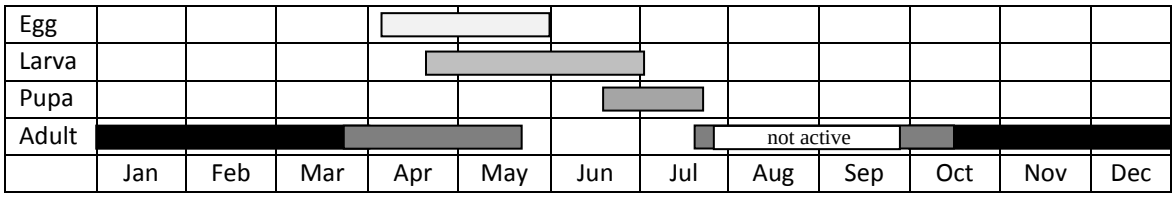


Figure 3-11. Life cycle of *T. horridulus*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period.

Impact

Adult feeding in the spring has minimal impacts, though larval feeding can weaken, reduce the seed production, and alter the growth of bull, Canada, Italian, musk, plumeless, and

slenderflower thistles. This species is most effective in combination with other biological control agents.

Figure 3-12. *Trichosirocalus horridus* larva and damage. Photo: Eric Coombs (Oregon Department of Agriculture).

Habitat Preference

This insect does best in open infestations of the target weed and on the perimeter where stems do not grow as tall. It is widely distributed but does not do as well at high elevations or under marshy conditions.

Availability

This species is eadily available for collection in the western states. Overwintering adults of this species can be hand collected in spring from rosettes of host plants. Alternatively, the summer generation can be collected in the adult stage using a sweep net and aspirator when host plants are flowering.

Comments

Trichosirocalus horridus has been observed feeding (at least in small numbers) on native thistle species. Although it is still approved for redistribution, care should be taken when releasing this agent in the proximity of native thistles.

Populations of this insect build up slowly, taking three to five years. However, once it is well established, this species disperses quite successfully.

Recent taxonomic work with this insect indicates that *T. horridus* is a complex of many species. Weevils released in North America are likely *T. mortadelo*. This weevil is also known as *Ceuthorhynchidius horridus* in the scientific literature.

Because of concerns over host specificity, some states do not recommend releasing this agent. Please check with your state department of agriculture before introducing this agent.

CHEILOSIA CORYDON

Thistle stem hover fly

Figure 3-13. *Cheilosia corydon* adult. Photo: Eric Coombs (Oregon Department of Agriculture).

Order	Diptera
Family	Syrphidae
Native distribution	Europe
Original sources	Italy
First U.S. release	1990: Maryland
Species attacked	bull, Italian, marsh, musk, plumeless, and slenderflower thistles
Nontarget effects	Other species in the tribe Cardueae might be marginal hosts
Establishment	OR

Description

Larvae are tan in color and grub-like, completing three instars and growing up to 19 mm (¾ inch) long. Adults are fuzzy with orange-tan hairs and have large black eyes. Adults can be up to 15 mm (⅝ inch) long, including their wings, and somewhat resemble bees.

Life Cycle

Adults emerge in very early spring and deposit eggs on young leaves as host plants bolt. Larvae soon emerge and mine into shoots and stems. As the season progresses, they mine into roots and continue feeding. Pupae overwinter in roots or in soil litter. There is one generation per year.

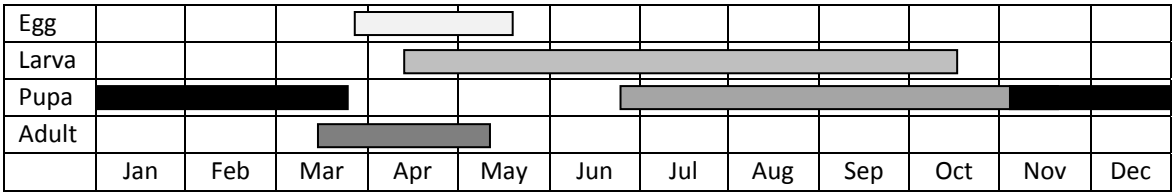


Figure 3-14. Life cycle of *C. corydon*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period.

Impact

Larval mining interferes with plant function and ultimately results in a decrease of seed production, sometimes even death. This insect attacks bull, Italian, marsh, musk, plumeless, and slenderflower thistles.

Figure 3-15. *Chelosia corydon* larval mining damage. Photo: Eric Coombs (Oregon Department of Agriculture).

Habitat Preference

This insect survives a wide array of climatic conditions throughout the range of its host thistles. It tends to do better in areas where host plants flower early.

Availability

This species is available for redistribution in the western states, but is not widespread. Adults can be collected with a sweep net in spring when host plants are beginning to bolt. Alternatively, pupae can be collected and transferred by digging roots in late summer and early fall as the host plants die back with lower temperatures.

Comments

Because emerging adults may need early flowering plants from which to collect nectar, this species may be limited in distribution. This has not been confirmed.

UROPHORA CARDUI

Canada thistle stem gall fly

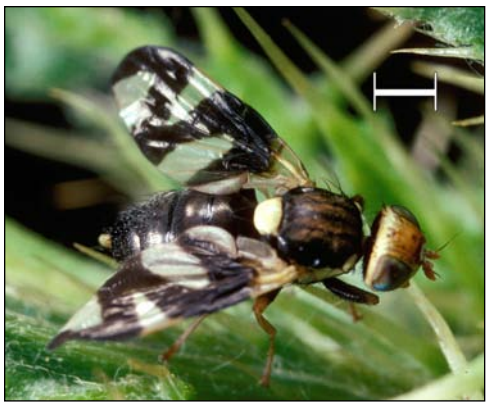


Figure 3-16. *Urophora cardui* adult. Photo: Laura Parsons, (University of Idaho).

Order	Diptera
Family	Tephritidae
Native distribution	Europe
Original sources	Central Europe
First U.S. release	1980 Oregon
Species attacked	Canada thistle
Nontarget effects	None reported
Establishment	CA, MD, MT, NV, OR, VA, WA, WY

Description

Larvae are barrel-shaped, white, and have dark brown anal plates. They complete three instars and can be up to 5 mm (1/5 inch) long at maturity. Adults have dark bodies and dark bands on their white wings that form a 'W'. Adults can be up to 8 mm (1/3) long.

Life Cycle

Larvae overwintering inside galls pupate in early spring. Adults emerge in late spring and early summer when new plants are flowering. Eggs are deposited on plant shoots in axillary buds throughout the summer. Hatching larvae burrow into stems and cause galls to form. There are often multiple larvae in one gall. Larvae overwinter in the third instar, with pupation occurring in early spring as plants start bolting. There is one generation per year.

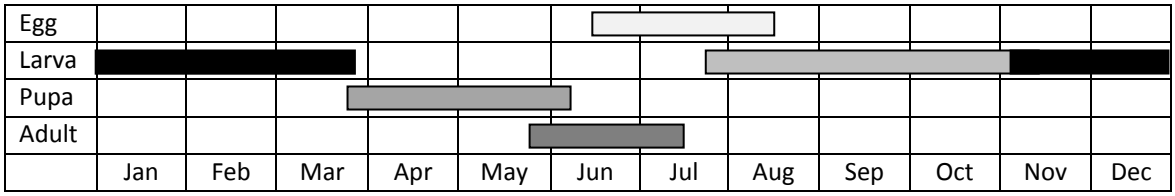


Figure 3-17. Life cycle of *U. cardui*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period.

Impact

Larval feeding causes galls to be formed that act as metabolic sinks, diverting resources away from normal plant development. Attacked plants produce fewer seeds, are less competitive, and may be more susceptible to pathogens and other insects.

Figure 3-18. *Urophora cardui* gall. Photo: Jennifer Andreas (Washington State University Extension).

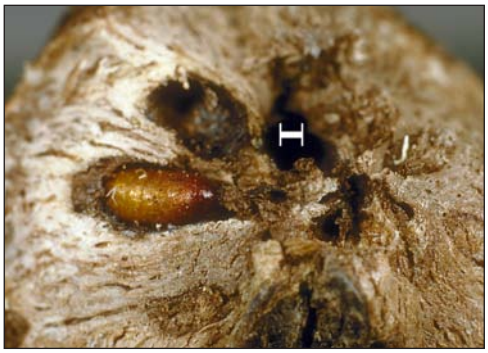


Figure 3-19. *Urophora cardui* pupa in multi-chambered gall. Photo: Norman Rees (USDA-ARS, Bugwood.org).

Habitat Preferences

This fly does well in moist, open and partially shaded areas where Canada thistle is scattered. Areas subject to other means of control (grazing, mowing, chemicaltreatment , etc.) are not suitable for this fly's survival.

Availability

This fly is available for collection, particularly in western Idaho, Oregon, and Washington. *Urophora cardui* is best distributed by collecting galls in fall after the first major frost or from dead stems throughout the winter and very early spring. Galls are then kept cool throughout winter. In spring when host plants begin to grow, galls are transferred to the new site. Alternatively, adults can be reared out in screened cages in early spring or collected with a sweep net and aspirator throughout the spring as Canada thistle is bolting. Rearing insects out of galls has the advantage of preventing the spread of parasitic wasps.

Comments

Galls and/or the larvae within them are often preyed upon by rodents, birds, and an unidentified mite.

UROPHORA SOLSTITIALIS

Musk thistle seed head fly

Figure 3-20. *Urophora solstitialis* adult. Photo: Eric Coombs (Oregon Department of Agriculture).

Order	Diptera
Family	Tephritidae
Native distribution	Europe to Central Asia
Original sources	Italy
First U.S. release	1993: Maryland
Species attacked	Musk and plumeless thistle
Nontarget effects	None reported
Establishment	Not established

Description

Larvae are white and barrel-shaped with a dark brown anal plate. Larvae can be up to 4 mm (1/6 inch) long at maturity and complete three instars. Adults are brownish black with a yellow head and yellow legs. Adults have two black, 'VII'-shaped markings on their wings and can be up to 5 mm (1/5 inch) long.

Life Cycle

Larvae overwintering in galls pupate in early spring. Adults emerge in later spring when plants have bolted. Eggs are deposited in developing seed heads. Hatching larvae feed on seeds and receptacle tissue; hardened galls form around them as they feed. There may be multiple larvae per seed head. Most larvae overwinter in the third instar, but early maturing larvae may pupate in early summer as a second generation. There are up to two generations per year.

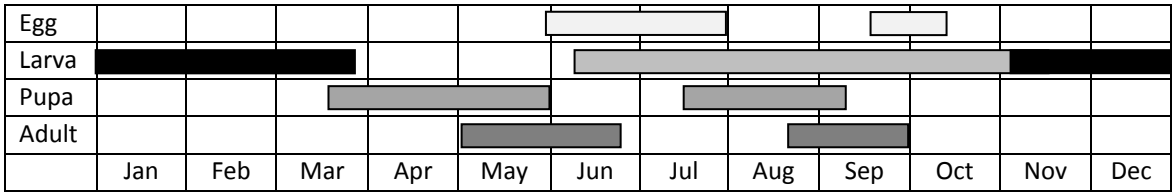


Figure 3-21. Life cycle of *U. solstitialis*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period.

Impact

Larval feeding reduces seed production in musk and plumeless thistles. Galls from larval feeding act as metabolic sinks, diverting resources away from normal plant development.

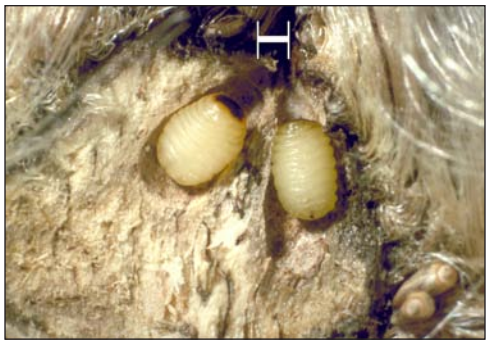


Figure 3-22. *Urophora solstitialis* larvae in a flower head. Photo: Peter Harris (Agriculture and Agri-Food Canada, Bugwood.org).

Habitat Preferences

Site preferences and habitat requirements are unknown.

Availability

This insect's establishment within the United States has not been confirmed, so it is unavailable for collection.

Comments

This fly may be outcompeted by *Rhinocyllus conicus*, an introduced biological control agent against exotic thistles that is no longer approved for re-distribution due to nontarget effects on native thistles.

UROPHORA STYLATA

Bull thistle seed head gall fly

Figure 3-23. *Urophora stylata* adult. Photo: Peter Harris (Agriculture and Agri-Food Canada).

Order	Diptera
Family	Tephritidae
Native distribution	Western Europe
Original sources	Germany and Switzerland
First U.S. release	1983: Washington
Species attacked	Bull thistle
Nontarget effects	None reported
Establishment	CO, MD, OR, WA

Description

Larvae are barrel-shaped, off-white in color, and have dark anal plates. Larvae complete three instars and can reach lengths of 5 mm (1/5 inch) at maturity. Adults are brownish gray with a yellow head and brownish legs. Wings are clear and with a gray-brown 'IV' marking, the 'V' being near the tip of the wing. Adult males can be up to 5 mm (1/5 inch) long while females can be 7 mm (¼ inch) long.

Life Cycle

Overwintering larvae pupate in galls in spring when new plants are bolting. Adults emerge throughout the early summer and deposit eggs on maturing buds. Hatching larvae burrow into seed heads and feed on seed producing tissue, inducing the formation of galls. There may be multiple larvae per seed head. Third instar larvae overwinter within galls. There is one generation per year.

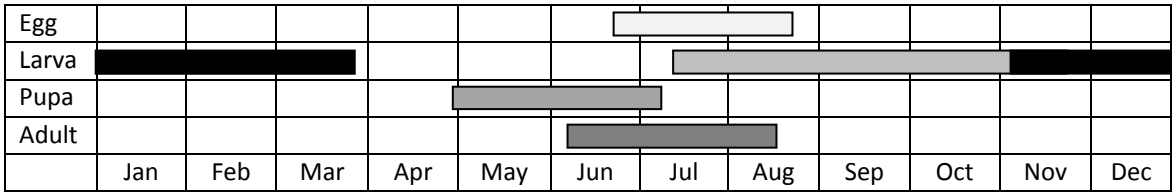


Figure 3-24. Life cycle of *U. stylata*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period.

Impact

Larval feeding reduces seed production in bull thistle. Galls from larval feeding act as metabolic sinks, diverting resources away from normal plant development. Seeds in infested seed heads are physically stuck to gall tissue, thereby reducing dispersal.

Figure 3-25. *Urophora stylata* larvae in a flower head. Photo: Peter Harris (Agriculture and Agri-Food Canada, Bugwood.org).

Habitat Preferences

This insect does best in open meadows with scattered plants. It does not do as well in dense stands of bull thistle. It does not favor sites with flooding and high winds.

Availability

Available for redistributrion in the western states, particularly in Oregon and Washington. *Urophora stylata* galls can be collected from fall through early spring so that adults might be reared out in the spring within screened cages held at room temperature. *Urophora stylata*-infested galls could also be transferred to uninfested sites in spring. Alternatively, adults can be collected with a sweep net and aspirator in spring and early summer when host plants are in bud and flowering.

Comments

Because bull thistle is short-lived, it is difficult to maintain large populations of *U. stylata*.

Native Natural Enemies of Exotic Thistles

There are many native insect species that attack exotic true thistles. Because it is likely that you will occasionally encounter them while monitoring your exotic thistle biological controls, we describe two species here (see Table 3-2). These insects are generalists and should not be collected for redistribution.

Table 3-2. Selected insects native to North America that attack exotic thistles.

Type of Insect	Scientific Name	Thistle Species Attacked			
		Bull	Canada	Marsh	Scotch
Moth	*Platyptilia carduidactyla*	X	X	X	
Butterfly	*Vanessa cardui*	X	X		X

Platyptilia carduidactyla

Artichoke plume moth

Figure 3-26. *Platyptilia carduidactyla* adult. Photo: Jack Kelly Clark (Courtesy University of California Statewide IPM Program).

Order	Lepidoptera
Family	Pterophoridae
Native distribution	North America
Exotic thsitles attacked	Bull, Canada, and marsh thistles

Description

Larvae are orange with black heads and black marks on the last abdominal segments during early instars but turn light yellowish white in later instars. Larvae complete five instars and can reach lengths of 15 mm (5/8 inch) at maturity. Adults are buff to brownish in color, with a wingspan of 32 mm (1¼ inches). Both front and hind wings are divided into lobes, and the hind wings are fringed.

Life Cycle

Adults emerge from overwintering pupal cases and fly to suitable host species prior to plant bolting. Pupation occurs in cocoons on leaves; adults are not long-lived. There are three to four overlapping generations per year; larvae of all generations feed on foliage and stems of thistles. Overwintering is done in the pupal stage within cocoons.

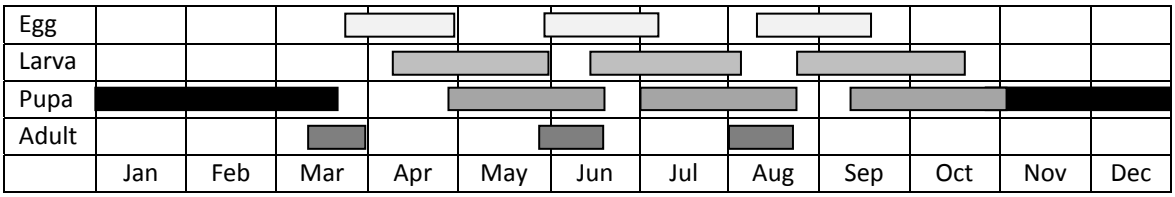


Figure 3-27. Life cycle of *P. carduidactyla*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period.

Impact

This native species can (with sufficient larval feeding) severely impact and prevent attacked plants of bull, Canada, and marsh thistle from flowering. Because the species is native, insect presence and density can vary tremendously. *Platyptilia carduidactyla* is also an economic pest of artichokes.

Figure 3-28. *Platyptilia carduidactyla* larva. Photo: Jack Kelly Clark (Courtesy University of California Statewide IPM Program).

Habitat Preferences

The artichoke plume moth has a wide distribution across North America and can tolerate a variety of climatic conditions.

Availability

Natural populations of this moth should not be augmented.

VANESSA CARDUI

Painted lady butterfly

Figure 3-29. *Vanessa cardui* adult. Photo: Whitney Cranshaw (Colorado State University, Bugwood.org).

Figure 3-30. *Vanessa cardui* larva and pupa. Photo: Eric Coombs (Oregon Department of Agriculture).

Order	Lepidoptera
Family	Nymphalidae
Native distribution	North America
Exotic thistles attacked	Bull, Canada, and Scotch thistles

Description

Larvae are spiny, green to mottled brown, and have a light back stripe and side stripes. They grow through five instars and up to 38 mm (1½ inches) long. The upper wings of adults have an irregular pattern of gold, orange and black marks and white spots near the tips of its forewings. The undersides of the hind wings have a large rosy area and four bluish eye-spots. The wingspan can reach 75 mm (3 inches).

Life Cycle

Adults live year-round in the Southwest of North America. They fly to the Northwest in spring and early summer when plants bolt and flower. Adults lay eggs on the upper leaf surface of host plants. Larvae feed on plant foliage and pupate within a cocoon attached to host leaves. There are two generations per year. Second generation adults migrate back to the southwestern U.S. in fall.

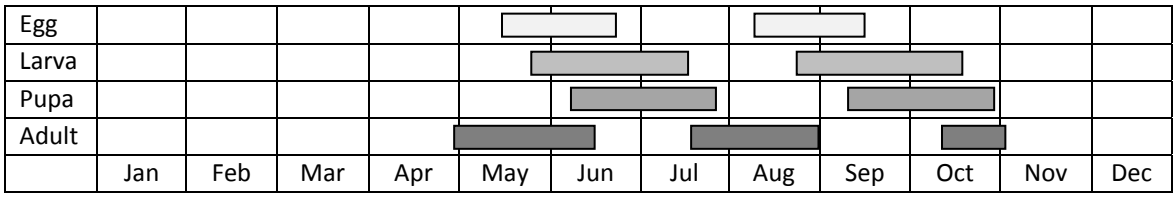


Figure 3-31. Life cycle of *V. cardui*. Bars indicate the approximate length of activity for each of the life stages. This species does not overwinter in the Northwest.

Impact

Swarms of this native species can rapidly defoliate patches of bull, Canada, and Scotch thistles, though plants are often able to recover. Because the species is native, insect presence and density can vary tremendously. Larvae also feed on sunflowers and other crop and native plants. At irregular intervals, mass migrations of adult painted lady butterflies from southern to northern states can occur in late spring or early summer. When mass migrations occur, subsequent larval populations on thistles and other plants can be quite high.

Figure 3-32. *Vanessa cardui larva* and damage. Photo: Whitney Cranshaw (Colorado State University, Bugwood.org).

Habitat Preferences

The painted lady butterfly has a wide distribution across North America and can tolerate a variety of climatic conditions.

Availability

Natural populations of this native insect should not be artificially supplemented.

Unapproved and Adventive Natural Enemies of Exotic Thistles

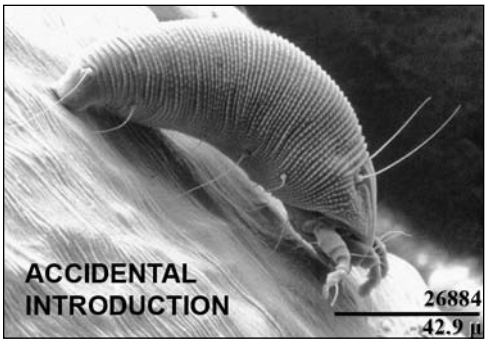
Numerous species attack exotic thistles throughout North America in addition to the ones already described. Unfortunately, some of these additional species were either unintentionally introduced or were intentional releases that attacked native thistles and so were not approved for interstate shipment. Most of these species are well established throughout the range of their host plants. It is important to be able to recognize these species to avoid collecting and redistributing them along with approved biological control agents.

Table 3-3. Thistle biological control agents and adventive natural enemies present in North America but not approved. PL= plumeless thistle, SF= slenderflower thistle.

Type of Agent	Scientific Name	Thistle Species Attacked								
		Bull	Canada	Italian	Marsh	Milk	Musk	PL	Scotch	SF
Beetle	*Cassida rubiginosa*	X	X							
	Cleonis pigra	X	X	X	X	X	X	X	X	X
	Larinus planus	X	X		X					X
	Rhinocyllus conicus	X	X	X		X	X	X	X	X
Fly	*Terellia ruficauda*		X							
Mite	*Aceria anthocoptes*		X							
Rust	*Puccinia carduorum*						X			
	Puccinia punctiformis		X							

ACERIA ANTHOCOPTES

Canada thistle rust mite



Order	Acari
Family	Eriophyidae

Figure 3-33. *Aceria anthocoptes*. Photo: Eric Erbe (USDA-ARS).

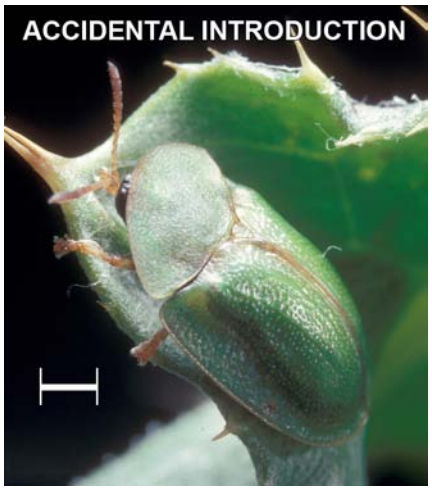
Description and Biology

Mites appear on Canada thistle foliage in the spring when rosettes begin to bolt and are present until plants die back in the fall. Nymphs and adults are white, tan, pink, or yellow, depending on the developmental stage. They are extremely small (0.15-0.20 mm long) and are visible only under a microscope. Females exist in reproductive (summer) and overwintering forms. Canada thistle rust mites feed by sucking out the contents of leaf cells. These mites have multiple generations per year and likely overwinter on roots or root buds.

While never approved as biological control agents, mite populations have recently been found throughout the U.S., suggesting one or more accidental introductions. Significant damage to Canada thistle is rarely if ever seen in the field. Eriophyid mites have also been collected from native *Cirsium* thistles, but it is not yet known if these are *A. anthocoptes* or another, unknown mite species.

CASSIDA RUBIGINOSA

Thistle tortoise beetle



Order	Coleoptera
Family	Chrysomelidae

Figure 3-34. *Cassida rubiginosa* adult. Photo: Laura Parsons (University of Idaho).

Description and Biology

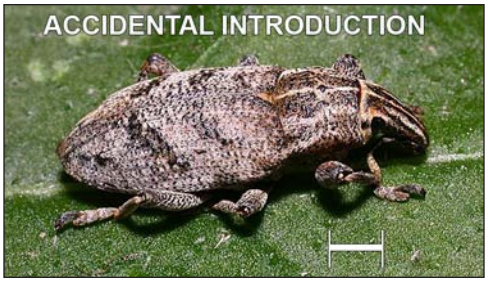
Adults are green, oval, and have black undersides. They can be up to 7.5 mm (1/3 inch) long and have a hard covering over their bodies resembling the shell of a tortoise. Overwintering adults emerge in early spring and feed on new foliage.

Eggs are deposited in spring and summer. Larvae are green, grow to 6 mm (¼ inch) long, and complete five instars. They have spines on their margins and a forked tail spine on which they accumulate molted skins and waste to serve as a protective parasol. Larvae pupate in late summer; pupae are brown, oval-shaped, and have black spikes along their margins. Young larvae feed on the undersides of new leaves, leaving a thin layer of leaf tissue ("window feeding"), while older larvae make irregular feeding holes from the top sides of leaves. Adults emerge and feed on young foliage until late fall and then overwinter in soil litter. There is one generation per year.

This species can significantly damage exotic thistle populations. However, it was an accidental introduction and is not a permitted biological control agent. It feeds on a wide array of plant species within the Cardueae, many of which are native or of economic importance in North America.

CLEONIS PIGRA

Stem-base weevil



Order	Coleoptera
Family	Curculionidae

Figure 3-35. *Cleonis pigra* adult. Photo: Ivo Tosevski (CAB International).

Description and Biology

Adults are oval-shaped and a mottled brown color. Their thorax and front part of the elytra have many shiny black lumps. Their wide snouts have two ridges on either side of a central groove. These weevils can be up to 7 mm (¼ inch) long. Overwintering adults emerge in spring and feed on young leaves.

Eggs are deposited about one month after emergence, with larvae hatching throughout summer. Larvae bore to the stem base of their target plant, where they feed internally. They are white with a brown head and are grub-like. Larvae complete four instars and are up to 3 mm ($^1/_8$ inch) long at maturity. Pupation occurs in soil litter near the base of host plants during late summer. Adults emerge throughout fall and then overwinter in soil litter. There is one generation per year.

This species was an accidental introduction. It feeds on a wide array of plant species within the Cardueae, many of which are native or of economic importance in North America. It does little damage to exotic thistles.

LARINUS PLANUS

Canada thistle stem weevil

Order	Coleoptera
Family	Curculionidae

Figure 3-36. *Larinus planus* adult. Photo: Alec McClay (McClay Ecosciences, Bugwood.org).

Description and Biology

Adults are elongate and have black bodies with mottled tan or yellow hairs and long snouts. Adults can be up to 8 mm ($^1/_3$ inch) long. Overwintering adults emerge in early spring and feed on young foliage near shoot tips as plants begin to bolt. Feeding damage results in holes within leaves and deformed bracts and seed heads.

Eggs are deposited inside developing flower buds in spring. Larvae feed on developing seeds and receptacle tissue throughout the summer. Larvae are white and grub-like, complete three instars, and can be up to 5 mm ($^1/_5$ inch) long. Pupation occurs within the seed head; adults emerge in late summer and early fall and overwinter in soil litter. There is one generation per year.

This species was an accidental introduction. It feeds on many native thistle species.

PUCCINIA CARDUORUM

Musk thistle rust

Order	Uredinales
Family	Pucciniaceae

Figure 3-37. *Puccinia carduorum*. Photo: USDA-ARS, Bugwood.org.

Description and Biology

This fungus has five stages in its life cycle and produces four types of spores. Teliospores are the overwintering stage of the musk thistle rust and can withstand freezing temperatures. These germinate in spring and produce basidiospores, which infect musk thistle plants in the early rosette and bolting stages. Aeciospores and urediospores are then produced. Urediospores are the most characteristic spore: they are gold brown, flat, round, and tiny (25 µ in diameter). The spore surface is covered with short spines. Spores occur in mass clusters (pustules) on infected leaves; pustules are reddish brown and powdery. Urediospores are easily blown to uninfected plants to repeat the cycle, a process that takes two weeks to complete. When host plants die back in the fall, the fungus produces teliospores in preparation for winter.

This species was purposely introduced throughout North America although it is not currently approved for general release. It is now widespread. Infected musk thistle plants experience stunted growth, a reduced seed production, and a higher susceptibility to interspecific competition and attack from additional biological control agents. It is easily spread by some thistle biological control insects.

PUCCINIA PUNCTIFORMIS

Canada thistle rust

Order	Uredinales
Family	Pucciniaceae

Figure 3-38. *Puccinia punctiformis*. Photo: Malcolm Storey (www.bioimages.org.uk).

Description and Biology

This rust occurs in four types of spores: overwintering teliospores, basidiospores. aeciospores, and urediospores. In the spring, Canada thistle root volatiles stimulate the teliospores to germinate and produce basidiospores. Aeociospores are then produced in a scented, sweet, sticky nectar that attracts flies to disperse spores of opposite mating types. Resulting urediospores form densely packed brown pustules on upper leaf surfaces that are easily blown to uninfected plants to repeat the cycle. There are many generations per year. When host plants die back in the fall, the fungus produces teliospores in preparation for winter.

This species was accidentally introduced to North America and is now widespread throughout the U.S. and Canada. It is not approved for redistribution. This rust can stunt the growth of young Canada thistle but does not provide significant control. It is easily spread by some thistle biological control insects.

RHINOCYLLUS CONICUS

Thistle seed head weevil

Order	Coleoptera
Family	Curculionidae

Figure 3-39. *Rhinocyllus conicus* adult. Photo: Laura Parsons (University of Idaho).

Description and Biology

Adults are dark brown or black with yellowish tufts of hair giving them a mottled appearance in spring. Overwintering adults emerge in early spring and deposit eggs on bracts of thistle flowers in late spring. Adult feeding leaves pits on stems and holes in leaves. Oviposition leaves bracts brown with bumps of chewed plant tissue. As they age, adults lose some of these hairs and turn brownish black. They can be up to 6 mm (¼ inch) long and have shorter snouts than *Larinus planus.*

Larvae hatch in spring and early summer. They burrow into seed heads and feed on receptacle tissue and developing seeds. Larvae are white with brown head capsules, complete four instars, and reach up to 4 mm (1/6 inch) long. Pupation occurs within the seed heads in late summer as seeds mature. Adults emerge for a brief time before overwintering in sheltered areas. There is one generation per year.

This weevil was originally approved for release in North America against exotic thistles, aiding the control of Italian and musk thistles. It is by far the most common insect found on Italian and musk thistles, often with several larvae attacking (and severely damaging) a single capitulum. However, after establishment, it was soon discovered feeding on a large number of native thistles even in the presence of its exotic hosts. Consequently, its interstate shipment permits were revoked.

TERELLIA RUFICAUDA

Canada thistle seed head fly

Order	Diptera
Family	Tephritidae

Figure 3-40. *Terellia ruficauda* adult. Photo: Peter Harris (Agriculture and Agri-Food Canada).

Description and Biology

Adults are yellow-orange with a black mark on the thorax and four large black marks that make the abdomen appear mostly black. Their wings have three black marks along the leading margins and fainter mark near the center of the hind margins. Adult flies are about 5 mm (1/5 inch) long. Adults emerge from overwintering pupae in early spring as plants begin to bolt.

Eggs are laid in immature female seed heads; larvae feed on developing seeds and receptacle tissue. They are white and grub-like, complete three instars, and are up to 6 mm (¼ inch) long at maturity. Just before seeds begin to disseminate, larvae form cocoons of tangled pappus hairs in which they overwinter. Pupation occurs in spring, and there is one generation per year.

This species was an accidental introduction. Its host range in North America has not been tested, but in Europe it feeds on many thistle species in the genus *Cirsium*. It does little or no damage to exotic thistle species in North America.

Chapter 4: Elements of an Exotic True Thistle Biological Control Program

Rich Hansen and Rachel Winston

Exotic thistles are difficult to control with any method, including biological control. When biological control agents are available against a particular exotic thistle, the level of control achieved may vary greatly from site to site due to varying conditions. Land managers need to develop biological control programs that address management conditions and objectives unique to their area. The following steps can help in this endeavor.

Defining Your Goals and Objectives

Defining your weed management goals and objectives is the first and most important step in developing a biological control program. By defining what you want to achieve, you will be able to determine if, when, and where you should use biological control.

The first thing to do is define as precisely as possible what will constitute a successful exotic thistle management program. For example, the goal of "a noticeable reduction in exotic thistle density over the next 10 years" might be achievable, but "a 50 percent reduction in exotic thistle stems over the next three years" is a more precise and measurable goal.

Biological control might be an appropriate exotic thistle weed management tool if your goal is to reduce the abundance of exotic thistles. However, by itself, biological control will not eradicate exotic thistles from the landscape. If your goal is to eradicate exotic thistles, then you should plan to employ other weed control techniques in addition to biological control (see Chapter 5 for more details).

Taking Stock: Your Infestation and Your Options

Before embarking on exotic thistle management activities, you should understand the scope of your exotic thistle problem, identify areas of special concern, and review and understand all weed management tools at your disposal.

Your first step should be to develop a distribution map of each species of exotic thistle at a scale that will allow you to address the exotic thistle problem in a manner consistent with your land-management objectives and your weed management resources. For example, in large management areas with significant exotic thistle infestations and limited resources, aerial mapping of large patches of exotic thistles may be sufficient to identify priority areas for additional survey and weed management activities (Figure 4-1a). In other management areas with small, discrete exotic thistle patches or where an exotic thistle infestation affects your ability to meet management objectives, intensive mapping and characterization of exotic thistle infestations (e.g., species of exotic thistle, location, size, density, and cover) may be necessary to develop an appropriate weed management strategy (Figure 4-1b).

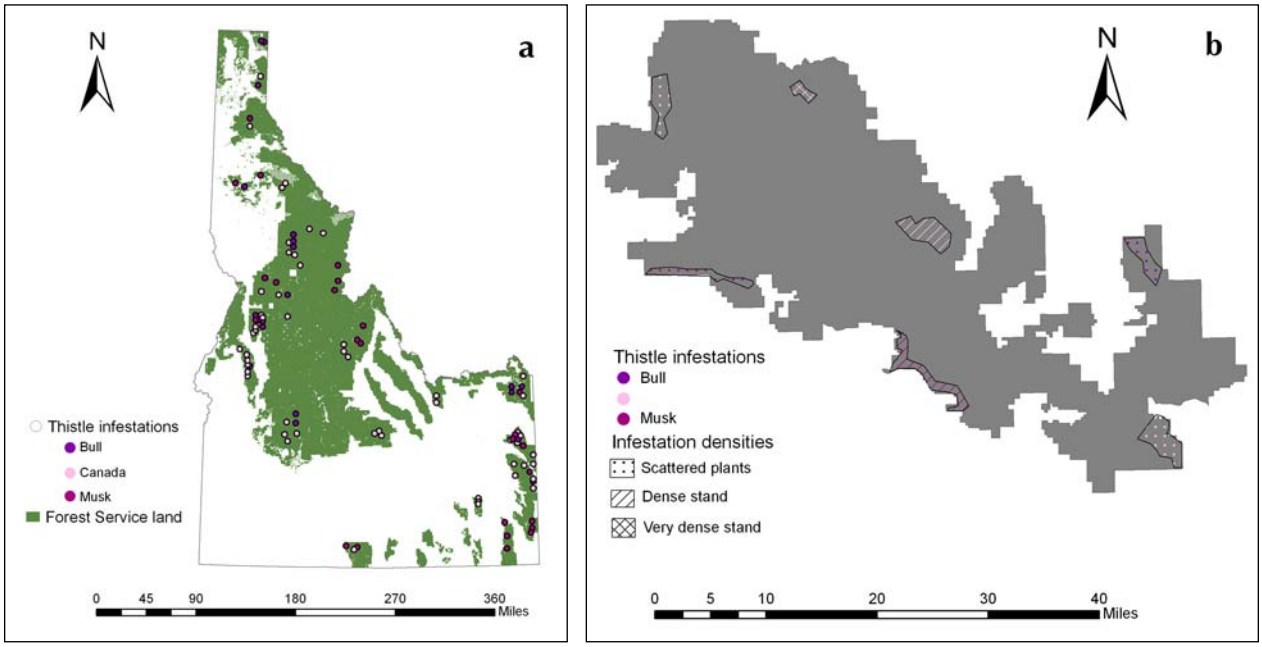


Figure 4-1. Hypothetical weed infestation maps for a) Idaho Forest Service land and b) Snake River Birds of Prey National Conservation Area.

Review the exotic thistle management tools available (Chapter 5)—including use of herbicides, mechanical treatments, cultural practices, and biological control—and determine the conditions (when, where, if, etc.) under which it might be appropriate to use each tool or combination of tools. Consult your agency or university biological control expert, cooperative weed management area, or county weed coordinator/supervisor to learn about other exotic thistle management activities, underway or planned, in your area and the level of control that might be achieved by each.

Identify the resources that will be available for weed management activities, and determine if these resources will be consistently available until you meet your weed management program objectives. If resources are not available, identify what will happen at the treatment site if the activities are not implemented.

With a map of each species of exotic thistle in your management area, an understanding of your land management objectives, and a list of the weed management tools available and the level of control you can realistically expect from each, you can identify the sites where biological control would be a good fit.

Developing, Implementing, and Managing a Biological Control Program

Important factors to consider when planning your exotic thistle biological control program include selecting appropriate release sites, obtaining and releasing insects, and monitoring the success of the program. These items are discussed below. If problems are encountered following the initiation of a biological control program, refer to the troubleshooting guide in Appendix I for potential responses.

Before You Begin

There is a fair amount of preliminary work to do before you can implement a biological control release program. Some factors to address include:

- Many biological control programs do not result in visible weed reduction for a number of years (typically, at least three to five years). Make sure that you can make a long-term commitment to the program.
- Decide how long you can let biological control activities continue if weed control goals are not being met.
- Discuss your biological control program plans with neighboring landowners and land managers. Ask local weed managers about their experiences with biological control. Determine which agents they have used, alone or in combination with other weed control tools, and what level of control they achieved. Would their level of control be acceptable for your management area? Talk to neighboring managers about any activities, such as herbicide use, grazing, or mowing programs they have planned on their land. These measures could have a direct impact on your proposed biological control activities.
- Set short- and long-term goals. For example, a short-term goal might be to release and determine establishment of biological control agents; a long-term goal might be to reduce exotic thistle density by 50 percent within 10 years.
- Determine what resources will be consistently available for 5 to 10 years for implementing, monitoring, and assessing your biological control program. These include:
  - Commiting resources for field equipment and supplies,
  - Recruiting and train personnel, and
  - Identifying sources of biological control agents.

Selecting Biological Control Agent Release Sites

Establish goals for your release site. The overall management goals for a given site must be considered when evaluating its suitability for the release of biological control agents. Additional factors must be evaluated even after deciding that biological control is appropriate for a given site. Suitability factors will differ, depending on whether the release is to be:

- A general release, where agents are simply released for exotic thistle management,
- A field insectary (nursery) release, primarily employed for production of biological control agents for distribution to other sites, or
- A research release, used to document biological control agent biology and/or the agent's impact on the target weed and nontarget plant community.

A site chose to serve one of the roles listed above may also serve additional functions over time (e.g., biological control agents might eventually be collected for redistribution from a research release).

Identify site characteristics. Consider accessibility, slope, and cover. Generally, all exotic thistle biological control agents do best on warm, sunny sites. Areas with a flat topography or a south-facing exposure are preferable to cooler, north-facing sites. Areas with an abundance of shade should be avoided; eventually, some agents might colonize shaded sites, but usually only after becoming established in adjacent, unshaded areas. Favorable biological control agent sites are generally not overly moist. Loamy soils are preferable to high clay or sand soils, especially for root-feeding insects: invasive thistles tend to prefer loamy soils as well, though many can grow under a variety of conditions.

For practical purposes, an exotic thistle infestation cannot be too large for biological control releases; however, it might be too small. Small, isolated patches may not allow biological control agent populations to build up and persist and may be better suited for other weed control tactics, such as herbicide applications. An area with at least 1 acre (0.40 hectares) of exotic thistles might be considered as a minimum release site size, but a larger area of infestation is more desirable, especially for field insectaries (Figure 4-2). Infestations should be contiguous; relatively uniform weed populations are preferable to scattered patches over a given area. Most thistle biological control agents do best in a moderately dense area of infestation.

Note land use and disturbance factors. Preferred release sites are those that experience little to no human (or other) disturbances. Fallow sites and natural areas are good choices for biological control agent releases. If a site must be disturbed (e.g., mowed or grazed), the activities should not take place during the spring and summer months when most biological control agents are active above ground. Sites where insecticide use is routine should not be used for agent releases. Such sites include those near wetlands that are subject to mosquito control efforts, where grasshopper

Figure 4-2. Canada thistle infestation suitable for a biological control program. Thistles are in the foreground and middle ground. Photo: Mark Schwarzländer (University of Idaho).

outbreaks routinely require chemical control, or near agricultural fields that receive regular insecticide sprays. Avoid sites prone to seasonal flooding. Do not use sites where significant conversion will take place, such as road construction, cultivation, building construction, and mineral or petroleum extraction. Do not use sites where burning practices occur regularly.

Survey for presence of biological control agents. Examine your prospective release sites to determine if one or more exotic thistle biological control agent is present. If an agent you are planning to release is already established at a site, you can release it at that site to augment the existing population, but it may be better to release it at another site. You should re-evaluate the release of the planned species if a different species of biological control agent is present.

Record ownership and access. In general, release sites on public land are preferable to sites on private land. If you must release biological control agents on private land, it is a good idea to select sites on land likely to have long-standing, stable ownership and management. Stable ownership will help you establish long-term agreements with a landowner, permitting access to the sites to sample or harvest biological control agents and collect insect and vegetation data for the duration of the project. This is particularly important if you are establishing a field insectary site because five years or more of access may be required to complete insect harvesting or data collection. General releases of biological control agents to control exotic thistle populations require less-frequent and short-term access; you may need to visit such a site only once or twice after initial release. If you are releasing insects on private land, it may be a good idea to obtain the following:

- Written permission from the landowner or land manager allowing use of the area as a release site,
- Written agreement by the landowner allowing access to the site for monitoring and collection for a period of at least six years (three years for establishment and buildup and three years for collection), and
- Permission to put a permanent location marker at the site.

You may wish to restrict access to release locations, especially field insectaries and research sites, and allow only authorized project partners to visit the sites and collect insects or plants. The simplest way to accomplish this would be to select only locations that are not visible to, or accessible by, the general public. Being practical, most if not all of your sites will be readily accessible, so in order to restrict access you should formalize arrangements with the landowner or public land manager. These formalities will involve such things as posting trespassing restrictions, installing locks on gates, etc.

Another consideration is the physical access to a release site. You will need to drive to or near the release locations, so determine if travel on access roads might be interrupted by periodic flooding or inclement weather. You might have to accommodate occasional road closures by private landowners and public land managers for other reasons, such as wildlife protection.

Choosing the Appropriate Biological Control Agents for Release

You should consider several factors when selecting biological control for release at a site, including agent efficacy, availability, and site preferences (Table 4-1).

Agent efficacy. Efficacy means the ability of the agent to directly or indirectly reduce the population of the target weed below acceptable damage thresholds or cause weed mortality resulting in control. Most of the available data on efficacy is anecdotal, observational, or based on limited experimental data. The potential efficacy of several agents that are not established in the U.S. is not known.

It is preferable to release only the most effective biological control agents rather than releasing all agents that might be available against a target weed. Consult with local weed biological control experts, neighboring land managers, and landowners to identify the agent(s) that appear more effective given local site characteristics and management scenarios.

Agent availability. Several exotic thistle biological control agents do not have established, collectable populations in the U.S. and are not available for distribution. Among established agents, readily available insects likely have several collectable populations in all states with exotic thistle infestations. These insects should be easy to obtain from intrastate and local sources. Exotic thistle agents with limited availability are likely to have collectable populations only in some states, and depending on the exact locations, might not be easily accessible. Federal agencies and commercial biological control suppliers may be able to assist you in acquiring exotic thistle agents that are not available

Table 4-1. Summary of general characteristics and site preferences of exotic thistle biological control agents released in the United States (through 2007).

Agent Characteristics			Release Site Characteristics		
Scientific Name	**Plants Attacked**	**Efficacy**	**Availability**	**Favorable Conditions**	**Unfavorable Conditions**
Ceutrorhynchus litura	Canada thistle	Low alone	Readily available	Moist, disturbed sites with dense thistle stands	Dry areas and where host thistle is stressed by drought, grazing, and other control methods
Psylliodes chalcomera	Italian, musk, plumeless, and slenderflower thistles	Moderate	Not established in North America	Little known; can survive both hot and cold climates	Unknown
Trichosirocalus horridus	Italian, musk, and plumeless thistles	Low alone	Readily available	Open sites on perimeter where thistle plants are not as tall	Marshy conditions or high elevations
Cheilosia corydon	bull, Italian, musk, plumeless, and slenderflower thistles	Moderate	Available in the West but not widespread	Does well under a variety of circumstances; best at early-flowering sites	Late-blooming thistle patches
Urophora cardui	Canada thistle	Moderate	Readily available	Moist, partially shaded sites with scattered thistle plants	Where host thistle is stressed by drought, grazing, and other control methods; sites where *R. conicus* is established
Urophora soltitialis	musk and plumeless thistles	Low alone	Not established in North America	Unknown	Unknown
Urophora stylata	bull thistle	Moderate	Readily available	Open meadows with scattered plants	Dense stands; sites with flooding or high winds

in your state (see Obtaining and Releasing Exotic Thistle Biological Control Agents, below). County weed managers, extension agents, or federal and university weed or biological control specialists should be able to recommend in-state sources for various exotic thistle biological control agents.

Release site characteristics. General physical and biological site preferences for each agent have been developed from anecdotal observations and experimental data. As noted above, most exotic thistle biological control agents seem to prefer exotic thistle stands of moderate density. Such sites also have well-drained, loamy soils, a medium to dry moisture regime, and level ground or south-facing slopes (Figure 4-3).

Figure 4-3. Typical musk thistle release site. Photo: Mark Schwarzländer (University of Idaho).

Obtaining and Releasing Exotic Thistle Biological Control Agents

You can obtain exotic thistle biological control agents either by collecting them yourself, having someone collect them for you, or by purchasing them from a commercial supplier. Typically, the last two methods will require packaging and shipping form the collection site to your release location (see Collecting Exotic Thistle Biological Control Agents, page 94). Be sure to only release approved biological control agents.

Here are factors to consider when looking for sources of biological control:

- You do not need to take a "lottery approach" and release all types of biological control agents at a site and hope that one of them will work. In fact, some biological control agents will not be available even if you want them, and some have shown to have little or no effectiveness even after released. The best strategy is to release the best agent! Ask the county, state, or federal biological control experts in your state for recommendations of agents for your particular region.

- If available, biological control agents from local sources are best. Using local sources increases the likelihood that agents are adapted to the abiotic and biotic environmental conditions present and are available at appropriate times for release at your site. Local sources may include neighboring properties or other locations in your county and adjacent counties. Remember: Interstate transport of biological control agents requires a USDA-APHIS-PPQ permit (see Regulations Pertaining to Exotic Thistles on page 99). Get your permits early to avoid delays.
- Some states, counties, and universities have "field days" at productive insectary sites. On these days, land managers and landowners are invited to collect or receive freshly collected exotic thistle biological control agents for quick release at their sites. These sessions are an easy and often inexpensive way for you to acquire biological control agents. They are good educational opportunities as well, because you can often see first-hand the impacts of various agents on exotic thistles and plant communities.

Figure 4-4. Participants in a field day in New Mexico, receiving information about musk thistle control and distribution of biological control agents. Photo: Mark Schwarzländer (University of Idaho).

Typically, field days are conducted at several sites in a state and on several dates during the summer. Although designed primarily for intrastate collection and distribution, out-of-state participants may be welcome to participate. (Remember that USDA permits are required for interstate movement and release of biological control agents.) Contact county weed supervisors, university weed or biological control specialists, or federal weed managers for information about field days in your state and/or adjacent states.

Collecting Exotic Thistle Biological Control Agents

Planning and timing of collection is critical. The species of biological control agent, the species of exotic thistle, and weather characteristics at your collection site will determine the best time in the season to collect. Ensure that all necessary collection supplies are on hand. Also, accurate identification of the biological control agents is essential, especially given the large number of unapproved biological control agents established in the U.S. General guidelines for collecting exotic thistle biological control agents are listed in Table 4-2. For all species, collect only on a day with good weather; insects are usually not active in rainy and very windy conditions.

Beetles. Beetles are best collected in the adult stage. Adults of *Ceutorhynchus litura* can be collected with a sweep net and aspirator during spring when host plants are bolting. Adult *Trichosirocalus horridus* are best collected after emerging from overwintering: this is done by hand-picking these weevils from among the rosette leaves of their host thistle plant.

Flies. Sweeping adult seed head flies is possible, though this is not always the best stage for collection. Adult flies are fragile and can be damaged during collection. Gathering heads and stem galls infested with larvae or pupae is the least-damaging way to collect and redistribute flies. If adults are to be collected, all exotic thistle fly species can be collected with a net and aspirator. For example, *Cheilosia corydon* in spring as host plants bolt and *Urophora cardui* and *Urophora stylata* in summer as host plants flower. Alternatively, *U. cardui* stem galls and *U. stylata* seed head galls may be collected in late fall or early spring and held in a screened cage or container and kept at room temperature until adult flies emerge in the spring. Freshly-emerged adults can then be collected and distributed for field release.

Sweep net. A sweep net is made of cotton or muslin on a hoop 10 to 15 inches in diameter (25 to 38 cm) attached to a handle 3 feet (0.9 m) long (Figure 4-5). As its name implies, it is used to "sweep" insects off the exotic thistles. A sweep is made by swinging the net through the plant canopy. It is relatively easy and efficient, though one should avoid breaking thistle seed heads in the process. It is best to alternate between sweeping insects off the thistle and aspirating them out of the net. Sweep no more than 25 times before aspirating. This reduces the potential harm that could result from knocking biological control agents around with debris or from other insects inside the net.

Figure 4-5. Canvas sweep net. Photo: Laura Parsons (University of Idaho).

Flies are very delicate, and collecting them with sweep nets can be damaging or fatal to them. For this reason, sweep-netting is not recommended for collecting flies, and alternative methods, such as aspiration (see below) should be used. However, this method is ideal for collecting adult beetles. The best time for sweeping exotic thistle insects is during the warmest part of the day (between 1 and 6 p.m.) as this is when they are most active. Sweep nets can be purchased from entomological, forestry, and biological supply companies, or you can construct them yourself.

Table 4-2. Recommended timetable and methods for collecting approved exotic thistle biological control agents in the U.S.

Type	Scientific Name	Life Stage	Plant Growth Stage	Timing	Method
Beetle	*Ceutrorhynchus litura*	Adult	Bolting	Spring (April-June)	Net and aspirator
	Psylliodes chalcomera	Not established in the U.S.			
	Trichosirocalus horridus	Adult	Rosette	Early spring (April-June)	Hand collected from rosettes
Fly	*Cheilosia corydon*	Adults	Bolting	Spring (April-June)	Net and aspirator
		Pupae	Flowering	Late summer/early fall (August-November)	Dig roots to harvest pupae
	Urophora cardui	Larvae or pupae in galls	Bolting	Collect in fall (October-November); transfer in spring (April-June)	Transfer galls, or rear adults from galls in laboratory to limit spread of parasitoids
		Adults	Flowering	Summer (June-September)	Net and aspirator
	Urophora soltitialis	Not established in the U.S.			
	Urophora stylata	Larvae or pupae in galls	Senescence to bolting	Fall, Winter, Spring (September-May)	Transfer galls, or rear adults from galls in laboratory to limit spread of parasitoids
		Adults	Flowering	Summer (June-September)	Net and aspirator

Aspirator. Use an aspirator (Figure 4-6) to suck the insects from the exotic thistles or sweep net. This provides selective sorting (no unwanted or unknown material is inadvertently collected). Aspirating can be done in the field or indoors. When aspirating indoors, cool the insects to make them less active and easier to collect. A variety of aspirators can be purchased from entomological, forestry, and biological supply companies, or you can construct them yourself. For the latter, make sure that tubing reaching your mouth is covered by fine-mesh screening, so that insects and small particles are not inhaled.

Figure 4-6. Aspirator. Photo: Laura Parsons (University of Idaho).

Hand-picking. Simply pick the insects from the exotic thistle plants by hand or tap them into a net or white plastic tray using a tool such as a badminton racquet. Forceps or tweezers may be helpful. Hand-picking works best for stationary or slow-moving insects, such as *Trichosirocalus horridus* upon its emergence in early spring. Use clippers if collecting galls.

Containers For Exotic Thistle Biological Control Agents

How biological control agents are handled after collection and transported to the release site can affect whether they will survive to multiply at the new site. It is best to redistribute the agents the same day they are collected to reduce mortality or injury.

Following collection, insects need to be transferred to containers intended to protect the biological control agents and prevent them from escaping. Containers should be rigid enough to resist crushing and ventilated to provide adequate air flow and prevent condensation. Unwaxed paperboard cartons (Figure 4-7) are ideal for all exotic thistle biological control agents. They are rigid yet permeable to air and water vapor and are available in many sizes. Unfortunately, most manufacturers have stopped producing them, and they are becoming increasingly difficult to find.

Figure 4-7. Cardboard containers. Photo: Martin Moses (University of Idaho, Bugwood.org).

As an alternative, you can use either light-colored, lined or waxed-paper containers or plastic containers, providing they are ventilated. Simply cut holes in the container or its lid, and cover the holes with a fine mesh screen. Untreated paper bags (lunch bags) work well for transporting agents across short distances. However, they are fragile and offer little physical protection for the agents within, and you must take care to seal them tightly to

prevent the agents from escaping. Do not use glass or metal containers; they are breakable and make it difficult to regulate temperature, air flow, and humidity.

Fill the containers two-thirds full with paper towels to provide a substrate for insects to rest and hide and to help regulate humidity. Include fresh sprigs of the proper host thistle (as food) before adding the agents. Thistle sprigs should be free of seeds, flowers, and any other insects. Do not place thistle sprigs in water-filled containers; if the water leaks, it will likely drown your agents. Seal the container lids either with masking tape or label tape. If you are using paper bags, fold over the tops several times and staple them shut. Be sure to label each container with, at least, the biological control agent(s) name, the collection date and site, and the name of the person(s) who did the collecting.

Transporting Exotic Thistle Biological Control Agents

Keep the containers cool at all times. If you sort and package the agents while in the field, place the containers in large coolers with forzen ice packs. Do not use ice cubes unless they are contained in a separate, closed, leak-proof container. Wrap the ice packs in crumpled newspaper or bubble wrap to prevent direct contact with containers. Place extra packing material in the coolers to prevent the ice packs from shifting and damaging the containers. Always keep coolers out of the direct sun, and only open them again when you are ready to remove the containers to place them in a refrigerator for overnight storage or to release the agents. If you sort and package your agents indoors, keep them in a refrigerator (no lower than 40°F or 4.4°C) until you transport or ship them.

Transporting short distances. If you can transport your biological control agents directly to their release sites within 3 hours after collecting them and release them the same day or early the next, you need not take any measures other than those already described.

Shipping long distances. You might need to use a bonded carrier service with overnight delivery (e.g., USPS, FedEx, UPS, or DHL) if your release sites are far from your collection sites or you have to deliver your biological control agents to several sites. In such cases, the containers should be placed in insulated shipping containers with one or more ice packs, depending on the size of the packs. Some specially designed foam shippers have pre-cut slots to hold agent containers and ice packs (Figure 4-8). This construction allows cool air to circulate but prevents direct contact between the ice and the containers. Laboratory and medical suppliers sell foam "bioshippers" that are used to transport medical specimens or frozen foods. If neither foam product is available, you can use a heavy-duty plastic cooler.

Careful packaging is very important regardless of the shipping container you use. Ice packs need to be wrapped in crumpled newspaper, wrapping paper, or bubble wrap, and should be firmly taped to the inside walls of the shipping container to prevent them from bumping against and possibly crushing the insect containers during shipping. Empty spaces in the shipper should be loosely filled with crumbled or shredded paper, bubble wrap, packing "peanuts," or other soft, insulating material. Use enough

Figure 4-8. Commercially made shipping container. Photo: University of Idaho, Bugwood.org.

insulation to prevent agent containers and ice packs from shifting during shipment but not so much that air movement is restricted. Tape the container lids shut. Enclose all paperwork accompanying the agents before sealing the shipping container. For additional security and protection, you may place the sealed shipping containers or coolers inside cardboard boxes.

Other factors to consider:

- Make your overnight shipping arrangements well before you collect your biological control agents, and make sure the carrier you select can guarantee overnight delivery.
- Plan collection and packaging schedules so that overnight shipments can be made early in the week. Avoid late-week shipments that may result in delivery on Friday, Saturday, or Sunday, delaying release of the agents for several days.
- Clearly label the contents of your containers and specify that they are living insects.

Common Packaging Mistakes

Excess heat. Do not expose biological control agents to direct sunlight or temperatures above 80°F.

Excess moisture. Remove spilled or excess water in the container.

Lack of air. Provide adequate ventilation; use only air-permeable containers.

- Check with a prospective courier to make sure that they can accept this type of cargo and will not X-ray or otherwise treat the packages in ways that could harm the biological control agents. If the courier cannot guarantee that such treatments will not occur, choose a different carrier.
- Contact personnel at the receiving end, tell them what you are shipping and when it is due to arrive, verify that someone will be there to accept the shipment, and instruct them not to open or X-ray the container.

Regulations Pertaining to Exotic Thistle Biological Control Agents

U.S., intrastate. Generally, there are few if any restrictions governing collection and shipment of biological control within the same state; however, you should check with your state's department of agriculture or agriculture extension service about regulations governing the release and intrastate transport of your specific biological control agent.

U.S., interstate. The interstate transportation of biological control agents is regulated by the U.S. Department of Agriculture (USDA), and an approved permit is required to transport living biological control agents across state lines. You should apply for a Plant Protection Quarantine (PPQ) permit from the Animal and Plant Health Inspection Service (APHIS) as early as possible—ideally, at least six months before actual delivery date of your biological control agent. You can check the current status of regulations governing intrastate shipment of weed biological control agents and obtain the permit application form, PPQ Form 526 (Appendix II), at the USDA-APHIS-PPQ website at http://www.aphis.usda.gov/ppq/permits. A recently initiated ePermit process can be accessed at this website; this allows the complete online processing of biological control agent permit requests

Canada. Canada requires an import permit for any new or previously released biological control agent. Permits are issued by the Plant Health Division of the Canadian Food Inspection Agency. Redistribution of exotic thistle biological control agents within a province is generally not an issue; however, you should consult with provincial authorities and specialists prior to moving biological control agents across provincial boundaries. More information on thistle biological control agents and their biology is available online at http://res2.agr.ca/lethbridge/weedbio/index_e.htm#toc.

Purchasing Exotic Thistle Biological Control Agents

A number of commercial suppliers provide exotic thistle biological control agents. County weed managers, extension agents, or university weed or biological control specialists maybe able to recommend one or more suppliers. Make sure that a prospective supplier can provide the species you want and can deliver it to your area at a time appropriate for field release. (You may want to know where and when the agents were collected.) Interstate shipments of exotic thistle biological control agents by commercial suppliers also require a USDA permit (see the box on the previous page). Determine in advance whether you or the shipper is responsible for obtaining the permit. **Do not purchase or release unapproved, non-permitted biological control organisms** (see Chapter 3, Table 3-2).

Releasing Exotic Thistle Biological Control Agents

Establish a permanent location marker. Place a steel fence post or plastic or fiberglass pole at least 4 feet (1.2 m) tall as a marker at the release point (Figure 4-9). Avoid wooden posts: they are vulnerable to weather and decay. Markers should be colorful and conspicuous: white, bright orange, pink, and red are preferred over yellow and green, which may blend into surrounding vegetation. If tall, conspicuous posts are not practical or suitable at your release site because of too much human or large animal traffic or a high risk of vandalism, etc., mark your release sites with short, colorful plastic tent or surveyor's stakes or steel plates that can be etched or tagged with release information and located later with a metal detector and GPS.

Figure 4-9. Permanent marker for biological control agent release site. Photo: Rachel Winston (MIA Consulting).

Record the geographical coordinates at the release point from a GPS unit. This should be done as a complement to, rather than a replacement for, a physical marker and will help locate release points if markers are damaged or removed. With the coordinates, be sure to record what coordinate system you are using (e.g., latitude/longitude or UTM).

Prepare a map that describes access to your release site, including roads, trails, and relevant landmarks. The map should be a complement to, not a replacement for, a physical marker and latitude and longitude or UTM coordinates. It will be especially useful for a long-lived project in which more than one person will be involved or participants are likely to change. Maps are often necessary to locate release sites in remote locations that are difficult to access.

Complete relevant paperwork at the release site before or just after releasing biological control agents. Your agency may have release forms for you to fill out. Typically, the information you would provide would include a description of the site's physical location, including GPS-derived latitude, longitude, and elevation coordinates; a summary of its biological and physical characteristics and use; the names of the biological control agent(s) released; date and time of the release; weather conditions during the release; and the names of the person(s) who released the agents. (See Biological Control Agent Release Form in Appendix III). The best time to record this information is while you are at the field site; don't wait until you are back in the office to do it. Once back in the office, submit the information to your county extension agent, university, or state department of agriculture. Keep a copy for your own records.

Set up a photo point. A photo point is used to visually document changes in exotic thistle infestations and the plant community over time following release of biological control agents at a site. Use a permanent feature in the background as a reference point (e.g., a mountain, large rocks, trees, or a permanent structure). Pre- and post-release photographs should be taken from roughly the same place and at the same time of year. Make sure each photograph includes your release point marker.

Release as many agents as possible. For practical purposes, there is probably no maximum number of biological control agents that could be released: in other words, you can never release too may insects! As a general rule of thumb, it is better to release as many individuals of an agent as you can at one site than to spread those individuals thinly over two or more sites. Concentrating the release will help ensure that adequate numbers of males and females are present for reproduction and reduce the risks of inbreeding and other genetic problems. Guidelines for a minimum release size are uncertain for most agents, but releases of 200 individuals or more are encouraged.

Adults of exotic thistle biological control agents should be released in a group at the marked release point from mid-morning to late afternoon on warm, sunny days. This is preferred to scattering released biological control agents throughout the thistle infestation. Avoid making releases on cold or rainy days. If you encounter an extended period of poor weather, however, it is better to release the insects than wait three or more days for conditions to improve as the agents' vitality may decline with extended storage.

When larvae or pupae are collected in galls and stems of infested thistle tissue, it is best to broadcast the infested plant material into the litter from previous years' thistle growth. Emerging biological control agents can utilize nearby soil and litter for pupation or shelter or crawl up new host thistle plants to complete their life cycles. If there are a number of ant mounds or ground dwelling animals in the area, a better option may be to tie a bouquet of infested material to a nearby fencepost.

Documenting, Monitoring, and Evaluating a Biological Control Program

Weed biological control success is measured by how well the biological control agents reduce the targeted weed densities near or below a pre-determined threshold. Measurement of the status of the weed population in relation to this threshold will determine if you efforts have been successful. The effects of biological control agents usually take much longer to appear than those of herbicide and mechanical management strategies and at least several years to have full impact on the targeted weed.

The Need for Documentation

Documenting outcomes (both successes and failures) will help generate a more complete picture of biological control impacts, guide future management strategies, and serve education and public relations functions. Documenting initial conditions, coupled with data from periodic evaluations of the biological control agent's establishment and impact, can indicate whether or not the biological control program is working as desired or if additional releases of the same or different biological control agents are needed. Similarly, it can provide critical information for other land managers and help them predict where and when biological control might be successful.

The value of monitoring and evaluation efforts will be greatly enhanced if the information you collect is recorded and accessible by other land managers and researchers. Institutional memory is short if based on personal recollection, and documentation of initial conditions, release locations, successes, and failures will provide critical information to those who will follow you. Documenting successes and failures can help prioritize future research and collection efforts. At the very least, it should help others avoid releasing biological control agents that do not work and concentrate on those that do. Publicly accessible information on release locations, sizes, and outcomes can be extraordinarily useful information for biological control researchers and policy makers. Finally, other land managers need to know the location of your releases so that they can avoid engaging in activities—such as cultivating, mowing, and applying herbicides or insecticides—that would harm your biological control agent populations.

Information Databases

Many federal and state agencies have electronic databases for archiving information from biological control releases. We have included a standardized biological control agent release form that, when completed, should provide sufficient information for inclusion in any number of databases (see Appendix III).

At the federal level, the USDA Animal and Plant Health Inspection Service (APHIS) maintains the Cooperative Agricultural Pest Survey (CAPS) database, which is part of the National Agricultural Pest Information System (NAPIS) (http://ceris.purdue.edu/napis/). Biological control release information is entered into CAPS by a number of state and federal agency personnel who serve on the state's CAPS survey committee. Contact your local APHIS officials or state department of agriculture for more information on participation.

The USDA Forest Service maintains a database that can store information on biological control agent releases on federal and non-federal lands. As of the writing of this document, biological control releases made on Forest Service lands should be entered into the FACTs database, and the extent of the targetted weed infestation should be entered into the TERRA database. Other agencies may maintain their own databases for this information. Many of the databases maintained by state and federal agencies have some safeguards in place to prevent undesirable uses of the information they contain.

Information Collection

For any weed biological control program, pre- and post-release monitoring is critical to determine if management goals have been achieved (Figure 4-10). Information on both biological control agent populations and the status of exotic thistles are collected during monitoring.

Populations of biological control agents

- Are biological control agents established at the release site?
- Are biological control agent populations increasing in size?
- How far beyond the initial release point(s) at a given site have biological control agents spread?
- Are surplus biological control agents collectable at the site?

Figure 4-10. Establishment of a Canada thistle biological control monitoring site. Photo: Mark Schwarzländer (University of Idaho).

Status of exotic thistles and other plants

- What is the distribution and density of the target exotic thistle plants?
- Are the biological control agents causing damage to the target exotic thistle plants and/or nontarget vegetation? What percentage of the plants or seed heads are attacked?
- Has there been a change in the exotic thistle population and distribution since introducing the biological control agents?
- Has there been a change in desirable vegetation at the release site?
- Is there a change in undesirable plants, such as other noxious invasive exotic weeds, at the release site?

To address these questions, monitoring activities must be focused on biological control agents, their impacts (damage) on individual exotic thistle plants, the exotic thistle population, and the rest of the plant community in the vicinity of the release.

Assessing the Status of Exotic Thistles and Other Plants

The ultimate goal of a biological control program is to reduce the abundance of the target weed and enable the recovery of more desirable vegetation on the site. To determine the efficacy of biological control efforts, there must be monitoring of plant community attributes, such as target weed distribution and density. Monitoring occurs before biological control efforts are started (pre-release) and at regular intervals after release.

The methods used in pre-release vegetation monitoring should enable land managers to determine later if they are achieving the objectives of the weed biological control program. Often, land managers use reductions in exotic thistle patch size or density to gauge the success of weed management efforts. Pre-release estimates of exotic thistle stem density, flowering and vegetative stems, patch size, and patch perimeter at the release sites are frequently measured to enable pre- and post-treatment comparisons.

Land managers may have a goal of changing the structure and composition of the plant community through biological control. Pre-release sampling techniques, which allow managers to describe pre-treatment vegetation, are integral to assessing progress towards this goal.

Pre-release monitoring should include the establishment of control plots where no insects will be released. These plots should be as similar as possible in habitat type (the same soil type, aspect, and exposure) to the release plots. Control sites should be far enough away from release sites so that it is unlikely they will be colonized by biological control agents at least during the monitoring period of the program. For consistency, the same data collection protocols should be used at control and release sites.

In order to measure biological control agent impact accurately, methods for assessing plant densities after biological control agents are released must be the same as the pre-release methods. Post-release assessments should be planned for at least three to five years after the initial agent release.

There are many ways to qualitatively (descriptively) or quantitatively (numerically) assess exotic thistle populations and other plant community attributes at release sites.

Qualitative (descriptive) vegetation monitoring. Qualitative monitoring uses descriptive elements about exotic thistles at the management site. Examples of qualitative monitoring include listing plant species occurring at the site, estimates of density, age and distribution classes, visual infestation mapping, and location of the photo points. Qualitative monitoring provides insight into the status or change of exotic thistle populations. However, its descriptive nature does not generally allow for detailed statistical analyses. Data obtained in qualitative monitoring may trigger more intensive monitoring later on.

Quantitative vegetation monitoring. The purpose of quantitative monitoring is to measure changes in the exotic thistle population before and after release of biological control agents. Quantitative monitoring may be as simple as counting the number of flowering exotic thistle plants in an area or as complex as measuring plant height, seed production, rosette diameter, biomass, or plant species diversity. If designed properly, quantitative data can be statistically analyzed and give precise information on population or community changes.

The simplified protocol used by the state of Idaho for exotic thistle vegetation monitoring is described in Appendix IV. It is a combination of qualitative and quantitative elements and can be easily modified to meet your personal or agency needs. For additional vegetation monitoring protocols, see Appendices VI and VII.

Assessing Exotic Thistle Biological Control Agent Populations

All biological control agents go through a population cycle of gradual increase, peak, and decline during the season. It is easier to assess insect establishment when populations are peaking, so we recommend you make multiple visits to a site throughout the season and sample when populations appear highest. Populations of some biological control agents take two to three years to reach detectable levels. Thus, if no agents are detected a year after release, it does not mean that the insects failed to establish. Revisit the site for three years. If no evidence of insects is seen, either select another site for release or make additional releases at the monitored site. Consult with your county extension educator or local biological control of weeds expert for their opinion.

General biological control agent surveys. If you wish to determine whether or not an exotic thistle biological control agent has established after initial release, you may simply need to find the biological control agents themselves and/or evidence (that is, plant damage) of their presence. The easiest way to confirm biological control agent establishment in the years following release is to find one or more of the insect's life stages at the release site (Table 4-3). Begin looking for biological control agents where they were first released. If you do not find any, continue to explore the area around the release site. Sometimes, biological control agents do not like the area where they were released and move to patches of exotic thistles nearby. Damage characteristic of individual biological control agents can also indicate successful establishment. Typical damage traits are listed in Table 4-3.

Table 4-3. Life stages/damage to look for to determine establishment of exotic thistle biological control agents.

SCIENTIFIC NAME	LIFE STAGE	WHERE TO LOOK	WHEN TO LOOK	DAMAGE
Ceutorhynchus litura, *Trichosirocalus horridus*, and *Cheilosia corydon*	Adults	Foliage	Spring (April-June)	Adult feeding by any of these species is minimal
	Larvae	In stems and in/around root crown	Summer (June-September)	Plants appear stunted and wilty; dissection will reveal mined tissue and dark frass
Psylliodes chalcomera	Not established in the U.S.			
Urophora cardui	Adults	Foliage and stems	Late spring (May-July)	Adults do not do any appreciable damage to host plants
	Larvae	In stem galls	Summer, Fall, Winter (July-March)	Form stem galls that stunt growth of host plants; give malformed appearance
Urophora soltitialis	Not established in the U.S.			
Urophora stylata	Adults	On foliage and seed heads	Summer (June-September)	Adults do not do any appreciable damage to host plants
	Larvae	In seed head galls	Summer, Fall, Winter (July-March)	Form seed head galls that prevent developing seeds from dispersing; give seed heads a malformed, swollen appearance

Additional monitoring methods. To determine the density of insects at the release site or how far the biological control agents have spread from the release point, a more systematic monitoring method is needed. Numerous approaches can be taken in setting up a monitoring program; these will vary depending on the information you wish to obtain from monitoring efforts.

A simple method for monitoring the abundance of two common species of exotic thistle biological control agents (*Ceutorhynchus litura* and *Urophora cardui*) used by the state of Idaho is described in Appendix IV. This approach was designed to be simple, efficient, and sufficiently versatile to allow for the collection of information from the same sites over multiple years. You can easily modify these protocols to meet your personal or agency needs. Alternative general biological control agent monitoring forms can be found in Appendix V.

Cheilosia corydon. To assess the density of the less widespread *Cheilosia corydon*, an even simpler method would suffice. This specie is not common and is difficult to collect in the adult stage. Consequently, the larval stage is easiest to observe.

- Randomly select 20 host (Italian, musk, plumeless, or slenderflower) thistle plants scattered throughout the target weed infestation.
- Harvest the plants during the flowering stage (throughout summer) by digging down to include collection of the roots.
- Dissect the stems and roots, looking for evidence of *C. corydon* larvae. Be sure that you properly distinguish between *C. corydon* larvae and *T. horridus* larvae, which may also be present in the same portions of the plant (Figure 4-11).

Figure 4-11. *Cheilosia corydon* larval mining damage. Photo: Eric Coombs (Oregon Department of Agriculture).

- Record the number of larvae found per plant, and repeat the process annually.

Assessing Impacts on Non-Target Plants

Sampling of vegetation other than exotic thistles should be included in a vegetation monitoring program in order to assess potential non-target impacts of the biological control program. Specific methods will depend on the species targeted for sampling in particular areas.

Changes in abundance of other desirable or undesirable vegetation. Biological control agent releases, among other land management strategies, can affect the presence and relative abundance of many other plant species even though the agents do not directly utilize them. If biological control works to remove exotic thistles at a site, it will create an empty niche to be filled by alternative—hopefully desirable—vegetation. These indirect effects are the result of changes in exotic thistle abundance. As exotic thistles become less abundant, the utilization of site resources is altered; some plants become more abundant, while others become less so. Within the overall management plan for your site, it may be important to document the changes in other vegetation after you release your biological control agents.

Depending on your program goals, you may need to document quantitative and/or qualitative changes for groups of plants, such as native forbs or exotic perennial grasses, or on individual species, such as a rare plant or a food plant for a native butterfly. Plant species may be considered beneficial (e.g., native and introduced forage plants) or deleterious (e.g., other invasive weeds). One important management goal should be to avoid invasion of a site by another exotic weed after successful biological control of exotic thistles; in other words, you do not want to replace one invasive weed with another. For this reason, we strongly recommend that you monitor populations of other exotic weeds that are known to be problematic in your area.

You will need to clearly define site management goals and become familiar with the plant communities at your release location and nearby sites. You can easily modify the vegetation sampling procedures described above to monitor changes in density and/or cover for exotic thistles as well as other plant species, both before and after you release your biological control agents.

Direct impacts of biological control on nontarget plants. The host ranges of all currently approved exotic thistle biological control agents are restricted to species of exotic thistles (see Chapter 3). Most other exotic thistle species in the western U.S. and Canada are considered weeds, so nontarget feeding on these plants should not be a cause for concern. Many native thistle species are found throughout the western U.S. (e.g., the wavy-leaved thistle in Figure 4-12) and are likely to occur within or relatively near exotic thistle infestations and releases of biological control agents. Some native thistle species may be at risk of non-target utilization by released agents, so we recommend monitoring native thistles that occur in exotic thistle infestations being treated with biological control agents.

Figure 4-12. Native *Cirsium undulatum*. Photo: Rachel Winston (MIA Consulting).

The first step in addressing possible non-target attacks on native thistles is to become familiar with the plant communities present at and around your release sites. A visual, pre-release survey may locate native thistles that are present. You may have to consult with a local botanist, if available, for advice on areas where these plants might be growing, what specific habitats they typically utilize, and how you can identify them. Some of the more common native thistles are presented in

Chapter 2. Herbarium records at a university or other research institution may provide guidance about the local or statewide distribution of native thistle species.

If you do find one or more native thistles at a potential biological control release site, you should not immediately cancel plans to release biological control agents; generally, native thistles are not attacked or may experience limited exploratory feeding. The vegetation sampling procedures described above can be easily modified to monitor changes in density and/or cover of specific, known native thistle species, before and after biological control agents are released. Concurrently, you may wish to collect additional data, such as the number of agents observed on non-target thistles, the amount of foliar feeding observed, or the presence of galls.

If you observe approved biological control agents feeding on and/or developing on native thistles, collect samples and take them to a biological control specialist in your area. Alternatively, you may send the specialist the site data so he or she can survey the site for nontarget impacts. Be sure not to ascribe native thistle damage to any specific insect and thus bias its identification.

Chapter 5: An Integrated Exotic Thistle Management Program

Rodney G. Lym, Rachel Winston, and Mark Schwarzländer

Introduction

Integrated weed management (IWM) is a systems approach to management of undesirable plants. IWM is described in the Federal Noxious Weed Act as a system for the planning and implementation of a program using an interdisciplinary approach to incorporate multiple methods for containing or controlling an undesirable plant species or group of species. Components include but are not limited to:

- Education and Outreach
- Prevention
- Monitoring
- Early Detection and Rapid Response (EDRR)
- Biological controls (insects, mites, or pathogens)
- Physical or mechanical treatments (tilling, mowing, etc.)
- Cultural practices (grazing, reseeding, etc.)
- Chemical treatment
- General long-term land management practices

An integrated, coordinated approach to weed management has two interdependent goals:

- The development of a long-term plan to manage all land in a designated area, with landowners and land managers working together towards effective management.
- The implementation of the most effective weed control methods for the target weed, regularly assessed and adjusted as needed.

A program that integrates multiple control methods—such as biological agents, chemical controls, and cultural practices—is far more likely to achieve long-term success against exotic thistles than any single control method used alone.

Integrating Biological Control Methods

Classical biological control has been applied to many invasive weed species, and there are several examples in which both single- and multiple-agent introductions have successfully controlled the target weeds, though this has not been commonly documented for exotic thistles. The use of biological control agents alone to control weeds can be effective with some invasive plants, but may take three to five years or more to reduce weed populations to manageable levels. The success rate for classical biological control may increase when multiple species of biological control agent are used so long as the different species attack different plant parts (leaves, roots, stems, etc.) of the target weed at different times during the growing season or are released over a larger range of infestation

Some agents have helped reduced exotic thistle densities (Figure 5-1), but biological control agents have not established in all areas where exotic thistles occur. Even when established, biological control agents do not eradicate the target weed. Where ideally suited, biological control can maintain some species of exotic thistle densities below economically significant levels. Biological control agents are not going to work against exotic thistles every time at every site; integration with other management tools or simply resorting to other tools may be required and is often encouraged in order to attain thistle management objectives.

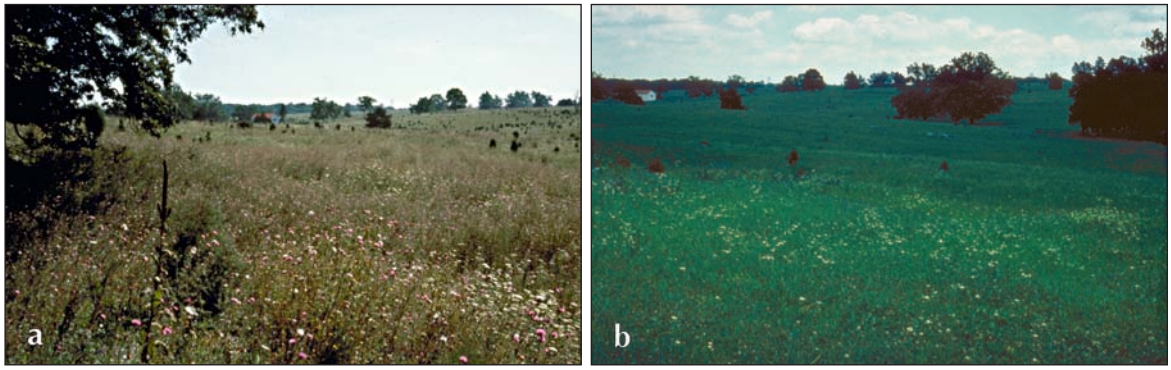


Figure 5-1. A pasture a) before and b) five years after the release of *Rhinocyllus conicus,* a biological control agent (no longer approved for release) released for must thistle control. Photos: Loke T. Kok (Virginia Polytechnic Institute and State University).

Land managers have learned successful, long-term exotic thistle control programs must be cost-effective. Because exotic thistles occur in a wide variety of environments across western North America, no single control method can be successful in all infestations (Figure 5-2). Land managers have also recognized that they must operate under social constraints that will limit the weed management tools they can use in sensitive areas, such as wilderness, near waterways, and on public lands. A wide variety of successful exotic thistle management methods—including herbicide mixtures, selective grazing practices, reseeding, and biological control agent release—have long been used. Each method was initially used alone, but long-term management is greatly improved when various control methods are used in combination according to infested habitat type, land use, ownership, and available resources.

Figure 5-2. Various habitats where exotic thistles can thrive: a. arid bunchgrass community (Rachel Winston, MIA Consulting); b. farmland (Ohio State Weed Lab Archive, Ohio State University); c. wet meadow (Malcolm Storey, www.bioimages.org.uk); d. sagebrush steppe (Mark Schwarzländer, University of Idaho); e. forest understory (Marianna Szucs, University of Idaho); f. rangeland (Mark Schwartzländer, University of Idaho).

Weed Control Methods Used to Manage Exotic Thistles

There are seven commonly cited activities for control of invasive plants: education; prevention; and biological, physical or mechanical, cultural, and chemical controls and practices. Associated activities include monitoring, early detection and rapid response (EDRR), and long-term management practices.

Education and Outreach

Education and outreach activities should aim to increase public awareness of noxious weeds and provide information on ways to manage the problem. Education efforts should be a significant component of any IWM strategy and program, regardless of the other weed control methods employed. Education and outreach should inform both the public and land managers of all available control methods.

Prevention and Exclusion

Prevention and exclusion activities are aimed at areas not currently infested by exotic thistles and intended to keep uninfested areas weed-free. Exotic thistles are spread by the movement of seed-contaminated hay, wind, motorized equipment, wildlife, or water dispersion into

uninfested areas. Where these factors can be controlled, preventing the spread of thistle requires cooperation among all local landowners.

In areas where exotic invasive thistles are not yet present, it is important to ensure that possible invasion avenues are identified and management actions taken to reduce the risk of spread. Prevention and exclusion activities are typically paired with education efforts (Figure 5-3). Examples of exclusion efforts include weed-free forage programs, state seed laws, and mandatory equipment cleaning before entering uninfested sites.

Figure 5-3. Weed education sign erected by Sublette County, Wyoming, on USDA Forest Service land. Photo: Rick VanBebber (USDA Forest Service, Region 4).

Monitoring

Monitoring supports prevention by using frequent surveys in weed-free areas to ensure that exotic thistles have not invaded. Similarly, mapping of known infestations allows land managers to document the direction and rate of spread.

Early Detection and Rapid Response

An early-detection and rapid-response (EDRR) program is a specific protocol for tracking and responding to infestation spread. It relies heavily on education and outreach activities to be effective. EDRR programs target areas into which a weed may spread and take a two-prong approach by: 1) educating the public to aid in detection of the weed and 2) initiation of rapid response eradication efforts at all verified locations of the weed.

Biological Control

Biological control involves the use of living organisms, usually insects, mites, or pathogens, to control a weed infestation and recreate the balance of plant species with their natural predators and pathogens. Classical biological control focuses on the introduction of natural enemies from the origin of the invasive weed.

Physical or Mechanical Treatment

Physical treatment uses hand pulling and hoeing to disrupt and remove weeds and is the oldest method of weed control. Mulching can be used to control regrowth. Physical methods are very effective in controlling biennial thistles, but are labor-intensive. Mechanical treatments include tilling and mowing: these methods are equipment-intensive.

Tilling. Tilling will control most species of exotic thistles if done on a timely basis and if roots are cut below the soil surface. Using farming equipment to cut annual or biennial thistles off below the crown area is an effective way to kill individual plants (Figure 5-4). Control is enhanced when an herbicide treatment is used in conjunction with tilling. Tilling is generally not practical or desirable in wildlands and nature preserves and is not recommended for Canada thistle, as this technique can result in the vegetative spread of the weed from root fragments.

Figure 5-4. Mechanical treatment. Photo: John Byrd (Mississippii State University, Bugwood.org).

Tilling is not always compatible with biological control efforts. Tilling and disking frequently disrupt and destroy biological control agents overwintering in exotic thistle roots and galls or in soil litter.

Mowing. Cutting back the above-ground portion of a plant will remove topgrowth and can reduce exotic thistle seed production, especially if the plants are mowed frequently and during flowering. Mowing should be done as close to the ground surface as possible when terminal flower heads start blooming (10% bloom). If the mowing height is too high, the plant may recover or produce flowers below the cutting height. Likewise, mowing conducted after plants have started producing seed may help distribute seed.

A single mowing treatment does not injure the root system, and long-term control is not possible on perennial species unless done often enough so that root carbohydrates are depleted and roots die. Mowing has been shown to be effective on annual and biennial species. Frequent mowing, however, might be too costly or infeasible for larger infestations. Mowing can be used to reduce non-target plant cover and litter prior to

herbicide application or the release of biological control agents, increasing the success of both techniques. Mowing in the summer prior to a fall herbicide application will improve coverage of the chemical on fall thistle rosettes. Mowing, if applied infrequently or if not well-timed, however, can increase the spread of Canada thistle (in particular) by encouraging new growth from underground rhizomes.

Prior to mowing, it is important to consider the life cycles of the biological control agents and when and where they will be on the plant. For example, mowing excess plant litter during late winter and very early spring when *C. litura*, *T. horridus*, and *C. corydon* are overwintering either in the soil litter or roots is compatible with, and perhaps even conducive to, biological control. However, mowing during this same time period would destroy larvae of *U. cardui* and *U. stylata* overwintering in galls within exotic thistle seed heads and stems if host plants are erect. Mowing during spring when all species are active in some stage in the above-ground portion of exotic thistles could kill large numbers of insects.

Cultural Practices

Cultural methods of weed control, including seeding with competitive grass species, burning, and grazing, can enhance the growth of desired vegetation, which may slow the invasion of exotic thistles onto a site. Regardless of which method is used, all cultural control methods are more successful when combined with other control methods, such as biological controls and chemical treatments.

Seeding competitive grasses. Seeding can be used to help establish competitive native species, such as grasses and forbs, in an exotic thistle infestation. Once grasses and forbs have established (usually one to two years after seeding), biological control agents can be released to help control surviving exotic thistles.

Exotic thistle control programs that include establishment of introduced and native perennial grasses have been more successful at increasing forage production and long-term weed control than any single method. Some perennial grasses can compete effectively with exotic thistles and provide a long-term reduction in density. The most competitive grasses include wheatgrass, wild rye, and smooth brome; however, the best type of grass to plant in competition with exotic thistles varies by region. Consult your local county extension agent or Natural Resource Conservation Services representative for best alternatives. Control of exotic thistles prior to seeding grasses is important: herbicides such as aminopyralid, clopyralid, MCPA, and 2,4-D can be applied once or twice (check the label) during the summer to reduce exotic thistle vigor prior to a fall or early spring seeding of grasses.

Incorporating biological control agents with re-seeding has been difficult, primarily because the methods used to establish a productive stand of competitive species are not always compatible with the establishment and survival of biological control agents. In order to establish a suitable site for re-seeding, either an area must be tilled to provide an acceptable seed bed and/or herbicides such as glyphosate must be applied to reduce competition from exotic thistles. Tilling can disrupt and destroy biological control

agents overwintering in soil litter and plant roots and heavy herbicide use will reduce the exotic thistle shoots on which biological control agents feed and may hinder suitable establishment of biological control agent populations.

Seeding of competitive species using a no-till seeder would be less disruptive of an established exotic thistle biological control population than conventional seeding techniques. Unfortunately, no-till seeding has been successful only when the site was mowed or burned prior to seeding and an herbicide was applied to control broadleaf and grass weeds. The thick thatch of dead thistle stems often found in old stands can reduce grass seedling establishment and ultimately may result in undesirable species replacing the seeded grasses. Intensive management techniques often establish competitive species first, using biological control agents only after the seeded species have become established and the weed has begun to re-grow.

Prescribed fire. This method of cultural control is used against many domestic and exotic plants (Figure 5-5). The success of prescribed fire against exotic thistles varies considerably depending on season of burn, burn severity, site conditions, and plant community composition and phenology before and after the fire. Prescribed burns can reduce thistle density if used in conjunction with other control methods such as reseeding or herbicide treatments. Fire may also increase competitive plant species (i.e., some perennial grasses), allowing them to compete with the exotic thistles.

Figure 5-5. Prescribed fire. Photo: Robert Masters (USDA Agricultural Research Service, Bugwood.org).

Biological control agents must be able to survive controlled burns that aid in returning native vegetation to exotic thistle-infested areas. Often, the timing of the controlled burn will determine if an agent survives. Generally, soil-inhabiting agents are able to survive fast-moving, low- or moderate-intensity fires. If a fire event occurs while the biological control agents are in the adult stage, they can often escape the fire by flying off, readily re-establishing on recovering thistles not killed during the fire event.

Grazing. Domestic livestock such as cattle, sheep, and goats have been observed grazing on seedlings, flower heads, and seeds of some exotic thistle species (Figure 5-6). It

has not been determined what effects such feeding has on the population dynamics of exotic thistles. Domestic livestock are discouraged from grazing the foliage and stems of exotic thistles due to their spiny nature. In most instances, domestic livestock actively graze species other than exotic thistles, thus decreasing the competition against exotic thistle species. Additional control methods should be used in conjunction with or in replacement of grazing by domestic livestock.

Figure 5-6. Cattle and sheep grazing. Photo: Scott Bauer (USDA Agricultural Research Service, Bugwood.org).

While grazing by domestic livestock would not likely control exotic thistle infestations alone, proper grazing of desirable range and pasture species can increase plant productivity to competitive levels. Precision grazing using cattle can successfully reduce Canada thistle stands in rangeland and pasture habitats. Unlike season-long grazing, so-called high-intensity, low-frequency (HILF) grazing reduces Canada thistle stem density and biomass while increasing range yield. A HILF grazing system uses higher stocking rates of cattle (high-intensity) to graze heavily on a pasture for a short period of time followed by an eight-week recovery time (no grazing) of the pasture or paddock (low-frequency) before the grazing treatment is repeated. The relatively long recovery time benefits the re-growth of grasses, increasing the competitive ability of the desired vegetation. It should be noted, however, that improper or over-grazing can result in conditions conducive to exotic thistle invasion (bare ground and an outright removal of desirable forage species) and may have led to the original infestation.

Integration of grazing and biological control agents for exotic thistles may be complicated. As stated above, thistle grazing is most successful when plants are heavily defoliated under high intensity grazing regimes. Under these conditions, a good proportion of the thistles get trampled. Both trampling and consumption of thistle shoots will kill juvenile biological control insects developing in galls or feeding in the stems of exotic thistles and adult insects hiding or overwintering in leaf litter. Integration of biological control and precision grazing can be more successful than each control method alone when grazing events are carefully timed and synchronized with the activity period of biological control agents.

Chemical Treatment

Herbicides are important tools for controlling noxious weeds and are available for exotic thistle control in a variety of environments (Figure 5-7). Herbicide timing and application rates and grazing and haying restrictions vary by state and region. Please consult your local weed officer or county agricultural extension agent to learn which herbicides work best and when to apply them in your situation. (See the following pesticide sse text box.) The most widely used products include the following.

Figure 5-7. Applying herbicides. Photo: James Miller (USDA Forest Service, Bugwood.org).

- Aminopyralid can be applied in the spring or early summer on rosettes or bolting plants or, alternately, in the fall on rosettes. Aminopyralid is less detrimental to desirable broadleaf species than most other auxin herbicides. Aminopyralid can also be applied near many tree species where dicamba and picloram cannot be used. However, legume species are especially susceptible to aminopyralid.
- Clopyralid can be used on young, actively growing thistles prior to the bud stage and on rosettes in the fall. Clopyralid will not injure established grasses. Clopyralid is more expensive than most other herbicides used for thistle control but is very effective.
- Use dicamba after thistles emerge. Annuals can be treated when small and actively growing. Biennial thistles are best treated prior to flowering and in the fall rosette growth stage. Dicamba should be applied in the fall for optimum Canada thistle control. A commercial mixture of dicamba plus diflufenzopyr (Overdrive®) is also available for thistle control in non-crop lands and wildlands.
- MCPA can be used when thistles are small and actively growing. MCPA will not control perennial thistles. MCPA is often used prior to and following reseeding of desirable grasses for annual weed control.
- Use picloram after thistles emerge, throughout active growth stages, or in late summer or fall. Picloram requires a higher use rates than aminopyralid and has a longer soil residual period, which will reduce regrowth from roots or seedlings.
- 2,4-D can be used when annual and biennial thistles are young and actively growing. 2,4-D will not reduce Canada thistle, but can be used to prevent flowering and allowing haying without weed spread.
- Metsulfuron should be applied post-emergence to actively growing thistles. It is best to use a nonionic or organosilicone surfactant with metsulfuron. Grazing restrictions apply to its use, as do restrictions for use on some grasses. Metsulfuron is often mixed with 2,4-D and/or dicamba to increase control of perennial thistles.

Application timing is very important to ensure the most effective use of herbicides. It is good to treat biennial and winter annual species with fall applications when plants are seedlings or rosettes as these stages are more vulnerable and are often easiest to control. Growth stage, stand density, and environmental conditions (e.g., drought or cold temperatures) all determine the best choice of product and application rate.

Depending on the species and the location, herbicides and biological control agents can be combined or used separately. For example, the Canada thistle stem gall fly, *Urophora cardui*, can be used to reduce seed production in forested areas where herbicides generally cannot be used; in turn, herbicides can be applied away from trees to reduce exotic thistle spread. In a separate example, recent research has shown that *Ceutorhynchus litura* can be well integrated with herbicide treatments for the control of Canada thistle if the herbicide is applied after the mature larvae have left the stems for pupation in the soil. The herbicide treatment is thought to reduce the weed's ability to compensate for the biological control feeding damage. In greenhouse trials, clopyralid was the most effective herbicide used in conjunction with *Ceutorhynchus* litura.

Herbicide application should occur at a time least disruptive to the biological control agent even if the timing is not ideal for the chemical. In order to ensure that the insects maintain viable populations as the exotic thistle infestation is reduced, 25 percent of the area should remain untreated to serve as "refuges" for biological control agents.

Use Pesticides Safely!

- Read the pesticide label, even if you have used the pesticide before. Follow the all instructions on the label.
- Wear protective clothing and safety devices as rec¬ommended on the label.
- Bathe or shower after each pesticide application.
- Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.

Peter M. Rice

General Long-Term Land Management Practices

Exotic thistles have persistent growth characteristics, and seed can remain viable in the soil for years. Therefore, you should implement long-term weed management programs. Long-term weed management includes re-treatment with herbicides or continued cultural, mechanical, or biological control practices to maintain low exotic thistle populations. Range improvements—such as grazing systems, cross-fencing, and water development—will help retard the invasion of many weed species, including exotic thistles. Sites with no desirable species should be reseeded with a competitive plant species as part of the total management program (Table 5-1).

Table 5-1. Comparison of exotic thistle management options.

Management Technique	Advantages	Disadvantages	Comments
Herbicides	Fast acting.	Expensive for large areas.	Best used on small patches when exotic thistles first appear or on the edges of a large infestation to keep it from spreading while other methods, such as biological control, have time to establish.
	High success rate for reducing exotic thistle densities.	May harm desirable vegetation, especially broadleaf species.	
	Rapidly enhances grass production.	Many natural areas are inaccessible to spray equipment. Public resistance to chemical controls. Regulations or policies may prohibit use in some areas.	
Biological Control	Can be very selective. Agents generally do not have to be reintroduced once established.	Some risk of undesirable effects on native plants. Biological control is not successful in all situations.	Most economical option for large infestations.
	Public acceptance is generally higher than with other weed control methods.	Permanent: cannot be undone.	Will control exotic thistles in a variety of environments in which the weed occurs, especially if multiple agents are introduced.
		Measurable changes in weed densities may take several to many years.	
Grazing	Allows use of the land even with heavy exotic thistle infestations.	Cannot be used in many natural areas such as national parks and wilderness areas.	Will remove top-growth only, but does not reduce the root mass.
	Can be used in combination with biological or chemical control methods.	Expensive. Non-selective. Can exacerbate the problem.	The same areas must be grazed annually or exotic thistles will rapidly reestablish.
Mechanical/Cultural Treatments	Very effective.	Not appropriate for natural areas and wildlands.	Not compatible with biological control agents.
	Can be used to reseed native species	Expensive for larger infestations.	Best used when an areas is being "reclaimed."

Glossary

abdomen	The last of the three insect body regions; usually containing the digestive and reproductive organs
achene	A small, one-seeded fruit that does not split at maturity
aeciospore	A binucleate spore of a rust fungus, formed in a chainlike series in an aecium
allelopathy	One plant harms another by exuding specific biomolecules
anal plate	Darkened segment at the tip of the abdomen
annual	A plant that flowers and dies within a period of one year from germination
antenna (pl. antennae)	In arthropods, an appendages on the head, normally many-jointed, and of sensory function
aspirator	An apparatus used to suck insects into a container. Can be as simple (as in-mouth aspirator) or mechanical (as in a gasoline- or battery-powered vacuum aspirator)
basal	Located at the base of a plant or plant part
basidiospore	A sexually produced fungal spore borne on a basidium
biennial	A plant that flowers and dies between its first and second years and does not flower in its first year
biological control	The reduction in the abundance of a pest through intentional use of its natural enemies (predators, parasitoids, and pathogens)
bolting	Plant stage at which the flower stalk begins to grow
bract	A small, leaf-like structure below a flower

capitulum (pl. capitula)	Seed head of a plant in the sunflower family
complete metamorphosis	An insect life cycle with four distinct stages (egg, larvae, pupae, adult)
compound eyes	Paired eyes consisting of many facets, or ommatidia, in most adult Arthropoda
coordinates	Any of a set of numbers used to specify a location on a line or in a plot
density	Number of individuals per unit area
dioecious	The condition in which male and female reproductive organs are on separate plants
dissemination	Dispersal. Can be applied to seeds or insects
elytron (pl. elytra)	Hardened front wing of a beetle
emergence	Act of adult insect leaving the pupal exoskeleton, or leaving winter or summer dormancy
exoskeleton	Hard, external skeleton of the body of an insect
exotic	Not native
floret	One of the small, closely clustered flowers forming the head of a composite flower in the sunflower family
flower head	A special type of inflorescence consisting of numerous florets that actually look like one flower
gall	An abnormal growth on a plant, usually induced by an insect that lives within the gall
genera	A taxonomic category ranking below a family and above a species and generally consisting of a group of species exhibiting similar characteristics. In taxonomic nomenclature the genus name is used, either alone or followed by a Latin adjective or epithet, to form the name of a species.
glandular	Having glands (a group of specialized cells often in the form of sticky hairs that produce and secrete a specific substance)
grub	A soft, thick-bodied, 'C'-shaped beetle larva

head (insect)	The segment of an insect that consists of mouthparts, antennae, and eyes
head capsule	Hardened covering of the head of an immature insect
herbivory	Feeding on plants
hermaphroditic	Having both male and female reproductive parts
host	The plant or animal on which an organism feeds; the organism utilized by a parasitoid; a plant or animal susceptible to attack by a pathogen
host specificity	The highly-evolved, often obligatory association between an insect and its host (i.e., weed). A highly host-specific insect feeds only on its host and on no other species.
inflorescence	The flowering part of a plant
instar	The phase of an insect's development between molts
integrated weed management	A system for the planning and implementation of a program, using an interdisciplinary approach, to select a method for containing or controlling an undesirable plant species or group of species using all available methods
involucre	A circle of bracts under an inflorescence
larva (pl. larvae)	Immature insect stage between the egg and pupa (examples include grubs, caterpillars, and maggots)
lobed	A leaf with shallow or deep, rounded segments, as in a thistle rosette leaf
marbled	Of variegated or mottled color
membranous	Thin and transparent
metabolic sink	Site of a plant that receives photosynthate (food) produced by the plant, diverting the resource away from the plant's normal use
molting	Process of insect development that involves shedding its exoskeleton and producing an exoskeleton for the next instar

nontarget effect	When biological control agents feed upon plant species other than the hosts they were introduced to control
oviposit	To lay or deposit eggs
pappus	A tuft of hairs, scales, or bristles at the base of an achene in flowers of the sunflower family
perennial	A plant that lives more than two years
proleg	A fleshy, unsegmented, abdominal walking appendage of some insect larvae, common among caterpillars
pupa (pl. pupae) (v. pupate)	Non-feeding, inactive stage between larvae and adult in insects
qualitative	Measurement of descriptive elements (e.g., age class, distribution)
quantitative	Measurement of quantity; the number or amount (e.g., seeds per capitulum)
ramet	An individual part of a clone
receptacle	Part of the stem to which the flower is attached
rhizomatous	A rootlike subterranean stem, commonly horizontal in position, that produces true roots and sends up shoots progressively to the soil surface
rosette	A compact, circular, and normally basal cluster of leaves
seed head	Synonym for *capitulum* of a plant in the sunflower family. The seed head consists of a receptacle and florets.
senescence	Final stage in a plant's lifecycle
snout	'Nose' of a weevil. The elongate head of a weevil with mouth parts at the tip (apex)
species	A fundamental category of taxonomic classification, ranking below a genus or subgenus and consisting of related organisms capable of interbreeding
spine	A stiff, pointed plant part

synchrony	Occurring at the same time (e.g., plant flowering and insect oviposition)
taxonomy	The classification of organisms in an ordered system that indicates natural relationships. The science, laws, or principles of classification; systematics
teliospores	A spore of certain rust fungi that carries the fungus through the winter and that, on germination, produces the basidium
thorax	Body region of an insect behind the head and abdomen, bearing the legs and wings
transect	A straight line of varying length along which plants are periodically sampled individually or in quadrants
urediospore	The spore of the rust fungi that appears between the aeciospore and the teliospore: commonly, the summer spore

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APPENDICES

Appendix I: Troubleshooting Guide; When Things Go Wrong

Appendix II: PPQ Form 526 Interstate Transport Permit

Appendix III: Sample Biological Control Agent Release Form

Appendix IV: Idaho Statewide Thistle Biological Control Agent 2-Pagers and Monitoring Forms

Appendix VI: Exotic Thistle Qualitative Monitoring Forms

Appendix VII: Exotic Thistle Biocontrol-Associated Vegetation Monitoring

Appendix I: Troubleshooting Guide; When Things Go Wrong

This guide is intended to assist those who encounter problems when establishing a biological control program. It identifies the probable cause of typical problems and offers solutions.

Problem	Probable Cause	Solution
Biological control agents unhealthy when received	Physical damage to agents in transport	Prevent containers from colliding; use crush-proof containers.
	Drowning	Do not put water in containers during transport; prevent accumulation of excess moisture; too much plant material causes condensation.
	Excess or prolonged heat or cold	Keep containers cool at all times; use coolers and ice packs; avoid exposure to direct sunlight while in transit.
	Starvation	Put thistle foliage (no flowers, seeds, or roots) in containers.
	Redistribution time	Transport or ship agents immediately after collection.
		Release agents at new site immediately upon arrival or receipt of agent.
	Parasitism and/or disease	Check source agents. Ensure the insect population is disease-free when collecting or receiving shipment.
Number of eggs low	Agents past reproductive stage	Collect at peak activity (i.e., when insects are mating).
	Sex ratio: not enough males or females	Observe mating among biocontrol agents before collecting; males often emerge earlier than females.
	Synchrony	Agents not synchronized with the exotic thistle growth stage; biological control agents require thistles to be at specific growth stage for optimal oviposition.
Few biological control agents collected	Wrong method used	Refer to Table 4-2 for recommended collection time and technique.
	Collection done at wrong time	Refer to Table 4-2 for recommended collection time and technique.
	Collection technique	Biological control agents can be killed/damaged during sweeping or aspirating, so sweep lightly.
		Use vacuum aspirator if aspirating by mouth is not working.
		Practice sweeping to avoid debris.
	Conditions at time of collection wrong	Refer to Chapter 4 “Collecting Exotic Thistle Biocontrol Agents” for guidelines on desirable weather conditions.
Agents not found after release	Site is unsuitable	Refer to Chapter 4 “Selecting Biocontrol Agent Release Sites.”
	Site too small	Select a larger site with a dense, uniform stand of exotic thistle.
	Pesticide used in area	Select pesticide-free site.
	Released on wrong thistle species	Ensure the correct species of thistle and biological control agent are used.
Cannot locate release site	Permanent location marker not obvious	Use bright-colored wooden, metal, or plastic stake.
	Map poorly or incorrectly drawn	Check map; redraw with more detail or add landmarks; GPS.

APPENDIX II: PPQ FORM 526 INTERSTATE TRANSPORT PERMIT

Please see http://www.aphis.usda.gov/ppq/permits to download permits.

According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information is 0579-0054. The time required to complete this information collection is estimated to average 0.50 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

FORM APPROVED
OMB NO. 0579-0054

No permit can be issued to move live plant pests or noxious weeds until an application is received (7 CFR 330 (live plant pests) or 7 CFR 360 (noxious weeds)).

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE
PERMITS AND RISK ASSESSMENT, UNIT 133
RIVERDALE, MARYLAND 20737

APPLICATION FOR PERMIT TO MOVE
LIVE PLANT PESTS OR NOXIOUS WEEDS

SECTION A - TO BE COMPLETED BY THE APPLICANT

1. NAME, TITLE, AND ADDRESS *(Include Zip Code)*

2. TELEPHONE NO. ( )

3. TYPE OF PEST TO BE MOVED

* ☐ Pathogens ☐ Arthropods ☐ Noxious Weeds
☐ Other (Specify) _____

This permit does not authorize the introduction, importation, interstate movement, or release into the environment of any genetically engineered organisms or products.

	A. SCIENTIFIC NAMES OF PESTS TO BE MOVED	B. CLASSIFICATION (Orders, Families, Races, or Strains)	C. LIFE STATES, IF APPLICABLE	D. NO. OF SPECIMENS OR UNITS	E. SHIPPED FROM (Country or State)	F. ARE PESTS ESTABLISHED IN U.S.?	G. MAJOR HOST(S) OF THE PEST
4.							
5.							
6.							

7. WHAT HOST MATERIAL OR SUBSTITUTES WILL ACCOMPANY WHICH PESTS *(Indicate by line number)*

8. DESTINATION	9. PORT OF ARRIVAL	10. APPROXIMATE DATE OF ARRIVAL OR INTERSTATE MOVEMENT

11. NO. OF SHIPMENTS	12. SUPPLIER	13. METHOD OF SHIPMENT
		☐ Air Mail ☐ Air Freight ☐ Baggage ☐ Auto

14. INTENDED USE *(Be specific, attach outline of intended research)*

15. METHODS TO BE USED TO PREVENT PLANT PEST ESCAPE	16. METHOD OF FINAL DISPOSITION

17. *Applicant must be a resident of the U.S.A. I/We agree to comply with the safeguards printed on the reverse of this form, and understand that a permit may be subject to other conditions specified in Section B and C.* SIGNATURE OF APPLICANT *(Must be person named in Item 1)*	18. DATE

WARNING: Any alteration, forgery, or unauthorized use of this document is subject to civil penalties of up to $250,000 (7 U.S.C. s7734(b)) or punishable by a fine of not more than $10,000, or imprisonment of not more than 5 years, or both (18 U.S.C. s1001).

SECTION B - TO BE COMPLETED BY STATE OFFICIAL

19. RECOMMENDATION
☐ Concur (Approve) ☐ Comments (Disapprove)
☐ (Accept USDA Decision)

20. CONDITIONS RECOMMENDED

21. SIGNATURE	22. TITLE	23. STATE	24. DATE

SECTION C - TO BE COMPLETED BY FEDERAL OFFICIAL

25. PERMIT NO.

PERMIT

(Permit not valid unless signed by an authorized official of the Animal and Plant Health Inspection Service)

Under authority of the Plant Protection Act of 2000, permission is hereby granted to the applicant named above to move the pests described, except as deleted, subject to the conditions stated on, or attached to this application. (See standard conditions on reverse side.)

* For exotic plant pathogens, attach a completed PPQ Form 526-1.

24. SIGNATURE OF PLANT PROTECTION AND QUARANTINE OFFICIAL	25. DATE	26. LABELS ISSUED	27. VALID UNTIL	28. PEST CATEGORY

PPQ FORM 526 (OCT 2001) *Previous editions are obsolete.*

APPENDIX III: SAMPLE BIOLOGICAL CONTROL AGENT RELEASE FORM

Exotic weed biological control: *General Release Site Information*
USDA-APHIS-PPQ

				Site code:	
State:		**County:**		**Site name:**	
Lat.:		**Long.:**		**Elev.:**	

Landowner and/or contact person

Name		**Title (if appl.)**	
Address			
City		**State**	**ZIP**
Phone	**e-mail**		

Extent of weed infestation: □ ≤5 ac (2 ha) □ 5 −100 ac (2 − 40 ha) □ 100 − 1000 ac (40 − 400 ha) □ > 1000 ac (400 ha)

Weed distribution: □ Largely or totally continuous □ Interrupted ('patches' separated by uninfested areas)

General site topography: □ Level □ Slight slope □ Moderate slope □ Steep slope □ Hilly

Aspect: □ North □ South □ East □ West □ Northwest □ Northeast □ Southwest □ Southeast

Soil type: □ Gravel/cobble □ Sand □ Sandy loam □ Loam □ Silt loam □ Clay loam □ Clay

Probability of flooding: □ Very low (rarely occurs) □ Low−moderate (occasional years) □ High (e.g. yearly)

Treatments at site in last year: □ Herbicide(s) [if so, chemical:_____] □ Grazing □ Burning □ Cutting □ Bulldozing/plowing □ Other:_____

Native (pre-infestation) plant communities at site, if known:

_____
_____
_____

Biocontrol agent(s) released:	
Date and time agent(s) released:	
Number of agent(s) released:	
Weather conditions at time of release:	
Released by (name and affiliation):	

APPENDIX IV: IDAHO STATEWIDE THISTLE BIOLOGICAL CONTROL AGENT 2-PAGERS AND MONITORING FORM

Monitoring Guidelines for *Ceutorhynchus litura* on Canada Thistle

Overview

A critical part of successful weed biological control programs is a monitoring process to measure populations of the biological control agents and the impact that they are having on the target weed. Monitoring should be conducted on an annual basis for a number of years. The Idaho State Department of Agriculture, in conjunction with the University of Idaho, Nez Perce Biocontrol Center, and federal land management agencies has developed the monitoring protocol below which enables land managers to take a more active role in monitoring populations and the weed control ability of the Canada thistle stem weevil, *Ceutorhynchus litura* (**CELI**) in efforts to control Canada thistle, *Cirsium arvense*. This monitoring protocol was designed to be implemented by land managers in a timely manner while providing data which will enable researchers to better quantify the impact of CELI on Canada thistle throughout the state.

Canada thistle (*Cirsium arvense*)

Canada thistle is an aggressive, colony-forming perennial weed that reproduces by seed and deep, extensive horizontal roots. Flowering occurs from June through August. The flowers are urn-shaped and purple (sometimes white), and male and female flowers occur on separate plants with heads ranging from ½ to ¾-inch in diameter. Fruits are about 1/8 inch long and brownish with a tuft of hairs at the top. Stems are typically 1 to 4 feet tall with alternate, oblong or lance-shaped leaves divided into spiny-tipped irregular lobes. Canada thistle is native to Eurasia and was introduced to Canada as a contaminant of crop seed in the 18th century. It can commonly be found in gardens, flower beds, pastures, cultivated fields, rangelands, forests, and along river banks, ditches and roadsides. Canada thistle can tolerate a wide range of environmental conditions, but requires good light intensity for optimal growth. It is highly competitive with crops and, in heavy concentrations, effectively prevents grazing. A number of accidentally introduced insects attack Canada thistle. However, only two insects are approved for release; *Urophora cardui* and *Ceutorhynchus litura*.

Canada thistle stem weevil (*Ceutorhynchus litura*)

CELI is a biological control agent that attacks Canada thistle stems and rosettes. Adults feed on rosette leaf foliage in spring, and larvae consume tissues while mining within shoots. At low densities, larval and adult feeding does not significantly impact populations of Canada thistle directly. Feeding does cause secondary damage, however, as pathogens and other organisms enter the stems of Canada thistle via holes made by exiting larvae. At high densities, feeding by CELI will reduce the vigor of both rosettes and flowering stems to the point of deterioration. Overwintering weevils emerge from soil litter and feed on leaf and stem tissue in early spring. Eggs are laid in spring within Canada thistle's bolting shoots, with hatching larvae mining in the stems and root crowns of Canada thistle throughout spring and summer. Multiple larvae (up to 20) can be found in individual stems. Mature larvae tunnel out of the stems, drop to the soil surface, and pupate in the soil. Adults of the new generation emerge in August and overwinter in soil litter. There is one generation per year. The weevil does best in open but moist areas with scattered Canada thistle plants.

APPENDIX IV (CONT.): IDAHO STATEWIDE THISTLE BIOLOGICAL CONTROL AGENT 2-PAGERS AND MONITORING FORM

Monitoring

This biological control monitoring protocol is based upon a permanent 20-meter vegetation sampling transect randomly placed in a suitable (at least 1 acre) infestation of Canada thistle and timed counts of CELI adults. Annual vegetation sampling will allow researchers to characterize the plant community and the abundance and vigor of Canada thistle. Visual counts of CELI adults will provide researchers with an estimate of CELI population levels.

Prior to monitoring activities and to filling out the form included below, it is necessary to first set out your permanent monitoring frames. This will require:

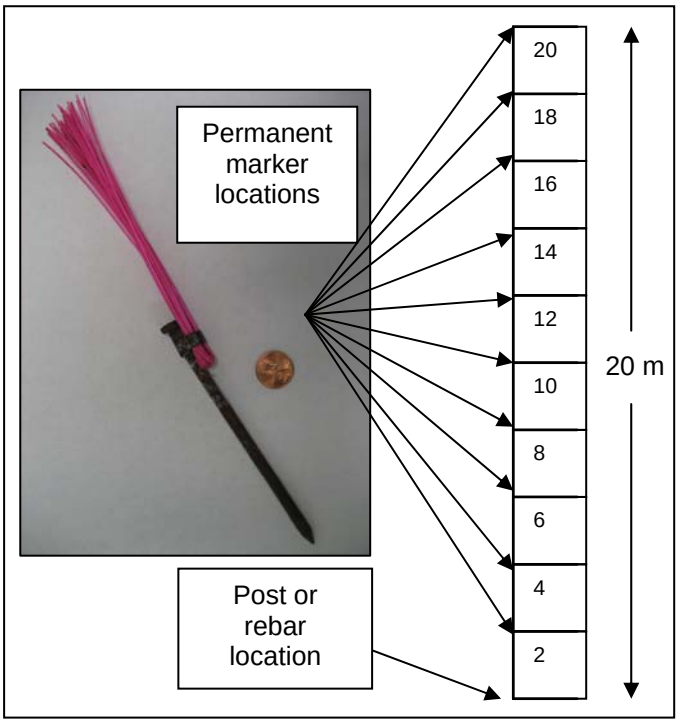
1) 25 x 50 cm (10 x 20 inches) Daubenmire frame made from PVC (preferred) or rebar

2) 20 m (66 ft) tape measure for the transect and plant height

3) 10 permanent markers (road whiskers and 16 penny nails)

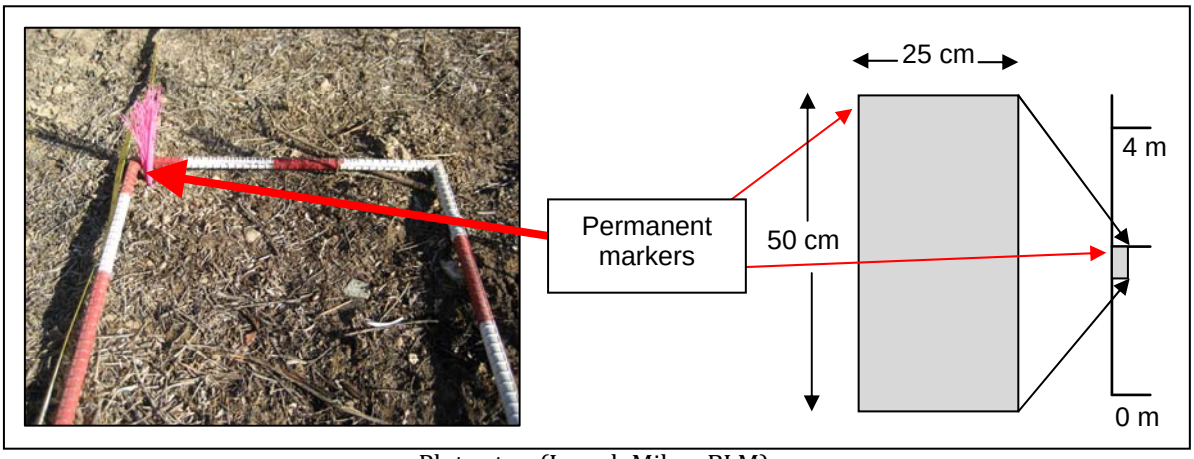
4) A post or rebar to permanently mark the site (see diagrams for examples of field equipment)

5) 1 hour during the peak phenological monitoring time of the target exotic thistle species (first week of May)



Transect breakdown (Joseph Milan, BLM)

To set up the transect, place the 20 m (66 ft) tape randomly within the infestation. Mark the beginning of the transect with a post. Place permanent markers every 2 m or 6.5 feet (for a total of 10 markers) beginning at the 2 m mark and ending with the 20 m mark on the tape measure (see diagram). Place the Daubenmire frame with the long (50-cm) side parallel to the tape and the permanent marker at 2 m in the upper-left corner(see diagrams). Conduct monitoring as described below, and then repeat the procedure at 2-m intervals along the tape for a total of 10 replicated measurement (at permanent markers).



Plot setup (Joseph Milan, BLM)

APPENDIX IV (CONT.): IDAHO STATEWIDE THISTLE BIOLOGICAL CONTROL AGENT 2-PAGERS AND MONITORING FORM

Monitoring Guidelines for *Urophora cardui* on Canada Thistle

Overview:

A critical part of successful weed biological control programs is a monitoring process to measure populations of the biological control agents and the impact that they are having on the target weed. Monitoring should be conducted on an annual basis for a number of years. The Idaho State Department of Agriculture, in conjunction with the University of Idaho, Nez Perce Biocontrol Center, and federal land management agencies, has developed a monitoring protocol that enables land managers to take a more active role in monitoring populations and the weed control ability of the Canada thistle stem gall fly, *Urophora cardui* (**URCA**) in efforts to control Canada thistle, *Cirsium arvense*. This monitoring protocol was designed to be implemented by land managers in a timely manner while providing data which will enable researchers to better quantify the impact of URCA on Canada thistle throughout the state.

Canada thistle (*Cirsium arvense*)

Canada thistle is an aggressive, colony-forming perennial weed that reproduces by seed and deep, extensive horizontal roots. Flowering occurs from June through August. The flowers are urn-shaped, purple (sometimes white), and male and female flowers occur on separate plants with heads ranging from ½ to ¾ inch in diameter. Fruits are about 1/8 inch long and brownish with a tuft of hairs at the top. Stems are typically 1 to 4 feet tall with alternate, oblong or lance-shaped leaves divided into spiny-tipped irregular lobes. Canada thistle is native to Eurasia and was introduced to Canada as a contaminant of crop seed in the 18th century. It can commonly be found in gardens, flower beds, pastures, cultivated fields, rangelands, forests, and along river banks, ditches and roadsides. Canada thistle can tolerate a wide range of environmental conditions, but requires good light intensity for optimal growth. It is highly competitive with crops and, in heavy concentrations, effectively prevents grazing. A number of accidentally introduced insects attack Canada thistle. However, only two insects are approved for release; *Urophora cardui* and *Ceutorhynchus litura*.

Canada thistle stem gall fly (*Urophora cardui*)

URCA is a biological control agent that attacks Canada thistle stems and forms a gall which acts as an energy sink. It takes nutrients which would normally be available to the plant, thereby reducing plant vigor and competitive ability. Adult flies emerge from galls in late spring to early summer and mate, and females deposit one to 30 eggs in Canada thistle's vegetative shoots. Larvae of the gall fly initiate gall development by tunneling into the plant stem. Larvae grow slowly while the gall is developing and attain 98% of their body weight as the gall matures. Multiple larvae (3 to 10) can be found in individual large galls. Pupation occurs within the gall in early spring. Galls resemble a small, green crabapple and are typically found in the upper third of the main stem (see photo above). They can vary in size but are generally marble- or walnut-sized. The fly does best in semi-shaded, moist areas with scattered Canada thistle plants.

APPENDIX IV (CONT.): IDAHO STATEWIDE THISTLE BIOLOGICAL CONTROL AGENT 2-PAGERS AND MONITORING FORM

Monitoring:

This biological control monitoring protocol is based upon a permanent 20-meter vegetation sampling transect randomly placed in a suitable (at least 1 acre) infestation of Canada thistle and timed counts of URCA galls. Annual vegetation sampling will allow researchers to characterize the plant community and the abundance and vigor of Canada thistle. Visual counts of URCA galls will provide researchers with an estimate of URCA population levels.

Prior to monitoring activities and to filling out the form included below, it is necessary to first set out your permanent monitoring frames. This will require:

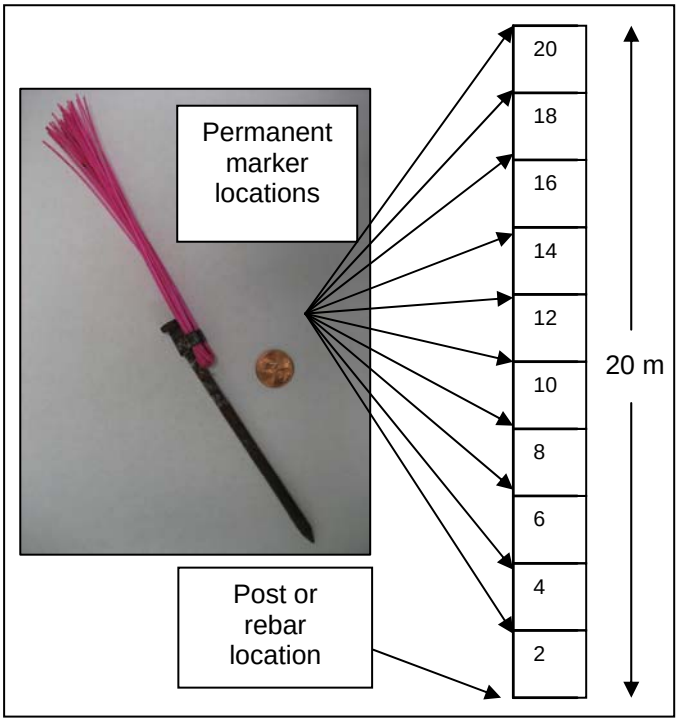
1) 25 x 50 cm (10 x 20 inches) Daubenmire frame made from PVC (preferred) or rebar

2) 20 m (66 ft) tape measure for the transect and plant height

3) 10 permanent markers (road whiskers and 16 penny nails)

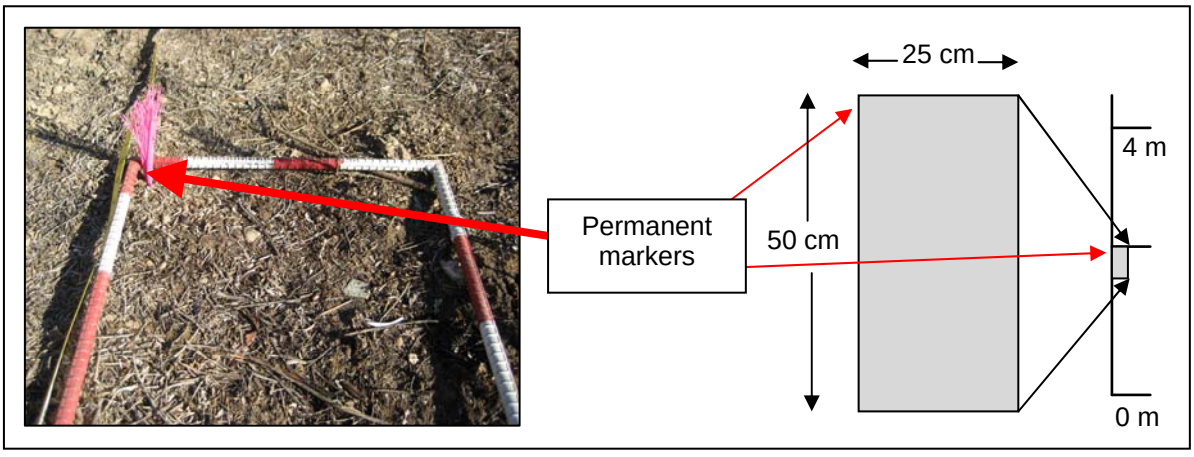
4) A post or rebar to permanently mark the site (see diagrams for examples of field equipment)

5) 1 hour during the peak phenological monitoring time of the target exotic thistle species (first week of August)



Transect breakdown (Joseph Milan, BLM)

To set up the transect, place the 20 m (66 ft) tape randomly within the infestation. Mark the beginning of the transect with a post. Place permanent markers every 2 m or 6.5 feet (for a total of 10 markers) beginning at the 2 m mark and ending with the 20 m mark on the tape measure (see diagram). Place the Daubenmire frame with the long (50-cm) side parallel to the tape and the permanent marker at 2 m in the upper-left corner(see diagrams). Conduct monitoring as described below, and then repeat the procedure at 2-m intervals along the tape for a total of 10 replicated measurement (at permanent markers).



Plot setup (Joseph Milan, BLM)

APPENDIX IV (CONT.): IDAHO STATEWIDE THISTLE BIOLOGICAL CONTROL AGENT 2-PAGERS AND MONITORING FORM

Timed (for use with *Urophora cardui* galls and *Ceutorhynchus litura* adults)

Monitoring biological control agents is an essential component of a successful biocontrol program that can be used to accurately document impact and safety of this weed management practice. This monitoring form has been endorsed by the Nez Perce Biocontrol Center, University of Idaho, Forest Health Protection, Bureau of Land Management, and Idaho State Department of Agriculture. The monitoring information from this form will be used to document vegetation cover, target weed density, and biological control agent abundance and the changes that occur over time.

General Information:

Observer(s):		Date:	Landowner:
Permanent site? Y N	Site name:		Weed:
Biocontrol agent:		Insect Stage: Adult Larvae Pupae Egg	
Lat/Long: N ° ‘	W ° ‘	UTM Datum:	UTM E:
		UTM Year :	UTM N:

Weed Infestation:

Size in acres:	Picture taken?	Yes No	If Y, picture direction:

Vegetation cover (all in %, rows add to 100%):

Frame	Target weed%	Other weed%	Forb/shrub%	Grass%	Bare ground%	Litter%	Moss%	Total%
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Target weed size/density:

Frame	Number of stems	Height of tallest stem (cm)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Biological control agent:

Count location	# insects (or galls) per 3 min. count
1	
2	
3	
4	
5	
6	

INSTRUCTIONS FOR APPENDIX IV: IDAHO STATEWIDE THISTLE BIOLOGICAL CONTROL AGENT MONITORING FORM

General Information:

- Observer(s) – Who are you?
- Date – Today's date.
- Landowner – Who is the landowner/land manager?
- Permanent? – Is this a permanent monitoring site?
- Site name – Which site are you monitoring? This could have a specific name if it is a permanent site.
- Weed – Which target weed are you are monitoring?
- Biocontrol agent – Which biocontrol agent you are monitoring?
- Insect Stage – What is the growth stage of the agent are you monitoring?
- Lat/Long OR UTM – What are the coordinates of the site you are monitoring? If UTM (preferred), what datum and year are your coordinate system?

Annual grass – note stems which are typically solitary or in a few stemmed tufts.

Vegetation Cover (all in %, rows should add up to 100%) – All percentages are to be estimated to the nearest 5%. Put a "T" on the form for trace amounts less than 5%.

- Frame – Which frame number are you working on (1= 2m, 2= 4m, …,10 = 20m on transect)?
- Target weed % – What is % cover of the target weed to the nearest 5%?
- Other weeds % – What is the % cover of any other weeds in the frame to the nearest 5%? Count undesirable annual grasses as weeds.
- Forb/Shrub % – What is the % cover of native forbs/shrubs in the frame to the nearest 5%?
- Grass % – What is the % cover of grass to the nearest 5%?
- Bare Ground/Litter % – What is the % cover of bare ground/litter to the nearest 5%?

Perennial grass – note the multiple stem base with multiple year's growth.

Target Weed Size/Density

- Frame – Which frame number are you working on (1=2m,…,10=20m)?
- Number of stems – How many stems of the target weed are in the frame?
- Height of tallest stems (cm) – How tall is the tallest stem in the frame (in cm)?

Biological Control Agent Density Monitoring

Here, you collect data for *Ceutorhynchus litura* (counting adults) and *Urophora cardui* (counting galls) that helps to get an unbiased assessment of the population size of the biological control agents. This is probably the most important part of the data collection.

- Count location – Do not count in the area where the transect is located. Instead, identify 6 similar locations around or close-by but at least 20 paces away from the transect.
- ***In 3 minutes, count as many URCA galls (search for stems with galls) or as many adult CELI (searching for and inspecting rosette leaf petioles, and crevices in between, throughout the center of the rosette). How many insects/galls can you find in the 3 minute period? For weevil counts, carefully approach the plants and be sure to count each insect only once. Repeat the weevil/gall count 5 times (for a total of 6 3-minute counts) in different areas. These are replications and provide the unbiased data to calculate the population size of the biological control agents.***

APPENDIX V: GENERAL BIOLOGICAL CONTROL AGENT MONITORING FORM

SITE: _____ **STATE:** _____ **COUNTY**_____ **DATE:** _____ _____ _____
year month day

DATA COLLECTOR: _____ **TIME:** _____
First and last name

UTM DATUM:_____ **UTM YEAR:**_____

LAT/LONG: N _____°_____' **W** _____°_____' **UTM E:** _____ **UTM N:** _____

ELEVATION: _____ **TEMPERATURE:** _____ **WEATHER:** _____

INSECT COUNTS:

Species	Method	# insects (use Chart A)
C. litura, T. horridus, C. corydon	Randomly select 25 plants, dissect root tissue and count larval tunnels	
U. cardui	Randomly select 25 plants, dissect galls and count larvae	
U. stylata	Randomly select 25 plants, dissect seed heads and count larvae	

Chart A: Insect abundance

1	1-10
2	11-25
3	26-100
4	100-500
5	>500

EXOTIC THISTLES:

Chart B: Damage Class

0	<1%
1	1-5%
2	6-25%
3	> 25%

Chart C: Cover Class

0	<1%
1	1-5%
2	6-25%
3	26-50%
4	51-75%
5	76-95%
6	>95%

Quad #	Exotic thistle		Stems					
	% damage (use Chart B)	% cover (use Chart C)	# mature stems	# immature stems	Height 4 tallest stems (cm)			
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

APPENDIX V (CONT.): GENERAL BIOLOGICAL CONTROL AGENT MONITORING FORM

Quad #	Exotic thistle		Stems					
	% damage (use Chart B)	% cover (use Chart C)	# mature stems	# immature stems	Height 4 tallest stems (cm)			
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

Notes:

INSTRUCTIONS FOR APPENDIX V: GENERAL BIOLOGICAL CONTROL AGENT MONITORING FORM

Materials needed: 1 meter (1.1 yard) stick, 0.2 x 0.5 m (0.2 x 0.55 yard) quadrat frame, stopwatch, sweep net, monitoring form, pencils, clipboard, camera, and GPS unit to relocate transects.

General: The purpose of this monitoring activity is to estimate the abundance of exotic thistle and its biocontrol agents at the site and to record measurements of a sample of exotic thistle plants. Conduct the monitoring when the biocontrol agents are at their peak. Monitoring is easier when conducted by two people: one to make the observations and the other to record data.

1) **Site information:** Fill out the site information at the top of the form.

2) Insect counting: Use the chart for the method to count insects. Carefully approach the site and avoid disturbing the vegetation as adult insects often drop from the vegetation once you touch stems (or even as you approach the quadrat). Use Chart A to record the category of abundance (1-5).

3) Locate the transect and position the quadrat: After you have completed the insect counts, locate the transect using the GPS coordinates and the permanent marker.

4) Position the quadrat: Position the quadrat along the transect, as close to the ground as possible, carefully positioning the quadrat along that transect line. Be sure not to damage the plants. The quadrat should be in the same location as the previous year's quadrat. Move stems in or out of the frame area so that all stems originating inside the quadrat are included.

5) Estimate feeding damage: Examine the exotic thistle for any damage to the leaves, shoots, flower heads, etc., such as malformed flower heads due to agents feeding on capitula and seeds. Standing over the frame, estimate the percent of damage over the entire quadrat, using Chart B to determine the category of damage.

6) Estimate percent cover: Standing over the frame, estimate how much of the quadrat is covered by exotic thistle. Use cover estimates in Chart C to estimate percent cover class.

7) Count stems: Count the number of exotic thistle stems, beginning at one corner of the quadrat and working systematically across the quadrat. Count the number of mature (floral) and immature (vegetative) stems.

8) Measure stems: Select the four (4) tallest exotic thistle stems in each quadrat (if there are fewer than 4 stems/quadrat, measure all that are present). Measure the stem height (to the closest cm)

9) Other observations: Record any general observations or useful information; disturbances, grazing, fire, etc., for the sample quadrat or the site in general.

APPENDIX VI: EXOTIC THISTLE QUALITATIVE MONITORING FORM

Name: _____Date: _____Time:_____ am/pm

Location:_____ Site #:_____

Biocontrol species:_____ Year of release: _____

Exotic thistle species_____

Cover class estimate by plant category						
	0%	1-5%	6-20%	21-45%	46-70%	71-100%
Exotic thistle						
Annual Grasses						
Perennial Grasses						
Forbs						
Shrubs						
Trees						

Dominant plant species on site:
Other noxious weeds:

Estimate exotic thistle density class (✓check one)			
Flowering plants/meter sq		Exotic thistle distribution	
0		Isolated	
1-25		Scattered	
26-50		Scattered-Patchy	
50-75		Patchy	
>75		Continuous	

Exotic thistle phenology class at time of monitoring	
Exotic thistle stage	Estimated percent
Seedling	
Rosette	
Bolting	
Flowering	
Senescent	

Comments/Observations _____

_____

_____

_____

_____

_____

APPENDIX VII: EXOTIC THISTLE BIOCONTROL - ASSOCIATED VEGETATION MONITORING

SITE: ______________________ **STATE:** ________ **COUNTY**______________________ **DATE:** _________ _________ _______
year month day

DATA COLLECTOR: ____ **TIME:** __________________________
First and last name

UTM DATUM:_______________ **UTM YEAR:**__________

LAT/LONG: N ______°__________' **W** _____°_________' **UTM E:** _________________ **UTM N:** _________________

ELEVATION: ______________ **TEMPERATURE:** _________ **WEATHER:** ____

Chart A: Cover Class	
0	<1%
1	1-5%
2	6-25%
3	26-50%
4	51-75%
5	76-95%
6	>95%

Percent of Quadrat (Use Chart A; total for each column is 100%)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Vegetated										
Soil, litter										
Rock										

Vegetation Cover (Use Chart A; total for column may exceed 100% due to overlapping of vegetation)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Exotic thistle										
All other vegetation:										
Forbs										
Grasses and Sedges										
Woody plants										

Individual Species (names) (Check if present or use Chart A to indicate percent cover)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10

INSTRUCTIONS FOR APPENDIX VII: EXOTIC THISTLE BIOCONTROL - ASSOCIATED VEGETATION MONITORING

Materials needed: 1 meter stick, 1.0 m^2 quadrat frame, data sheets, pencils, clipboard, camera, and GPS unit to relocate quadrats.

G**eneral:** The purpose of this activity is to estimate the abundance of other vegetation in the community and to record measurements of exotic thistle plant attributes. Monitoring is easier with two people, one to make the observations and the other to record data.

1) **Site information:** Fill out the site information at the top of the form.

2) Position the quadrat: Position the quadrat frame as close to the ground as possible, carefully positioning the quadrat along that transect line. Be sure not to damage the vegetation. The quadrat should be in the same location as the previous year's quadrat.

3) Estimate amount of vegetation: Standing over the frame, estimate how much of the quadrat is vegetated and how much is not vegetated (bare ground, rock, etc). Use cover estimates in Chart A to estimate percent cover.

4) Estimate percent cover of vegetation: Standing over the frame, estimate how much of the quadrat is covered by exotic thistle and how much is covered by other forbs, grasses, or shrubs. Use cover estimates in Chart A to estimate percent cover. Because vegetation can naturally overlap, it is possible to have a combined total percent cover to exceed 100%.

5) Estimate percent cover of individual species: Standing over the frame, estimate how much of the quadrat is covered by individual species other than exotic thistle. Use this section to track specific species: for example perennial grasses, native forbs, etc.

6) Other observations: Record any general observations or useful information, such as disturbances, grazing, fire, etc.